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THE CORRELATION OF RAPID AKR VARIATIONS WITH CHANGES IN THE FLUXES OF PRECIPITATING ELECTRONS

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ABSTRACT

Since AKR is believed to be generated by anisotropic electron distributions on auroral field lines, it is important to investigate the correlations of AKR with precipitating electrons. At present little is known about the corresponding variations for short duration events since direct electron measurements have generally been made with limited temporal and spatial coverage. Now, with both AKR and X-ray image measurements performed from the POLAR spacecraft it is possible to investigate the correlations between AKR and the intensities and energy spectra of multi-keV electrons with a time resolution of minutes or less. The rise times, durations and fall times of both species are intercompared for events with significant fast time variations in the fluxes of AKR waves and/or X-rays. Observed time delays between X-ray and AKR enhancements are also considered as well as their relative intensities.

INTRODUCTION

Auroral Kilometric Radiation (AKR) and auroral electron precipitation are two phenomena resulting from the energetic electrons populating auroral field lines. AKR is believed to be produced by a cyclotron maser instability driven by an anisotropic distribution of energetic electrons (Wu and Lee, 1979). Such anisotropic distributions are expected in the upward moving electrons above aurora or in trapped distributions with a pronounced loss cone. It is also believed that strong AKR will scatter trapped electrons into the loss cone (Calvert, 1995). Consequently, one would expect a relationship between AKR and auroral electron precipitation, although it is arguable which of the two phenomena is responsible for the other.

Also required for AKR production is a low density in the background plasma, so that the electron plasma frequency is less than the electron gyrofrequency. Since the emission frequency of AKR is near the electron gyrofrequency, the frequency of AKR decreases as the altitude of the generating site increases. Previous studies of AKR have shown that source regions are on magnetic field lines connected to discrete auroral arcs (Huff *et al.*, 1988) and that AKR is refracted into a broad upward cone.

The NASA POLAR satellite offers an excellent opportunity to study the relationship of AKR and auroral precipitation. The Plasma Wave Instrument (Gurnett *et al.*, 1995) records AKR. The PIXIE X-ray imager (Imhof *et al.*, 1995) obtains images of the X-ray production (> 2 keV) throughout the auroral region, and thus measures the distribution in local time of the electron precipitation.

In a previous report Imhof *et al.* (1998) showed for a POLAR pass on 19 April 1996 that there was a good correlation between the time structure of AKR and X-ray emission. This result supports the argument that AKR is produced by upward moving electrons whose loss cone has been depleted by precipitation. The correlation was strongest during the pre-midnight sector even though in general X-ray production is strongest post midnight (Petrinec *et al.*, 1998). Much of the difference in the local time distributions reported in these two investigations may be attributed to the fact that the short duration X-ray enhancements considered by Imhof *et al*, (1998). were primarily those associated with substorms in the near midnight time sector whereas many of those published by Petrinec *et al.*, (1998). were produced by the precipitation of electrons that drifted eastward from the midnight sector. In this paper we examine a larger body of X-ray and AKR data to investigate the relationship between these two phenomena.

PRESENTATION OF DATA

Data were processed from several northern apogee passes of the POLAR satellite. For January 31, 1997 an image of 2 to 12 keV X-rays arising from the polar cap over a 20 minute interval is displayed in Figure 1. The X-ray counts and AKR electric field strengths are plotted together in Figure 2 for the same 20 minute interval. In this comparison only X-rays originating in the 20 to 24 local time sector are plotted. A spectrogram of the wave data is shown in the lower section of Figure 2. The local time of X-ray production is shown in Figure 3 where the flux profiles of the X-rays emitted from each 2 hr MLT interval are plotted in the upper sections. The X-rays in the 20 to 24 MLT sector and the AKR waves were correlated with a coefficient of 0.83. During the two enhancements at 02:04 and at 02:14 the AKR wave increases occurred first, consistent with some POLAR perigee events reported by Anderson *et al.*, (1998). The X-ray fluxes and the AKR wave intensities are plotted against each other in Figure 4, and a best fit line is included.

