# Simultaneous observations of proton auroras from South Pole and from the IMAGE satellite

S. B. Mende, H. U. Frey, Space Science Laboratory, University of California, Berkeley

Abstract. A special purpose four wavelength channel (488.0, 485.5, 484.5 and 427.8 nm) all sky camera was operated at South Pole Station Antarctica to observe proton precipitation. From the four wavelength simultaneous images it is possible to image the proton aurora unambiguously. The Keograms of the 4 wavelengths show the regular pattern of auroral precipitation at South Pole in which at midnight the auroral oval is generally equatorwards of the station and at midday it is generally poleward with two local time regions when the aurora over-crosses the station in the dawn and dusk periods. Protons are regularly most intense during the period of dusk over-crossing. During a typical day, i.e. the Keogram taken on 5/31/2005, showed that in addition to the dusk overcrossing there was a latitudinally distinct soft proton precipitation that occurred in the pre-midday local time region. Although this region was in the IMAGE SI-12 proton imager's field of view it was not seen by the imager. On the other hand the similar intensity proton aurora taken during the auroral over-crossing in the dusk local time region was clearly seen by both instrument. This observation verifies that the ground based observations of the proton precipitation has an advantage when it comes to detecting very soft proton precipitation features because the space based cameras have to reject geocoronal Lyman alpha and they are less likely to detect Lyman alpha created by soft (<1 keV) dayside protons.

## Introduction.

A special purpose camera was deployed at South Pole station to observe cusp hydrogen precipitation. This camera was operated during the winters of 2004 and 2005. During these periods the IMAGE satellite had its apogee in the Southern hemisphere approaching –90 degrees in 2005.

The hydrogen aurora (proton) imager produces 4 simultaneous exposures in four wavelengths band. We get therefore four complete two dimensional images of the sky in 20 Angstrom wide filters centered at 488.0, 485.5, 484.5 and 427.8 nm. Note that the band centers are selected to allow for the shorter wavelength (bluer) Doppler shifted Hydrogen emission through the filter. The non-Doppler shifted Balmer Beta (Hbeta) line is at 486.1 nm and the 488 filter does not pass it. Therefore this channel is used as a background channel intended to be subtracted from the active Hbeta channels. The next channel the 485.5 channel is centered on moderately blue Doppler shifted Hbeta and includes the line center of the non-Doppler shifted emission. The next, the 484.5 channel is only responding to significantly Doppler shifted emission and therefore it is observing the light created only by faster more energetic protons. The last channel measures the 1$^{st}$ negative of N2+ a significant emission in all aurora. This emission is used as an additional cautionary background measure because we realize that in the presence of very strong electron aurora it may not be possible to observe the Hbeta emission due to contamination either by some otherwise weak Vegard Kaplan and other bands excited by intense particle precipitation or by leakage through the interference filter.

To survey a complete 24 hour data set keograms were made. An example of such a Keogram is shown on Figure 1 for the data taken on the 31st of May, 2005.

