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ALIS – HIGHLIGHTS, STATUS, AND FUTURE PLANS

U. Brändström[1], I. Sandahl[1], T. Sergienko[1], A. Pellinen-Wannberg[1], B. Gustavsson[2], M. Rietveld[3], T. Aso[4], and Å. Steen[5]

[1]*Swedish Institute of Space Physics, Kiruna, Sweden*
[2]*Institute of Physics University of Tromsø, Norway*
[3]*EISCAT, Ramfjordmoen, Norway*
[4]*National Institute of Polar Research, Tokyo, Japan*
[5]*RemSpace group, Övlandehult, Kvillsfors, Sweden*

Abstract. In this paper, scientific achievements, present status and future plans are presented. ALIS has been used to study a number of optical phenomena in the atmosphere including aurora, meteors and polar stratospheric clouds. ALIS made the first unambiguous observations of Radio-induced optical emissions at high latitudes and the first detection of water in a Leonid meteor trail. The present (2006) incarnation of ALIS consists of six stations, spaced about 50 km. Each station has a CCD imager with a six-position filter wheel equipped with narrow-band interference filters. The field-of-view is roughly half all-sky. A positioning system enables imaging from several sites with overlapping fields-of-view for any desired part of the sky thus making triangulation and tomography possible. The whole system can be remote controlled. Raw data from ALIS are freely available at http://alis.irf.se. Present work and future plans include studies in collaboration with the Japanese satellite Reimei for studies of auroral fine structures, collaboration with EISCAT and other ground-based instruments, and activities during the International Polar Year, IPY.

1. Introduction

Optical emissions contain a wealth of information regarding the physics of aurora, and different types of optical instruments are able to extract different types of information regarding these emissions. Color cameras, such as many modern all-sky cameras, cover all wavelenghts in the visible part of the spectrum and give information fairly similar to what the human eye sees. For quantitative physical studies it is, however, usually desirable to use filters narrow enough to pick out specific emissions. ALIS, Auroral Large Imaging System is a system of scientific-grade monochrome CCD-imagers using filter-wheels with up to six narrow-band interference filters. The imagers are located at six unmanned stations in northern Scandinavia. Table 1 lists presently available filters. The field-of-view of the ALIS imagers is about half of that of an all-sky camera, about 70 degrees diagonally. A comprehensive description of ALIS is given by Brändström (2003).

λ[nm]	$\Delta\lambda$[nm]	Remarks	#
395.0	9.2	Meteors (Ca; Fe)	1
422.7	28.0	Meteors (Ca, Fe, H_2O, . .)	1
434.1	2.5	Meteors ($H\gamma$, Balmer series)	1
427.8	5.0	Aurora/Airglow (N_2^+ 1Neg.)	6
486.1	2.5	Meteors (H_β, Balmer series)	1
510.0	4.0	Background	4
557.7	4.0	Aurora/Airglow ($O(^1S)$)	6
589.3	20.0	Meteors (Na, . . .	1
623.0	4.0	Background	4
630.0	4.0	Aurora/Airglow ($O(^1D)$)	6
656.3	2.5	Meteors (H_α, Balmer series)	1
844.6	4.0	Aurora/Airglow ($O(3p^3P)$)	4

Table 1. Overview of ALIS interference filters. The first column gives the center wavelength and the last the number of available filters.

2. Some scientific applications of ALIS

2.1 Auroral tomography

The spacing of the ALIS station allows overlapping fields of view and this allows auroral tomography and a possibility to obtain the three-dimensional luminosity distribution. Figure 1 is an example of a luminosity profile at 557.7 nm calculated from ALIS images from 3 stations at the time of a pass by the satellite FAST. From the luminosity profile it is possible to perform an independent calculation of the energy spectra of precipitating electrons. A comparison of the tomography method and the spectroscopic ratio method to obtain primary electron spectra is given by Gustavsson et al. (2001b)

2.2 Radio-Induced Optical Emissions (RIOE)

Figure 2 shows a patch of luminosity that was the first to be unambiguously identified as a radio-induced optical emission at auroral latitudes

