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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, with a view to establishing statistics on occurrence frequency, intensities and spectral characteristics, and emission morphology and its time evolution, as well as on related phenomena such as ionization (if any) associated with the faint diffuse emission, the background ionization distribution, local ionospheric convection, and on occurrence versus IMF and solar wind conditions and history, and the resulting configuration of the auroral oval.

In the longer term, efforts will be directed toward establishing the excitation mechanism(s) for the diffuse emission (precipitating energetic particle impact excitation, thermal electron impact excitation, dissociative excitation by plasma recombination). Examination of particle precipitation and ionospheric convection data should allow the diffuse emission regions to be located relative to the auroral oval and the large-scale convection in the winter polar cap, and the magnetospheric significance of the Sun-aligned emission boundary and its motions to be determined.

Literature review pertinent to the proposal:

Polar arcs are believed to be excited chiefly by precipitating electrons which carry the upward Birkeland currents needed to maintain current continuity in regions of ionospheric current (and electric field) convergence (Valladares and Carlson, 1991). The structure of ionospheric convection for northward IMF is dependent on the season, the sign and magnitude of all three components of the IMF, and the position within the polar cap (Cumnock *et al.*, 1995), and from one to four convection cells can exist.

Theory indicates that such cells may include closed field lines ("viscous" cells), open field lines ("lobe" cells), or both ("reclosure" cells) (Reiff and Burch, 1985), generated by complex interactions between the IMF and the magnetospheric magnetic field (*e.g.,* Crooker, 1992).

Statistically, in the northern hemisphere polar arcs bright enough to be imaged from space form preferentially in the dawn sector for IMF $B_y < 0$ conditions (IMF "toward"), and in both the dawn and dusk sectors when $B_y > 0$ (IMF "away") (Elphinstone *et al.*, 1990). However, Valladares *et al.* (1994) observed no clear separation for subvisual polar arcs observed poleward of 80° geomagnetic latitude, seeing instead a marked preference for arc appearance in the dawn sector. They observed both dawnward and duskward arc motions, irrespective of the sign of IMF B_y, with the motions directed toward a Sun-aligned boundary located duskward of the geomagnetic pole for IMF $B_y > 0$ and dawnward for $B_y < 0$. Thus, except for very small B_y, an imager at the pole would observe arcs drifting in the direction of the IMF y component. This is consistent with the observed diffuse emission boundary drifts.

There exists little consensus as to whether polar arcs occur on open (Weiss *et al.*, 1993; Gussenhoven *et al.*, 1990; Gussenhoven and Brautigam, 1994) or closed (Murphree *et al.*, 1981; Frank *et al.,* 1986; Austin *et al.*, 1993) field lines. The latter identification is usually made on the basis of observations that particle precipitation extends 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; Feldstein *et al.*, 1995).

The existence of diffuse, rather than discrete, auroral emission in the central polar cap cannot be explained on the basis of convection shears, as the observed extent of such shears is 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 distinct mechanism must be responsible for the characteristic features of the emission distribution.

There have been numerous satellite observations of "diffuse" emissions in the polar cap, typically associated with bright polar arcs (Murphree *et al.*, 1981; Frank *et al.*, 1986; Austin *et al.*, 1993). Measurements of the precipitating particles exciting the diffuse emissions, when available, have been interpreted as placing the particles on closed magnetospheric field lines, usually on the basis of spectral similarities between the measured particles and those observed to precipitate 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, and this has not always been available. The clearest ground-based observation of polar diffuse auroral emission was obtained by Oznovich and McEwen (1994) from Eureka. Their results from a single event corroborate many of the polar diffuse auroral characteristics observed thus far by the Polar Camera at Eureka, although the emission brightnesses were higher than those typically observed by the Polar Camera.

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, 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* (see below). 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 for latitudes up about 85° geomagnetic latitude, 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 (precipitating energetic particle impact excitation, thermal electron impact excitation, dissociative excitation by plasma recombination) using the optical (and ionosonde) data together with both precipitating particle and ionospheric electrodynamics data from the DMSP satellites (and others such as Polar and FAST as they become available). Examination of particle precipitation patterns and ionospheric convection data from the DMSP satellites should allow the diffuse emission regions to be located relative to the auroral oval and the large-scale convection in the winter polar cap, and the magnetospheric significance of the Sun-aligned emission boundary and its motions to be determined. The latter questions can be addressed much more definitively with particle data covering the full pitch angle distribution, as well as Birkeland current measurements. The ISTP Polar spacecraft and the NASA FAST spacecraft, both in polar orbits, are due to be launched within the next 12 months, and their data, which meet 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. The U.S. Polar Cap Observatory at Resolute Bay may 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 reveal previously unobserved structure in the soft electron precipitation, heretofore measured only by satellite instruments during occasional overflights, and enable study of the dynamics of this soft precipitation with the temporal and spatial resolution possible only with ground-based instruments. Such soft precipitation is associated (in one way or another) with the boundary layers of the magnetosphere, where plasma is entering from the solar wind, and observations of the dynamics of soft particle precipitation at very high latitudes should yield insights into processes in these boundary layers. 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, although a source for such a heat flux is difficult to envisage, *a priori*.

Training aspect of the proposal:

The research proposed herein is envisaged as being carried forward by a M.Sc.-level student, at least 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 interaction with the wider community of space physicists. Both of these aspects of the research will provide valuable experiences, as well as opportunities, for the student involved in the research. Experience with 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 learning not only the conduct of top-flight science, but gaining valuable experience in the practical matters of coordinating efforts toward a joint goal among diverse cooperating groups of scientists. This mode of interaction is clearly the most fruitful means of advancing scientific knowledge in a field such as space physics, where the coordinated, cooperative efforts of many scientists are frequently required to acquire, assimilate, and digest sufficient data to characterize the phenomena of interest. 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 larger community.

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