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Form 101, Part II

Progress for research activities related to the proposal:

Observations with a highly sensitive CCD-based all-sky camera at Eureka, NWT, Canada, near the geomagnetic pole, have revealed numerous instances of faint (20-300 rayleighs) diffuse emission at [OI] 630.0 nm from the *F* region. A survey of the occurrence of these faint diffuse emissions at Eureka during the 1994-95 winter revealed some 20 events. A preliminary study of five events, together with simultaneous interplanetary magnetic field (IMF) and solar wind data from the WIND spacecraft, and precipitating particle data from the DMSP satellites, revealed the following characteristics: emission predominantly at 630.0 nm, sometimes in association with previously- or simultaneously-existing polar arcs, with emissions at other wavelengths (*e.g.,* [OI] 557.7 nm) much fainter and sometimes undetectable; typical occurrence during northward IMF conditions, when the auroral oval has contracted to near 80° geomagnetic latitude in the dusk and dawn sectors; a well-defined sun-aligned poleward boundary of diffuse emission; occurrence in the evening sector, and boundary motion toward the morning sector, for negative IMF B_y, and conversely for positive IMF B_y; and occurrence beyond the poleward limit of particle precipitation associated with the auroral oval, in a region of apparent polar rain precipitation. The results of this preliminary study were reported at the XXI General Assembly of the International Union of Geodesy and Geophysics (IUGG) at Boulder, CO on July 7, 1995 (Steele, 1995).

Objectives: both short and long term:

In the short term, the objective is to extend the study of this phenomenon from five events to the full two winters of Polar Camera data presently available, as well as the further set of data now being acquired at Eureka. In order to clarify the nature of the phenomenon, we will establish statistics on occurrence frequency, intensities and spectral characteristics, and emission morphology and its time evolution. as well as on related phenomena. These include ionization (if any) associated with the faint diffuse emission, the background ionization distribution, and the local ionospheric convection. We will also examine occurrence patterns versus IMF and solar wind conditions and history, and the resulting configuration of the auroral oval and the high-latitude convection pattern.

In the longer term, we seek to establish the excitation mechanism(s) for the diffuse emission (*e.g.*, precipitating particle impact, thermal electron impact, dissociative excitation by plasma recombination). By examining particle precipitation and ionospheric convection data, together with global imaging and incoherent scatter radar observations as they become available, we will be able to locate the diffuse emission regions relative to the auroral oval and the large-scale convection in the winter polar cap, and determine the magnetospheric significance of the Sun-aligned emission boundary and its motions.

Literature review pertinent to the proposal:

Feldstein and Galperin (1985) introduced the term "polar diffuse aurora" to describe a weak optical emission excited by fluxes of soft (< 0.5 keV) electrons poleward of the auroral oval as defined by bright discrete auroras. They provided ample evidence from satellite particle experiments for the existence of a region where such fluxes are common, and referenced the much more limited (statistical) optical evidence

for the resulting emission, chiefly by atomic oxygen at 630.0 nm (Eather and Mende, 1972). They presented a model depicting the commonly observed polar arcs as embedded in this diffuse emission background, a view partially corroborated by subsequent imaging of polar auroras from space (Makita *et al.*, 1991; Austin *et al.*, 1993) and from the ground (Oznovich and McEwen, 1994). However, definitive reports of polar diffuse aurora are lacking in the literature, perhaps due to the expected low brightness of the emissions. The proposed work will assess the connection, if any, between the emissions observed at Eureka and those predicted by Feldstein and Galperin (1985), from the multiple viewpoints of optical, particle, and ionospheric measurements. Confirmation of this specific prediction would provide needed evidence for choosing between two distinct and fundamentally incompatible mappings between the auroral oval and the magnetosphere (Winningham *et al.*, 1975; Feldstein and Galperin, 1985).

Ground observations of individual events of diffuse aurora at Eureka (Oznovich and McEwen, 1994; Steele, 1995) have revealed its dynamics to be only loosely coupled to those of simultaneously observed polar arcs, which are becoming increasingly well understood in relation to the ionospheric convection pattern for northward IMF (Reiff and Burch, 1985; Crooker, 1992; Cumnock *et al.*, 1995). However, the statistical picture of Valladares *et al.* (1994) shows both dawnward and duskward arc motions near the geomagnetic pole, with the motions directed toward a Sun-aligned boundary located duskward of the pole for IMF $B_y > 0$ and dawnward for $B_y < 0$. Thus, an imager at the pole would observe arcs drifting in the direction of the IMF y component, consistent with the observed diffuse emission boundary drifts.

There exists little consensus as to whether polar arcs (and, by implication, polar diffuse aurora) occur on open (Weiss *et al.*, 1993; Gussenhoven *et al.*, 1990) or closed (Frank *et al.,* 1986; Austin *et al.*, 1993) field lines. The latter identification is usually made on the basis of particle precipitation extending from the normal location of the auroral oval poleward to, and sometimes beyond, the location of the polar arc (Makita *et al.*, 1991; Austin *et al.*, 1993). Precipitating particle measurements accompanying satellite images of diffuse emissions in the polar cap have been interpreted as beng on closed magnetospheric field lines, usually on the basis of spectral similarities between the measured particles and those found on closed field lines in the auroral oval (Makita *et al.*, 1991). An unambiguous identification of closed field lines requires pitch angle coverage spanning both loss cones, which has not always been available.