(Brändström et al., 1999). It was observed by ALIS during an experiment performed 16 February 1999

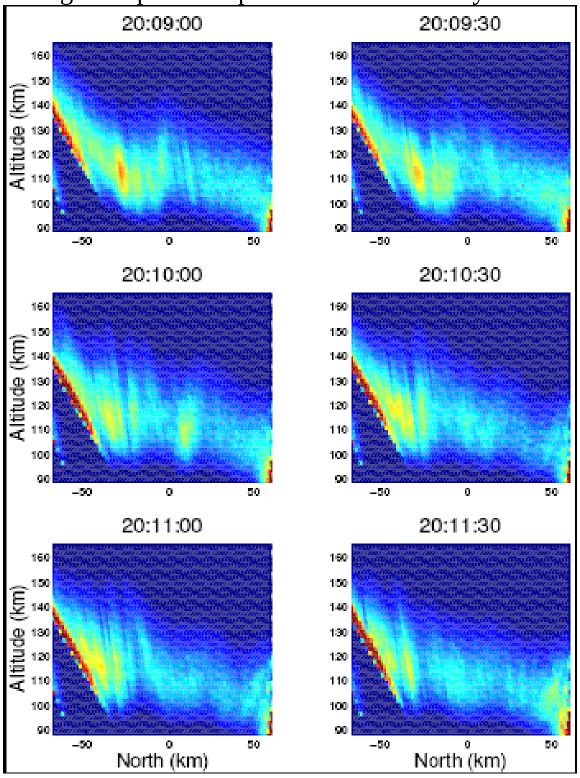

Fig. 1. Auroral luminosity profile at 557.7 nm calculated by a tomographic method using data from 3 ALIS stations.

using the EISCAT heating facility. The corresponding heater pulse was on between 17.40 and 17.44 UT. The three-dimensional luminosity distribution (not shown) was obtained using data from three ALIS stations (Gustavsson et al., 2001a).

2.3 Water in a Leonid meteor trail

When meteors enter the Earth's atmosphere different elements are released at different times and altitudes. This process is called differential ablation (McNeil et al., 1998). Optical emissions from meteor trails give information about these elements. Figure 3 shows a meteor trail imaged during the 2002 Leonid shower using the 422,7 nm and 589,3 nm filters. The signal at 422,7 nm, to the left, was much stronger than expected. The corre-sponding filter was intended for calcium and iron, but the passband also contains a water band around 423,0 nm, that could explain the strong signal (Pellinen-Wannberg et al., 2003).

2.4 Other applications

Enell (2002) used ALIS to study the development of polar stratospheric clouds. Rees et al. (2000) used an ALIS imager combined with two Fabry-Perot etalons and a narrow-band (0.2 nm) filter to image daytime aurora.

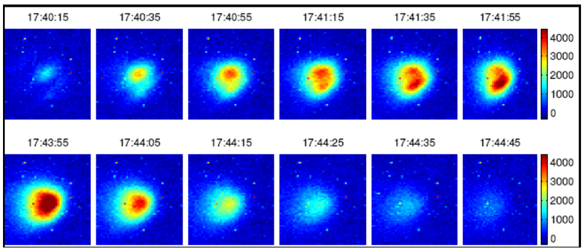

Fig. 2. Radio-Induced Optical Emission at 630.0 nm observed by ALIS during an experiment with the EISCAT heating facility.

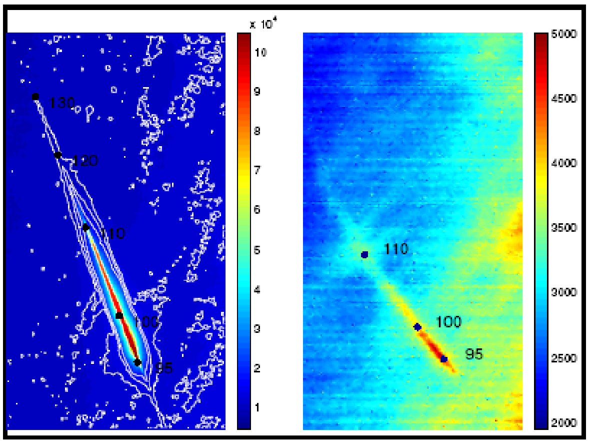

Fig. 3. Leonid trail measured 2002-11-19 by two ALIS imagers using a 427,7 nm filter (left) and a 589,3 nm filter (right). The numbers along the trails denote altitude. The strong signal in the left image is due to water.

