Sección Especial: 37th AMASON / Special Section: 37th AMASON
Aurora

A study on the possibility to deduce the 2D distribution of the auroral electron precipitation from multi wavelength optical measurements with auroral imagers

K. Axelsson(*), T. Sergienko, I. Sandahl†, U. Brändström

Swedish Institute of Space Physics, Kiruna, Sweeden.

(*) Email: katarina@irf.se

Recibido / Received: 30/01/2011. Aceptado / Accepted: 30/08/2011.

ABSTRACT:

The intensity ratios of auroral emissions at different wavelengths are widely used for reconstruction of auroral electron parameters. This method works quite well if the measurements of the auroral emissions are conducted in the magnetic zenith direction. In this study we want to investigate the possibility to use the intensity ratio method in the case where the observations are made in a direction not parallel to the magnetic field. In particular, we want to check the possibility of using auroral data for deducing the 2D distribution of the auroral electron precipitation. We use ALIS multi-station measurements of the auroral red and green line emissions (6300 Å and 5577 Å) to get data in zenith and non-zenith directions. We also take into account that the red line emission peak and the green line emission peak are at different altitudes. The results of this investigation show we can obtain reliable results for angles up to 35° away from magnetic zenith.

Keywords: Aurora, Intensity Ratios, Groundbased Observations, Primary Electron Distribution.

REFERENCIAS Y ENLACES / REFERENCES AND LINKS

[1]. U. Brändström, *The Auroral Large Imaging System - Design, Operation and Scientific Results*", IRF Scientific Report 279, ISBN: 91-7305-405-4 (2003).

[2]. M. H. Rees, D. Luckey, "Auroral electron energy derived from ratio of spectroscopic emissions 1. Model computations", *J. Geophys. Res.* **79**, 5181 (1974).

[3]. J. H. Hecht, D. J. Strickland, M. G. Conde, "The application of ground-based optical techniques for inferring electron energy deposition and composition change during auroral precipitation events", *J. Atmos. Sol.-Terr. Phy.* **68**, 1502-1519 (2006).

[4]. G. J. Romick, A. E. Belon, "The spatial variations of auroral luminosity – I. The behaviour of synthetic model auroras", *Planet. Space Sci.* **15**, 475 (1967a).

[5]. G. J. Romick, A. E. Belon, "The spatial variations of aurora luminosity – II. Determinations of volume emission rate profiles", *Planet. Space Sci.* **15**, 1695 (1967b).

[6]. V. E. Ivanov, A. S. Kirillow, T. I. Sergienko, Å. Steen, "Modelling of the altitude distribution of green line (5577Å) luminosity in aurora", *Proc. SPIE* **2050**, 105-113 (1993).

[7]. S. C. Solomon, P. B. Hays, V. J. Abrey, "The auroral 6300 Å emission – Observations and modeling", *J. Geophys. Res.* **93**, 9867-9882 (1988).

1. Introduction

At auroral latitudes, precipitating energetic particles collide with atoms and molecules in the atmosphere. In these collisions the kinetic energy is transferred from the incoming electrons to the atmospheric particles. The energy transfer processes causing the aurora are complex. Some auroral emissions are results of direct electron excitation of atoms and molecules, but others can be produced due to chemical reactions. Studying the aurora is a way to remote-sense magnetospheric processes. The vertical profile of the aurora can give us information about thermospheric composition and characteristics of auroral particles. Using the intensity ratio between measured auroral intensities is one way of retrieving the characteristic energy of the auroral electrons. Rees and Luckey [2] were among the first to decuce the characteristic energy from ground based optical data in 1974. They developed an algorithm for determining the characteristic energy using the 6300 Å to 4278 Å emission intensity ratio. Since then several attempts have been made to improve the model, e.g. Hecht et al. [3]. The method of deducing the characteristic energy from intensity ratios works quite well if the measurements of the auroral emissions are conducted in the direction of magnetic zenith, but in auroral imaging only a minor fraction of the measurements are along the field lines.

In this study we want to investigate if it is possible to use the ratio technique if the measurements are not conducted along the field lines. These types of measurements are difficult to interpret because of the varying thickness of the auroral forms and different altitudes of the auroral emissions [4,5]. Since the general solution for any auroral form is very complicated, we chose to start with something relatively simple, namely two quiet arcs. We look at the ratio between the 5577 Å and the 6300 Å emissions of atomic oxygen, taking into account the fact that the green line has its intensity peak about 100 km below the red line. If the result shows that we can use this technique, we would be able to deduce a number of properties of the 2D distribution of the auroral electron precipitation

2. Instrumentation

ALIS (Auroral Large Imaging System) currently consists of six remote controlled stations in northern Scandinavia. Each station is equipped with a sensitive CCD detector with a 1024x1024 pixel chip and a filter wheel with six positions for different narrow-band filters. The stations are separated from each other by a distance of approximately 50 km (Fig. 1). The stations are located so that their fields-of-view overlap, which makes it possible to study the aurora from different angles simultaneously [1].