A tabulation of selected data from several cases of X-ray and AKR enhancements is presented in Table 1. The table lists the dates, geocentric height of the satellite in earth radii and the time interval of the data set. The correlation coefficients between X-rays and AKR over this time interval are given in the fourth column. Times of significant enhancement events are then listed along with the MLT interval of the X-ray production. The last three columns state which measurements exhibited enhancements and, when both showed maxima, which was the first to increase and which was the first to decrease. During many of the events the onset times of the X-rays and the AKR waves were the same within the resolution of the analyses. However, on 4 occasions in Table 1 the AKR onset was significantly first whereas on 2 occasions the X-rays occurred first. During 3 enhancements the AKR started to fall to background level before the X-rays decreased, whereas the X-rays were first on only one satellite pass. On certain passes, such as the one listed on December 11, 1996 at 12:43, only the AKR waves displayed an enhancement. At that time there was no significant change in the X-ray flux. The AKR may have been produced by trapped particle anisotropies which do not lead to strong precipitation. On some apogee passes major changes were observed in the X-ray flux versus time profiles relative to the AKR profiles. Therefore, although AKR is often strongly correlated with electron precipitation on a time scale of many minutes the relationship is sometimes complex at shorter times.

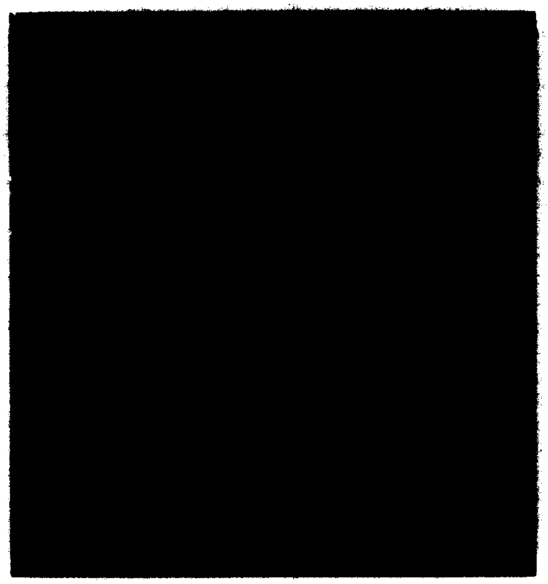

Fig. 1. X-ray Image

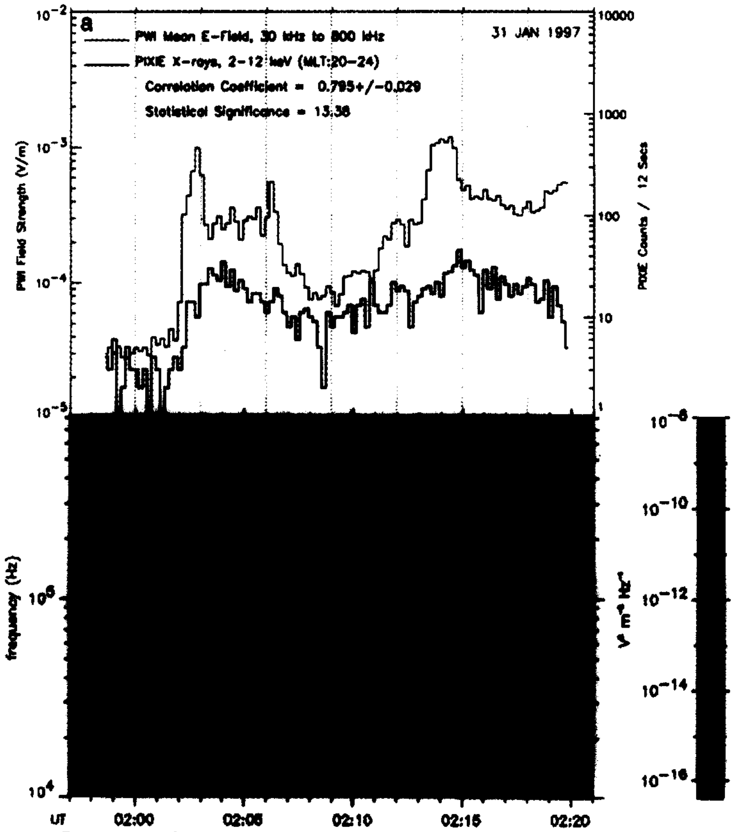

Fig. 2. a) Comparison between AKR electric field and PIXIE x-rays emitted at MLT=20-24 hrs. b) Electric field spectrogram from Sweep Frequency Receiver A in PWI.

