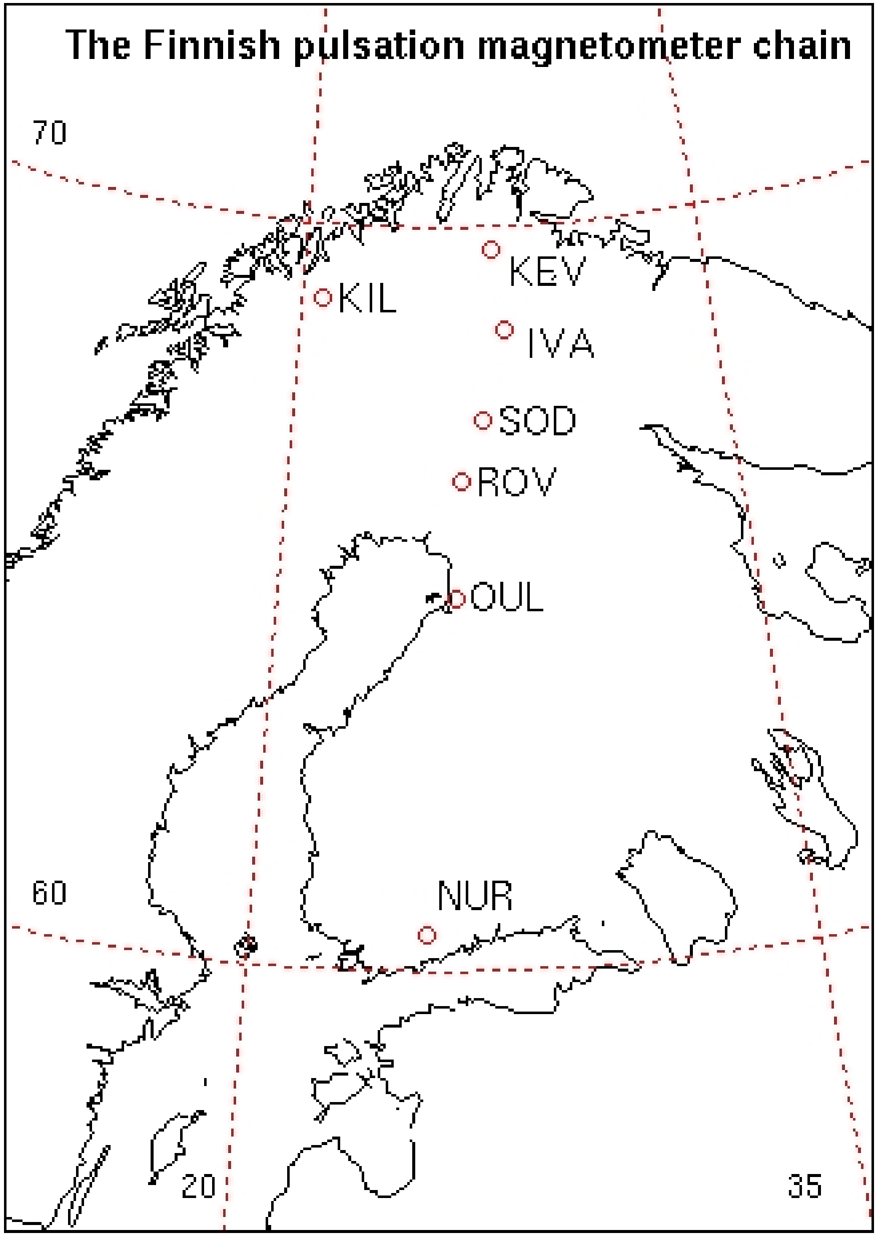
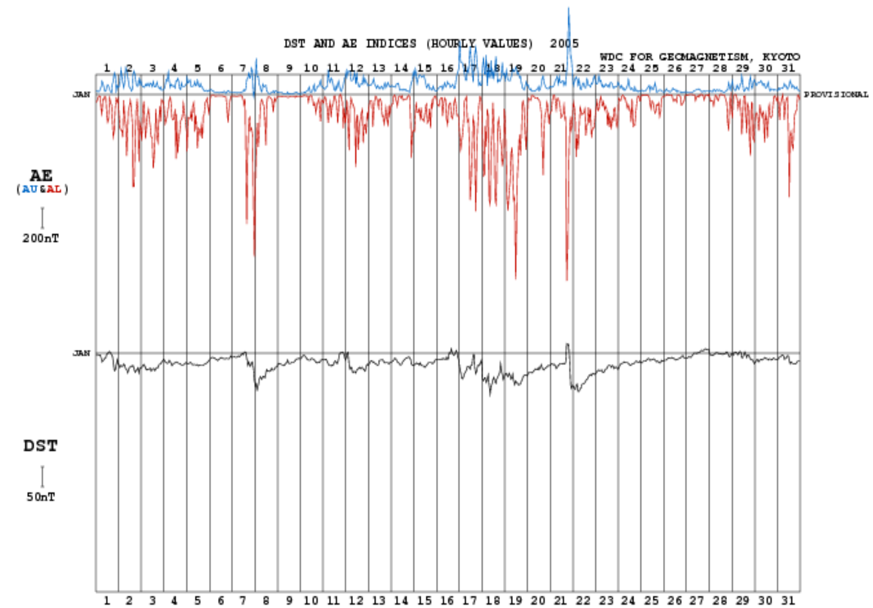
Propagation properties of ULF waves during magnetic storm commencement - a case study.

