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IMAGING AND PHOTOMETRIC OBSERVATIONS OF PROTON AURORA DYNAMICS AT SYOWA STATION, ANTARCTICA

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Abstract: Using aurora data obtained with a multicolor all-sky imaging system (MAIS) and a tilting-filter photometer at Syowa Station (invariant magnetic lat., $-66.1°$), Antarctica, we have investigated the dynamics of proton auroras (Hβ emissions) and its relation to electron aurora dynamics. An all-sky SIT camera was also operated to monitor electron auroras. We obtained 4300 proton aurora images with MAIS on 29 nights in the period from May 1992 to September 1992. These data cover the magnetic local time sector from 14 h to 4 h and include various types of proton auroras in different substorm phases. It is found that when bright N-S auroras are seen in the bulge formed in an auroral breakup event, the region of proton aurora contracts poleward as the electron aurora in the bulge fades out, while when there are no N-S auroras in the bulge, the proton aurora remains equatorward.

1. Introduction

Proton aurora dynamics during auroral substorms has been investigated by means of meridian-scanning photometers or spectrograms (MONTBRIAND, 1971; FUKUNISHI, 1975; VALLANCE-JONES *et al.*, 1982). Since their observations were limited to the local meridian plane, data obtained on different nights and at different local times were collected in order to make a morphological diagram of a proton aurora substorm. Although imaging observations of proton aurora are quite useful in understanding of proton aurora dynamics, especially related to east-west motions, only a few studies have been done using proton aurora image data (MENDE and EATHER, 1976; ONO *et al.*, 1987). This is mainly because proton auroras are very weak compared with the electron auroras and are significantly affected by contamination from electron auroras and other background emissions. We have developed a new-type monochromatic imaging system and carried out Hβ emission observations on 29 nights. The background contamination was precisely corrected and many distinctive features in proton auroras were found.

2. Instrumentation

A newly developed multicolor all-sky imaging system (MAIS) can obtain monochromatic all-sky images at two different wavelengths simultaneously and has a filter turret containing of 6 pairs of filters. Two pairs of filters are prepared for proton aurora observatons, *i.e.*, 486.1/481.8 nm for Hβ and background measurement, and 484.0/557.7 nm for Doppler-shifted Hβ and electron aurora measurement. The full width half maxima of these filters are 1.8, 2.0, 1.8, and 2.0 nm, respectively. Rotation of the filter turret, shutter open-close, and data acquisition are automatically controlled by a personal computer. An accumulation time of 27–134 s is required to obtain one Hβ proton aurora image. Subtracting the background image from the Hβ image, we can easily make background corrections and obtain true proton aurora images without contamination from electron aurora and Milky Way emission.

A tilting-filter photometer which scans the range from 482.5 to 488.5 nm in the magnetic zenith direction provides information on Doppler-shifts of Hβ emissions every 30 s. The average energy and pitch angle distributions of incident protons can be estimated from the Doppler-shift and Doppler-broadening of Hβ emissions. An all-sky SIT camera was also operated to monitor rapid motions of electron auroras. The exposure time is 1/30 s par video frame shot.

3. Results

We obtained 4300 proton aurora images with MAIS on 29 nights in the period from May 1992 to September 1992 at Syowa Station, Antarctica (invariant lat.: $-66.1°$). These data cover the magnetic local time sector from 14 h to 4 h and include various types of proton aurora in different substorm phases. The magnetic local time at Syowa Station roughly coincides with universal time (UT). It is found that the types of proton auroras and the values of Doppler-shifts are dependent on phase of substorms and type of electron auroras. One of the most important proton aurora features was observed in westward traveling surges or bulges expanding poleward (or westward). One typical breakup event observed in the premidnight sector is reported in this paper.

All-sky images obtained with an SIT camera (F.O.V. $=180°$) on July 1, 1992 are shown in Fig. 1; they represent mostly emissions from electron auroras. The exposure time of each image is 1/30 s and observation time in UT (hh mm ss) is indicated on each image. Magnetic south (poleward) is the up side and east is the right side. All-sky images observed in the Hβ emission line in the same period with MAIS (F.O.V. $=170°$) are displayed in Fig. 2. Background contamination, van-Rhijn effect and atmospheric extinction are corrected in all images obtained with MAIS. The accumulation time for each image is 34 s and the exposure interval is 135 s. Figure 3 shows peak intensities (solid line) and Doppler-shifts (open circle) measured by a tilting-filter photometer fixed in the magnetic zenith direction. The intensity scale (right side) is linear but diplayed in an arbitrary unit.

