Observations of Auroral Pulsations at Sanae, Antarctica

G. J. Kühn

Antarctic Geomagnetic Programme,
of Potchefstroom University for C.H.E.,
Potchefstroom

Introduction

Rapid variations in the intensity of auroral light emission are a well-known manifestation of auroral activity. It is however, only in recent years that this field of study has begun to attract more widespread attention. A possible reason for this is the technical difficulty of observing this phenomenon. Some important work has however, been done in the past, as reviewed by *Omholt* (1971).

General agreement seems to exist between different workers that pulsating aurora generally occurs at about 100-130 km altitude, and somewhat equatorward of the auroral oval – more particularly in the region 59-67° geomagnetic latitude *(Egeland & Omholt*, 1967; *Kvifte & Pettersen*, 1969; *Heppner*, 1954). Periods observed in pulsating aurora vary from fractions of a second (e.g. 10 ± 3 Hz in flickering aurora) to several minutes.

The fact that Sanae, at 60° S geomagnetic, lies in the region of occurrence of pulsating aurora, and also in a region which is very sparsely covered by observing stations, led to the establishment of a photometric auroral pulsation programme in 1973. The main aim is to develop the programme into a correlative study of auroral pulsations, magnetic pulsations, and pulsations observed on the riometer. For this purpose a fast-response riometer was put into operation at Sanae in 1974.

In the present paper some of the observations made during the first year of operation of the photometer are presented briefly without delving to any extent into the physics behind the observed events. Adverse meteorological conditions and "teething troubles" of the instrument led to some loss of data, so that no purpose will be served by any attempt at a statistical study of this year's data. This report is therefore restricted to a few events illustrating different manifestations of the pulsating aurora observed at Sanae.

Instrumentation

The pulsation photometer at Sanae records the intensity of the N_2 band at 4278 Å through interference filters with a half power bandwidth of 12 Å. Three completely independent photometer channels are used to monitor the sky at three separate points, each channel having a field of view of 5°. One channel is always directed at the zenith, while the viewing direction of the other two may be selected by the observer. During the events discussed below the viewing directions were always 30° and 60° above the southern (poleward) horizon.

Electronic filtering is used on the output signal of the photomultipliers, resulting in a passband between 1 Hz and 0,0025 Hz. Recording of the data is on stripchart at a speed of 60 mm per minute.

Data Analysis

The stripchart records were scaled directly by hand at 5 s intervals (2 s intervals for the data used in Figure 1), and the results then used in a power spectrum density analysis.

The method used is the maximum entropy method (MEM) which was originated by Burg in terms of probability theory (see *Smylie et al.*, 1973, and references therein). This fundamentally new approach to power spectrum analysis, based on the information or entropy content of time series, was shown by *Bolt & Currie* (1974) and *Currie* (1974) to be more effective than conventional techniques. The method eliminates constraints on resolution and the resultant spectrum possesses a high degree of smoothness and stability.

Magnetic pulsation data used for comparison with some of the auroral pulsation events below, were also scaled by hand at 5 s intervals.

Experimental Results

Four different events were analysed for the purpose of this paper to illustrate different conditions of auroral pulsation activity recorded. The results of the power spectrum density analysis are graphically presented on a scale which is linear in frequency. The relative amplitudes given in the graphs mean that the amplitudes of all peaks were normalized taking the amplitude of the dominant peak as unity. Whenever the viewing direction of a photometer channel is mentioned, this is referred to the southern (poleward) horizon, that is, the angle above the horizon.