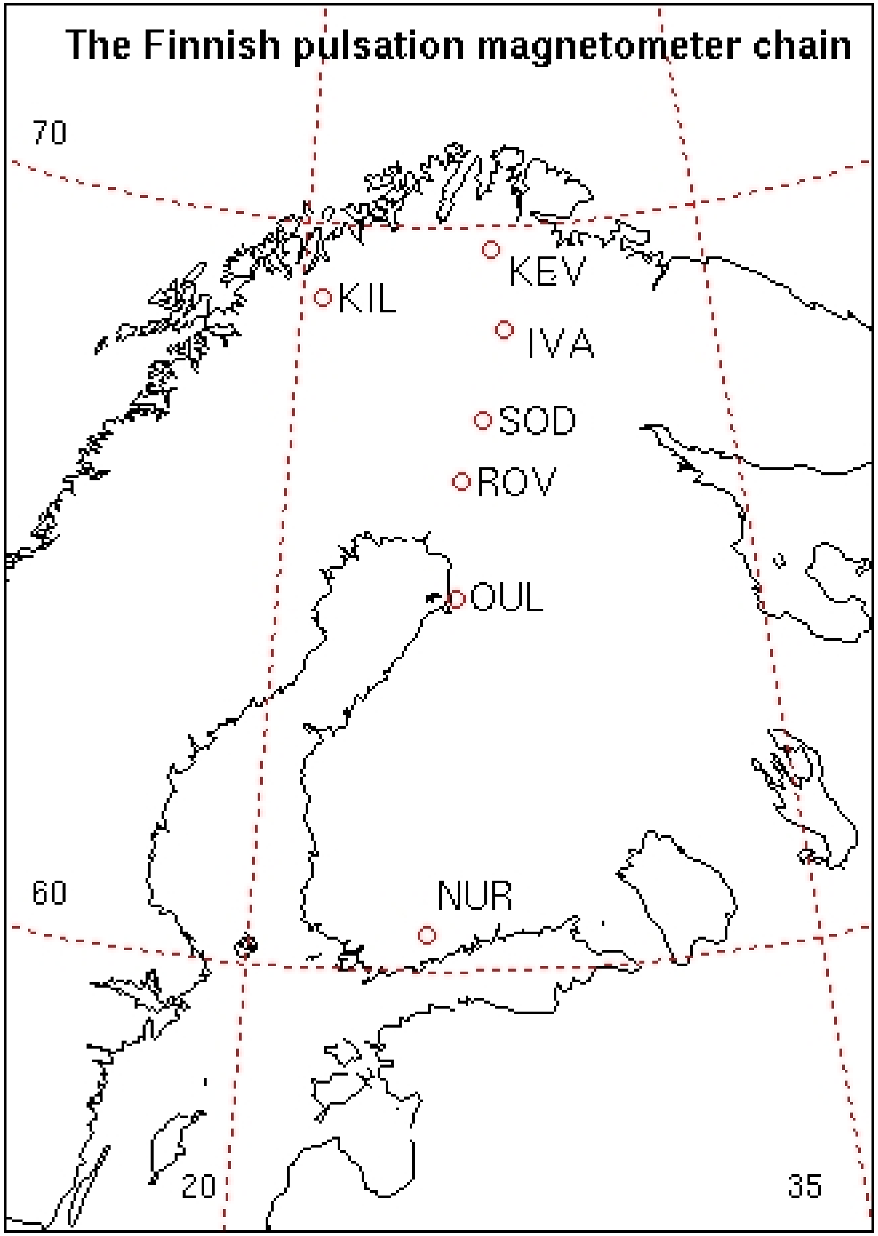
Piotr Koperski (1), Marcin Grzesiak (1), Zenon Nieckarz (2)

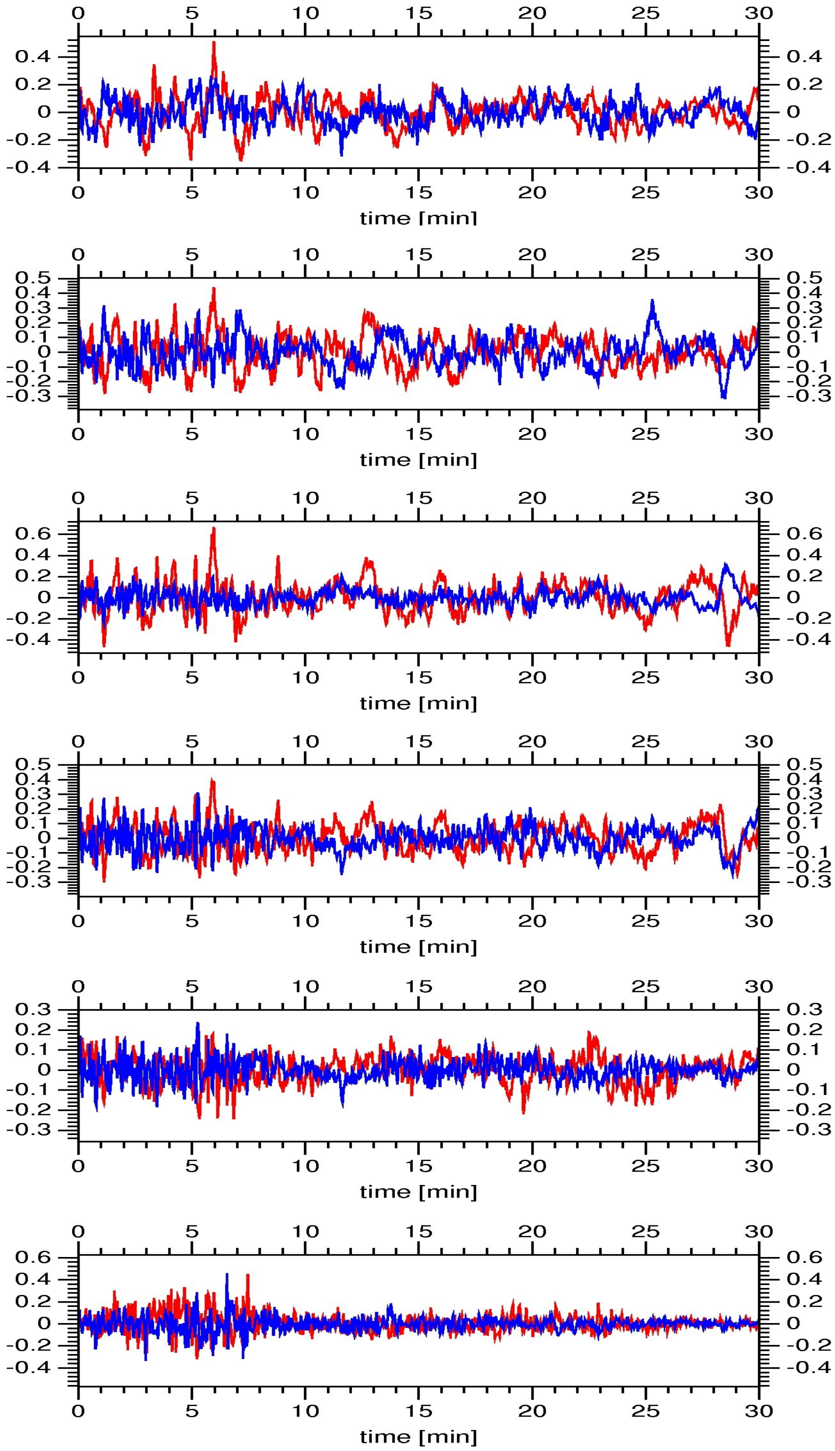
1 - Space Research Center of Polish Academy of Sciences (Warsaw)
