plausible to suggest that the arc was formed from an auroral disturbance in the direction of the north magnetic pole and was propagated southward, spreading out and becoming aligned along the isoclinic lines while so moving. Since the arc was detected again the following night in much the same geographic position as when the encroachment of dawn halted the observations the previous morning, it is hypothesized that the stable red arc existed from the time of its formation (0930 UT October 25, 1960) until it was no longer observed at the onset of dawn (1230 UT October 26, 1960) 2 days later.

Acknowledgement

The author gratefully acknowledges the aid of Mr. Carroll Evans and Mr. William Dale of the Test Department in the programming and machine computation of the geographic coordinates of the stable arc.

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Journal of the Physical Society of Japan Vol. 17, Supplement A-I, 1962
International Conference on Cosmic Rays and the Earth Storm Part I

I-4-3. Hydrogen Emissions and Sporadic E Layer Behaviour*

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Contribution from the Defence Research Telecommunications Establishment Ottawa, and the Defence Research Northern Laboratory, Churchill, Canada

The occurrence and intensity of hydrogen emissions have been studied for several years at Churchill, Manitoba (geomagnetic latitude $\varphi=68.8°$N) in an attempt to determine the diurnal variation of the emissions and their relation to auroral luminosity. Sporadic E (E_s) occurrence was also examined as it was felt that the precipitation of protons into the upper atmosphere could be associated with some particular type of E_s.

The diurnal variation of the intensity of hydrogen emissions observed in the zenith at Churchill are shown at the top of Fig. 1. The individual curves refer to the period November-March for three years. Observations for the period 1958/59 were made with a moving plate spectrograph, while in the later two periods, observations were made with scanning photometers of increased sensitivity and time resolution. The curves show a marked minimum at local midnight, a well defined maximum at 0500 hrs. and a maximum at about 2000 hrs. In contrast to the variation of the hydrogen emissions the zenithal auroral intensity as measured by an all sky camera during the December-March 1959/60 period shows a maximum at local midnight. This is given at the bottom of Fig. 1.

The different behaviour points to protons not being associated with normal visible aurora. This view was strengthened by results of a study using a scanning spectrometer to measure the hydrogen emissions arising from various auroral forms. As

* This paper was presented by C. O. Hines.

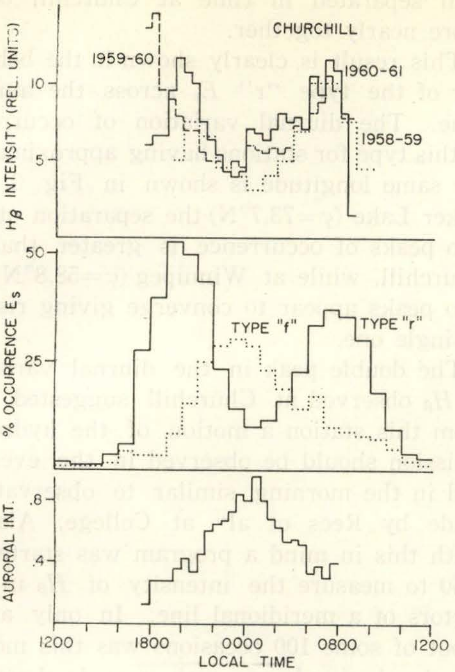

Fig. 1. Diurnal variation of H_β, E_s and aurora measured at Churchill, Manitoba.

shown in Table I H_β was observed in only 50% of the aurora viewed, the percentage being approximately the same for all forms. This is in contrast to results from southern stations where H_α appears to predominate in homogeneous forms. Furthermore, hydrogen emissions occurred over Churchill for an appreciable amount of time when no visible aurora was present.

The first view of this report is then that hydrogen emissions are unrelated to normal visible aurora. This is not the case during times of large geomagnetic storms such as occurred on November 12/13, 1960[1]. At these times type A aurora predominates and is accompanied by intense hydrogen emissions.

The diurnal variation of occurrence of various sporadic E layers, shown in Fig. 1, was deduced from data provided by vertical incidence ionospheric sounding stations. The most notable result is that the diurnal curve for type "r" E_s as observed at Churchill is very similar to that of the hydrogen emissions whereas type "f" sporadic E has a maximum occurrence at the time of maximum auroral intensity. This is also the case for type "a". The major difference between type "r" and types "a" and "f" is that type "r" is non blanketing and shows an increase in virtual height at the high frequency end similar to group retardation whereas the latter are blanketing and show no group retardation.