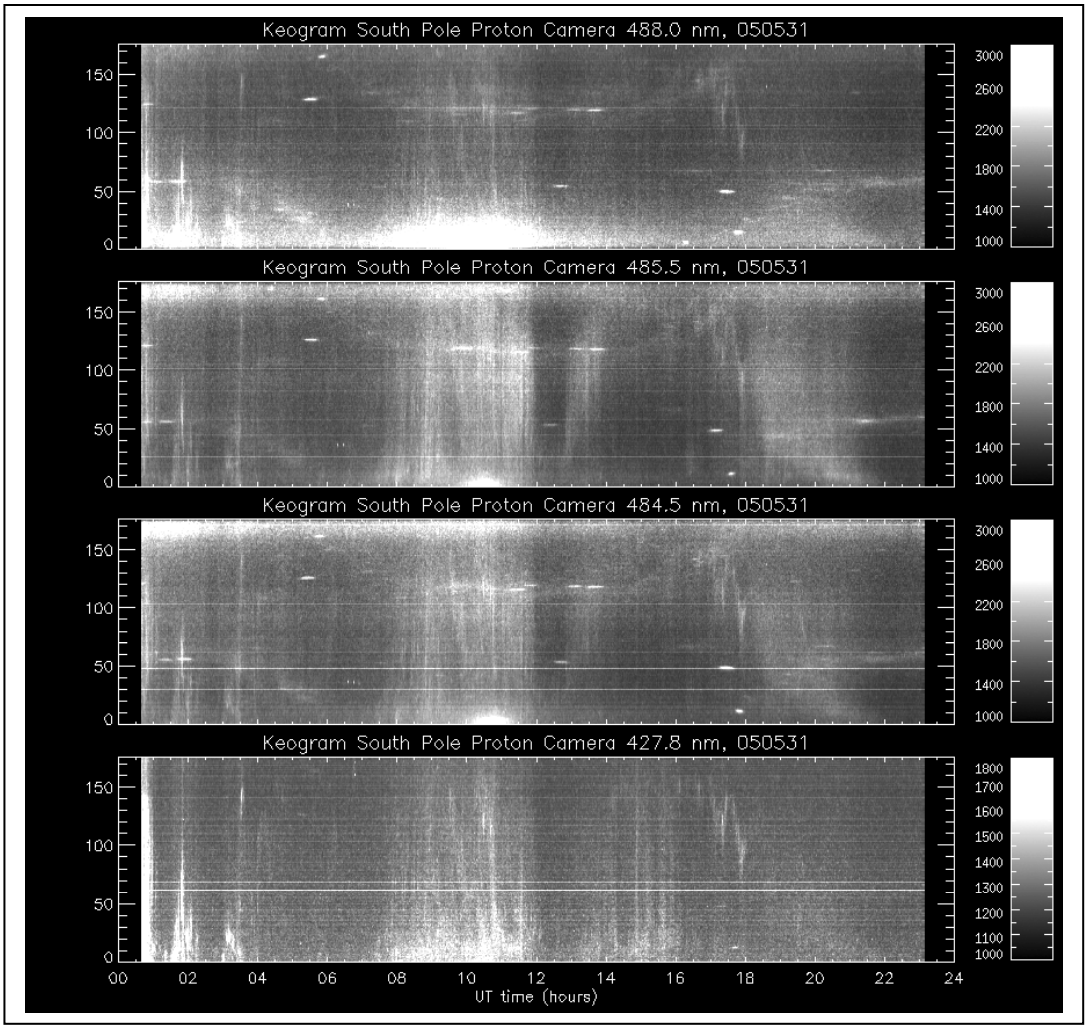


Figure 1. Keogram for May 31, 2005. The four wavelength channels are displayed under each other. Proton auroral features should show only in channels 2 and 3.

The Keogram on figure 1 is a typical Keogram obtained with the South Pole proton camera. Midnight magnetic local time is at 0330 UT. At this time the proton and generally all other auroras are below the equatorward horizon except when intense substorm poleward expansions occur. We see three examples of that centered at ~00:00, 01:45 and 03:20. Usually the auroral oval over-crosses at magnetic dawn (9:30 UT) and is mostly poleward of the station at midday to return equatorward during magnetic dusk (21:30 UT) local time. On the day shown here we see a patch of proton auroras that appear 12:45 UT and last until about 14:00. We know that these are proton auroras because there is no sign of this feature in the first (background) frame and there is no response in the 427.8 nm channel either. It should be noted that this patch is most pronounced in the 485.5 low energy proton channel and it is weaker in the more Doppler shifted 484.5 channel. It is therefore produced by low energy proton precipitation.

There is another time period when there is extensive proton precipitation. This starts around 1800 UT and ends about 21:30 and is associated with the over-crossing of the auroral oval towards the equator. This is a broad diffuse zone of proton precipitation and it is almost equally bright in the 485.5 and 484.5 channels. This signifies that this patch is harder precipitation. In the following presentation we will discuss the two regions separately.

