

Optical Auroral Instrumentation of University of Oulu

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Abstract. Space physics group of University of Oulu is making optical auroral measurements with several different kinds of instruments and in several locations. Measurements are made both in Northern Scandinavia and in Antarctic. Instrumentation consists of photometers and cameras. Also spectrometers have been developed. Both real-speed auroral TV-cameras (ATV) and snapshot auroral cameras (AP7) are developed and used. Field-of-view is normally narrow, around 50° . Also all-sky recordings have been made earlier. Almost all the recordings are made in white light. Photometers (MSP) have 5 or 6 measurement channels in the the main auroral emissions. Each measurement channel is equipped with interference filter with 0.5 - 2 nm half-bandwidth. Field-of-views are from 0.5° to 3° . Photometers can be used either in fixed direction or scanning mode. Also a combination of these modes is possible. We present in this paper the measurement sites, technical details and measurement modes of the instruments and data sample. Also some future plans are presented.

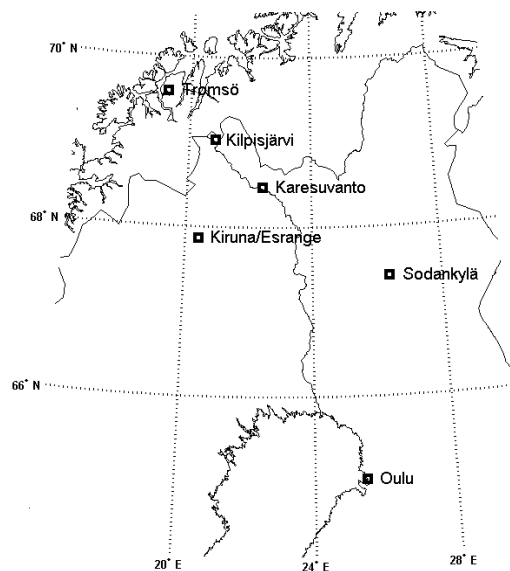


Fig. 1. Locations of the measurement sites at Scandinavia.

1 Introduction

Table 1. The coordinates of the measurement sites and instruments used in them.

Site	Latitude	Longitude	MSP	ATV	AP7
Kilpisjärvi	69.02°N	20.85°E	*	*	*
Karesuvanto	68.46°N	22.43°E	*	*	
Sodankylä	67.42°N	26.39°E	*		
Tromsö	69.59°N	19.23°E	*	*	*
Kiruna	67.84°N	20.41°E	*		
Esränge	67.89°N	21.11°E	*	*	
Zhong Shan	-69.40°S	76.40°E	*		

The main scientific objective of the versatile optical instrumentation of the university of Oulu is the fine structure of

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the auroras. Measurements have been made with high spatial and temporal resolution, so they can be used for several studies. Measurements have often been done in conjugacy with EISCAT (European Incoherent Scatter radar) to study e.g. pulsating auroras (Bösinger, T. et al., 1996), auroral substorms (Aikio and Kaila, 1996), and energies of the auroral particles (Lanchester et al. (1994) or Holma et al. (2000)). Measurements in Antarctic are also used to study dayside auroras (Kaila et al. (1997) and Pitkänen et al. (2002)). The stochastic inversion methods have been used for the obtained data (Nygren et al., 1996). Optical devices of University of Oulu have also been used to study meteor fluxes in accordance with EISCAT radar (Pellinen-Wannberg et al., 1998).

Locations of the measurement sites are shown in Table 1 and in Figures 1 and 2. Zhong Shan site in Antarctic have been used from 1996 onward. Normally, the instruments in the northern Scandinavia are located to Kilpisjärvi, Karesu-

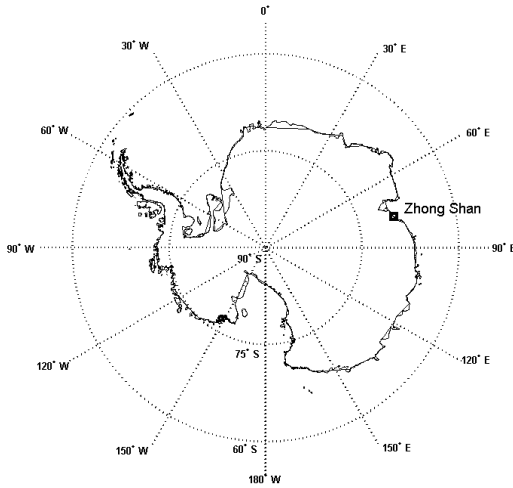


Fig. 2. Locations of the Zhong Shan site at Antarctica.

vanto and Sodankylä. However, during the EISCAT measurement campaigns, instruments from Sodankylä and partly from Karesuvanto are moved to the EISCAT site at Tromsø. Measurements have also been made in Kiruna and Esrange, Sweden. All the used instruments are been planned for flexible measurements and campaigns. They are built into insulated and heated boxes, which can be used outdoor even in harsh conditions. Computers, monitors and videos can be located 50 m away from the instruments into an indoor environment. This way the instrumentation can easily and fast be moved from an observation site to another.