The results indicate the existence of two phenomena ; one which occurs in the evening and the morning associated with precipitation of protons and occurrence of type "r" E_s, and one giving rise to auroral activity and type "a" and "f" E_s.

In order to study these phenomena in somewhat greater detail similar data was secured from published work and from the ionospheric recordings made at College, Alaska (geomagnetic latitude 64.5°N). The picture from this station which is just south of the auroral zone is shown in Fig. 2. Here the occurrence of hydrogen emissions[2] shows a single maximum at about 0100 hrs. as does the type "r" E_s. Further type "f" is observed to be a maximum at about 0400 hrs. similar to the occurrence of aurorae[1] shown at the bottom. Thus, at stations on the southern edge of the auroral zone it appears that the two phenomena which were

Table I.

Occurrence of H_β in auroral forms

Type	Time observed (min)	Time H_β detected (min)	Percentage of time H_β present
Rays	629	374	59
Rayed Arcs and Bands	247	126	51
Diffuse Surfaces	192	78	41
Coronas	145	55	38
Homogeneous Arcs and Bands	652	239	37
No Aurora	639	76	12

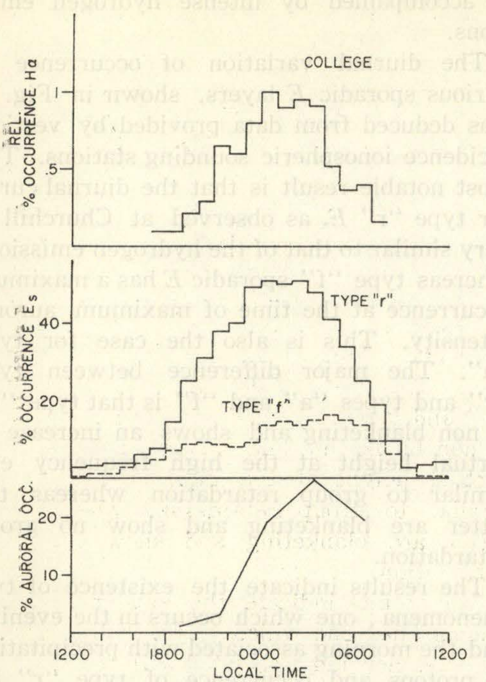

Fig. 2. Diurnal variation of H_α, E_s and aurora measured at College, Alaska.

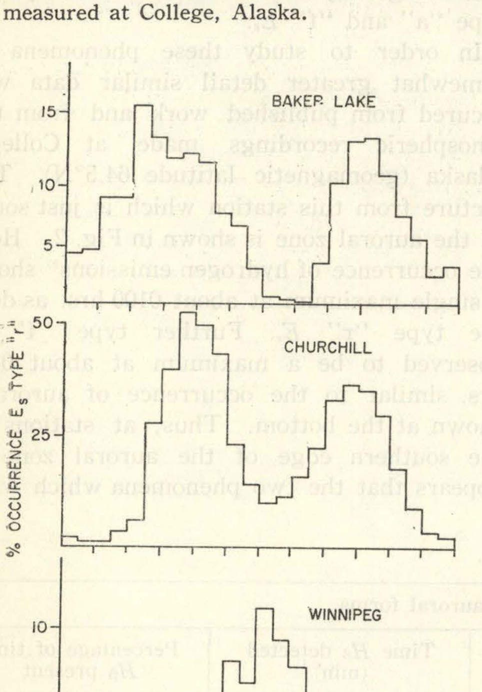

Fig. 3. Variation of type "r" E_s across auroral zone.

well separated in time at Churchill occur more nearly together.

This result is clearly shown in the behaviour of the type "r" E_s across the auroral zone. The diurnal variation of occurrence of this type for stations having approximately the same longitude is shown in Fig. 3. At Baker Lake (φ=73.7°N) the separation of the two peaks of occurrence is greater than at Churchill, while at Winnipeg (φ=58.8°N) the two peaks appear to converge giving rise to a single one.