3. Using ALIS

3.1 ALIS stations

ALIS has a number of field stations, all with Internet access. The spacing is of the order of 50 km. All imager functions and pointing directions can be fully remote controlled. Figure 4 shows the stations that have been used during the winter 2005/2006. The Silkkimuotka station is shown in Figure 5.

3.2 ALIS Imagers

There are at present six ALIS imagers. The maximum spatial resolution is 1024x1024 pixels, corresponding to about 100x100 meters at an altitude of 100 km. The detectors are thinned backside-illuminated scientific grade CCDs. Since there are no image intensifiers the detectors are linear, which simplifies quantitative measurements. The typical quantum efficiency is 85-90 % at 550 and 80-85% at 400 nm and the read noise is only 6-10 e^-. The full well

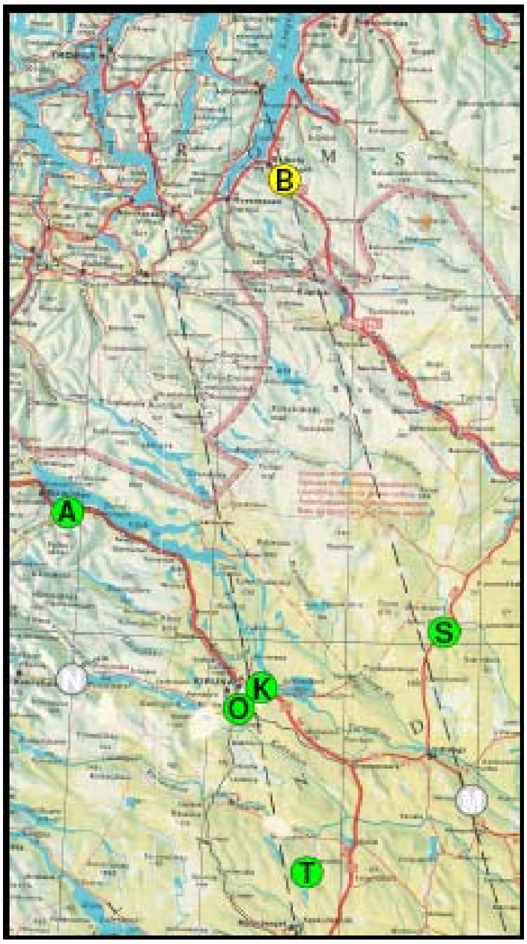

Fig. 4. ALIS stations used during the winter 2005/2006. A=Abisko, B=Skibotn (Bus), K=Kiruna, Knutstorp, O=Kiruna, IRF Optics lab, S=, Silkkimuotka, and T=Tjautjas.

Fig. 5. The ALIS station at Silkkimuotka.

capacity is 300 ke^-. The CCD is read out in 4 quadrants using a 16-bit ADC. Sensitivity can be increased at the expense of spatial resolution using on-chip binning.

3.3 Configuring ALIS

ALIS as a versatile system that can be configured in many different ways to suit different needs. Step one is to select stations and viewing directions. With the camera positioning system the imagers can be pointed in any direction, but for most measurement situations one of the standard positions can be used. Figure 6 shows the fields of view for the most important standard positions.

The imager gain/noise setting and the binning factors are chosen to get the optimum trade off between sensitivity, readout time, and frame rate.

The filter and exposure time sequence is determined. Here it is often possible to find smart solutions, so that readout is taking place as the same time as the filter change. An example of a filter/expose sequence is shown in Figure 7.

