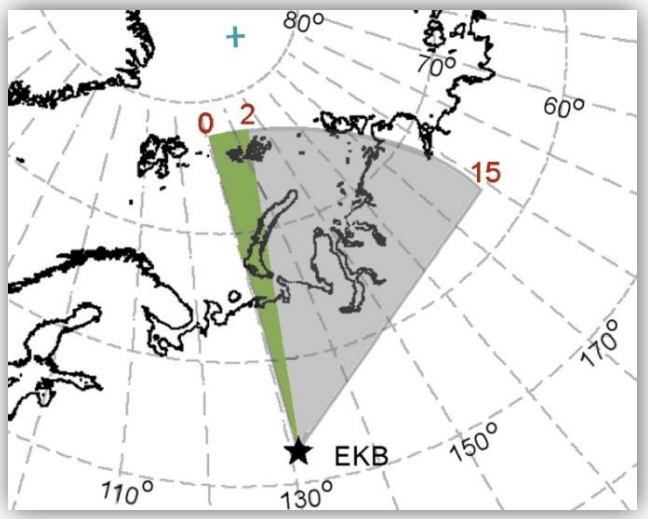
ULF waves registered with the Ekaterinburg radar: Statistical analysis and case studies

Maksim A. Chelpanov, Olga V. Mager, Pavel N. Mager, Dmitri Yu. Klimushkin

Institute of Solar-Terrestrial Physics, Irkutsk, Russia

The Ekaterinburg midlatitude decameter radar was designed analogously to SuperDARN radars. It started operating in late 2012. Three of its beams have been working in high time resolution mode (18 s at each beam). They are directed approximately towards the magnetic pole → the radial component of ULF magnetic disturbances is registered.
Here is an overview of ULF wave studies conducted using the EKB radar.



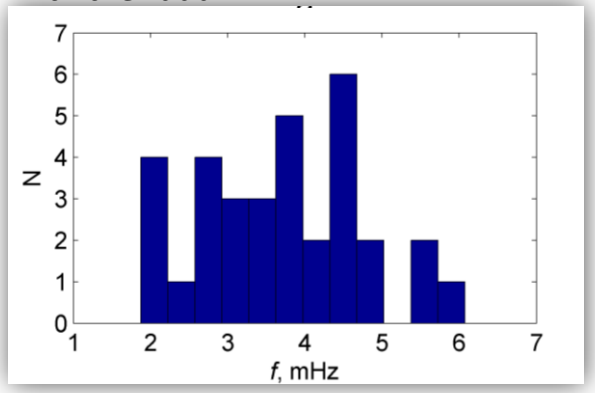
Main results (in more details in further slides):

- A major part of ULF pulsations observed with the radar in the nightside ionosphere have frequencies that are considerably lower than appropriate FLR frequencies estimated based on spacecraft data. [Chelpanov et al., 2018];
- A dependence of frequency on azimuthal wave number m is shown for an individual case. Such dependence indicates that the drift compressional mode was observed [Chelpanov et al., 2016];
- Coupling of drift compressional and Alfven modes was shown [Mager et al., 2015];
- A case of simultaneous radar and spacecraft wave observation is presented. A drift resonance with the substorm injected protons was shown [Mager et al., 2019].

1. [Chelpanov et al., 2018]
Comparison of wave frequencies with FLR frequencies estimated based on spacecraft data

33 waves registered in 2014 and 2015 in the nightside ionosphere were chosen where spacecraft data were available from the longitudinal sectors of radar observations.