At the beginning of Fig. 2 proton auroras are seen in the equatorward region. That is, the center of the proton aurora belt lies equatorward of Syowa Station. At the beginning of Fig. 1 an east-west aligned electron aurora arc, which is separated from the poleward boundary of the proton aurora belt, is enhanced, but the proton

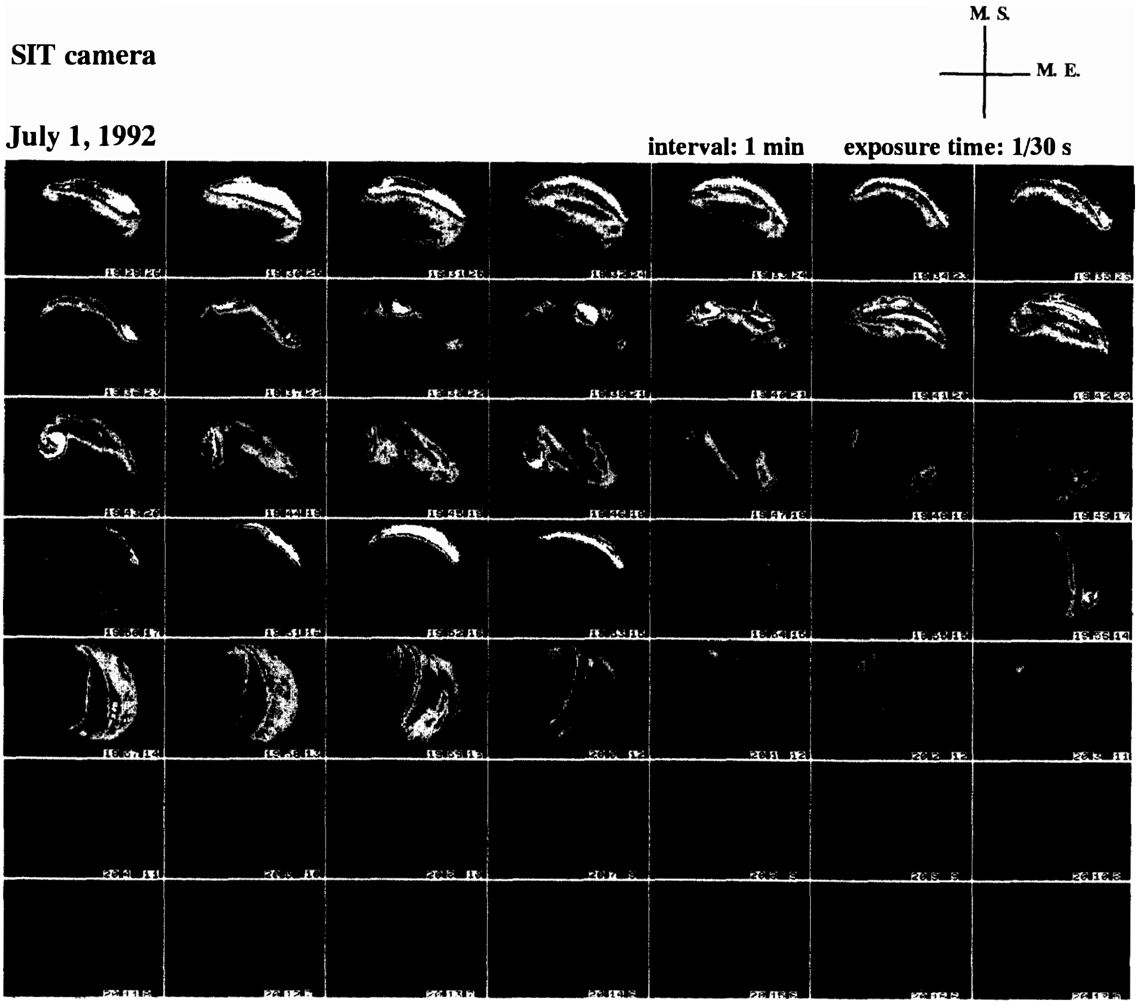

Fig. 1. All-sky images obtained with an SIT camera (F.O.V. = 180°) on July 1, 1992. These images represent mostly electron auroras. The exposure time is 1/30 s and the observation time (hh mm ss) is indicated in UT on each image (time interval; ~1 min). Magnetic south (poleward) is the up side and east is the right side.

aurora shows no remarkable enhancement until 1939 UT. From 1941 UT to 1948 UT an intense proton aurora region emerges poleward of the pre-existing proton aurora belt. Around 1939 UT a surge structure appears in the east-west aligned electron aurora arc. The proton aurora intensity is enhanced in the surge region and equatorward of it and the proton aurora region expands westward as the electron aurora surge structure moves westward. The most intense portion of the proton aurora remains equatorward until the electron aurora in the surge becomes weak at 1950 UT.