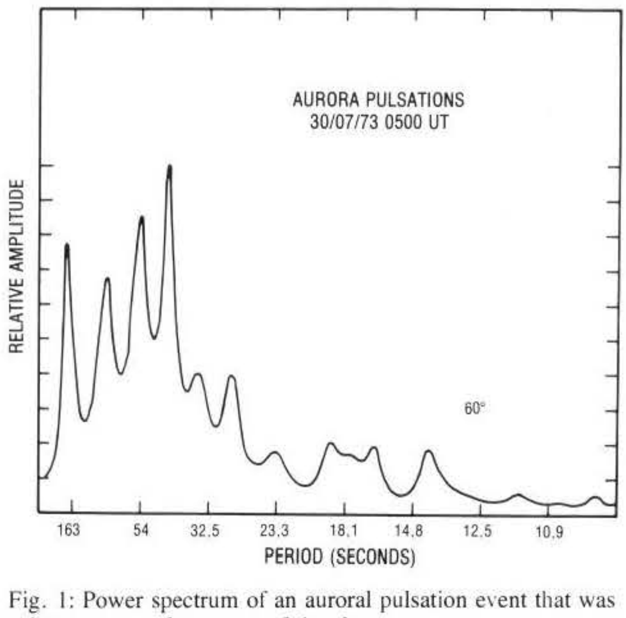

Fig. 1: Power spectrum of an auroral pulsation event that was coherent over a large part of the sky.

1. Event of 05 h 00, July 30

During this event well-defined auroral pulsations were recorded on all three photometer channels. These pulsations were completely in phase to the extent that even occasional small irregularities occurred simultaneously on all three channels. Unfortunately no magnetic pulsation data were readily available for this period, but, according to *Omholt* (1971), one would expect fairly good correspondence between these auroral pulsations that were coherent over a large part of the sky, and possible magnetic pulsations that may have occurred at the same time.

The power spectrum of the event, shown in Fig. 1, exhibits a number of significant peaks at periods at long as 200 s. The data from the 60° viewing direction channel was used to determine this spectrum because the pulsations recorded on this channel had the largest amplitude. A closer inspection of Fig. 1 suggests a harmonic nature of the spectrum.

Accepting the first peak at 184 s as the fundamental, one finds that all peaks from the second at least up to the seventh may be considered to be harmonics of the first peak. This is illustrated in Table 1.

Table 1

Peak No.	Har-monic	Observed Period (s)	Derived fundamental (s)
1	0	184	
2	1	84,8	170
3	2	55,5	167
4	3	43,2	173
5	4	35,0	175
6	5	28,5	171
7	6	23,6	165

With a prediction error coefficient of 25% used in the analysis, the spectrum is fairly stable, but more auroral pulsation events of a similar nature are needed to prove the harmonic nature conclusively.

2. Event of 01 h 20, August 24

This event showed well-defined auroral pulsations on all three photometer channels, but the three series of pulsations were out of phase and no peak-to-peak correlation could be made. Looking at the power spectra in Fig. 2, however, it is clear that the three spectra are very similar at the long period end. At periods down to about 60 s the peaks in the power spectra could be directly correlated with one another. An interesting feature is the peak at 256 s which is the dominant period in the zenith pulsations. On the 60° viewing channel this peak is observable but with a very much decreased amplitude and at 30° above the horizon, it was not resolved at all.

The auroral pulsations observed in the zenith were again used to look for a possible harmonic structure and the resultant analysis again suggested a harmonic relation between the peaks in the power spectrum, at least up to the 10th peak at 32 s. In this case however, the fundamental is the second peak at 256 s and not the first peak at 397 s. It is difficult to distinguish between motions of the aurora and true pulsations with a photometer, so the possibility is not ruled out that the first peak at 397 s may have resulted from motion of the aurora rather than from pulsations.