2 - Institute of Physics of Jagiellonian University (Krakow)

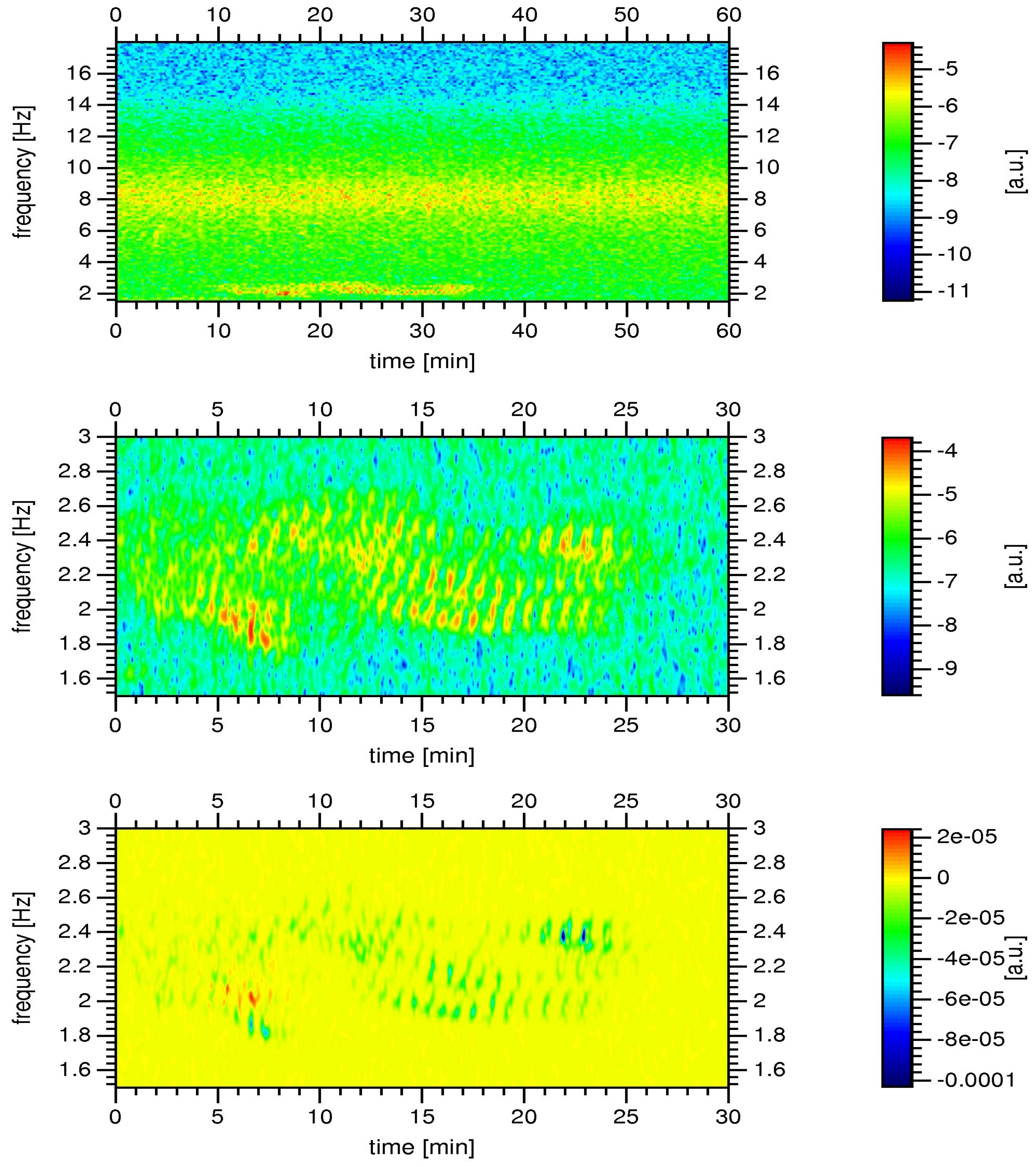




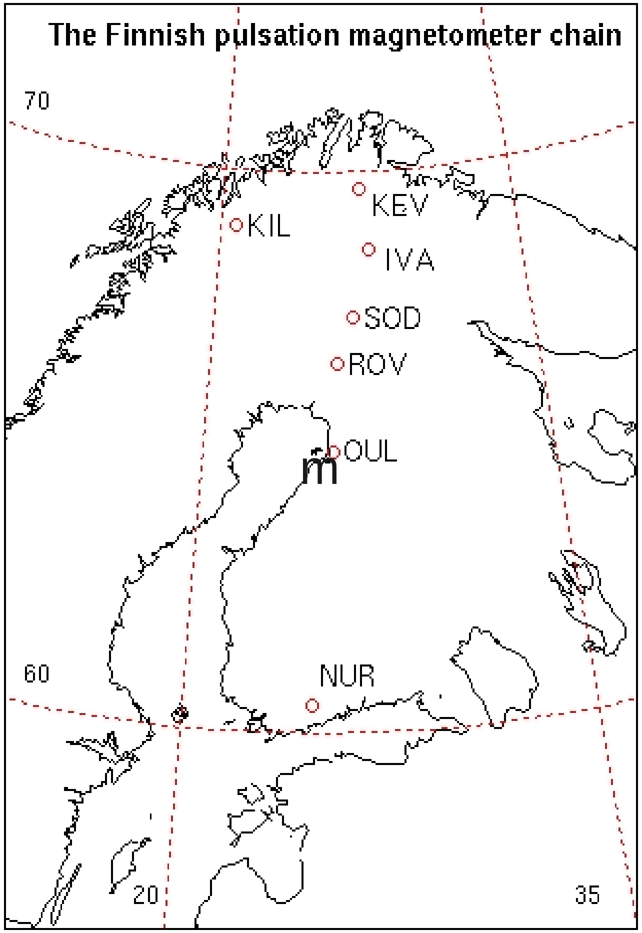
Sation	Code	Lat	Long
Kilpisjärvi	KIL	69.0	20.7
