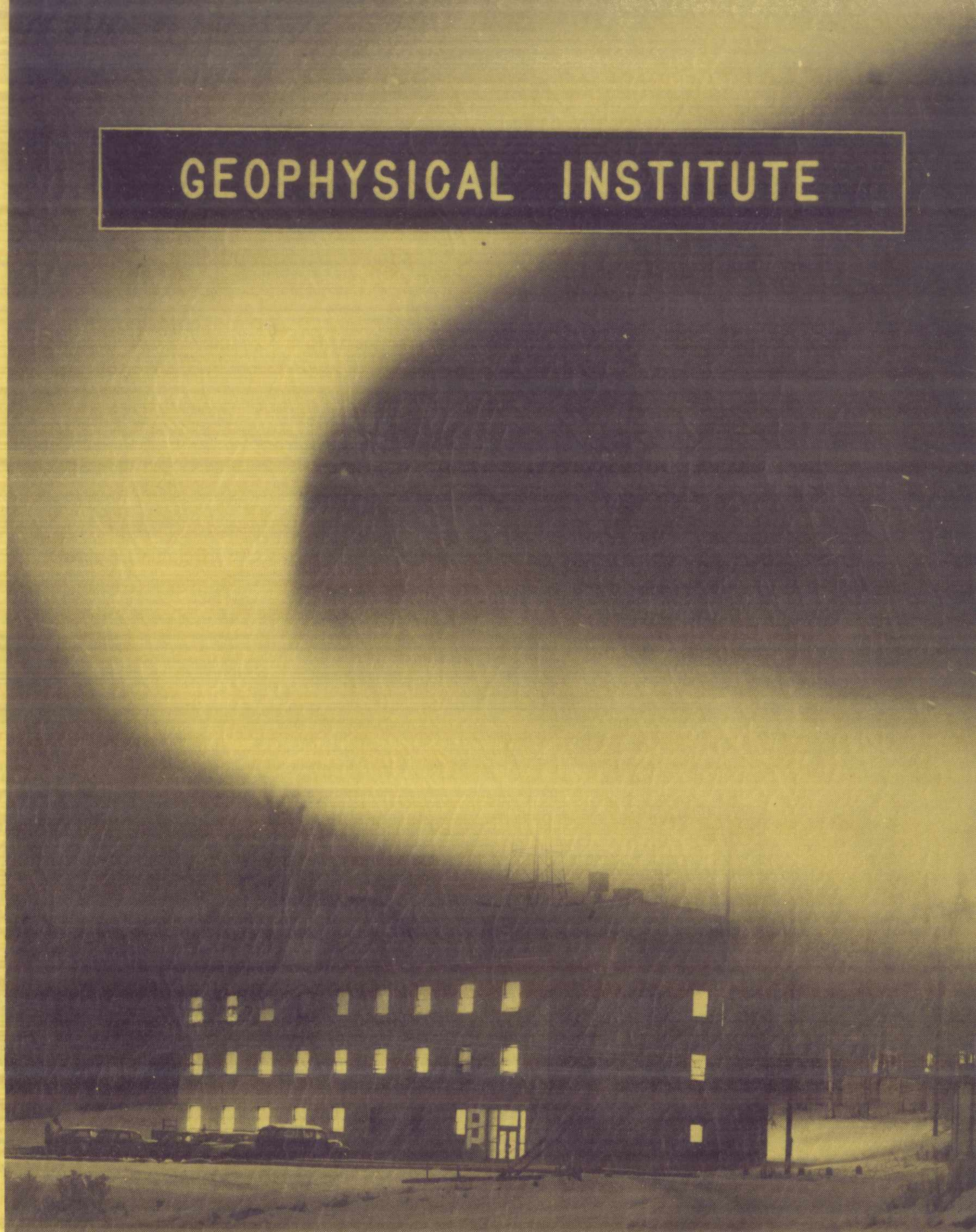

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AN EVALUATION OF AURORAL ALL-SKY CAMERA OBSERVATIONS

by

T. N. Davis, C. S. Deehr, and H. Leinbach

Scientific Report No. 5
NSF Grant No. Y/22.6/327

Principal Investigator: C. T. Elvey

GEOPHYSICAL INSTITUTE

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ABSTRACT

From photometric, all-sky camera, and visual observations of a moderate auroral display, it is found that the all-sky camera compares favorably with the visual observer in detecting and recording auroral forms. The visual observer can make instantaneous observations and so can detect rapid changes and auroral forms lasting only a few seconds, whereas the poorer time resolution of the all-sky camera prevents it from recording very short-lived phenonema. However, the ability of the all-sky camera to accurately record the shape and intensity of the majority of auroral forms allows it to yield more precise and complete information about these aspects of auroral morphology than is normally obtained through visual observation.

