Aust. J. Phys., 1974, **27**, 855–8

λ 557·7 nm Pulsations within Quiet Pre-breakup Aurorae at $L = 8 \cdot 7$

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Abstract

Pulsations in the [OI] λ 557·7 nm emission, with a typical period of 10–20 s, were consistently observed within quiet pre-breakup auroral forms from Mawson, Antarctica ($L = 8 \cdot 7$), during 1967. By relating these observations to the modal location of the auroral oval, an indication of the parent magnetospheric region is gained. From these results, and other reports, it is concluded that optical pulsations are a basic feature of the auroral display. The occurrence of an 'optical auroral pulsation pearl necklace' is reported.

Introduction

The periodic waxing and waning in intensity of complete auroral forms (patches, arcs etc.) has been commonly reported from cis-auroral latitudes ($3 \cdot 5 \lesssim L \lesssim 7$) (e.g. Heppner 1954; Cresswell and Davis 1966; Omholt and Berger 1967). Confirmation that optical auroral pulsations occur at other than low auroral latitudes has been afforded by the short duration studies of Eather (1968) at Churchill ($L = 8 \cdot 6$) and Brekke and Pettersen (1971) at Svalbard ($L = 15$), and the report by Lassen (1967) of a pulsating patch near $L = 33$. Previously, however, pulsations within quiet faint arcs have only been extensively studied from Saskatoon ($L = 4 \cdot 4$) (Iyengar and Shepherd 1961; Paulson and Shepherd 1966). These factors motivated an investigation into optical auroral pulsations at Mawson, Antarctica (67·60° S., 62·88° E. geographic; $L = 8 \cdot 7$) during the period June–October 1967 inclusive, using a narrow band photometer to monitor variations in the [OI] λ 557·7 nm emission.

Instrumentation

Whilst the long radiative lifetime of the quadrupole oxygen ^{1}S state (0·7 s) does tend to mask the more rapid intensity variations, the λ 557·7 nm emission was chosen in preference to the λ 391·4 nm N_2^+ 1NG (0–0) band for two reasons: The former emission is usually the most intense in the aurora, and hence is of greater use in studies of faint auroral forms. Also, by using the longer wavelength emission the influence of scattering is diminished, when comparing observations taken at different instrumental orientations.

The light was incident upon a 3 in. (7½ cm) diameter narrow band interference filter tuned to λ 557·73 nm. The transmitted light was defocused by a 3½ in. (9 cm) diameter converging lens onto the S20 photocathode of an EMI 9558B photomultiplier. A circular field of view of 4° was employed. Linear amplifiers were used and intensity variations both below and above approximately 1 Hz were independently displayed on separate chart recorder channels, to give total intensity and pulsation chart traces respectively. The frequency response of the system was 'flat' from 0·02 to 10 Hz. Intensity calibration facilities then available for field use were inadequate and this precluded reliable power spectral studies or an accurate estimation of the percentage modulation within the pulsations.

All of the results reported here were obtained looking into the local magnetic zenith but should not be regarded as being peculiar to that location. Pulsations in particle fluxes can occur as changes in number density or energy, or both. Viewing along the local field line includes both types of variations. Such a viewing position also permits an observer to readily identify contaminatory auroral form movements within the field of view.

Results

This study of quiet pulsations was directed at intensity variations of, or occurring within, a single auroral form to the total exclusion, as far as was discernible, of structural movements within the form or of dynamical movements of the form itself. The extensive use of visual observations resulted in the rejection of any results that may have been contaminated by ray or band motions, or due to multiple forms being in the field of view.

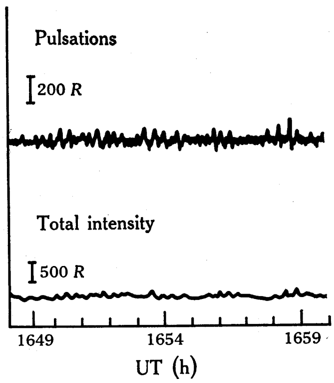

Fig. 1. Typical example of the PQHAT pulsations detected at Mawson, showing the tendency of these pulsations to occur in groups. This particular set of pulsation and total intensity traces (see text) was recorded on 7 October 1967. The indicated scales of 200 and 500 R are estimated values only.

The typical auroral display commenced at Mawson with an iso-L contour aligned $qHA(\frac{1}{2}\text{–}1)c$ polewards of the station and towards the midnight sector of the auroral oval. (The symbolism of the International Auroral Atlas (1963) is used throughout to classify auroral forms.) As the faint arc 'passed' slowly through the local magnetic zenith sampling region, optical pulsations as portrayed in Fig. 1 were detected. These occurred within a Pre-breakup Quiet Homogeneous auroral Arc. They were not due to spatial variations but rather were of Temporal origin, as far as could be visually inferred from the prevailing auroral dynamics surrounding the observation. This type of pulsation has been classified as PQHAT. At Mawson these pulsations were always subvisual.

