Auroral Kilometric Radiation polarization revisited

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AKR - basic facts

(A)uroral (K)ilometric (R)adiation

- powerful e-m emission, generated along auroral field lines, mostly in evening-night sector, propagating mainly in Right-hand Circularly Polarized X-mode
- frequency range 40 - 1000 kHz, wavelengths 7.5 km – 300 m
- source altitudes 2000 - 20 000 km
- generation near gyro-frequency of electrons, via electron cyclotron maser mechanism *[Wu and Lee, 1979]*
- energy supplied by unstable "horseshoe" velocity distribution of electrons
- strongly beamed in the plane tangent to the auroral oval

Dynamic spectrum of AKR Stokes parameters

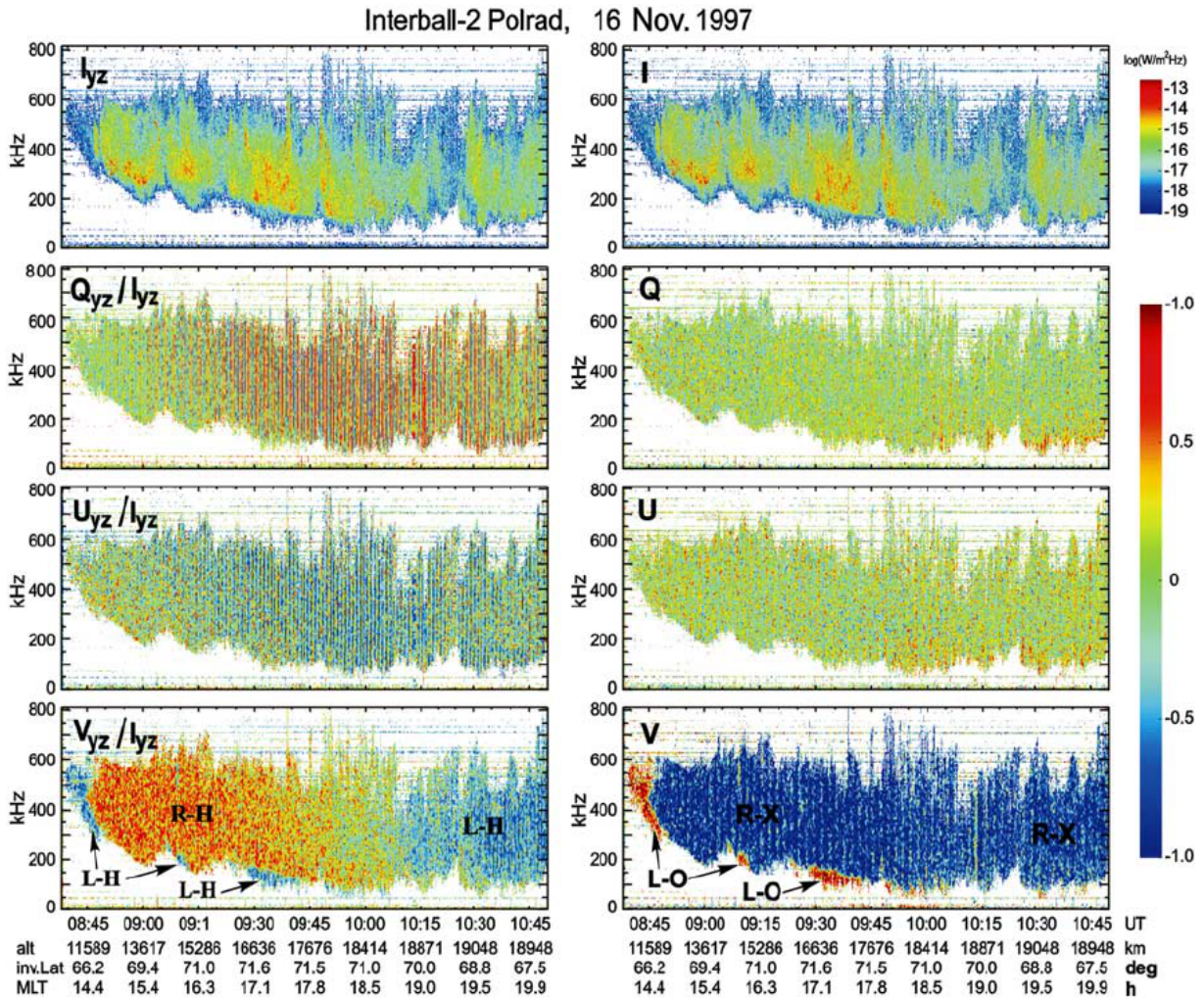

Figure 2. Dynamic spectra of the Stokes parameters of AKR: intensity (I), degrees of linear (Q/I, and U/I) and circular (V/I) polarizations. (left) Dynamic spectra of the Stokes parameters determined with the pair of Y and Z antennas deployed in the spin plane (reproduced from *Hanasz et al.* [2003]). (right) Stokes parameters in the wave plane of AKR.