During this experiment the cameras were observing a volume in magnetic zenith above Kiruna. Data from the Kiruna (67.86°*N*, 20.42°*E*), Silkkimuotka (68.03°*N*, 21.69°*E*) and Tjautjas (67.33°*N*, 20.75°*E*) stations were used to calculate ratios of the green to red line intensities. The images were obtained using the 5577 Å and 6300 Å filters, the exposure times were 1 s and 2 s respectively. The image size used was 256×256 pixels, with a 70º field-of-view. Thus the pixel field of view is approximately 480×480 m at an altitude of 100 km and 960×960 m at 200 km. All cameras are absolute calibrated in laboratory.

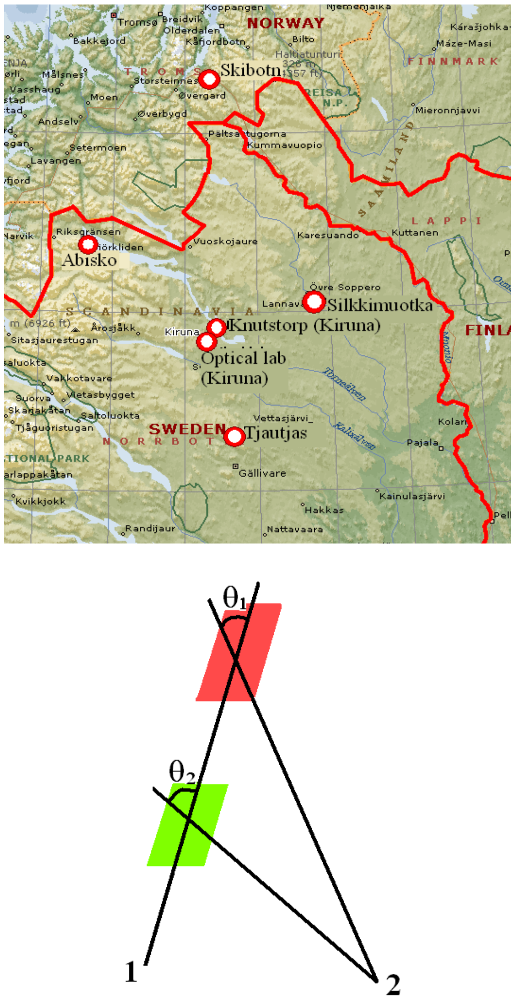

Fig. 1. Up: Map of the ALIS stations. In this study we use data from three stations: Kiruna (67.86°*N*, 20.42°*E*), Silkkimuotka (68.03°*N*, 21.69°*E*) and Tjautjas (67.33°*N*, 20.75°*E*). Down: An illustration of the geometry for magnetic zenith (1) and non-magnetic-zenith measurements (2).

3. Analysis

ALIS multi-station measurements of the auroral red and green line emissions (6300 Å and 5577 Å) on the 18th of December 2006 are used to get data in zenith and non-zenith directions. The ratios were calculated for the green to red line intensities for the time between 21:30 UT and 23:00 UT using data from three stations: Kiruna, Silkkimuotka and Tjautjas. The upper panel in Fig. 2 shows a keogram from the images obtained with the ALIS camera in Kiruna at 5577 Å. The keogram shows an auroral event starting with two equatorward moving arcs at around 21:40 UT, and an auroral substorm breakup at around 21:45 UT.

3.a. Characteristic energy deduced from intensity ratios

For accurate absolute measurements of auroral intensities the optimal situation is when the observation is conducted along the magnetic field lines. Figure 1 illustrates the geometry when conducting measurements in a direction that is not parallel to the magnetic field line. Station 2 in this case represents the Silkkimoukta or Tjautjas station or any pixel field-of-view from the Kiruna station that is not along the field line. We can clearly see that we are not measuring the same volume from the two stations. Therefore the angles θ_1 and θ_2 need to be considered when calculating the intensity ratios. The dependence of the emission intensity ratio on the electron characteristic energy is obtained using two numerical models of the auroral emissions, the green line model by Ivanov *et al.* [6] and the red line model by Solomon *et al.*[7].