AN EVALUATION OF AURORAL ALL-SKY CAMERA OBSERVATIONS

Introduction

A great bulk of auroral data was accumulated in the form of all-sky camera film during the IGY, 1957-58. In order to make the maximum use of these data it is necessary to know the capability of the all-sky camera to record auroral forms, not only arcs, rays, and bands, but those forms which are diffused or rapidly varying in shape and intensity.

Observations were made at College, Alaska on the night of September 11-12, 1959 to compare the all-sky camera observations with those of other types. This effort was rewarded by a completely clear sky and a weak to moderate visual auroral display lasting from evening nautical twilight to morning nautical twilight.

Instrumentation and Observing Techniques

Optical equipment in operation at College on September 11-12, 1959 included two all-sky cameras, Huet and Patrol spectrographs, and two photometers on a scanning mount. Also, two persons visually observed and recorded the display in a fashion described by Heppner (1954). Their combined observations formed a continuous description of the visual aurora throughout the night.

Spectroscopic data were gathered from along the geomagnetic meridian by an IGY Patrol grating spectrograph using exposure times of 5 to 90 minutes. The spectrum of an 11-degree field in the geomagnetic zenith was recorded continuously throughout the night by an f/0.7 Huet prism spectrograph equipped with a moving photographic plate.

The main photometer used in this study employs a Dunn-Manring birefringent filter (Dunn and Manring 1956) and a RCA 6217 end-view photomultiplier. This instrument is sensitive only to emission lines and is not affected by a continuous background emission. In order to facilitate absolute intensity measurements of λ5577 emission the main photometer was compared to a second calibrated photometer (Roach and Rees, in press) with the same 5-degree field of view and employing a Baird interference filter having a 17Å bandwidth at half transmission. All photometric observations presented here are corrected for extinction and air mass and so provide the absolute intensity of the λ5577 emission at the source (Roach, 1956).

The two all-sky cameras, U. S. model, were operated in the same manner as the Alaskan cameras operated during the IGY (Young, 1959). Each camera took photographs on 16-mm film with an exposure time of 15 sec at the beginning of each minute during the dark hours. Two differences existed in the operation of the two cameras. One camera, operated atop the Geophysical Institute, was surrounded by building and street lights while the other camera, located at the regular optical site 2 miles away, was free of nearby lights. Also, the camera at the optical site photographed the aurora through a plexi-glass dome, whereas the dome was removed from the other camera. Development of the films (Kodak Tri-X) was in D-19 for 10 min at 68° F.

A Brief Visual Description of the Display

The display of September 11-12 was typical of those frequently observed at College. It began with the appearance of a homogeneous arc above the northern horizon at 2029 (150° WMT). During the next hour one or more quiet forms were visible in the northern sky. Between 2116 and 0021 the display developed southward until it extended from 5° above the northern horizon to 45° above the southern horizon as viewed from College. Well-defined homogeneous and active forms, arcs and bands, predominated during this period. Later, between 0021 and 0130, most of the visible forms had a somewhat diffused appearance, although they remained quite active. All forms in the display became diffused and there were irregular pulsations during the interval 0130-0220. From 0220 until 0310, when twilight prevented further observations, the diffused and previously pulsating forms tended to reform into wide arc-like forms and their intensity steadily decreased.

Intensity and Spectral Characteristics of the Display

Figure 1 contains a curve which gives a measure of the $\lambda 5577$ intensity along the geomagnetic meridian. This curve is obtained by integrating under the curves of Figure 4, to be discussed later. It shows that the $\lambda 5577$ intensity increased to a maximum near midnight, decreased, and then reached an even higher maximum near 02^h.

A reproduction of the Huet spectrogram, Figure 2, gives a continuous spectral record of the entire night with a time resolution of about one hour. The spectrum indicates that the greatest overall intensity occurred near 01^h and that the display was predominantly green ($\lambda 5577$). Hydrogen is evident in the zenith between 22^h and 01^h with a maximum intensity near midnight.

Observations during Evening Twilight

Beginning shortly after sunset, the photometers were operated in almucanter sweeps at progressively greater zenith distances as the sky brightness decreased. Toward the end of nautical twilight, at 2013, the birefringent photometer detected an auroral arc in the north while sweeping at zenith distance 80°. The arc was recorded as two peaks of intensity east and west of geomagnetic north, corresponding to the intersections of the arc and the photometer sweep. Later, at 2028-2039, the visual observer first detected the arc, and it was visible on the all-sky photograph taken at 2029. At that time the lower border of the arc was at zenith distance 71° N. Only the eastern part of the arc was at first visible to the observer and the all-sky camera. Figure 3 shows the maximum absolute intensities of the arc at the two intersections with the photometer sweep.