Search for possible AKR linear polarization

RADIO SCIENCE, VOL. 43, RS1006, doi:10.1029/2006RS003606, 2008

Estimation of linear wave polarization of the auroral kilometric radiation

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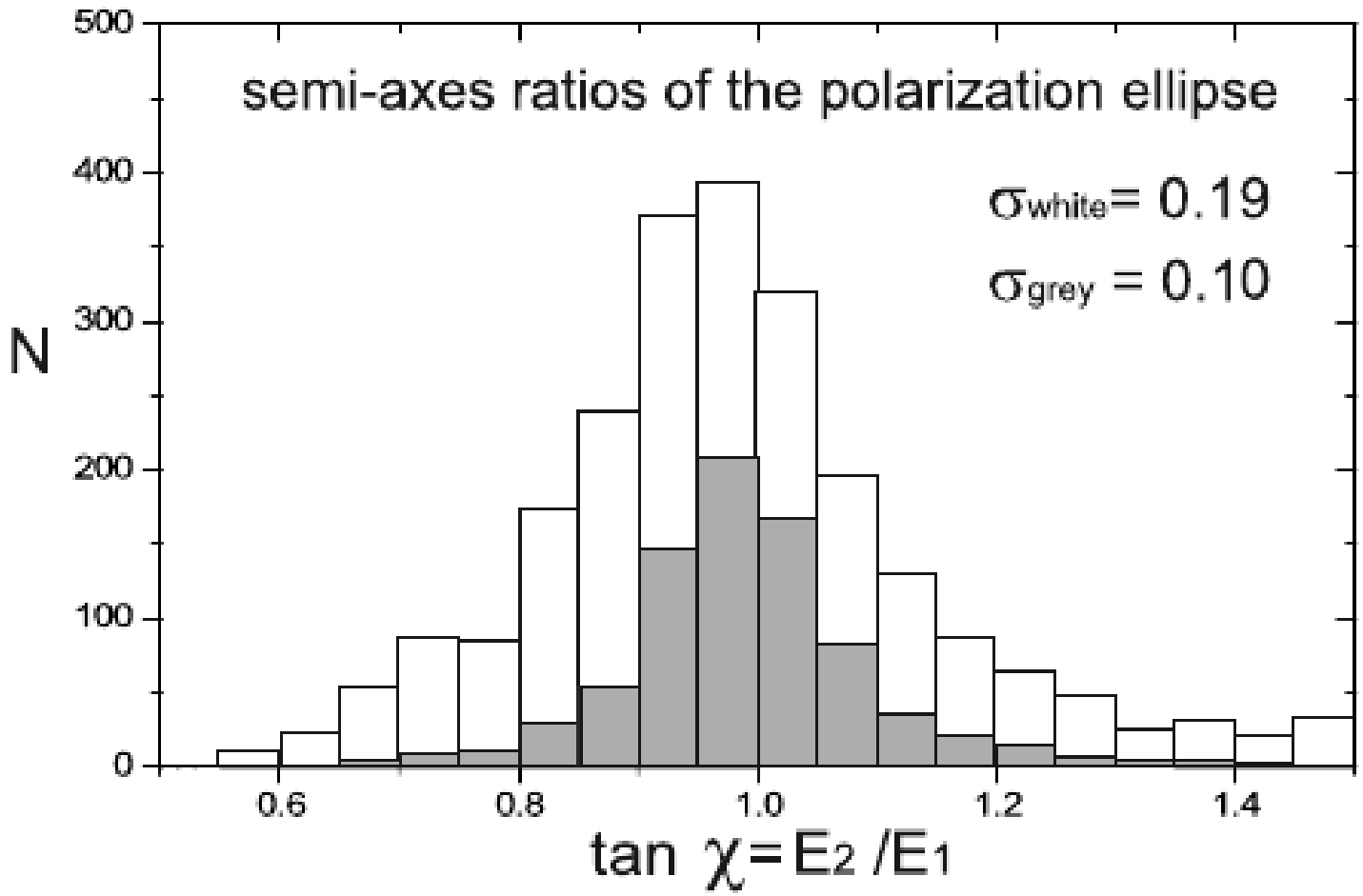
[1] There is a general view that the auroral kilometric radiation (AKR) polarization is fully circular with dominating right-hand extraordinary mode and some admixture of the left-hand ordinary mode. Most of up-to-date determinations of the wave modes of the AKR have been based on measurements of the circular component of the wave polarization, leaving the linear polarization parameters unknown. In space observations the polarimeter is usually not directed to the AKR source. However, having determined the polarization parameters in each of the three perpendicular planes, one is able to determine the polarization ellipse in the 3-D space. Results of statistical estimations of the AKR polarization parameters in the wave plane are presented. Data were provided by the Interball-2/Polrad triaxial polarimeter. It is the first time the dynamic spectra of all four Stokes parameters of the AKR are displayed in the wave plane. The AKR polarization is mostly circular with an estimated mean value of the semiaxes ratio of 0.99 ± 0.10 rms error, with a small contribution of the linear component at a level of 0.07 ± 0.09 rms error, and an unpolarized component at a level of 0.10 ± 0.08. The uncertainties of these estimations are too large to definitely conclude on presence or absence of some small contributions of the linear and upolarized components in the AKR. However, in the limits of the above uncertainties these estimations do not contradict expectations that the linear polarization is absent in the AKR. Some small contribution of the unpolarized component can be explained by a relatively high level of noise and board interefences.