3.b. Zenith measurements

We start by looking at data from Kiruna were the observations are conducted in the magnetic zenith direction and compare them to the ratios from Silkkimuotka and Tjautjas. The ratios are calculated for different altitudes of the green and red line emission peaks. We use the altitudes where we get the best agreement between the zenith and non-zenith measurements throughout the whole auroral event, which are 110 km for the green line emission and 190 km for the red line emission. Figure 2 shows the characteristic energy obtained from these ratios. The match is good during the whole auroral event except at around 21:50 UT, during the auroral breakup phase. The match for Tjautjas is not as good as for Silkkimuotka. If we look at the geometry of the stations (Fig. 1) we see that Tjautjas is south of Kiruna while Silkkimuotka is at almost the same latitude. This shows that non-zenith measurements have better agreement when they are conducted along the same latitudinal line.

3.c. Quiet auroral arc

Let us now consider a simple case by looking at two quiet arcs that appeared around 21:49 UT (Fig. 3). The altitudes for these two arcs were determined using triangulation. For the equatorward arc the intensity peak of the green line emission lies around 110 km and the peak for the red line emission at 151 km. For the poleward arc the altitudes are 140 km and 190 km for the green and red line emission peaks respectively.

Imagine that a plane at 110 km corresponds to the image projection of the Kiruna station at this altitude. The image from the Silkkimuotka station is projected in the same plane. To get the ratio, $I(5577\text{ Å})/I(6300\text{ Å})$, the images from the two stations are projected in the same way at an altitude for the red line emission peak, following the magnetic field line from the first projection. The situation is the same as described for station 2 in Fig. 1, where there are two different θ angles, one for each altitude. These angles are of course different depending on where in the image the pixel is located, which then means that we have four different theta angles that need to be considered, two for each station. Figure 4 shows the energy plots of the two arcs as seen from both stations. The colour scale shows the characteristic energies obtained from Kiruna and the superimposed contour plots the characteristic energies from Silkkimuotka.We can see that we have good agreement along the whole arc, an area corresponding to a viewing angle of approximately 35º from the Silkkimuotka camera.

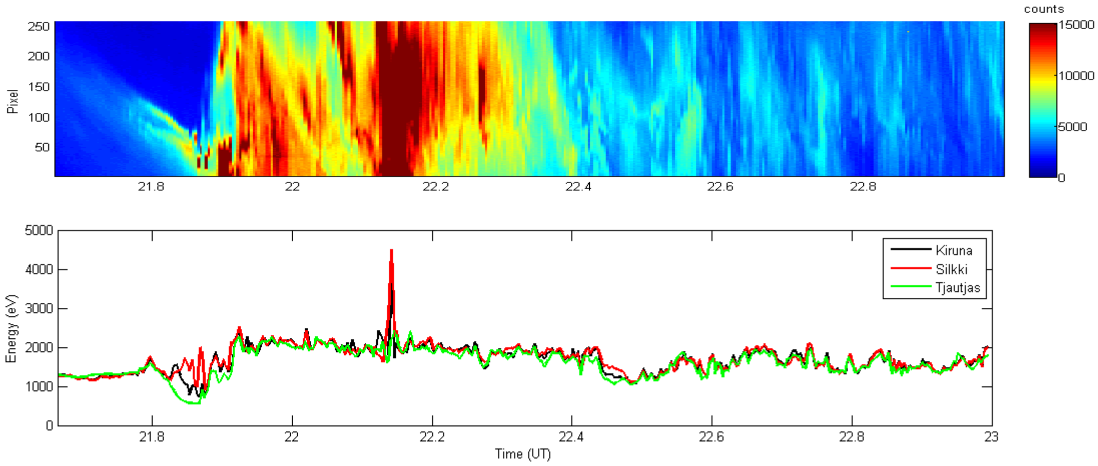

Fig. 2: The upper panel shows a keogram along the North-South direction of images taken from Kiruna at 5577 Å. The bottom panel shows the characteristic energy deduced from the ratio of $I(5577\ Å)/I(6300\ Å)$ from Kiruna in the zenith direction compared to the energy based on measurements from the Silkkimuotka and Tjautjas stations.

