Conjugate observations of VLF periodic emissions by Van Allen Probe and ground-based station: a case study

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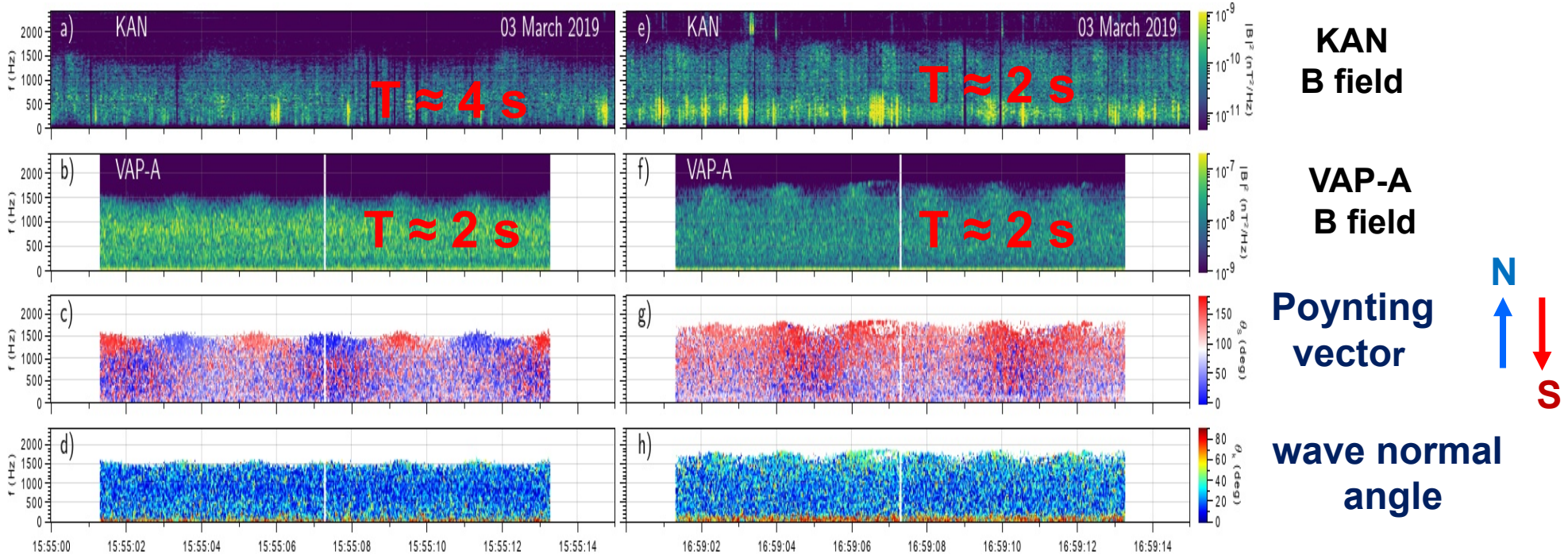
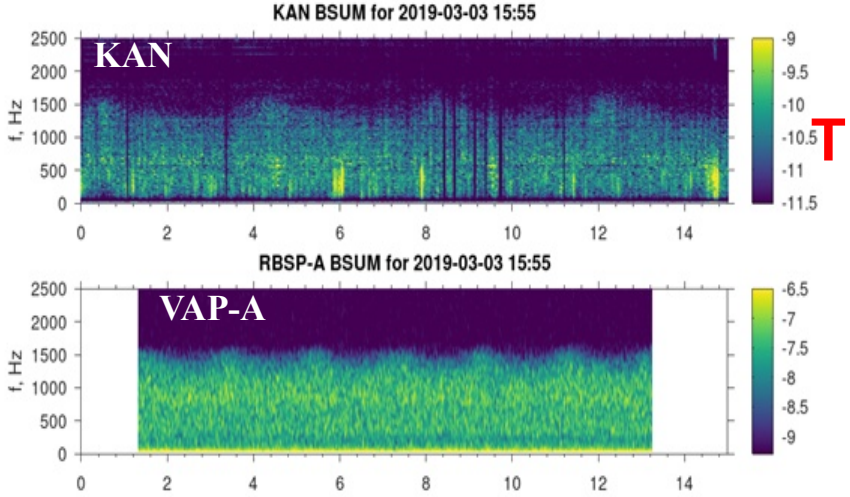
We present for the first time the results of observations of VLF periodic emissions (PE) with T<10 s in the equatorial region of the magnetosphere detected by Van Allen Probe (VAP) satellite. These VLF emissions were also observed by the ground-based stations Kannuslehto (KAN) and Lovozero (LOZ).