**The pre-midday proton aurora as sen by South Pole and IMAGE SI-12.**

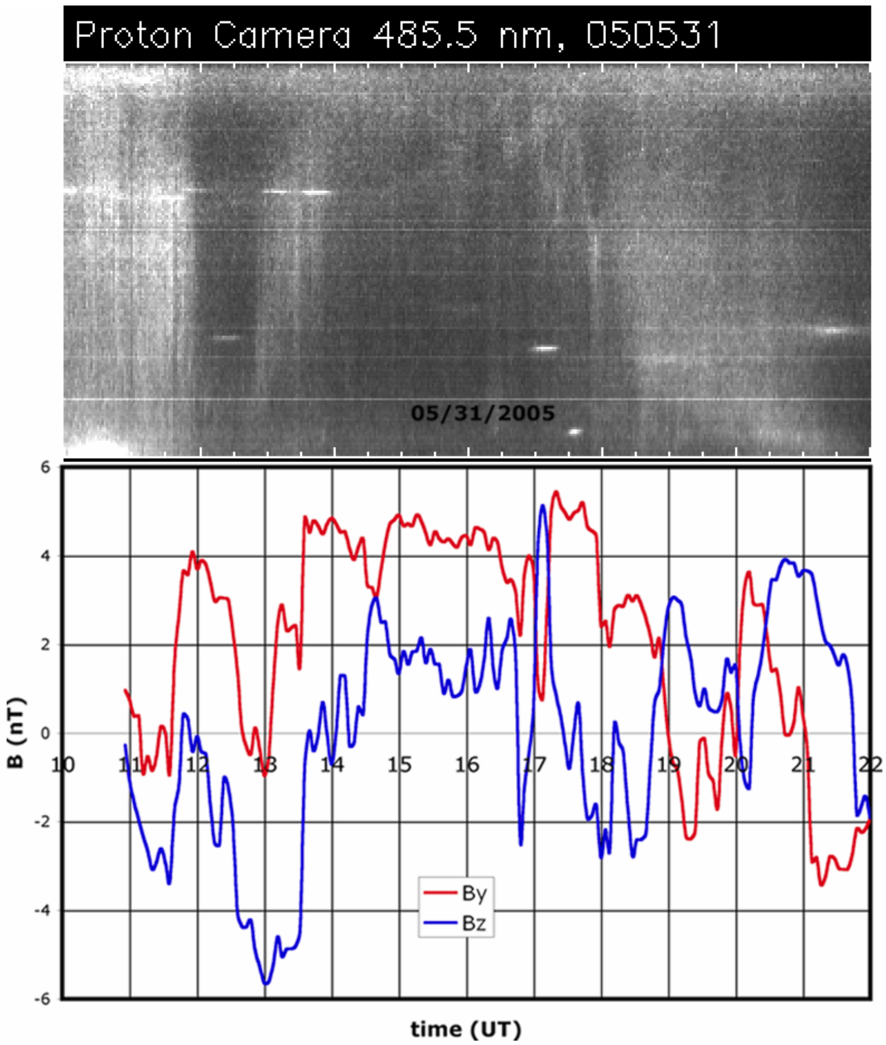


Figure 2. Enlargement of the Keogram of Figure 1 with the 2 components of the IMF field shown below.

In Figure 2 we show the 485.5 Keogram with the IMF field shown below. The IMF field is the ACE magnetic field data suitably delayed by 57 minutes calculated from the solar wind speed and from ACE to Earth distance. This calculation was double checked by using GEOTAIL magnetic field data which confirmed this delay. The bottom line is that the first proton event started during a Bz negative period and the field switched to Bz positive. The By component was zero at the beginning and became fairly strongly positive through the event.

After 13:30 UT Bz turned positive (~+2 nT) and the auroral oval moved to the poleward horizon.