2 Photometers

The main instruments are the photometers, which can be used to measure 5 or 6 auroral emissions concurrently. The emissions are shown in Table 2. Half bandwidth of the used interference filters for Nitrogen emissions is 0.5 -1.2 nm, for proton emission and for the oxygen emission 2 nm. Diameter of the used filters is either 2 inch or 1 inch depending on the instrument. Backgrounds of measured emissions are measured by tilting the filter. Normally this is done after every 15 minutes. In three photometers the proton channel (486.1 nm) is equipped with continuously tilting filter, which moves the filter passband over the proton band continuously. This way, in addition to the intensity, also the shape and width

Table 2. Wavelengths, emissions and used field-of-views for photometers.

Wavelength	Source	FOV [°]
425.2 [nm]	N_2^+ 1NG (0-1) R-band	0.5
426.7 [nm]	N_2^+ 1NG (0-1) R-band	0.5
427.8 [nm]	N_2^+ 1NG (0-1) P-band	0.5
486.1 [nm]	H+	3
630.0 [nm]	O(1D)	1.5
557.7 [nm]	O(1S)	0.5

Table 3. Photometer measurement modes and possible integration times.

Mode	Description	Integration times
1	Normal mode; fixed direction or scan	0.05-0.5 s
2	Fast mode with different integration times for different channels; fixed direction	0.01-1 s
3	Mixed mode; both fixed direction and scan	0.1-0.3 s
11	Mode 1 with fast scanning speed	0.1-0.3 s
13	Mode 3 with fast scanning speed	0.1-0.3 s

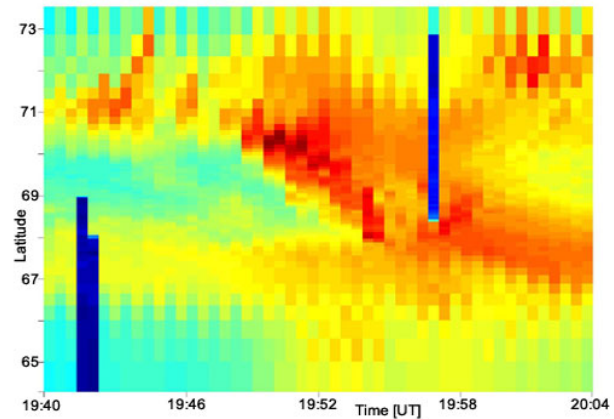


Fig. 3. Example of photometer data. Image shows north-south evolution of 557.7 nm oxygen emission during 24 minutes. from Kilpisjärvi, 6th December 1996. Blue parts show the times when the background is measured.

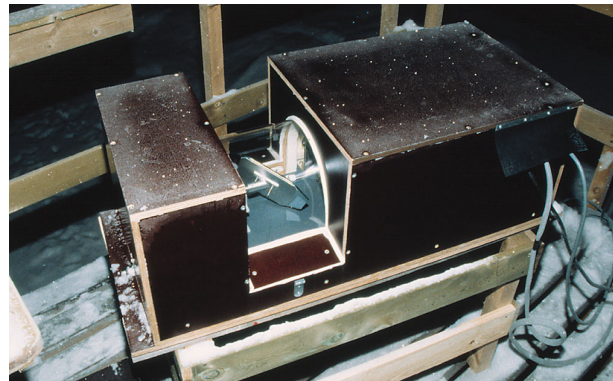


Fig. 4. One of the photometers at the measurement site at Karesuvanto.

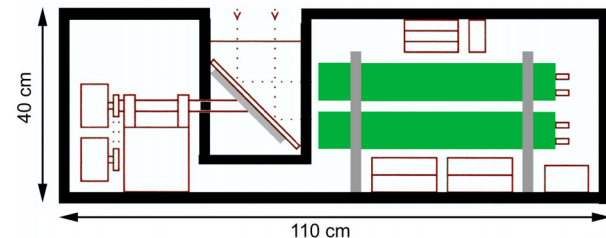


Fig. 5. The structure and the dimensions of the photometer. Photomultiplier tube, lens and filter are packed inside a tube for each channel (marked with green) and fixed horizontally inside the box. These look to the sky through a window with a turning mirror, which is moved with stepping motor. This way the structure can be kept small.