At 1950:17 UT a very intense electron arc comes from the southeast into the field of view of the all-sky SIT camera. The arc alignment rotates clockwise from east-west to north-south. Note that in this period the sensitivity of the SIT camera was reduced depending on auroral luminosity enhancement. It is found that in the period from 1955:14 to 2000:12 UT there are some north-south directed arcs, so called N-S auroras, within a diffuse electron aurora region and that these arcs move

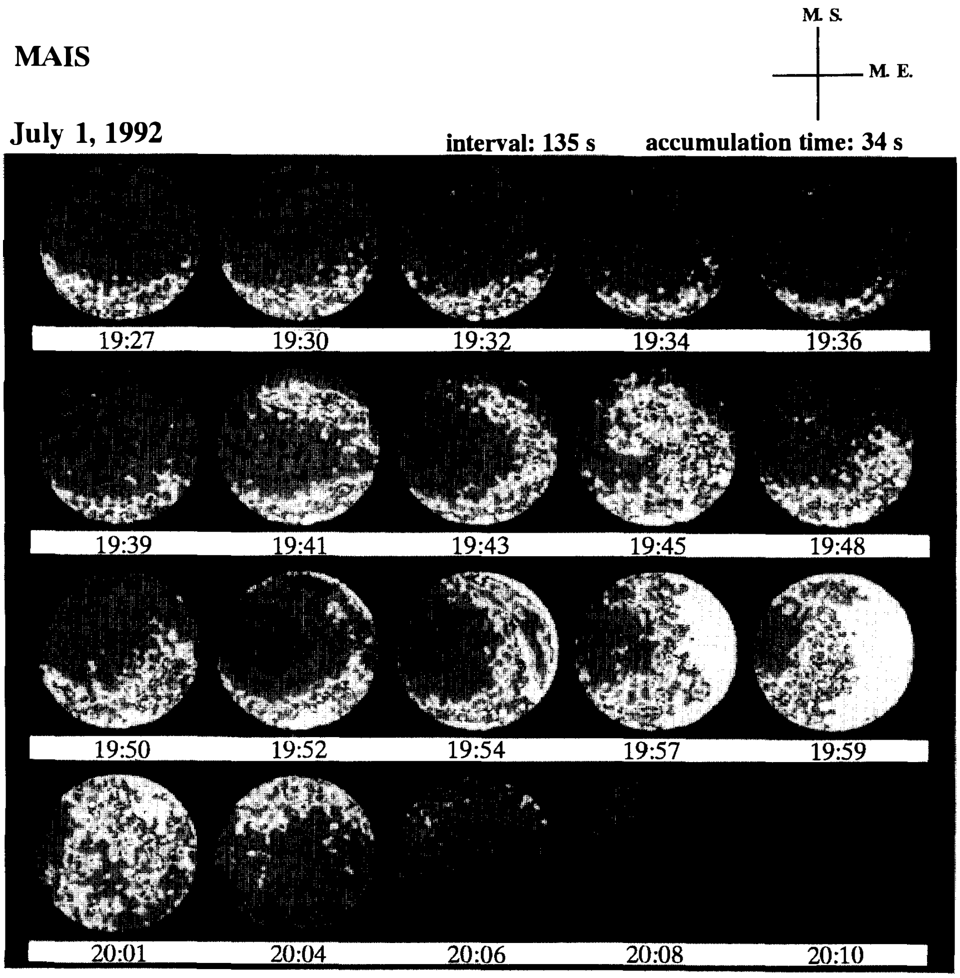

Fig. 2. All-sky images of Hβ emission observed with MAIS (F.O.V. = 170°). Background contamination, van-Rhijn effect and atmospheric extinction are corrected in all images. The accumulation time in each image is 34 s and the interval between exposures is 135 s.

westward. After 2001:12 UT they become weak and diffuse. As an important feature, proton aurora intensity is found to be significantly enhanced in the N-S aurora region and the westward boundary of the proton aurora region is found to be roughly aligned to the direction of the N-S electron auroras. Note that on the MAIS image at 1954 UT the intensity of the most active portion is saturated and the gray scale display is incorrect. After the maximum activity, the proton aurora region contracts poleward within a short period (~10 min).