PE were detected simultaneously by the spacecraft VAP-A (MLat = ± 1°, L = 5.9-5.5) and the ground based stations (KAN, LOZ) from 15:50 to 17:07 UT in the frequency range 1.4-1.7 kHz near the upper frequency of the hiss.



PE periods on Earth and on VAP-A satellite

PE spectrograms for two intervals
near the beginning 15:55:00 — 15:55:15 UT and the end of the event 16:59:00 — 16:59:15 UT

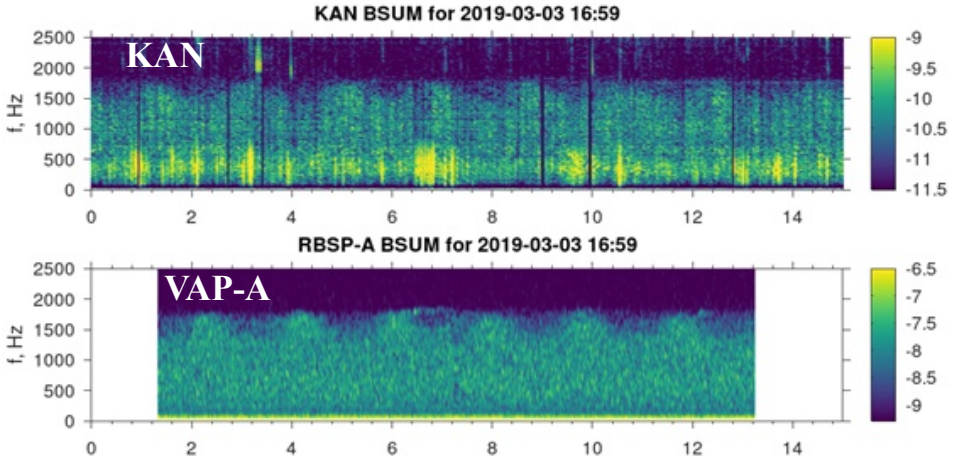