The sudden decrease in intensity of both parts of the arc at 2024 does not appear to be associated with decrease in sunlight because the widely-separated parts of the arc simultaneously become weaker. It is interesting to note that, although the arc reached an intensity of more than 11 kilo-rayleighs, it was not detected by the visual observer or the all-sky camera until several minutes later, at which time the intensity had dropped to less than 7 kilo-rayleighs. The visual observer did not see the arc earlier despite his knowing that the photometer was detecting aurora in the northern sky.

Photometric, All-sky Camera and Visual Observations at Half-hour Intervals

Data scaled from meridian sweeps (of duration 1 min) by the birefringent photometer were analyzed to obtain the absolute intensity of λ5577 emissions versus zenith distance at intervals of approximately one-half hour throughout most of the display (see Figure 4). The curves of intensity versus zenith distance show that during the evening hours there were high peaks of intensity superimposed on a relatively low background. Later, especially during pulsating aurora, the peak intensities were little greater than the overall background between zenith distances 70° south and 60° north. However, during this later period the background level was several times that of the evening hours.

Figure 5 presents reproductions of all-sky photographs taken at the times of the photometer sweeps analyzed to prepare Figure 4, and Figure 6 presents visual observations taken at or near those times. A comparison of these three figures indicates the similarities and differences to be expected between visual and all-sky camera observations as well as the absolute intensites of the observed forms. Several of the observations will be discussed further below.

Observations During Pulsating Aurora

The visual observer saw irregular pulsating aurora during the time interval 0135-0223. An interpretation of the all-sky photographs by a person unaware of the observed times of pulsating aurora resulted in the statement that pulsating aurora occurred between 0131 and near 0230. This interpretation, in good agreement with the visual observations, was made by scanning the film on a hand-operated movie projector and observing the character of the display, which was distinctive during the interval. The aurora occurred during this time within a well-defined zone and exhibited moving lineations of varying intensity. These small-scale lineations can be observed in the photograph taken at 0200, Figure 5.

That minute-to-minute intensity fluctuations do occur is evident by examination of Figure 7. This figure shows birefringent photometer data taken from five consecutive meridian sweeps during pulsating aurora. The resulting plots of absolute intensity versus zenith distance, have the appearance of an imperfect "square wave" with an average amplitude of approximately 20 kilo-rayleighs. Part of the observed variation in intensity is in the form of an overall decrease during the five scans, but in addition to this there are intensity fluctuations of approximately 10% occurring from one minute to the next. These fluctuations apparently correspond to those readily observed visually and which give the pulsating aurora its name.

Comparison of All-Sky Camera and Visual Observations

Following are visual and all-sky camera observations demonstrating the similarities and differences between the results of the two observational techniques:

1) 2029 Visual observer and camera detect first aurora in twilight at the same time.

2) 22^h Visual observer occasionally notices minor ray structures on some arcs and these are not easily detectable on the all-sky film.

3) 2335 Visual observer sees "long rays converging at magnetic zenith, no lateral motion but fade in and out". It is evident from the all-sky photograph taken at this time that these are not rays, but rather are parts of a thin arc passing through the magnetic zenith.

4) 2340 Visual observer draws approximate location for bright band in north and describes it as "moving". It is possible from the all-sky film to trace out this feature which is quite complex and has several loops.

5) 2344 All-sky camera detects faint arc with lower border 30° south of zenith. Visual observer does not see arc but observes "glow, southern limit ill-defined" just south of zenith.

6) 2356 Visual observer notes corona. On the all-sky film the feature appears to be a rayed band with the horseshoe bend opening west and encircling the zenith. Viewing of all-sky photographs taken before and after this time shows that the horseshoe bend moved from the eastern horizon, through the zenith, and continued to move rapidly west.

7) 0016 Both observer and camera can now detect southern limit of glow near to and south of the zenith. The observer also sees diffuse rays near the zenith. In the northwest is a feature which the observer describes as a "bright diffuse patch" and which viewed on the film appears to be a segment of a bright rayed band.

8) 0100 Both observer and camera detect three diffuse rayed arcs overhead, but the observer also notes glow between the arcs.

9) 0127 Both observer and camera detect very long rays extending from a poorly-defined arc at approximately 50° N to near the magnetic zenith. South of the zenith there are a number of thin diffuse arcs; 8 are seen on the all-sky film.

10) 0245 to end of observations. During this twilight period, the visual observer is better able to detect and describe the auroral forms. Most are visible on the all-sky film, but only faintly.