Figure 3 shows that though the emission intensity is relatively large before 1920 UT, the Doppler-shift is fairly small (~0.4 nm). These values of the Doppler-shift are rather small compared with the values obtained from former observations. EATHER and JACKA (1966) concluded that the Doppler-shift remained fairly constant at 0.6 ± 0.1 nm (for Hβ) over a wide range of conditions of Hβ intensity and auroral and magnetic activity. As seen in Fig. 3, the scatter of Doppler-shift becomes large after 1935 UT. Since the error in Doppler-shift estimation is expected

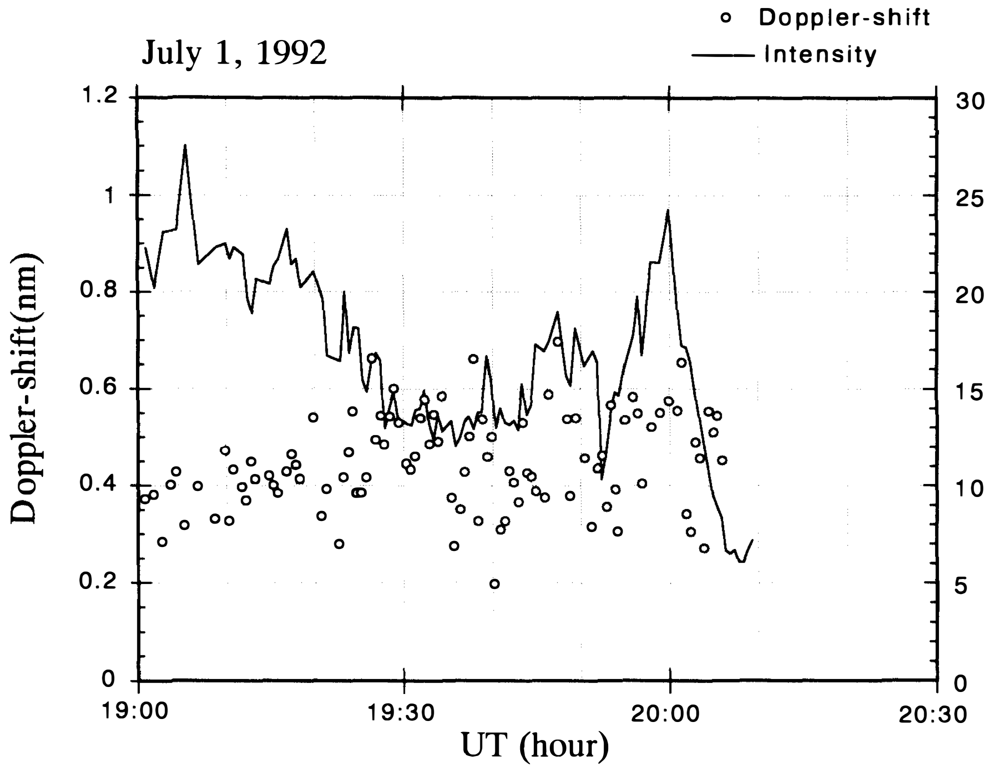

Fig. 3. Intensities of Hβ emission (solid line) and Doppler-shifts (open circle) in the magnetic zenith direction which were derived from tilting-filter photometer data. The intensity scale (right side) is linear but displayed in an arbitrary unit.

to be less than ±0.1 nm, the variation in Doppler-shifts suggests changes of plasma condition in the source region. The amplitude of the Doppler-shift of the emission depends on the energy and pitch-angle distribution of incident protons, while the brightness of the emission depends on the flux and energy of the incident protons. Around 1946 UT and 2000 UT the intensity becomes large which is consistent with MAIS observation. At these times the Doppler-shift is ~0.6 nm or more. The present analysis, based on data on 29 nights, suggests that the Doppler-shift becomes large (0.6–1.0 nm) when a westward traveling surge or an N-S aurora structure passes the field of view of the tilting-filter photometer.

We have concluded from 23 event studies that auroral breakup events can be categorized into two cases. When bright N-S auroras are seen in the bulge, the region of proton aurora contracts poleward as the electron aurora in the bulge fades out, while when there are no N-S auroras in the bulge, the proton aurora region remains mainly on the equatorward side. These phenomena seem to be associated with different particle injection mechanisms during substorms.

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