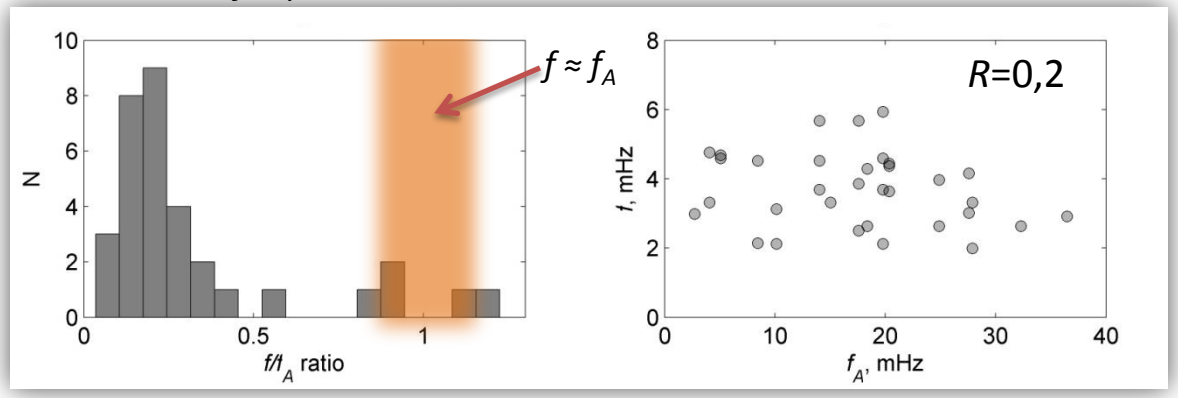
Frequencies of the waves observed with the radar



For each case FLR frequency at the appropriate L shell was calculated using spacecraft data. It was estimated based on magnetic field amplitude and particle space density.

Frequency f of each oscillation observed with the radar was compared with that of standing Alfven wave f_A. In 28 out of 33 cases the wave frequencies were at least 40% lower than the appropriate Alfvénic frequencies. There is no noticeable dependence $f(f_A)$, correlation coefficient is 0.2.

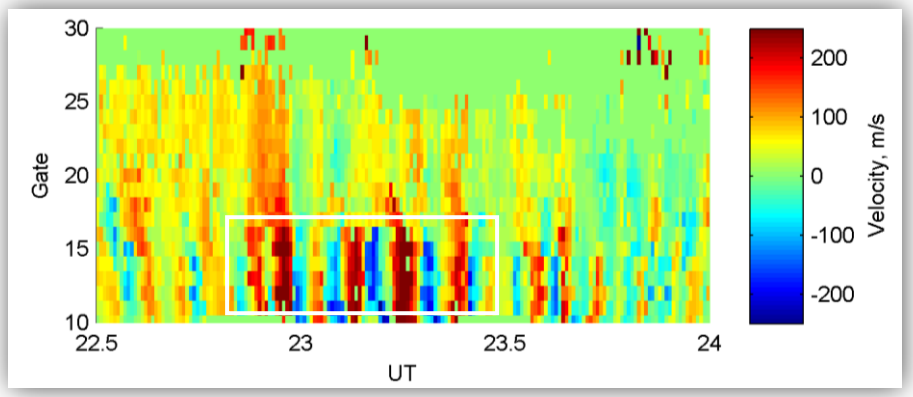
Comparison of frequencies of the waves observed with the radar and estimated FLR frequencies



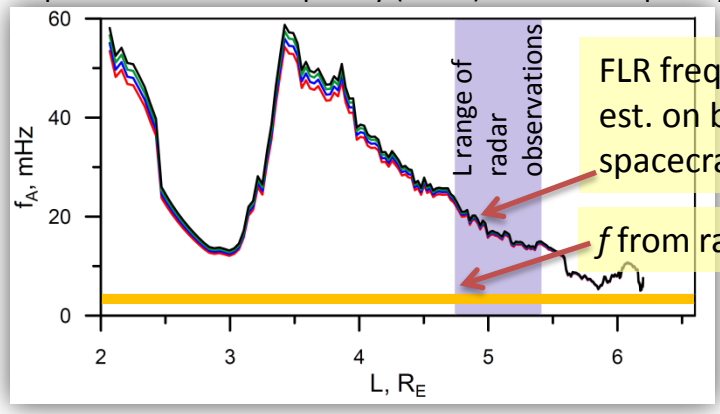
In some cases waves with different frequencies were observed at the same L shell, which also contradicts theory of Alfvén waves and other MHD waves. In kinetics, the drift compressional mode might be the most suitable explanation.