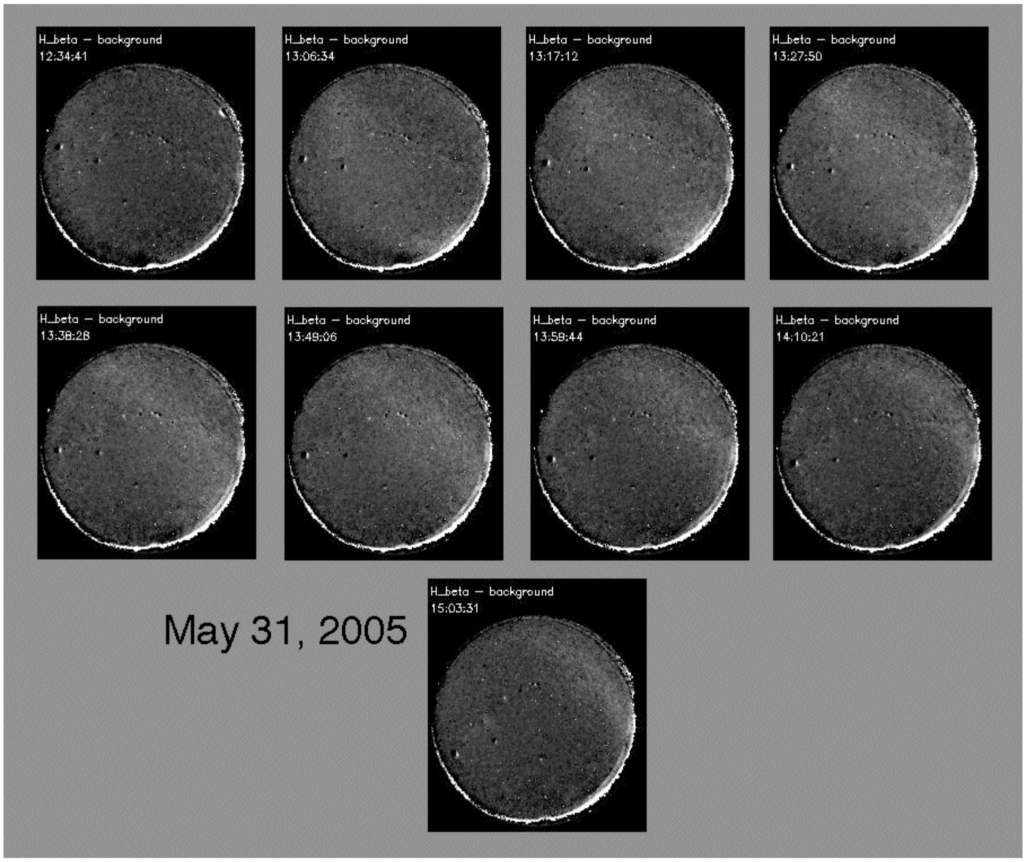


Figure 3. Proton images taken at South Pole 12:34, 13:06, 13:17, 13:27, 13:38, 13:48, 13:58, 14:10 and 15:03. In agreement with the Keogram the proton precipitation starts just after 13:00 where it occupies the lower half of the field. It slowly moves poleward and by 14:10 it occupies the poleward and right edge of the sky. The small spots in the images are mostly stars.

On Figure 3 the proton images were presented. These images are obtained using the 485.5 nm channel and subtracting the background channel. In reality the process is much more complex involving a field flattening normalization which is derived from multiple exposures during times when there is no aurora in the field of view. The night sky glow produced by scattered starlight and other diffuse atmospheric sources is a significant component of the image signal. It was necessary to remove any non-uniformities in this this backgroun prior to the subtraction of the background channel images from the Lyman alpha (chnnel 2 and 3).