Panchenko et al., (2008) AKR polarization measurements



Grey shading - linearly independent solutions, white - all solutions

MEMO – Interball 2 polarization measurements

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 106, NO. A1, PAGES 315–325, JANUARY 1, 2001

Propagation characteristics of auroral kilometric radiation observed by the MEMO experiment on Interball 2

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Abstract. The MEMO experiment is a part of the Interball 2 wave consortium. It is connected to a total of six electric and nine magnetic independent sensors. It provides waveforms associated with the measurement of two to five components in the three frequency bands: ELF (5-1000 Hz), VLF (1-20 kHz), and LF (20-250 kHz). Waveforms of three magnetic components and one electric component recorded during observations of auroral kilometric radiation (AKR) allow a detailed study of the characteristics of these emissions. In particular, the wave normal directions of AKR relative to the Earth's magnetic field are determined using several methods: the classical methods based on the plane wave approximation [*Means*, 1972] and the wave distribution function method which represents the evaluation of the wave energy density distribution with respect to the angular frequency and the wave normal direction(s). One event is fully analyzed in this paper. It is shown that AKR propagates with a polarization quasi-circular (ellipticity value ~ 0.9), a right polarization (i.e., R-X mode), and wave normals weakly oblique (~ 30°).

AKR polarization – CASSINI mission measurements

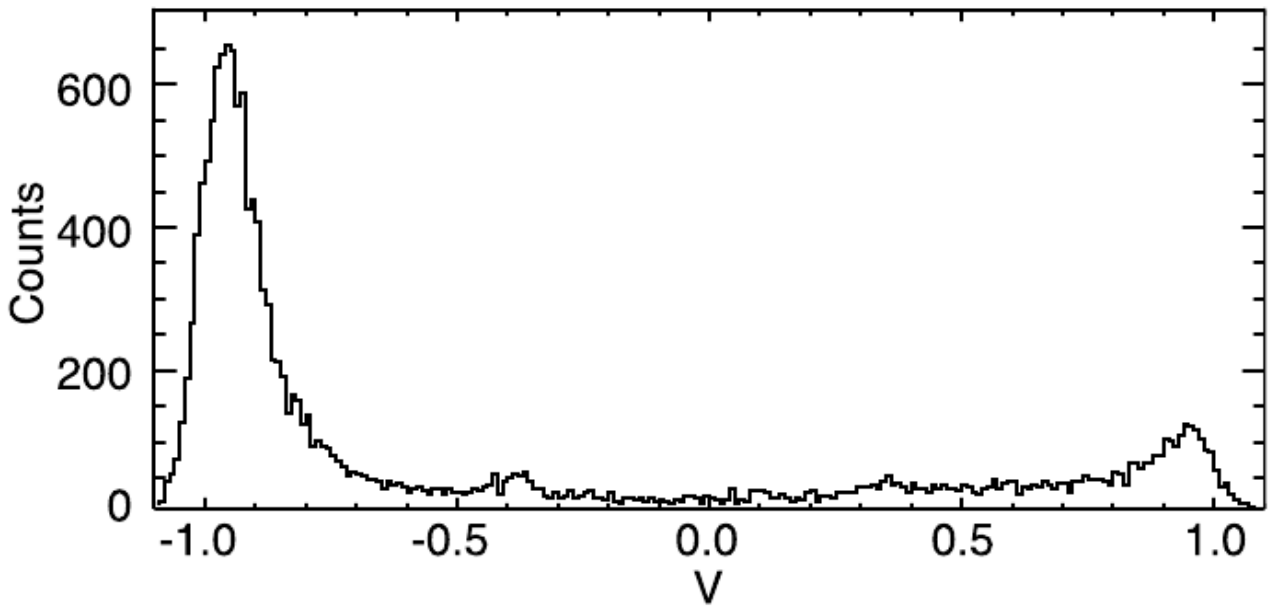

Figure 4. Distribution of the circular polarization degree V measured from polarimetric two-antenna measurements spread over the whole month of Cassini observations at Earth, over a selection of time intervals containing only AKR (i.e., excluding solar emissions), between 40 and 500 kHz, and satisfying the criteria SNR $\geq$ 15 dB for each antenna, and $\beta \geq 20°$.

Lamy et al., 2010

SKR – elliptical polarization for higher latitudes!

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Elliptical polarization of Saturn Kilometric Radiation observed from high latitudes

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[1] The high-inclination orbits of the Cassini spacecraft from autumn 2006 until spring 2007 allowed the Cassini/RPWS (Radio and Plasma Wave Science) instrument to observe Saturn Kilometric Radiation (SKR) from latitudes up to 60° for the first time. This has revealed a surprising new property of SKR: above ~30° in observational latitude, a significant amount of SKR is strongly elliptically polarized, in marked contrast to previous observations from low latitudes, which showed only circular polarization. There are transitional latitudes where the elliptical polarization occurs in "patches" in the time-frequency spectrograms next to regions of still completely circularly polarized SKR. From ~45° to 60° in northern latitude, it is found that most of the SKR is elliptically polarized throughout its entire frequency range with an average degree of ~0.7 in linear polarization. We demonstrate the ellipticity of SKR by using the concept of "apparent polarization" in case of two-antenna measurements, but also show three-antenna measurements from which the polarization can be unambiguously determined. Possible reasons for the variation of SKR polarization with the observer's latitude will be discussed.