These observations lead to the following conclusions regarding the comparative ability of the all-sky camera, and visual observer to detect and record auroral forms:

a) The all-sky camera, when operated as described here, is slightly less able than the experienced visual observer in detection of very weak, diffused forms and perhaps is comparable to the visual observer in detecting very weak but well-defined forms. It was found that the all-sky camera operated without a dome was superior to the one with a dome in the detection of weak auroral forms. Also, moonlight and building lights caused much less interference when the dome was removed. The operation of most United States cameras beneath domes frequently hampers the detection of the weakest auroras photographed during the IGY. Moon and building light reflections from the dome also obscure some auroras.

b) The all-sky camera is much superior to the visual observer in accurately locating and recording the shape of most auroral forms.

This is because the camera automatically records the position and shape of each form, whereas the accuracy of the visual observer is limited by the task of writing down a complete description.

c) Due to the eye's ability to make instantaneous observations, the visual observer is better able to see the details of very bright or fast moving forms, but the difficulty of accurately recording observations limits the observer's usefulness.

d) More continuity of auroral forms is evident from examining the compressed image of the sky on all-sky photographs than is apparent to the visual observer.

e) The visual observer frequently records seeing isolated diffuse surfaces furing the morning hours. Many of these appear to be segments of arcs or bands when viewed on the all-sky film.

f) During the times when visual observers report pulsating aurora, the overall appearance of the display is quite distinctive and readily identified on the all-sky film. The pulsating aurora appears on the film to be a zone of high but irregular intensity. This zone may show well-defined southern and northern limits. The intensity at a point in the sky may vary a few percent from minute-to-minute, and these variations frequently can be detected on the film. The intensity fluctuations and movement of pulsating aurora are best observed by viewing the film in movie fashion.

g) An advantage of using all-sky camera data is that it is possible to view the film both forwards and backwards in time. This is a considerable aid to following changes of the auroral forms.

Comments on the Use of All-Sky Cameras

In addition to the above conclusions derived primarily from the observations during one display, we present the following remarks which may be useful to those operating all-sky cameras or using data from them.

Visual observers at College occasionally see, particularly during the morning hours, auroral forms which develop and disappear within one or more seconds. This points out that a complete description of the vusual aurora cannot be given by the all-sky camera alone. Also, visual observations are helpful to the person attempting to visualize and interpret detailed auroral forms from all-sky camera data. Another aid to visualizing the auroral forms is to examine film from two or more all-sky cameras located so as to observe a common portion of the sky.

It was pointed out earlier that the all-sky camera gave better results without the enclosing plexi-glass dome. Several of the all-sky cameras operated in Alaska during the IGY (at Fort Yukon, Healy, and Northway) were an improved model of one described by Davis and Elvey (1955). The optical system of this type camera is such that light from the sky undergoes one mirror reflection and then passes directly to the recording lens. This system gives considerably better definition than the one used in the U. S. IGY model all-sky cameras, which requires light rays to suffer two mirror reflections and then pass through a glass plug before reaching the camera lens. The definition obtained with the U. S. IGY camera has been improved by the removal of the glass plug in the spherical mirror just above the camera lens.

Acknowledgement

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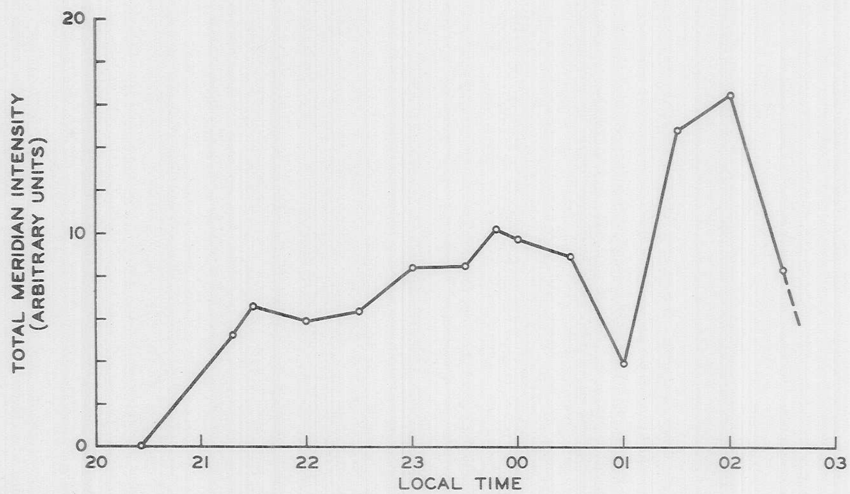

Fig. 1. Intensity of λ 5577 Along the Geomagnetic Meridian.