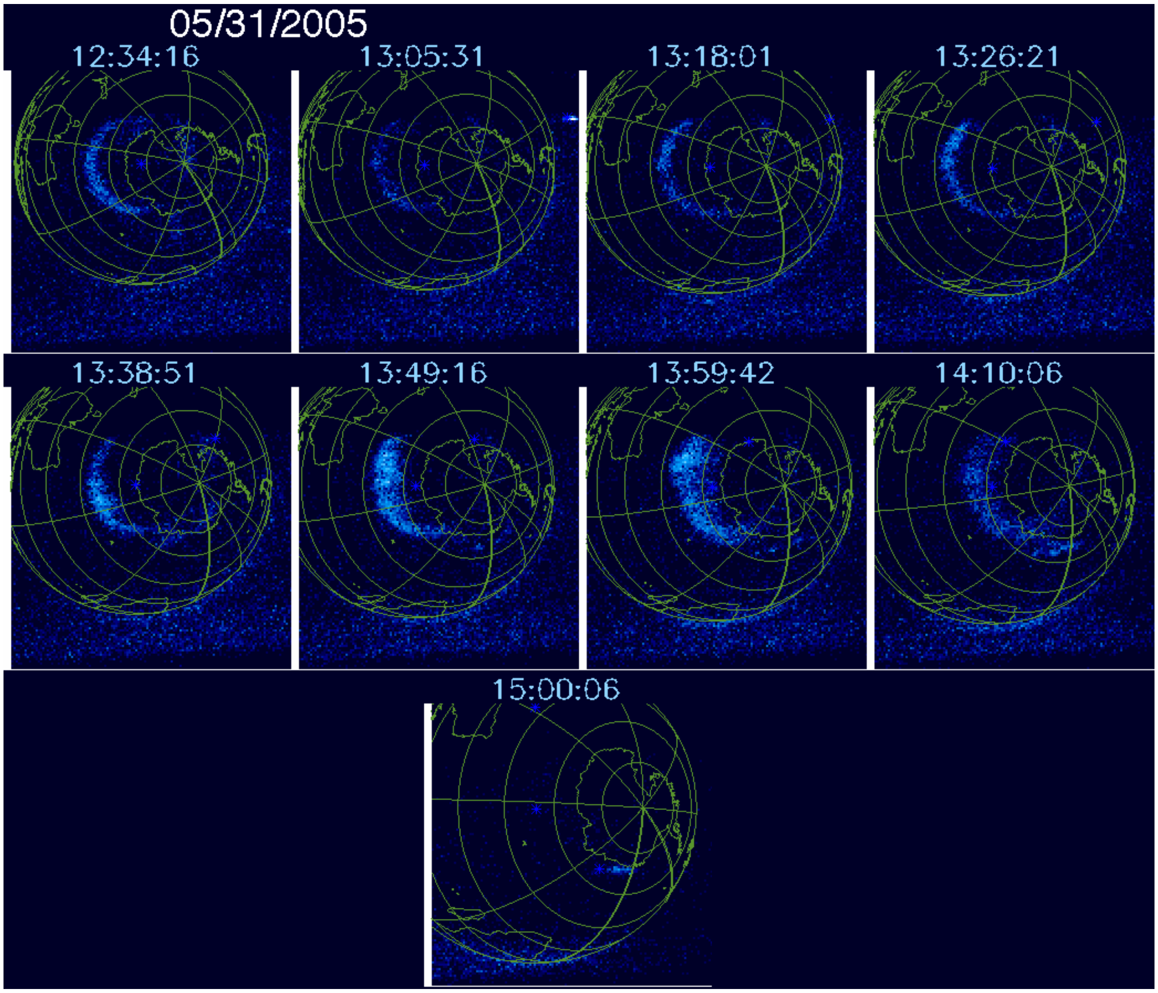


Figure 4. The auroral oval in Doppler shifted Lyman alpha emission as seen from the IMAGE satellite with the SI-12 imager. These views provide an unambiguous description of the global coverage of the IMAGE instrument. The absence of proton aurora at South Pole is evident.

On figure 4 we present the simultaneous IMAGE views of the aurora. From these images we can use the geographic map frame to see that the IMAGE spacecraft does not see the proton aurora seen from the ground at South Pole station.

Figure 5 is a collage of the same data as on Figure 4 except that it was projected into a magnetic latitude (ML) magnetic local time frame. In this presentation South Pole is “rotating” counter clockwise and we have indicated its position with an orange dot on 3 of the frames presented. In all the frames except the last one taken at 15:00:06 there is substantial proton aurora in the afternoon and evening sector. South Pole is in the pre noon region. There is hardly any or minimal aurora observed at the region of South Pole.