Diffuse auroral emission in the central polar cap cannot be explained on the basis of convection shears (Valladares and Carlson, 1991) as such shears are too small to account for emissions over dawn-dusk distances of a few hundred kilometers. As well, the faintness of the emissions, the relative absence of other emissions (*e.g.,* [OI] 557.7 nm), and direct measurements of the precipitating particle spectra from polar-orbiting satellites, all indicate an unaccerated electron population if, in fact, precipitating particle impact is responsible for the observed emission. Thus, a mechanism distinct from shear-induced electron acceleration must be responsible for the characteristic features of the emission distribution.

Weiss *et al.* (1993) observed no increase in ionization associated with faint polar arcs excited by electron precipitation below 100 eV energy, although a marked increase in electron temperature was observed. This suggests that the polar diffuse auroras to be investigated may not possess an ionization signature, and may thus be undetectable by ionosondes. However, the SSIES instrument package aboard the DMSP spacecraft includes a Langmuir probe to measure electron temperatures, so measurement of an enhanced electron temperature above a diffuse emission region will indicate excitation by particle impact.

Methods and proposed approach:

Statistics on occurrence frequency, intensities and spectral characteristics, and emission morphology and its time evolution will be determined from the existing and newly acquired Polar Camera image data from Eureka. These will be supplemented as necessary with University of Saskatchewan meridian scanning photometer (MSP) data from Eureka. In particular, the relation between diffuse emission and neighbouring polar arcs will be investigated. In addition, Canadian Advanced Digital Ionosonde (CADI; MacDougall *et al.*, 1994) data from Eureka will be used to generate statistics on ionospheric effects such as ionization (if any) associated with the faint diffuse emission, the background ionization distribution, and local ionospheric convection. A search will be made of University of Tokyo magnetometer data for evidence of ionospheric currents associated with the diffuse emission, although these are not expected *a priori*. DMSP particle data (courtesy of E. J. Weber, US Air Force Phillips Laboratory) and IMF and solar wind data from the WIND spacecraft (obtained from the International Solar-Terrestrial Physics (ISTP) program Central Data Handling Facility (CDHF)) will be surveyed to extend the statistics on occurrence versus IMF and solar wind conditions and history, and the resulting configuration of the auroral oval. Super Dual Auroral Radar Network (SuperDARN) convection maps (courtesy of G. J. Sofko, P.I.) will be surveyed to provide the large-scale convection pattern during the events.

In the longer term, efforts will be directed toward establishing the excitation mechanism(s) for the diffuse emission using the ground-based optical (and ionosonde) data together with both precipitating particle and ionospheric electrodynamics data from the DMSP satellites (and others such as the ISTP Polar and NASA FAST spacecraft as they become available). Examination of particle precipitation patterns and ionospheric convection data from the DMSP satellites should allow us to locate the diffuse emission regions relative to the auroral oval and the large-scale convection in the winter polar cap, and to determine the magnetospheric significance of the Sun-aligned emission boundary and its motions. The latter questions can be addressed much more definitively with particle data covering the full pitch angle distribution, as well as Birkeland current measurements. Polar and FAST, both in polar orbits, are due to be launched within the next 12 months, and their data, meeting the above criteria, should become available as the proposed study enters its second phase. In addition, ground-based imagers at other sites (notably Qaanaaq and Sondre Stromfjord) may prove useful in the short term in enlarging the picture of the polar cap provided by Polar Camera images. Global auroral images from the Visible Imaging System (VIS) and Far Ultraviolet Imager (FUI) on board Polar, and potentially from the Ultraviolet Auroral Imager (UVAI) on the Interball Auroral Probe spacecraft, will provide a clear picture of the polar cap emission distribution above a certain threshold. Current plans call for the U.S. Polar Cap Observatory at Resolute Bay to be equipped with an incoherent scatter radar by the second phase of the proposed work; if so, this would be an extremely powerful tool for determining convection, plasma temperatures, and vertical ionization profiles over a large area, possibly including the Eureka zenith.

Anticipated significance of the work:

If the observed emission is found to be excited by particle impact, it will allow imaging of structure in the soft electron precipitation heretofore measurable only in one dimension from satellites, and enable study of the dynamics of this soft precipitation with the temporal and spatial resolution possible only with ground-based instruments. It will provide important confirmation of the alternate mapping between the

auroral oval and the magnetosphere proposed by Feldstein and Galperin (1985), and yield new insights into the behaviour of the boundary layers where solar wind plasma enters the magnetosphere. If the measured precipitation proves to be inadequate to account for the observed emission, but elevated electron temperatures indicate a particle impact source, this would be evidence of significant heat flux from the magnetosphere, the explanation of which would be a challenging problem. Discovery of a role for ionospheric dynamics in the excitation of the emission would also open a new window for study of the polar ionosphere.

Training aspect of the proposal:

The research proposed herein is envisaged as being carried forward by a M.Sc.-level student in the first phase, under the co-supervision of D.P. Steele and a tenured faculty member. The work will involve analysis of a variety of diverse data sets from both ground and space platforms, and collaborative interaction with the wider community of space physicists. Both of these aspects of the research will provide valuable experiences and opportunities for the student involved in the research. Knowledge of more than one type of experimental data will position the student to take advantage of the full range of opportunities for further study, and will allow the student to demonstrate his or her ability to assimilate data from diverse sources and synthesize a unified picture of the physics involved. Especially in the second phase of the work, the student will be making contacts and developing working relationships with leading space scientists, thereby gaining valuable experience in the practical aspects of coordinating effort among diverse cooperating groups of scientists in pursuit of a joint goal. This mode of interaction is clearly the most fruitful means of advancing scientific knowledge in a field such as space physics. For these reasons, funds have been requested in each phase to support the student on an extended (1 week) visit for collaborative purposes, and to allow the student to attend a major conference, to present his or her results to the scientific community.

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