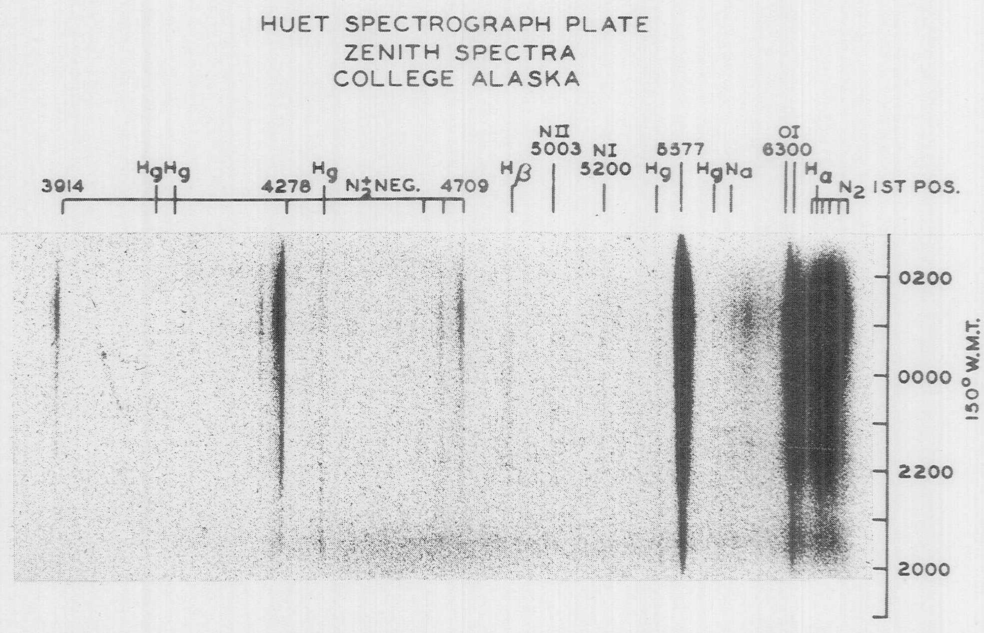

Fig. 2. Huet spectrogram for the night of September 11-12, 1959.

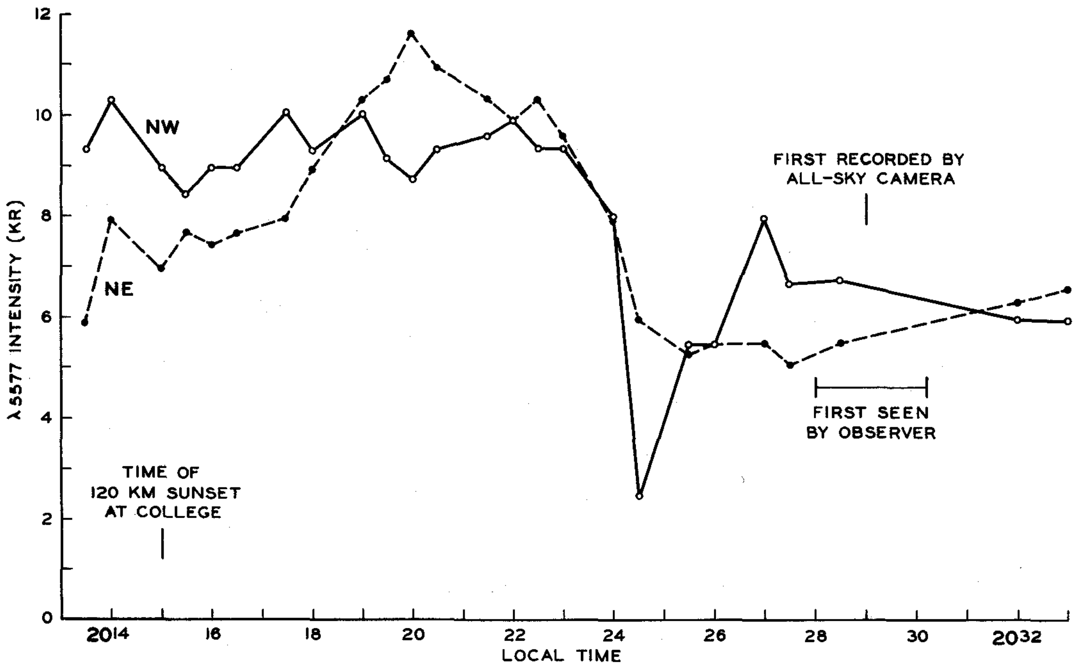

Fig. 3. Absolute intensity of λ5577 at the intersections of the almucanter photometer sweep at zenith distance 80° and an auroral arc crossing the geomagnetic meridian at zenith distance 71°. NW and NE indicate the intersections with the northwest and northeast limbs of the arc, respectively.