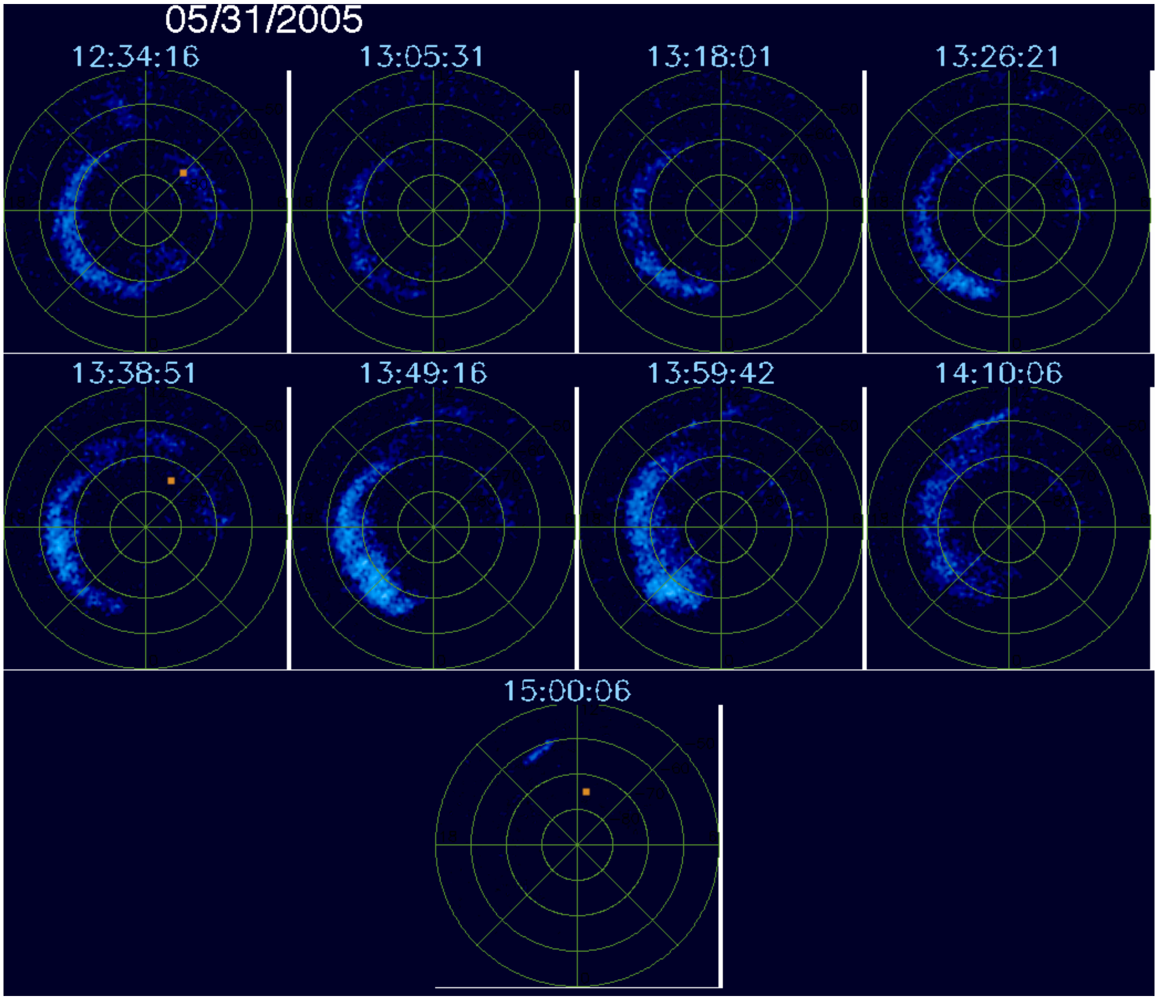

Figure 5. The same images as in Figure 4 presented in Magnetic Latitude (ML) and Magnetic Local Time (MLT) plots. The position of south Pole station is shown as orange spots in frames 12:34:16, 13:38:51 and 15:00:06.

**Post noon (dusk) proton aurora seen by South Pole and IMAGE SI-12.**

Proton aurora was also detected in the late afternoon dusk sector on 5/31/2005 during the period between 18:00 and 21:30, when the aurora is visibly moving equatorward. We have presented the corresponding IMAGE data in figure 6 and 7. In both presentations starting from 19:37 and ending at 20:59 proton aurora is observed over South Pole station. In figure 7 (ML-MLT projection) the rotating South Pole is illustrated with an orange dot on the first frame (19:37) and the frame labeled 20:29. This presentation shows nicely that the aurora should appear to be moving equatorward in the south Pole station frame of reference.