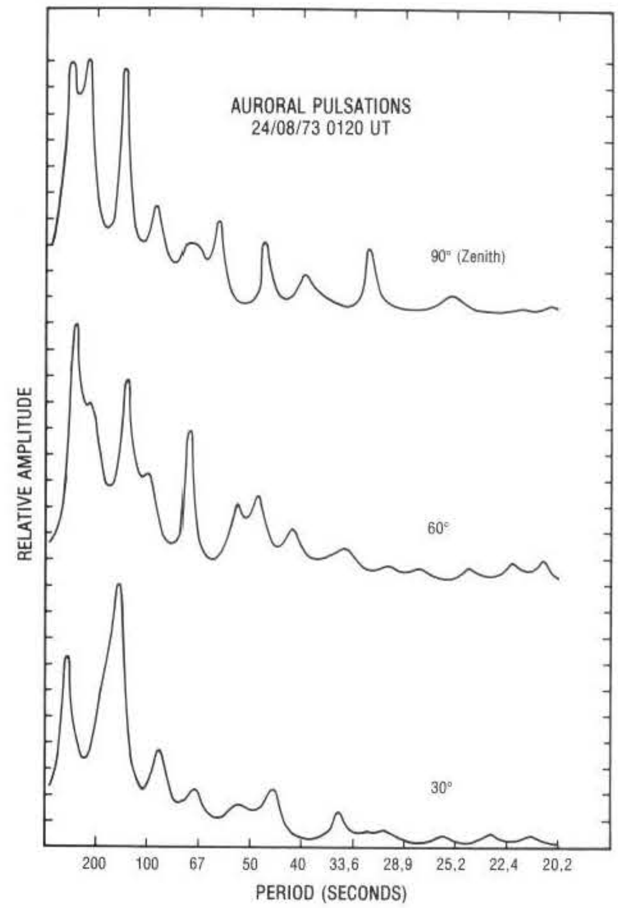

Fig. 2: Power spectra of auroral pulsations observed over a large part of the sky, that were incoherent.

3. Event of 23 h 45, August 23

Well-defined auroral pulsations were observed both in the zenith and at 60° above the horizon and at one stage also at 30° above the horizon. The pulsations were not generally in phase, but some maxima and minima could be correlated. Somewhat irregular magnetic pulsations were observed at the same time, but again no satisfactory peak-to-peak correlation could be made. When the power spectra (Fig. 3) of the zenith and 60° auroral pulsations are compared with the magnetic pulsations, a high degree of similarity is found. The peaks do not have the same relative power in the three different power spectra, but they can be correlated directly for all periods down to about 35 s. No harmonic relation was evident between the peaks in the spectrum.

Fig. 3 may also be compared with the spectra in Fig. 2, which represents a pulsation event that occurred some 90 min later. The two figures show a marked degree of similarity in the power spectra. The dominant spectral features at approximately 400 s and 140 s are in fact similiar in the two figures, but the later event seems to contain more spectral features at higher frequencies than does the earlier event.

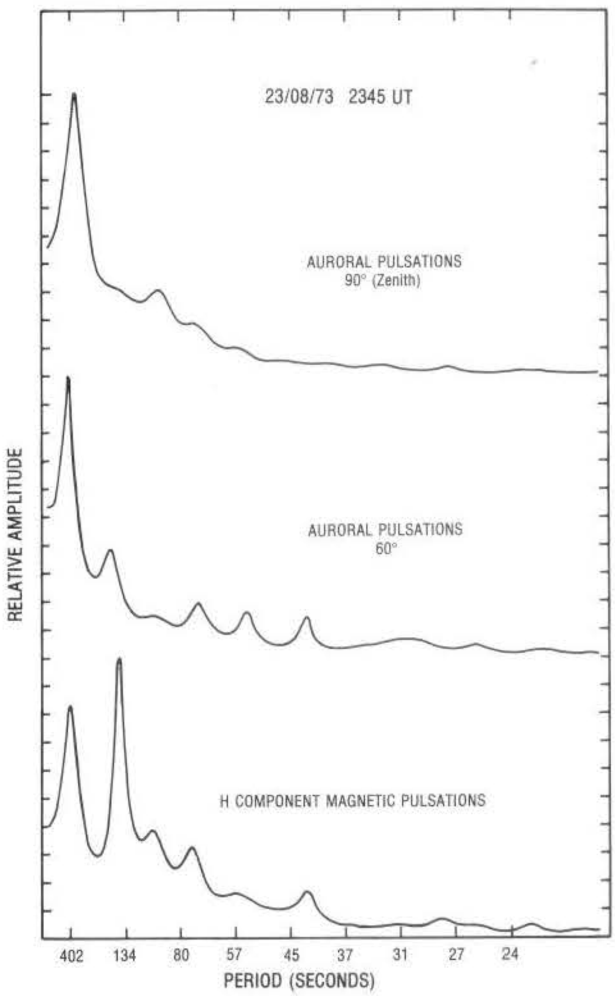

Fig. 3: Power spectra of an event where smooth, well-defined auroral pulsations occurred simultaneously with very irregular magnetic pulsation activity.