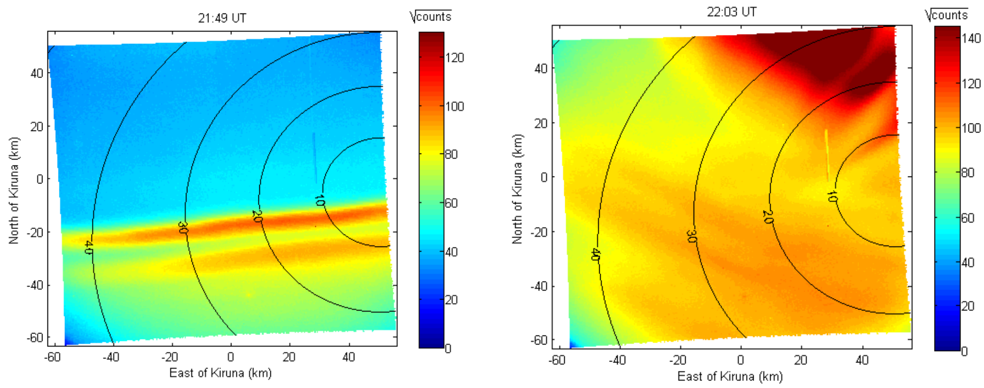

Fig. 3: Images taken from Kiruna station of the measured intensity, the square root of the intensity is used for better visualisation. First we look at two quiet arcs (left) at 21:49 UT and the more general case (right) at 22:03 UT. Superimposed on the images are the magnetic zenith angles from the Silkkimuotka station.

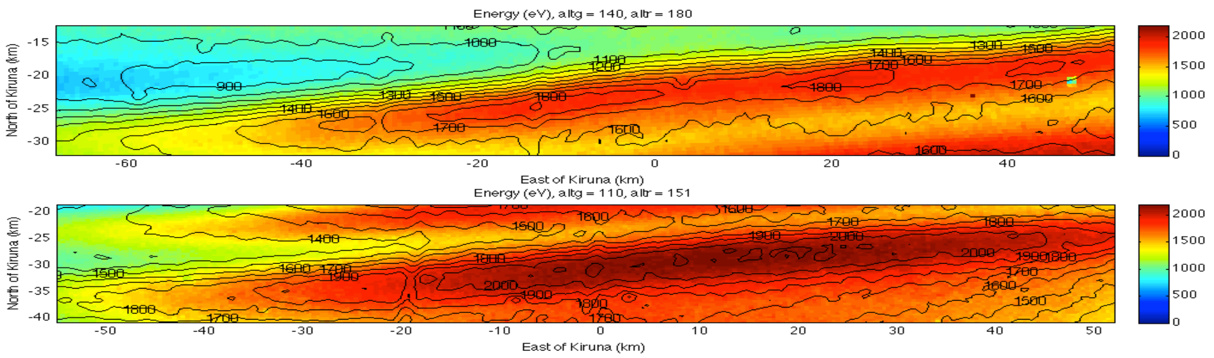

Fig. 4. The characteristic energy of the poleward (upper panel) and equatorward (bottom panel) arc seen from the Kiruna station with the contour of the characteristic energy from the Silkkimuotka station superimposed. altg and altr refer to the altitudes for the green and red line emission peaks respectively.

3.d. A more general case

We also looked at a more general case (Fig. 3) with several structures; it was chosen in such a way that there was good agreement between the zenith and non-zenith measurements using the general altitude in section 3.b. The result is shown in Fig. 5. We can see that the agreement is good but if we look closer at the auroral form in the upper right corner of the image we see that there are some errors, this is probably due to the fact that the peak energy deposition for this form is at another altitude.

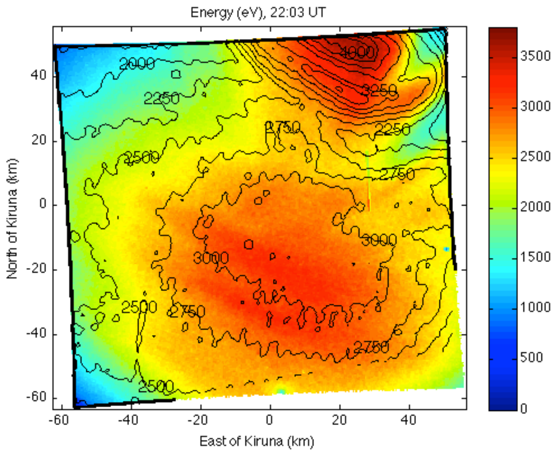

Fig. 5: A more general case - The characteristic energy observed from the Kiruna station with the contour of the energy from Silkkimuotka superimposed.

† Ingrid Sandahl sadly passed away in May 2011.

4. Conclusions

In Fig. 4 we can see an excellent match between the energies measured from the two stations. This shows that we can use the method of intensity ratios to derive the characteristic energy of the precipitating particles for angles up to 35º. Even in the more complicated case the agreement is good, but we can also see that there are some discrepancies due to the use of an average altitude.

Acknowledgements

K. Axelsson is supported by The Swedish National Graduate School of Space Technology, Luleå University of Technology. ALIS is supported by the Swedish Research Council.