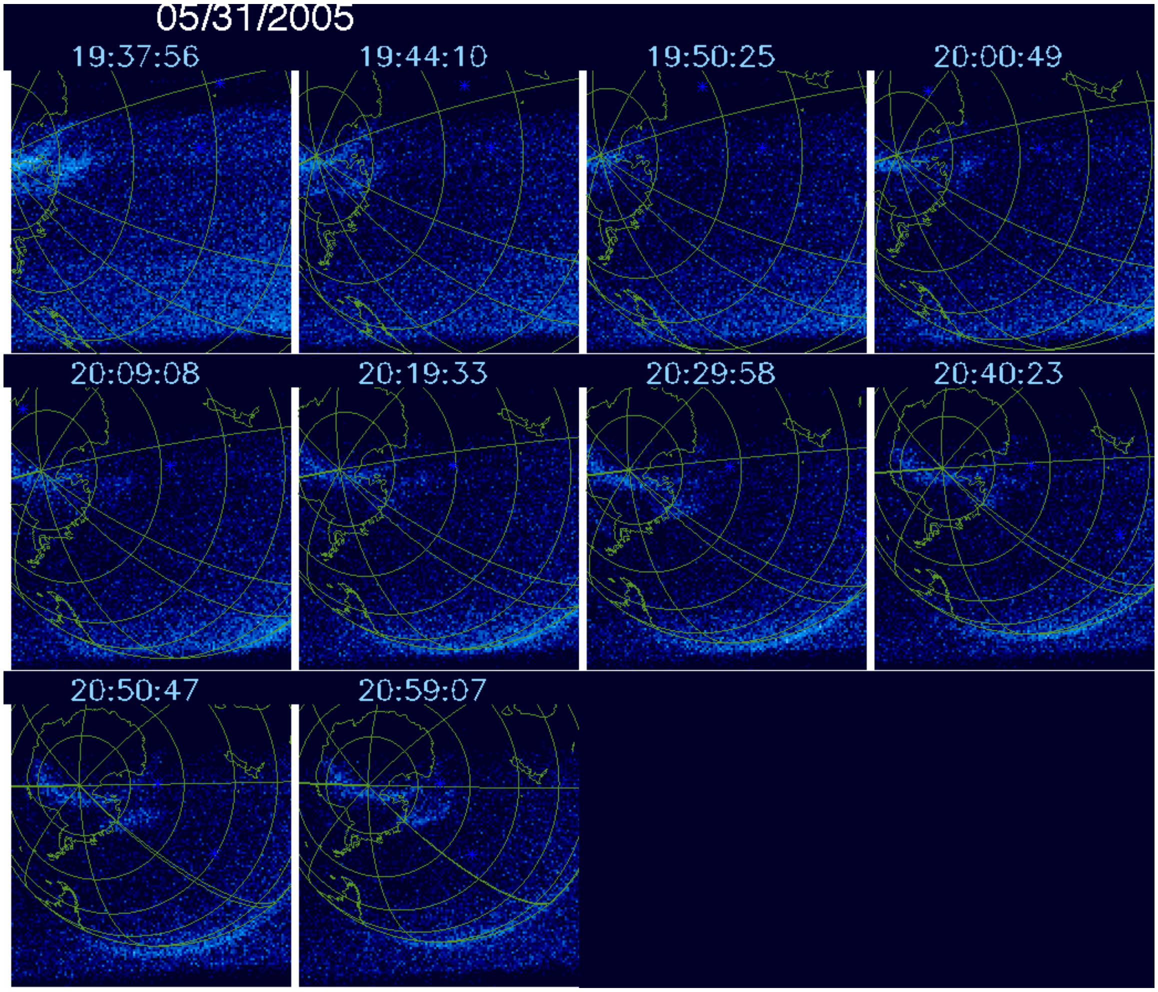

Figure 6. The auroral oval in Doppler shifted Lyman alpha emission as seen from the IMAGE satellite with the SI-12 imager. These views show the global coverage of the IMAGE instrument unambiguously. There is an aurora seen at South Pole.

**Discussion**

We have seen that the proton aurora can be detected and distinguished by the ground based instrument pre midday when we observed a distinct proton aurora representing a limited latitude region. The ground-based images taken at south Pole showed that the proton aurora was an east west elongated broad region that was distinctly moving poleward. Since the interplanetary field was negative this feature could not be associated with the spot representing the auroral spot associated with the positive Bz reconnection region [Frey et al., 2003]. From the ratio between the two proton channels it was evident that this was softer auroral precipitation since it showed up more weakly in the highly Doppler shifted proton emission.

The SI-12 instrument on the IMAGE spacecraft [Mende et al., 2000] uses the Doppler wavelength shift property of the hydrogen emission to distinguish it from and remove the non-Doppler shifted geocoronal Lyman alpha which is a contaminant emission in the vicinity of the Earth. To facilitate this rejection with a moderate size instrument the threshold below which the photons are rejected corresponds to about 1 – 2 keV protons. Any photon that was emitted by hydrogen which had less energy would not make it through the spectrographic filter of the SI-12 instrument. As a result, low energy cusp precipitation, below the 1-2 keV energy threshold, would not be seen by the spacecraft instrument. So our conclusion is that the pre-midday proton event seen on 5/31/2005 was a low energy proton precipitation and therefore could only be seen on the spacecraft.

The afternoon precipitation is most likely caused by recently injected protons on the nightside and these are expected to be considerably more energetic and therefore they should show up in both the ground and the space based instrument. The data confirm this qualitatively.