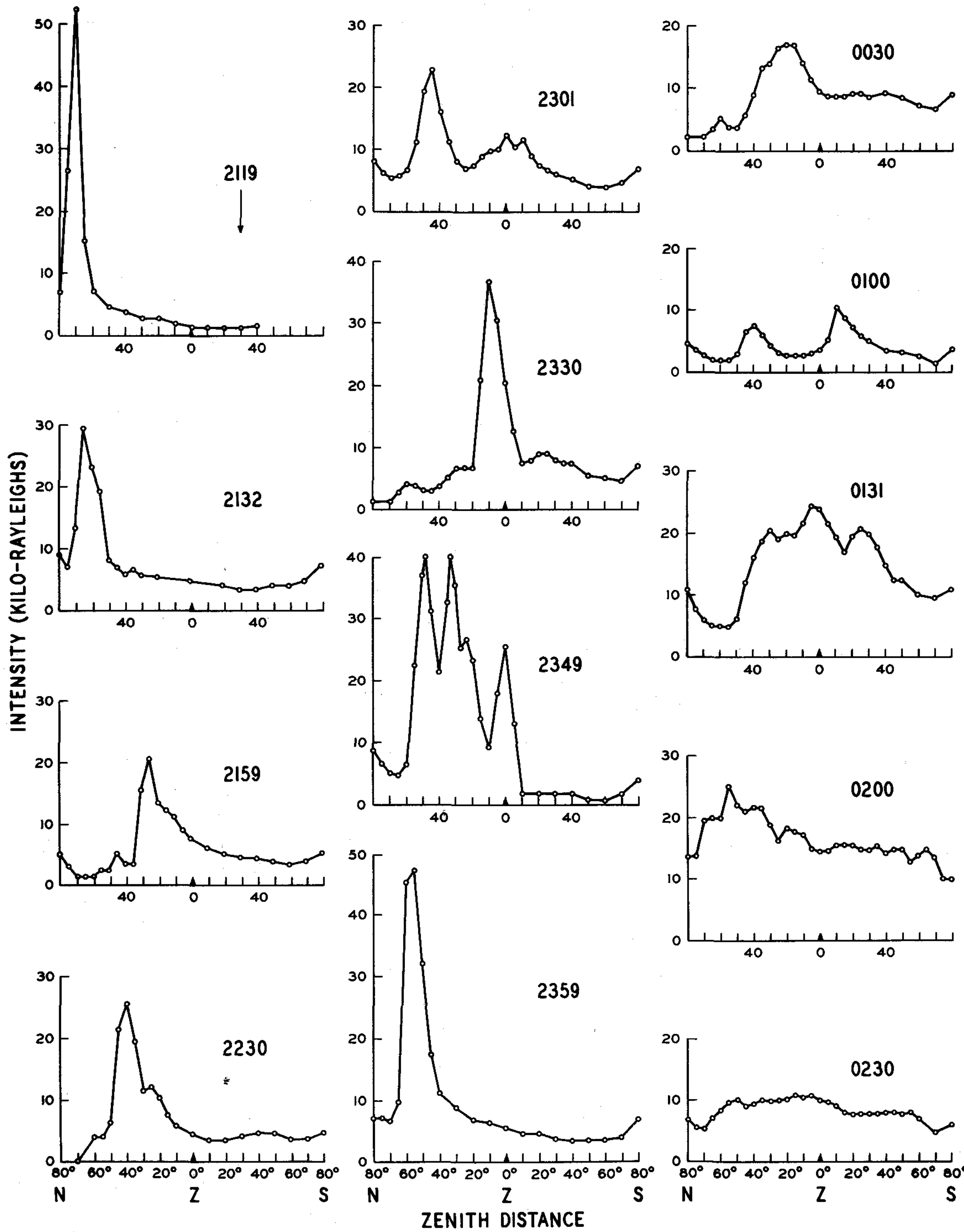

Fig. 4. Absolute intensity of λ5577 along the geomagnetic meridian at approximately half-hour intervals.