3.4 Data storage and retrieval

Raw data are stored on local hard-disks at the stations as FITS images. As the station disks fills the raw-data are moved to the central ALIS data-archive at IRF-Kiruna at http://alis.irf.se. The data then directly become available on the world-wide web. Due to the large amount of data, Internet is not yet used for transfer of raw data from the stations to IRF, and thus it usually takes a number of days for data to reach the

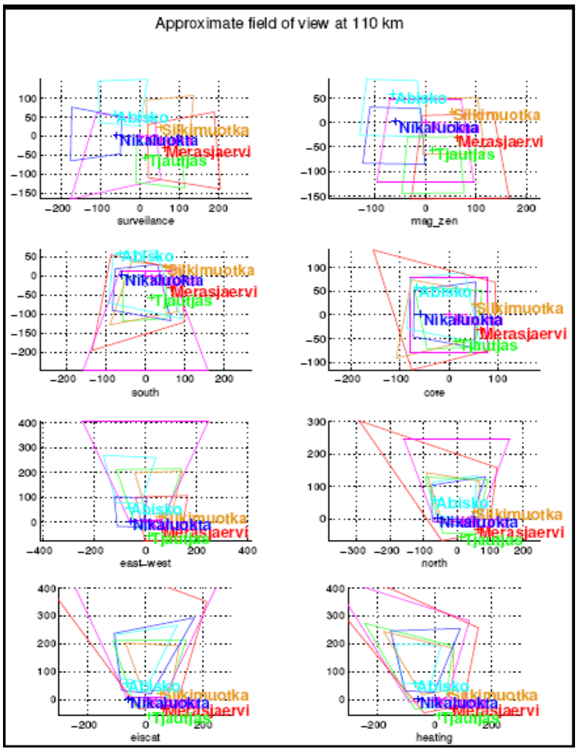

Fig. 6. Fields-of-view at 110 km for standard positions.

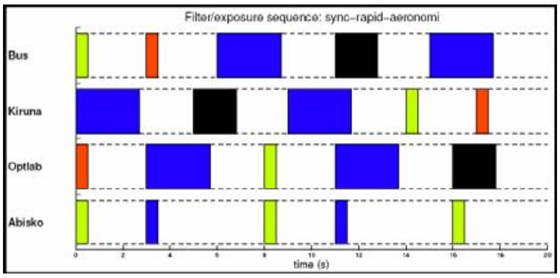

Fig. 7. Filter/expose sequence for four ALIS stations. In this experiment four different filters were used. From left in the top row the filters are 557,7 630,0, 427,8, and 844.6 nm. The sequence duration is 20 s.

archive. Plans for the future are to also provide preprocessed data in physical units.

3.5 Data analysis

Tools for ALIS data analysis are freely available at http://alis.irf.se. Work is ongoing to make these tools more user friendly. The tools include software for the following applications:

- Geometrical calibration using the star background.
- Converting measured values to physical units.
- Triangulation of altitudes.
- Tomography and 3-D analysis.
- Creating keograms and movies.
- Characteristic energies from spectroscopic relations.

4. Future plans

The following campaigns are planned for 2006:

- Coordinated measurements during the Japanese Reimei (INDEX) mission – auroral fine structure.
- Aurora, RIOE/EISCAT-Heating, etc.
- Meteor showers, Geminids, Leonids, Quadrantids.

We welcome collaboration and co-ordination with other observations and campaigns. The ALIS group coordinates the International Network for Auroral Optical Studies of the Polar Ionosphere, which is a part of the IPY project ICESTAR as well as a project named Network for Groundbased Optical Auroral Research in the Arctic Region.

5. Summary

- ALIS is a multi-station narrow-band spectroscopic imaging facility capable of quantitative imaging of optical emissions.
- ALIS allows tomography and triangulation.
- ALIS has been used in different fields such as Aurora, Radio-Induced Optical Emissions, Meteor studies, Polar Stratospheric Clouds.
- ALIS is a campaign-oriented instrument requiring configuration prior to observation.
- ALIS is open to the scientific community.
- The ALIS teams welcomes wide collaboration.

6. Contact information

Ingrid Sandahl, ingrid.sandahl@irf.se
Urban Brändström, urban.brandstrom@irf.se
ALIS web-site and online data-archive: http://alis.irf.se
International Network for Auroral Optical Studies of the Polar Ionosphere: alis.irf.se/auropt

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