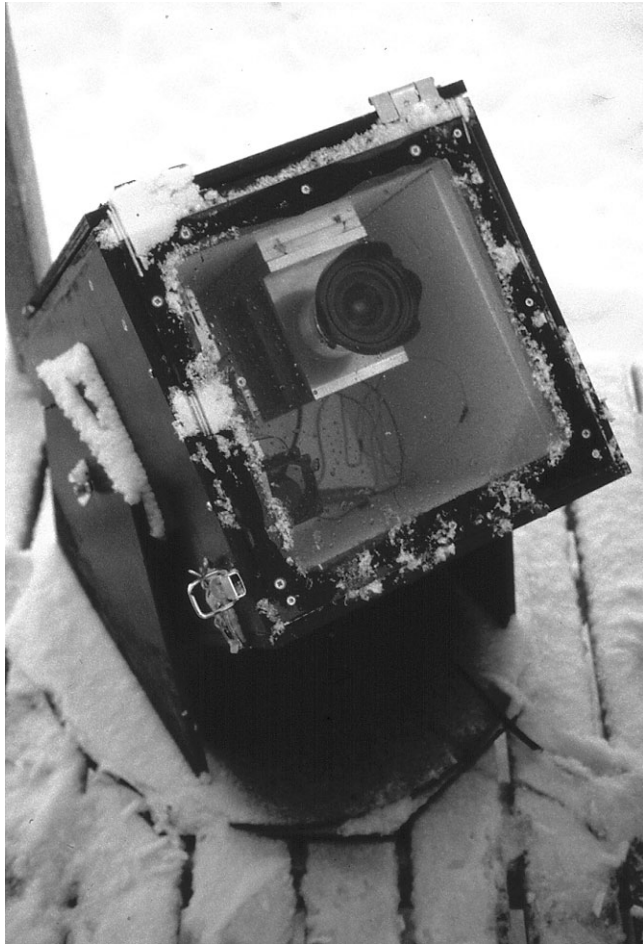


Fig. 6. Auroral TV-camera inside a heated and insulated box at a measurement platform. Dimensions of the box are 40 cm (w) * 40 cm (d) * 50 cm (h). It can be freely rotated and tilted.

of the proton band can be measured. Field-of-view (FOV) varies from 0.5° to 3° , depending on the relatively intensity of the measured emission. Photometers can be used in different modes, which are defined in the table 3. When using scanning mode, different scanning times are also available. Fastest scan (160°) takes 30 s and slowest 2 minutes. All the photometers have been absolute calibrated (Kaila and Holma, 2000).

3 Auroral TV-cameras

The real-speed auroral TV-cameras (ATV) provide high time resolution image data from auroras. Used video standard is B/W CCIR that has 25 frames/s frame rate. Data is currently recorded on to a VHS tapes and digitized afterwards for further analysis. Time information is mixed to the data with a video timer. Cameras are normally located next to the photometers to give overview of auroral conditions. Data is captured in white light, i.e. no interference filters are used. Due to lack of filters recordings are not made during full moon conditions. All the cameras have changeable optics with

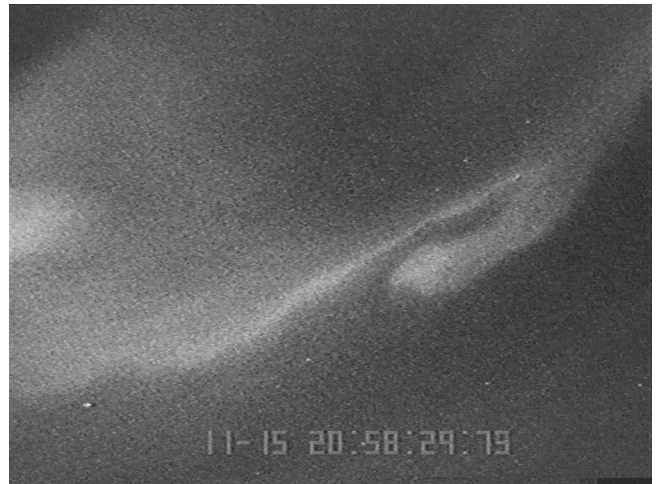


Fig. 7. Example image of the ATV data. Picture shows one frame digitized from VHS-data. Time resolution is 0.04 s.