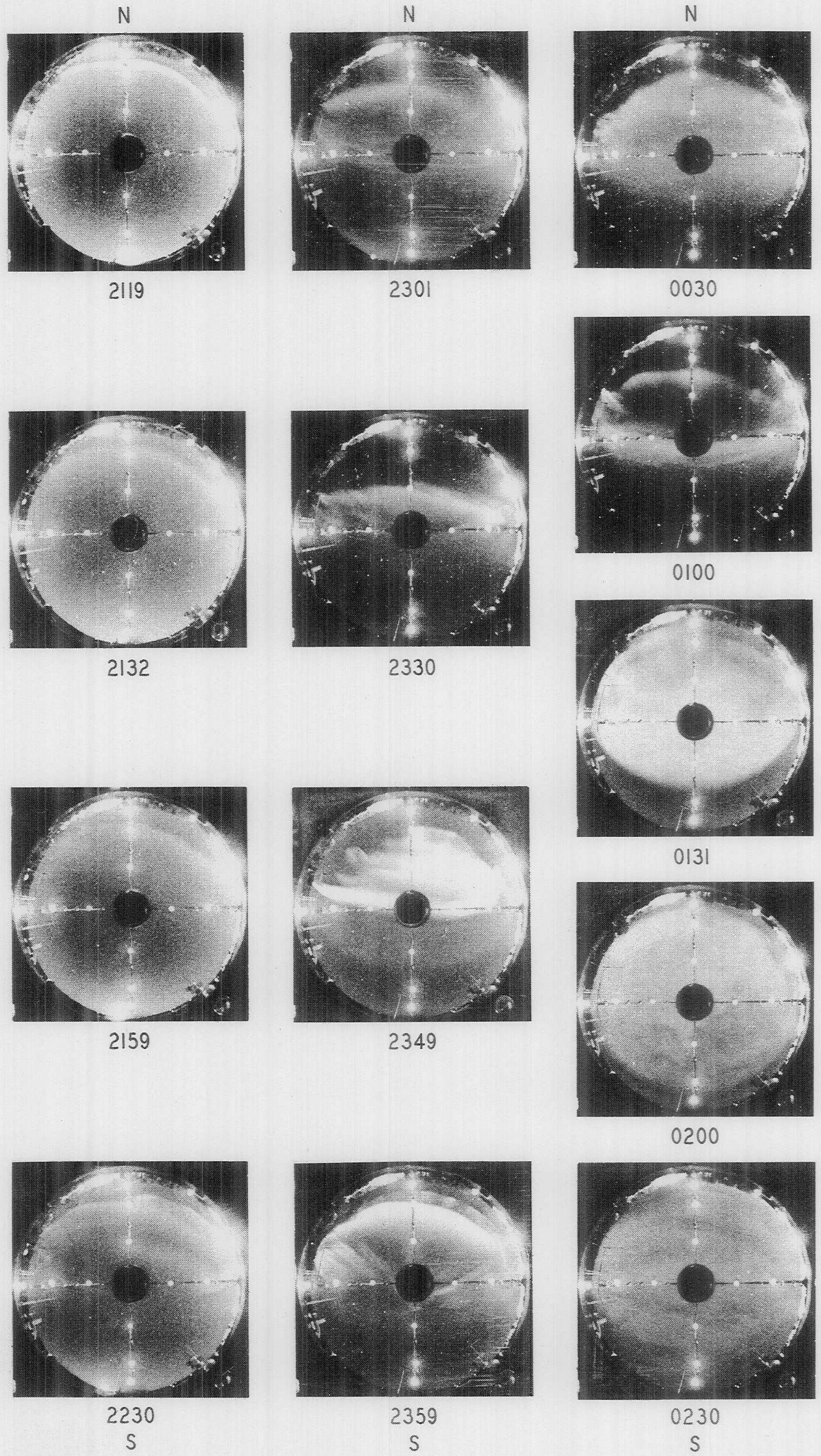

Fig. 5. All-sky photographs taken at the times of the drawings shown in Figure 4.