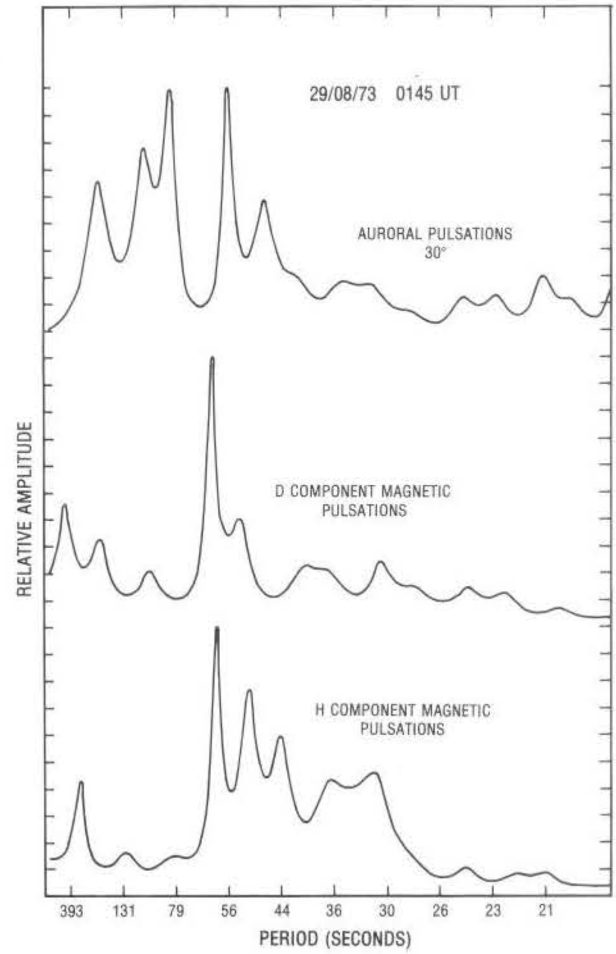

Fig. 4: Power spectra of an event where well-defined Pi 2 magnetic pulsations were accompanied by irregular pulsation-like auroral activity.

4. Event of 01 h 45, August 29

In this event well-defined Pi2 magnetic pulsations occurred simultaneously with irregular pulsation-like activity in the auroral light emission. The auroral activity was more pronounced in the direction 30° above the horizon, and these data were therefore compared with the H and D magnetic pulsation data. The power spectra in Fig. 4 do have the same general shape, but direct correlation of individual spectral features is not possible. No conclusive evidence for a harmonic relation between the different spectral peaks of the auroral pulsations could be found, but the spectrum of the H magnetic pulsations did suggest a possible, but somewhat inconclusive, harmonic relation. This single event is however not sufficient for definite conclusions.

It may be mentioned that, in the rather limited amount of data obtained in 1973, no event could be found where smooth Pi 2 magnetic pulsations were associated with smooth, well-defined auroral pulsations. The auroral pulsations always exhibited erratic behaviour during such events. It is however, interesting that, in spite of this, the magnetic and auroral power spectra showed a high degree of similarity in shape.

Discussion

The events discussed above present some interesting results that still need much more detailed study. The harmonic nature of the first two events is most interesting, but not conclusive until more events of a similar nature are available for analysis. The relation between auroral and magnetic pulsations also needs further attention, in particular as regards the lack of harmonic features observed and the different degrees of correlation between the two phenomena. It was found by *Sutcliffe* (1974) that Pi 2 magnetic pulsations do not characteristically exhibit a harmonic structure, which supports the above observations that auroral pulsations associated with Pi 2 pulsations do not exhibit harmonic features either.

One important problem of the photometric method of observation is that one cannot distinguish between motions in the aurora and auroral pulsations. This problem should be resolved when an image intensifier video system is put into operation at Sanae in 1975. However, the results presented above are considered to be relatively free of the effects of auroral motions because the spectra of different types of pulsations and at different points in the sky correlate very well.

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