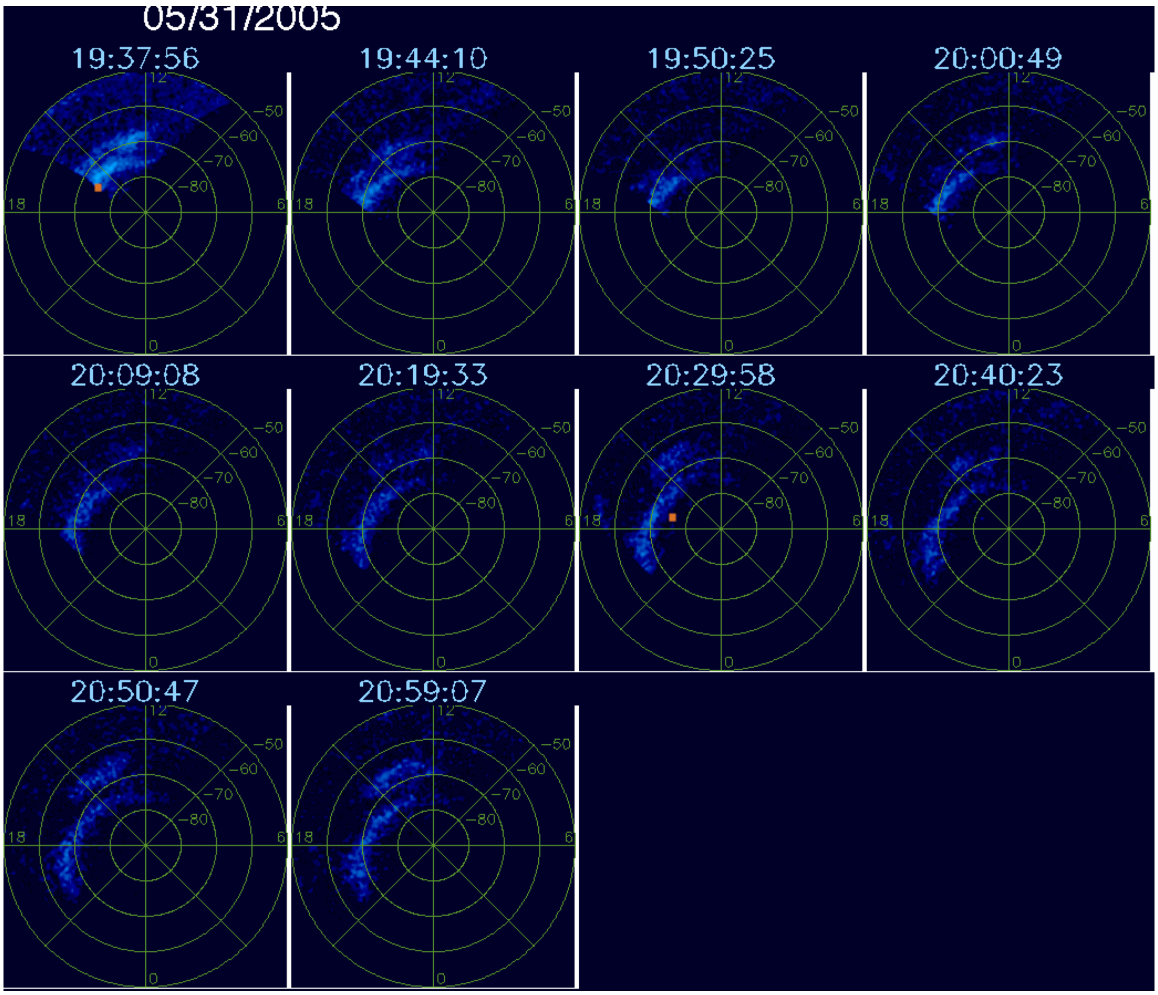


Figure 7. Collage of the ML-MLT plots for 05/31/2005. The position of South Pole Station was indicated by an orange spot on frames 19:36:56 and 20:29:58 UT.

The proton auroral spot in the pre-midday hours at the latitude where it was seen is highly unusual. It is possible that the sudden negative turning of the IMF Bz between 12:30 and 13:30 brought the cusp temporarily to these low latitudes (~74 degrees) and the soft auroral event was indeed cusp aurora signifying that it was the region of dayside reconnection. When the Bz field turned positive the feature disappeared and the cusp presumably went to very high latitudes.