2. [Chelpanov et al., 2016]
Dependence of frequency on azimuthal wave number *m* for an individual event. 26 Dec. 2014

Ionospheric flow velocity fluctuations at the EKB radar, beam 0

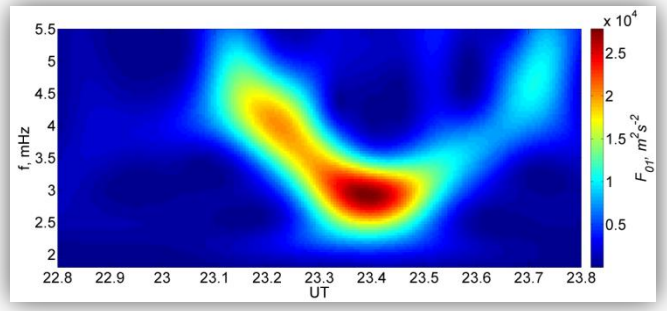


Comparison of wave frequency (radar) and FLR frequency (spacecraft)

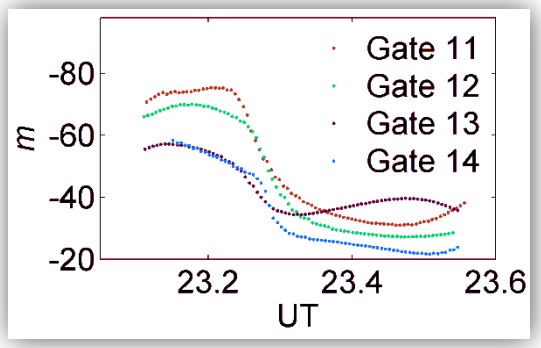


- The frequency of the wave was considerably lower than the appropriate FLR frequency;
- The requency and azimuthal wave number *m* decreased during about 20 minutes → approximate **linear *f(m)* dependence**;
- Such dependence at a fixed L shell in the inner magnetosphere is only typical for the drift compressional mode: $\Omega_M = \frac{m}{L} \frac{\frac{2}{3}\frac{L_b}{\beta_{eq}}\Lambda_N V_d + V_n^* + V_T^*}{1 - \frac{V_T^*}{V_d}}$ [Mager et al., 2013]

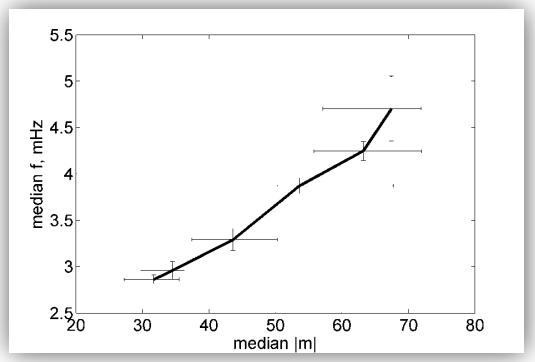
Decrease in *f* ($F_{12}(\omega,\tau)$, gate 13, beams 0 and 1)