Morioka et al., (1990) – short AKR bursts

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Title:	Polarization and mode identification of auroral kilometric radiation by PWS system onboard the Akebono (EXOS-D) satellite
Authors:	Morioka, Akira; Oya, Hiroshi; Kobayashi, Kaori
Affiliation:	AA(Tohoku University, Sendai, Japan), AB(Tohoku University, Sendai, Japan), AC(Tohoku University, Sendai, Japan)
Publication:	Journal of Geomagnetism and Geoelectricity (ISSN 0022-1392), vol. 42, no. 4, 1990, p. 443-458.
Publication Date:	00/1990
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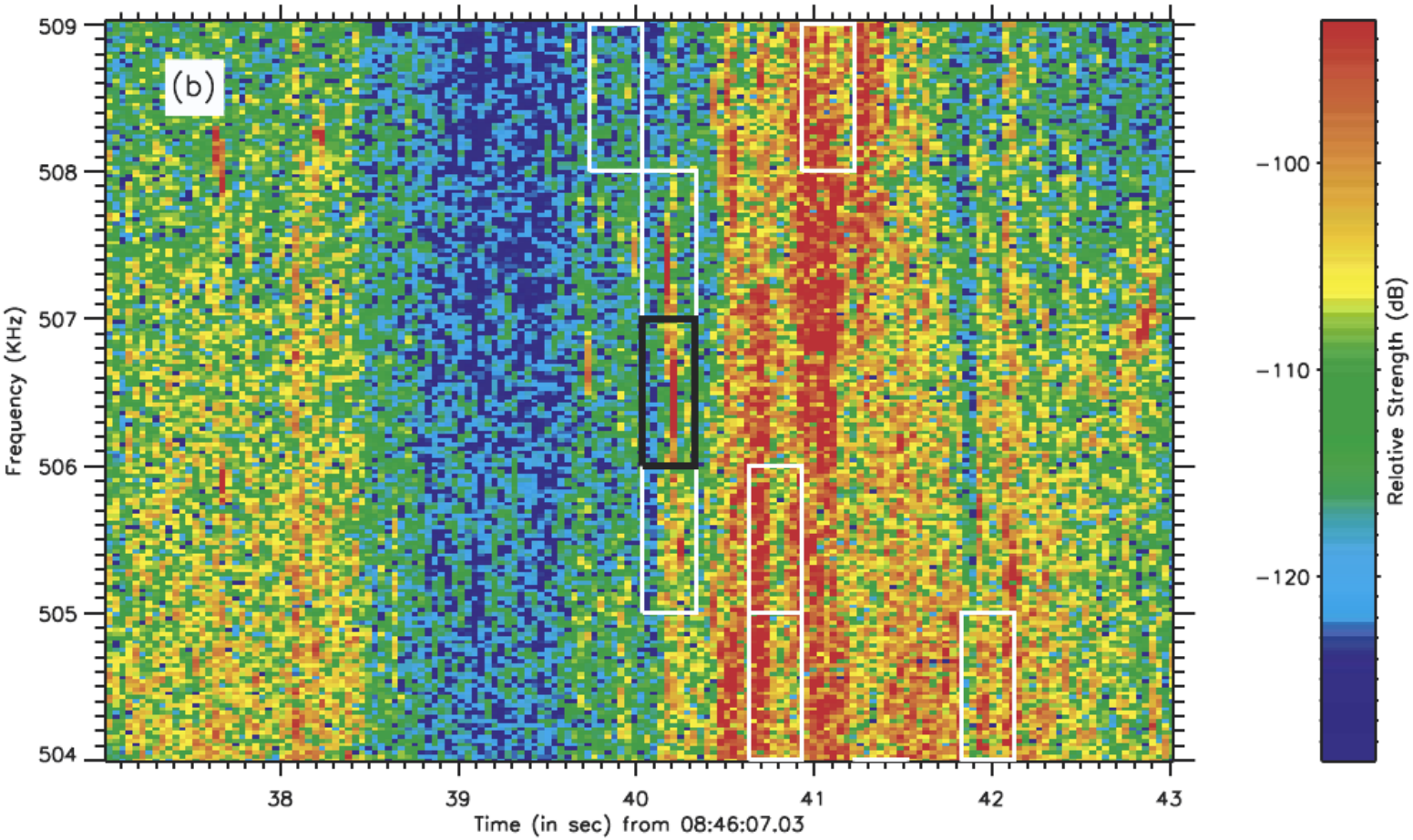
Abstract

The EXOS-D satellite's Plasma Waves and Sounder experiment has conducted a study of the auroral kilometric radiation (AKR) Poynting flux on the basis of the detected waveforms' amplitude and phase angle; AKR propagation mode determinations were also made. Attention is given to a case where medium-intensity AKR indicates L-O mode propagation, and to one in which sudden polarization reversal from the L-O mode to the R-X mode occurred in association with explosive AKR bursts. The intensity and direction of the AKR Poynting flux vary in periods as short as 10 msec, suggesting very fast motion of the AKR source location.

Bibtex entry for this abstract Preferred format for this abstract (see Preferences)