PE period at KAN

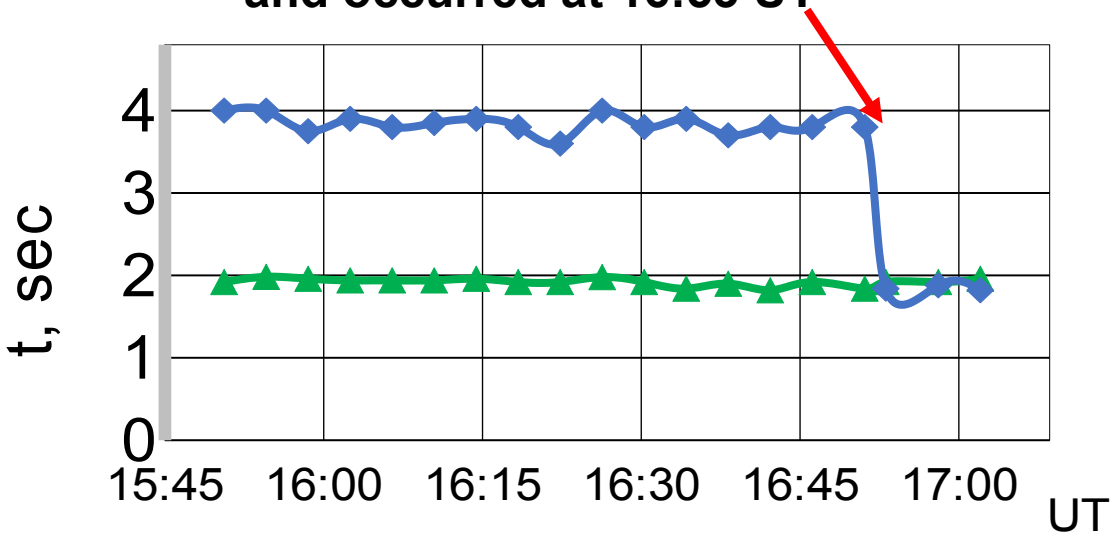
T ≈ 4 s

T ≈ 2 s

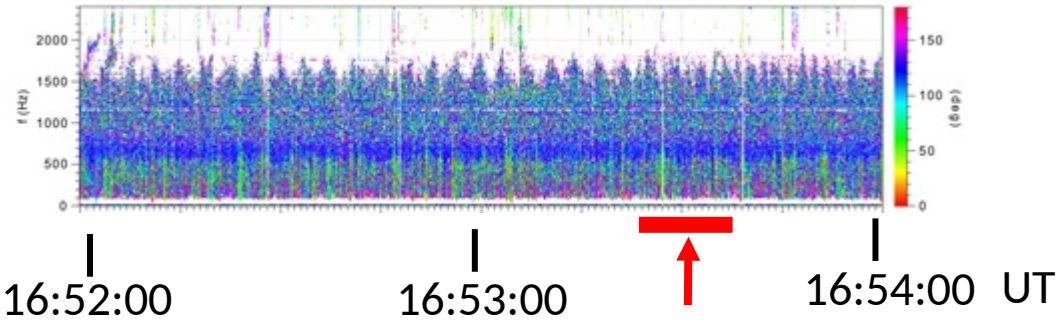
PE period at VAP-A was unchanged, T ≈ 2 s



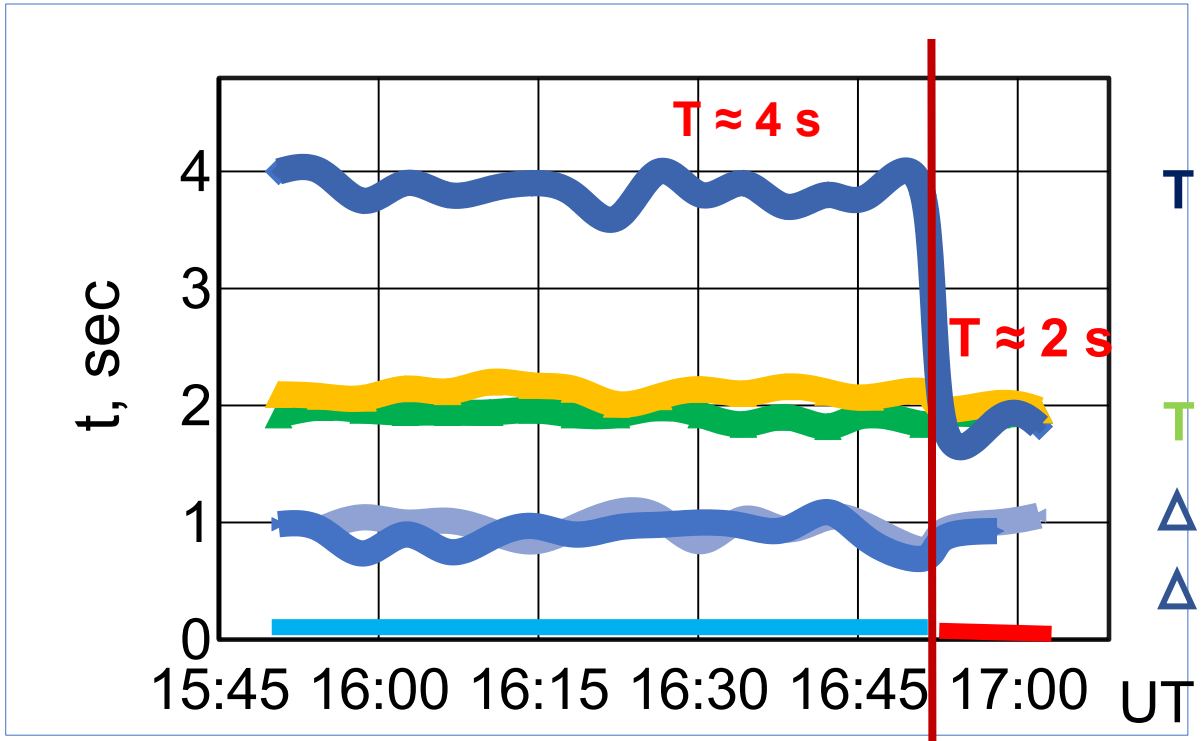
The twofold period decrease was sharp and occurred at 16:53 UT



After a sharp decrease in the periods, the direction of propagation of PE remained from the southwest, which means that the source of PE most probably did not change.