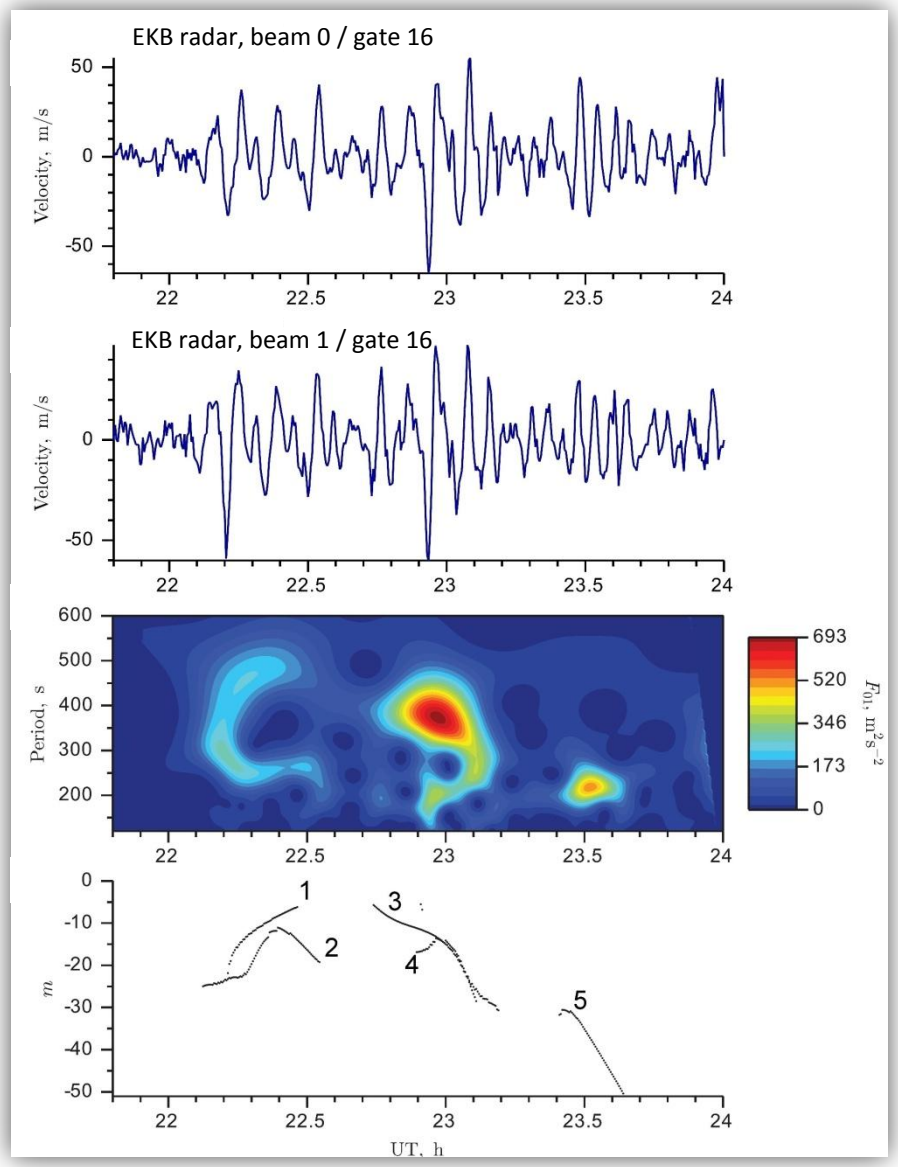
Decrease in *m* (Gates 11–14, beams 0)



f(m) dependence



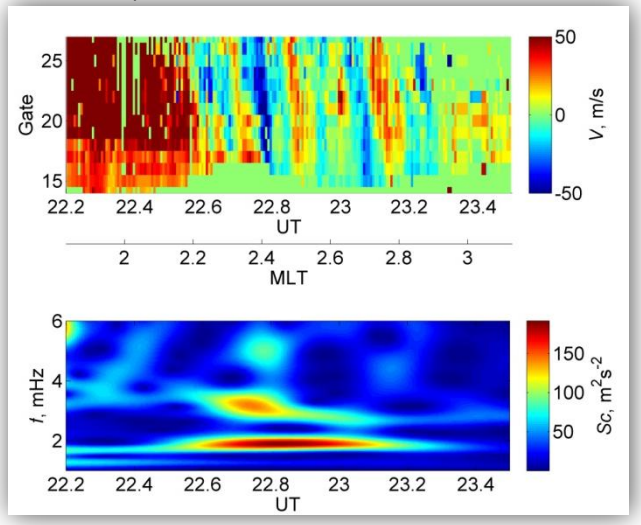
3. [Mager et al., 2015]
Observing merging the drift compressional and the Alfven modes.
14 Dec. 2013