The double peak in the diurnal variation of H_β observed at Churchill suggested that from this station a motion of the hydrogen emission should be observed in the evening and in the morning similar to observations made by Rees et al[4] at College, Alaska. With this in mind a program was started in 1960 to measure the intensity of H_β in five sectors of a meridional line. In only about 4 out of some 100 occasions was this motion clearly observed; one such case is shown in Fig. 4. Thus, it is concluded that at southern latitude stations this motion is more readily discernible perhaps because the motion takes place over a longer period of time.

The rapid fluctuations of the H_β intensity shown in Fig. 4 occurring just after local midnight coincide with the occurrence of strong visible aurora. It is suggested that at such times the strong emissions are not associated with a large influx of protons but

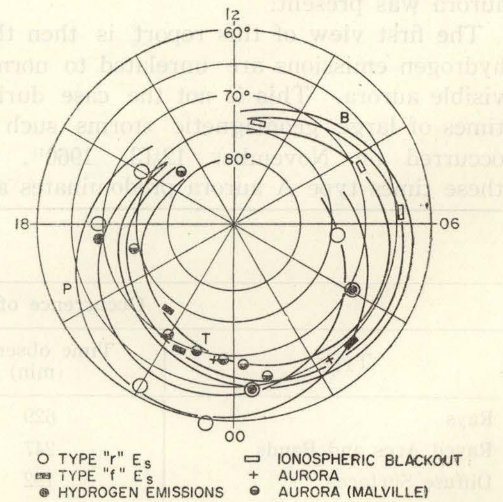

Fig. 4. Variation of H_β intensity across a meridional line over Churchill, Manitoba, for the night of February 27/28, 1960.

rather is due to increased ionization within the auroral forms.

The results presented here may be explained qualitatively on the basis of the earth rotating under a pattern fixed in space. The pattern is shown in Fig. 5 where the times of maximum of occurrence of the various diurnal curves has been plotted. Curve P refers to the zone where protons precipitate and where type "r" E_s occurs most frequently. The mechanism given by Reid and Rees[5] of the solar wind distorting the geomagnetic field on the day side of the earth would give rise to such a zone.

The zone labelled T refers to an area where auroral activity is a maximum and

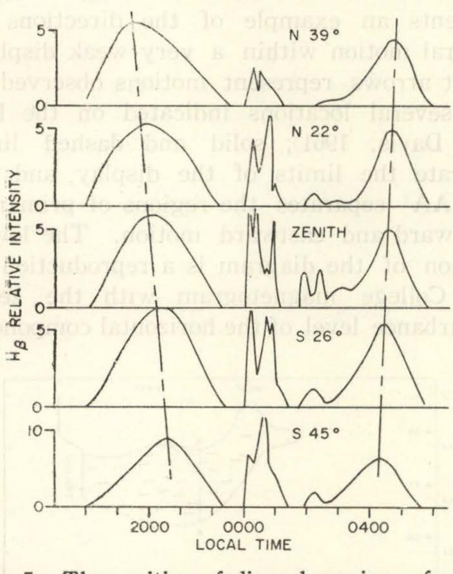

Fig. 5. The position of diurnal maxima of various phenomena in geomagnetic coordinates. *P* refers to hydrogen emissions and type "*r*" E_s. *T* refers to visual aurora and type "*f*" E_s. *B* refers to ionospheric blackouts.

where type "f" and "a" E_s occur most frequently. The times for maximum occurrence of aurora as measured by Malville[6] are also included. This zone corresponds to the turbulent zone suggested by Axford and Hines[7] in their theory of the interaction of the solar wind with the magnetosphere.

The area labelled B is the time when the frequency of occurrence of blackouts is a maximum and suggests that the more energetic particles precipitate to low altitudes at that time forming an ionospheric absorption layer. This data was secured from the November-March 1959/60 ionospheric records.

The pattern shows that for a station such as Churchill the motion of hydrogen emissions would be rapid whereas for College the N–S and S–N motion take place over several hours. As shown in Fig. 3 the N–S motion at Churchill occurred in about 1 hour and the S–N motion was observed in about a 20 minutes interval. In one instance the interval was as short as 10 minutes. At College[4] the motion was observed in a 3–4 hour interval.

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