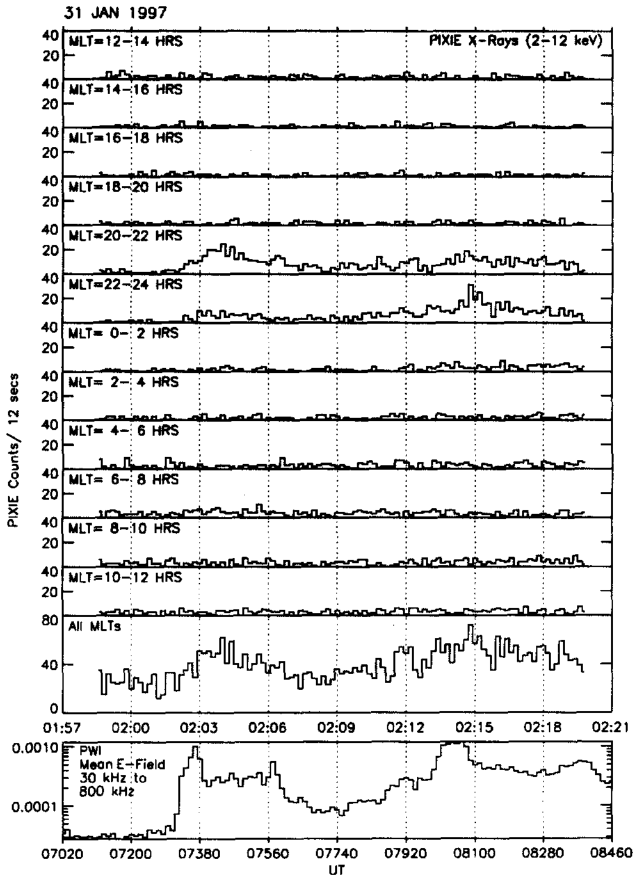

Fig. 3. Counting rates of x-rays in successive two hour MLT intervals and at all MLT. The mean electric field strength is plotted in the bottom section.

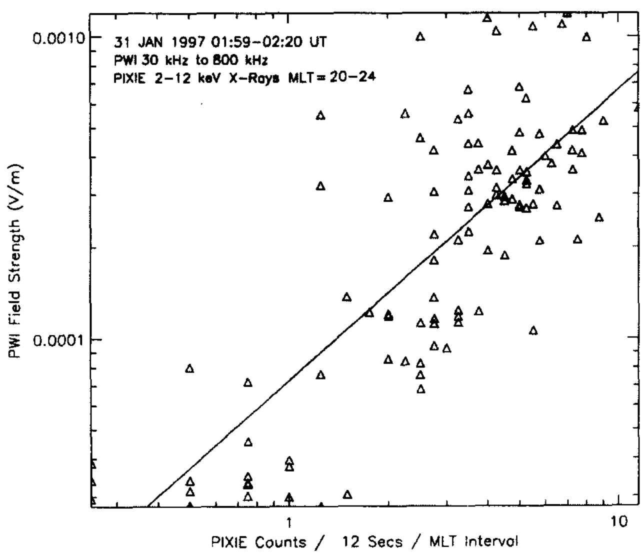

Fig. 4. X-ray fluxes versus AKR wave intensities.