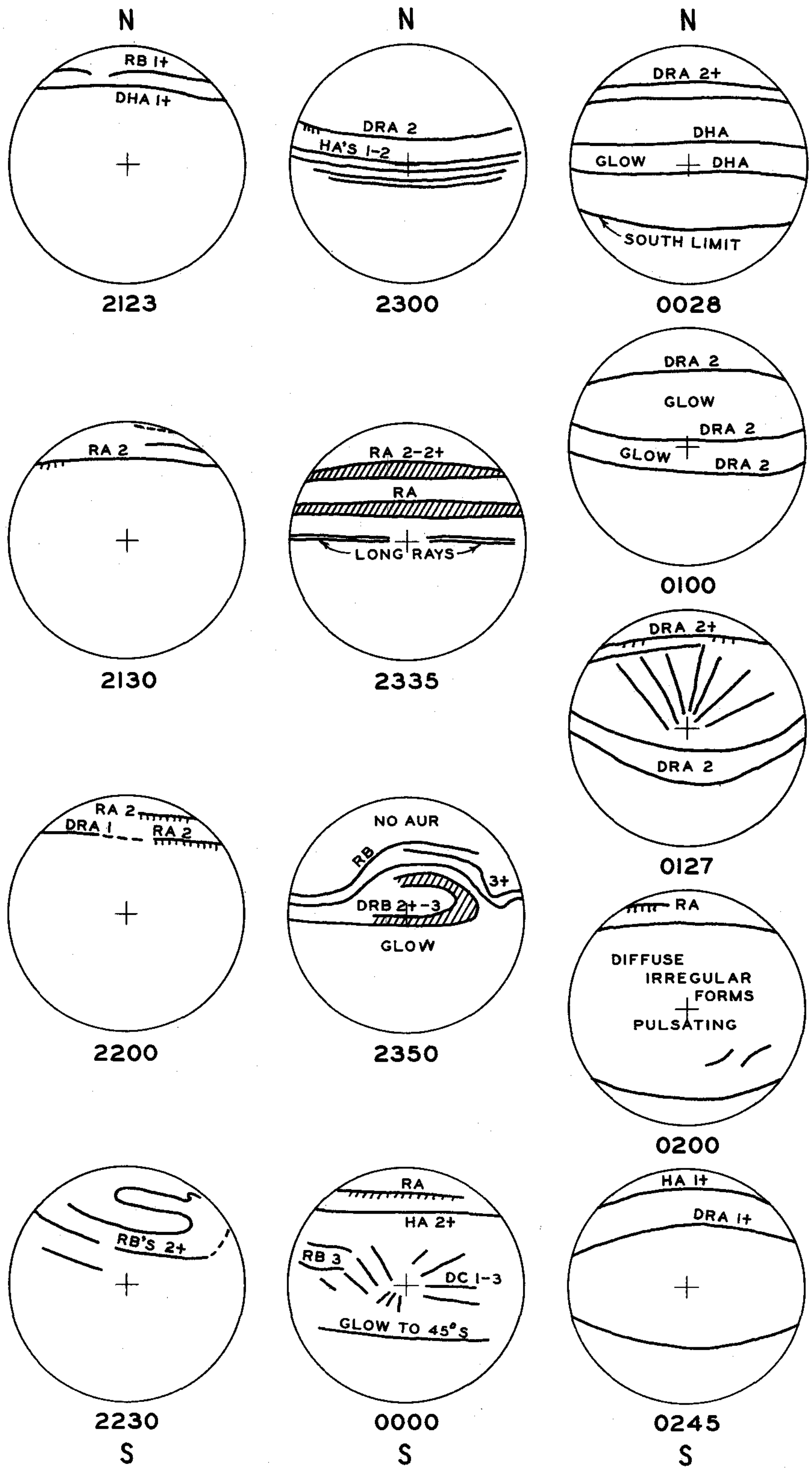

Fig. 6. Reproductions of visual observer reports obtained at times near those shown in Figures 4 and 5.

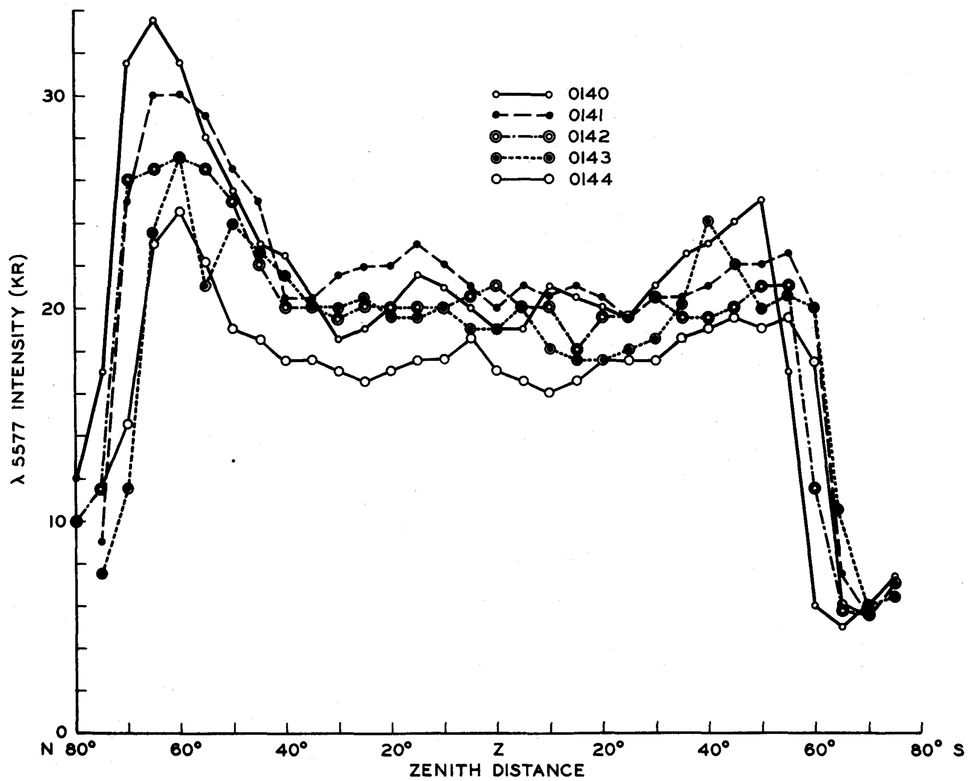

Fig. 7. Absolute intensity of λ5577 along the geomagnetic meridian for five consecutive sweeps during pulsating aurora.