Nikon F-mount, allowing different kind of FOVs. A FOV of 60 degrees (diagonal) is used normally. The older camera is ISIT-based and new cameras have ICCD-based detectors. Used camera is manufactured by DEP, the image intensifier is II-generation DEP XX1710 with S20 photo cathode. Size of the input area is 24 mm (diagonal) The image sensor is SONY ACX-024. Video resolution is 450 lines.

4 Digital auroral cameras

Bare-CCD digital auroral camera is planned for continuous imaging of auroral forms at the locations of photometers. Imaging frequency is planned to be 10 s. Camera head is produced by Apogee Instruments Inc. The used model, Apogee AP7, is connected straight to the measurement computer with a dedicated ISA-bus controller card. AP7 uses $512 * 512$ pixel SITE SIA502AB back-illuminated and thinned CCD-sensor. The digital resolution of the sensor is 16-bit (i.e. 65536 grey levels). Size of the sensor is 12.3 mm * 12.3 mm and the pixel size is 24 μ m. The main advantage of the camera head is the high quantum efficiency from 300 nm to 800 nm with peak of 85 % at 680 nm. The exposure time can be selected from 0.02 seconds to almost 3 hours and sensor has also on-chip binning. Camera is also equipped with mechanical shutter and it is cooled with Peltier-element and forced air. Sensor can be cooled to $50 - 55^\circ$ under ambient temperature. Objectives with Nikon F-mount can be used.

5 Other devices and future plans

In the near future also different FOVs will be used in the photometers. Current design provides possibility to use 8 simultaneous measurement channels in each photometer. With modern I/O-card this number can even be increased. The current 6-channel scanning design will be maintained, and the new channels will be fixed. Wide field-of-view of 50° with

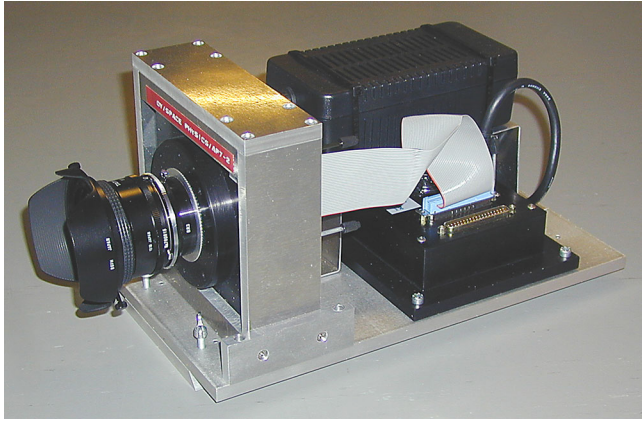


Fig. 8. AP7 and the electronics in the aluminium body. Used camera box is similar to ATV-camera boxes. AP7 is normally equipped with 17 mm objective, which provides 50 diagonal FOV.



Fig. 9. Example image from the AP7 showing an auroral corona. Exposure time is 1 s. Image is converted from 16-bit to 8-bit for printing.

filters in N_2^+ emission is planned to be used in the Sodankylä site. In the Kilpisjärvi site, two channels with 13° FOV will be used to measure auroral intensities in the same ionospheric region as the Kilpisjärvi IRIS riometer field-aligned beam (Browne, S. et al., 1995). Currently the photometer measurement computers run under DOS environment. The software will be moved under LINUX environment to allow more flexible usage of the instruments, and also broadcasting data real-time to the network.

Currently all the cameras are used without interference filters. However, plans to install filters to TV and digital cameras have been made. The main purpose of the cameras is to give overview of the auroral conditions, while photometers provide the spectral information. Due to this filters will probably be high- or low pass filters cutting away for example $O(^1S)$ emission at 557.7 nm and allowing more detailed information e.g. from N_2^+ band emissions at around 427.8 nm. Also even narrower FOVs will be used i.e. to support EISCAT measurements. The proper automatic imaging software for AP7s is still to be written. It should also contain automatic analysis with machine vision methods to cut down the number of the stored images. Also the storage media for the ATVs is hopefully changed to digital to maintain the high quality that cameraa are able to provide. The new storage media will probably be either DVCPRO tape or digital disk recorder.

Earlier a spectrometer has been used for auroral observations. In addition to this spectrometer, also a new imaging spectrometer, having a grating and bare-CCD detector is under design. These instruments are needed to provide more information especially from N_2^+ emission band. This band is of main interest as it provides the possibility to calculate precise energies of precipitating particles and neutral temperatures of the atmospheric particles.

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