Table 1 Apogee Passes

Date	RE	Time Interval	30s Res. Corr. Coef.	Time Of Event	X-Ray MLT Interval (hr)	Enhance.	1st To Rise	1st To Fall
4/19/96	8.5	22:08-23:30	0.42	22:53	18-24	AKR		
4/19/96	8.5	22:08-23:30	0.42	22:59	18-24	both	AKR	AKR
4/19/96	8.3	22:08-23:30	0.42	23:16	18-24	both	AKR	x-ray
12/11/96	8.6	12:27-12:47	0.57	12:33	16-20	both	x-ray	both
12/11/96	8.6	12:27-12:47	0.57	12:40	16-20	x-ray		
12/11/96	8/6	12:27-12:47	0.57	12:43	16-20	AKR		
1/13/97	8.2	17:45-18:07	0.81	17:54	20-02	both	x-ray	both
1/31/97	7.8	01:58-02:21	0.83	2:04	20-24	both	AKR	AKR
1/31/97	7.8	01:58-02:21	0.83	2:14	20-24	both	AKR	AKR

CONCLUSIONS

By comparing the time variations of X-rays from electron precipitation in the auroral oval with AKR intensities we have found that: a.) AKR intensities are best correlated with electron precipitation in the 20 to 24 MLT sector. The correlation coefficients between AKR electric field strength and X-ray flux in the 2 to 12 keV energy range vary from 0.4 to 0.8 with high statistical significance. b.) The peaks in X-ray and AKR intensities do not show a systematic time difference within the 12 second time resolution of the analyses. However, sometimes one component or the other had an earlier onset time. On rare occasions X-ray bursts are observed without enhanced AKR, or AKR enhancements occur without simultaneous X-ray bursts. c.) In the cases selected for this study the X-ray production was largest in the pre-midnight sector. Petrinec *et al.*, (1998) found that the overall X-ray intensities were higher post midnight. This result suggests that the selection of events based on strong time variations tends to favor pre-midnight precipitation.

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REFERENCES

Anderson, R. R., J. D. Scudder, H. Matsumoto, W. Imhof, D. Chenette, J. Mobilia, M. Walt. G. Rostoker, S. Kokubun, D. H. Fairfield, Examining Indications from POLAR and GEOTAIL that Auroral Kilometric Radiation Can Trigger the Aurora, EOS Trans. AGU, 79 (17), Spring Meet. Suppl. S330 (1998).

Calvert, W., An Explanation for Auroral Structure and the Triggering of Auroral Kilometric Radiation, *J. Geophys. Res.*, **100**, 14887 (1995)

Gurnett, D. A., A. M. Persoon, R. F. Randall, D. L. Odem, S. L. Remington, T. F. Averkamp, M. M. Debower, G. B. Hospodarsky, R. L. Huff, D. L. Kirchner, M. A. Mitchell, B. T. Pham, J. R. Phillips, W. J. Schintler, P. Sheyko, and D. R. Tomas, The POLAR Plasma Wave Instrument, *Space Science Reviews,* **71**, 597 (1995).

Huff, R. L., W. Calvert, J. D. Craven, L. A. Frank, and D. A. Gurnett, Mapping of Auroral Kilometric Radiation Sources to the Aurora, J. Geophys. Res., **93**, 11445, 1988.

Imhof, W. L., K. A. Spear, J. W. Hamilton, B. R. Higgins, M. J. Murphy, J. G. Pronko, R. R. Vondrak, D. L. McKenzie, C. J. Rice, D. J. Gorney, D. A. Roux, R. L. Williams, J. A. Stein, J. Bjordal, J. Stadsnes, K. Njoten, T. J. Rosenberg, L. Lutz and D. Detrick, The POLAR Ionospheric X-ray Imaging Experiment (PIXIE), *Space Science Reviews*, **71**, 385 (1995).

Imhof, W. L., D. L. Chenette, D. W. Datlowe, J. Mobilia, M. Walt, and R. R. Anderson, The Correlation of AKR Waves With Precipitating Electrons as Determined by Plasma Wave and X-ray Image Data from the POLAR Spacecraft, *Geophys. Res. Lett.*, **25**, 289 (1998).

Petrinec, S.M., J. Mobilia, D. L. Chenette, and W. L. Imhof, Statistical Survey of Auroral X-ray Emissions - PIXIE Observations. Submitted to Proceeding of the International Conference on Substorms-4, edited by Y. Kamide Terra Scientific Publishing, Tokyo, Japan (1998).

Wu, C.S., and L. C. Lee, A Theory of the Terrestrial Kilometric Radiation, *Astrophys. J.*, **230**, 621 (1979).