An inspection of Fig. 1 shows that there is a tendency for the PQHAT pulsations to occur in groups. This feature, when observed in Pc1 magnetic micropulsations, has been likened to the beads of a necklace, and hence could here be regarded as forming an 'optical auroral pulsation pearl necklace'.

Occasionally during the pre-dawn hours, similar pulsations were again detected in just-visible quiet arcs as they passed back through the local magnetic zenith. Once more the distinctive photometric signature was in evidence. (PQHAT pulsations have also been recently detected under similar auroral display conditions by the author at a northern hemisphere site, Primrose Lake (54·78° N., 249·95° E. geographic; $L = 5 \cdot 0$).)

A total of 537 PQHAT pulsation events were recorded in $qHA(\frac{1}{2}–1)c$ parent auroral forms. Their periods were typically 10–20 s with a mean of $14 \cdot 8 \pm 0 \cdot 5$ s.

The modal auroral ovals, used herein and discussed further by Thomas (1971), were obtained by fitting a series of spherical harmonic functions to the quiet auroral occurrences detected by austral all-sky cameras during periods contained within the IGY (1957–58) and the IGC (1959). The mode of this derived function was regarded as the maximum probability contour of auroral occurrence and yielded a set of 10 modal auroral ovals, one for each K_p level, expressed in terms of invariant colatitude and magnetic local time (MLT). On relating the locale of the pulsations, expressed in similar coordinates, to the relevant location of the magnetically disturbed auroral oval it was concluded that the PQHAT pulsations were related to that feature within the uncertainty associated with the modal oval position (some $\pm 2°$ latitude; Thomas 1971). Consequently, we may infer that the PQHAT pulsations are associated with the transition region between the 'closed' and 'open' tail field lines. This, in all probability, places the parent magnetospheric region in the cusp or near-plasma sheet locales.

On no occasion were any of the total form spatial or temporal intensity pulsation types, which are commonly detected at cis-auroral latitudes, observed at Mawson.

Discussion

The present $L = 8 \cdot 7$ results add latitudinal breadth to the $L = 4 \cdot 4$ findings on pulsations within quiet forms by Iyengar and Shepherd (1961) and Paulson and Shepherd (1966). Pulsations within such quiet ordered forms may be indicative of basic causal processes in the auroral display. This contention is reinforced by combining these quiet-form studies with those from other latitudes and auroral display phases; optical auroral pulsations appear to be symptomatic of fundamental processes occurring in auroral dynamics.

The waxing and waning of complete auroral forms was not observed at Mawson on any occasion. Since this type of pulsation is frequently observed at cis-auroral stations, it leads to the inference that the causal mechanisms for optical pulsations differ with the magnetospheric domain sampled.

The occurrence of the optical auroral pulsation pearl necklace could indicate a regular stifling of modulating mechanisms within the magnetosphere. Such modulations may be of a self-limiting nature.

Acknowledgments

The guidance and assistance of Professor V. D. Hopper, Professor N. R. Parsons, Dr J. A. Thomas, Dr I. A. Bourne, Mr F. R. Bond, Mr I. G. Bird, Mr C. R. Simpson, Mr A. G. Kerr, Mr R. S. Unwin and Mr G. M. Allcock during the execution of this study is gratefully acknowledged. The work was assisted by a CSIRO Postgraduate Studentship and Grant No. A–3131 from the NRC Canada, and could not have been undertaken without the support of the Antarctic Division, Department of Science, Australia.

References

Brekke, A., and Pettersen, H. (1971). *Planet. Space Sci.* **19**, 536.
Cresswell, G. R., and Davis, T. N. (1966). *J. Geophys. Res.* **71**, 3155.
Eather, R. H. (1968). *Ann. Geophys.* **24**, 525.
Heppner, J. P. (1954). Ph.D. Thesis, California Institute of Technology.
International Auroral Atlas (1963). Edinburgh University Press.
Iyengar, R. S., and Shepherd, G. G. (1961). *Can. J. Phys.* **39**, 1911.
Lassen, K. (1967). *In* 'Aurora and Airglow' (Ed. B. M. McCormac), p. 453 (Reinhold: New York).
Omholt, A., and Berger, S. (1967). *Planet. Space Sci.* **15**, 1075.
Paulson, K. V., and Shepherd, G. G. (1966). *Can. J. Phys.* **44**, 837.
Thomas, I. L. (1971). Ph.D. Thesis, University of Melbourne.

Manuscript received 28 February 1973, revised 15 July 1974