AKR dynamic spectrum (CLUSTER), Mutel et al., 2003



Black box - short AKR burst seen in more details on the next slide

Filtered AKR waveforms seen onboard four CLUSTER s/c

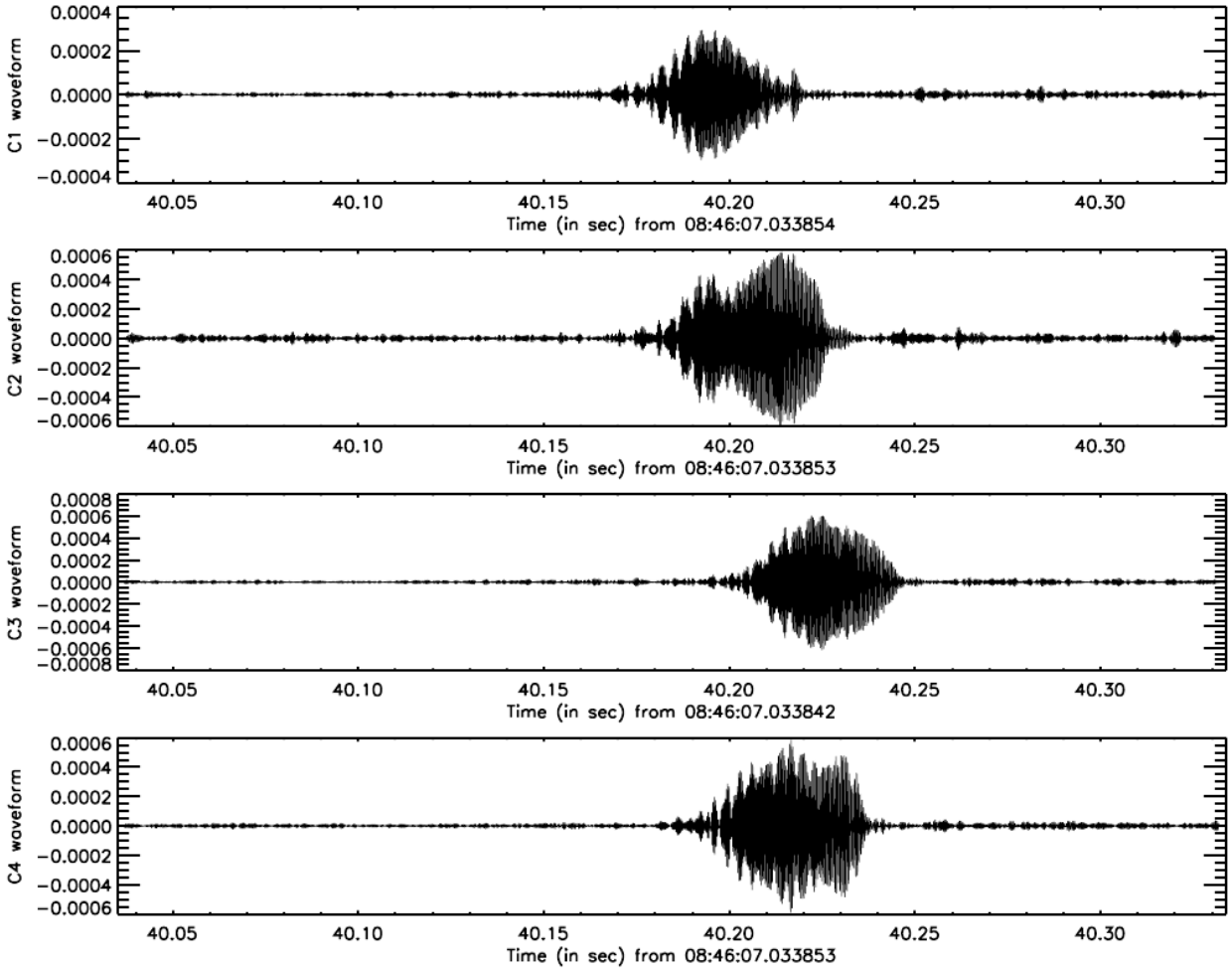


Figure 5. Filtered AKR burst waveforms received on cluster spacecraft C1, C2, C3, and C4. The waveforms are for the checkered box illustrated in Figure 4 (300 ms time interval, 1 KHz bandpass filtered from 506 to 507 KHz).

Mutel et al., 2003

Final comments

Russian multispacecraft RESONANCE mission

- two pairs of s/c (with changing spacing) that can be located on the same magnetic field tube
- SRC PAS in Warsaw builts four High Frequency Analysers able to record AKR waveforms in 1 MHz frequency band

What does it mean for single AKR wave packets?

- they can be identified and recorded on different spacecraft

And for AKR polarization determination?

- possibility of simultaneous polarization measurements close and far from the AKR source
- determination of polarization transfer on the way to observer
- full polarization measurements inside of the AKR source