Periods and the time delays between the periodic elements detected on the ground and by VAP-A



Tgr - whistler wave propagation time between hemispheres for longitudinal propagation and plasma density measured on VAP-A, calculated for a gyrotropic field-aligned density profile

⇦ the time delays between the periodic elements detected on the ground and by VAP-A

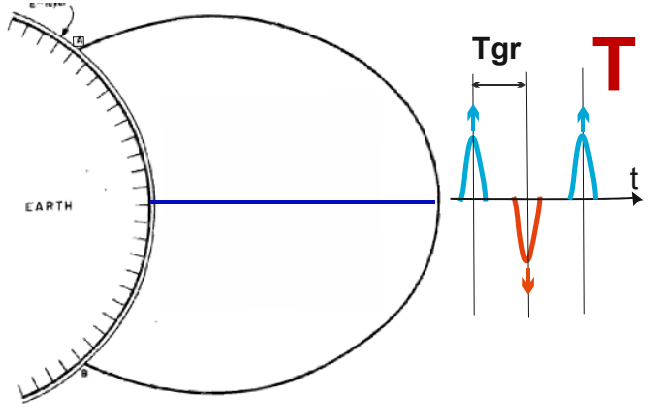
When the periods of PE on the ground were T ≈ 4 s, the delays of the PE signals at KAN relative to the PE at VAP-A, propagating northward, were Δ t ≈ 1 s

i.e. ½ ½ T (VAP-A), Tgr and ¼ T (KAN)

When the periods of PE on the ground were T ≈ 2 s, the delays of the PE signals at KAN relative to the PE at VAP-A, propagating southward, were Δ t ≈ 1 s

i.e. ½ T (VAP-A), Tgr и ½ T (KAN)

Two regimes of PE

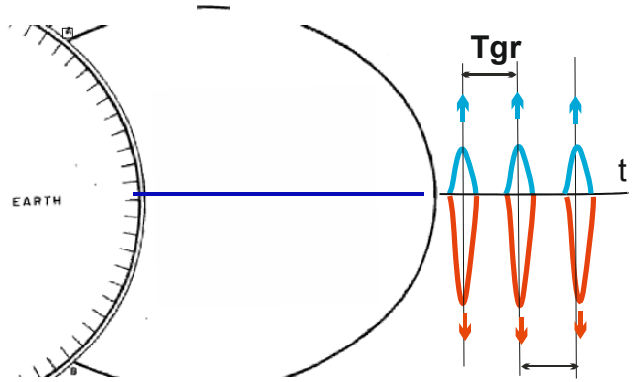


T = 2Tgr ≈ 4 s

First regime. The periods of PE on the ground T ≈ 4 s correspond to the two-hop whistler transit time 2Tgr, the periods on the satellite are equal to Tgr, and the delays between the signals on the ground and the PE pulses moving northward at the equator were ¼ Tgr.

The direction of the PE Poynting flux in the magnetosphere alternates, and the period of the bursts is half that on the ground.

In this case, PEs are formed by a single isolated wave packet, which propagates repeatedly between conjugated hemispheres.



T = Tgr ≈ 2 s

The second regime. The periods of PE on the ground and on the satellite coincide T ≈ 2 s and correspond to the one-hop whistler transit time Tgr. The delay between the signals on the ground and the PE pulses moving southward at the equator were ¼ Tgr. The direction of PE Poynting flux in the magnetosphere is southward.

In this case, the PEs can be formed by two symmetrically propagating wave packets that meet synchronously at the equator, and the amplitude of the pulse moving southward exceeds the amplitude of the signal propagating northward.

The properties of PE detected in magnetosphere and on the ground including the halving of the periods of VLF emissions observed on the ground, from the two-hop to one-hop whistler transit time can be interpreted within the framework of the passive mode locking mechanism in the magnetospheric cyclotron maser [Bespalov, 1984, 2010].