- Linear dependence *f(m)* of the drift compressional mode can be broken when |*m*| is high because of coupling with the Alfvén mode [Klimushkin et al., 2012].
- Two waves with initially different frequencies were registered within two wave packets. Each wave had |*m*|<30.
- The third packet was a quasi-monochromatic wave with |*m*| growing from 30 to 50. All the waves propagated westward and had negative *m*.
- The wave activity coincided with a bay-like 10 nT decrease in SYM-H. The disturbance most likely led to an injection of hot protons in the magnetosphere.
- Merging of the modes complies with the theory of mode coupling due to the magnetic field line curvature and plasma inhomogeneity. Another such case is presented in the paper, with lower-*m* branches registered with ground-based stations, and higher-*m* — at the radar.

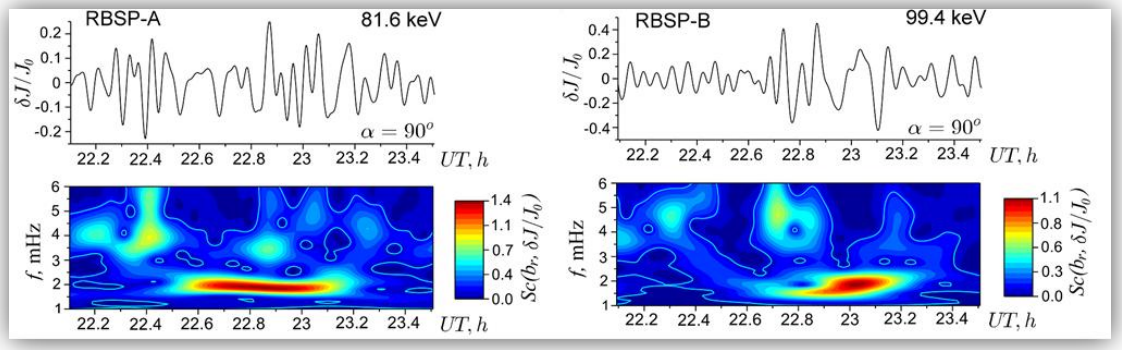
4. [Mager et al., 2019] Simultaneous wave observations with the EKB radar and the spacecraft. 22 Nov. 2014

Oscillations and heir spectrum (gate 24) at the EKB radar, beam 0

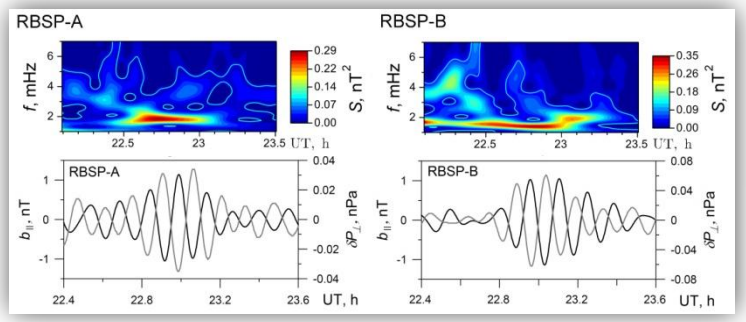


A case of simultaneous radar and spacecraft wave observation is presented. Although the wave had intermediate value of *m*, its properties were typical for high-*m* waves: it was compressional and diamagnetic, had poloidal structure, and propagated westward and equatorward in the ionosphere.

Relative modulations $\delta J/J_0$ of the proton fluxes with energies 81.6 keV and 99.4 keV at Van Allen Probes; dynamic cross-spectra S_c between $\delta J/J_0$ and radial component of magnetic field.



Wavelet spectra of magnetic field radial components and pressure oscillations with field-aligned magnetic components at the Van Allen Probes



Its source was a drift resonance with the substorm injected protons, as particle fluxes at the corresponding energies were modulated with the frequency of the wave.

Pressure variations are in antiphase with the $b_{//}$ oscillations → diamagnetic property of the wave

EKB radar data:
http://sdrus.iszf.irk.ru/ekb/page_example/simple
For questions, contact berng@iszf.irk.ru

References

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