Ivalo	IVA	68.6	27.4
Sodankylä	SOD	67.4	26.5
Rovaniemi	ROV	66.6	25.8
Oulu	OUL	65.0	25.5
Nurmijärvi	NUR	60.5	24.7


The Finnish pulsation magnetometer chain
70
60
20
35
KIL
KEV
IVA
SOD
ROV
OUL
NUR


time [min]
time [min]
time [min]
time [min]
time [min]
time [min]



frequency [Hz]
time [min]
[a.u.]



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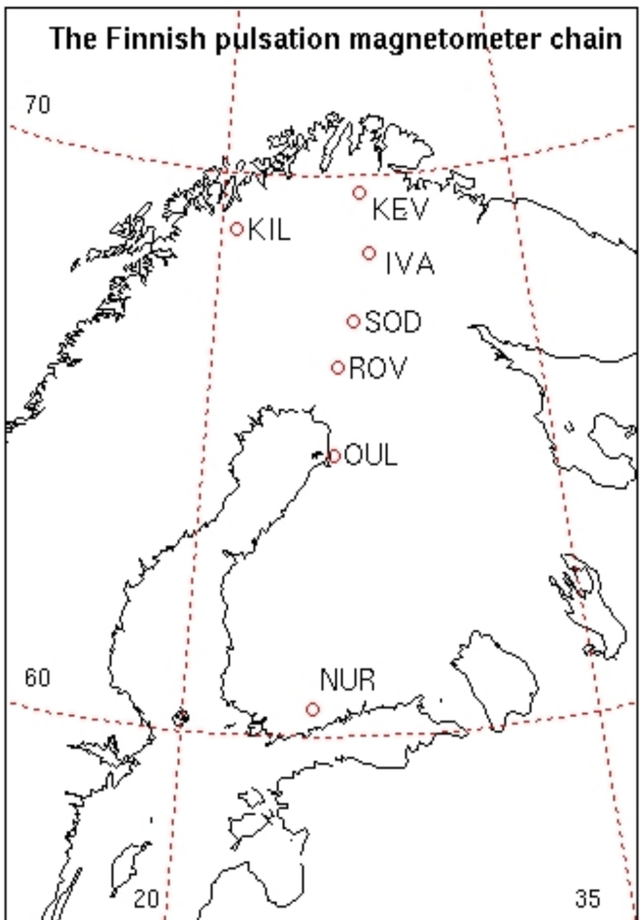
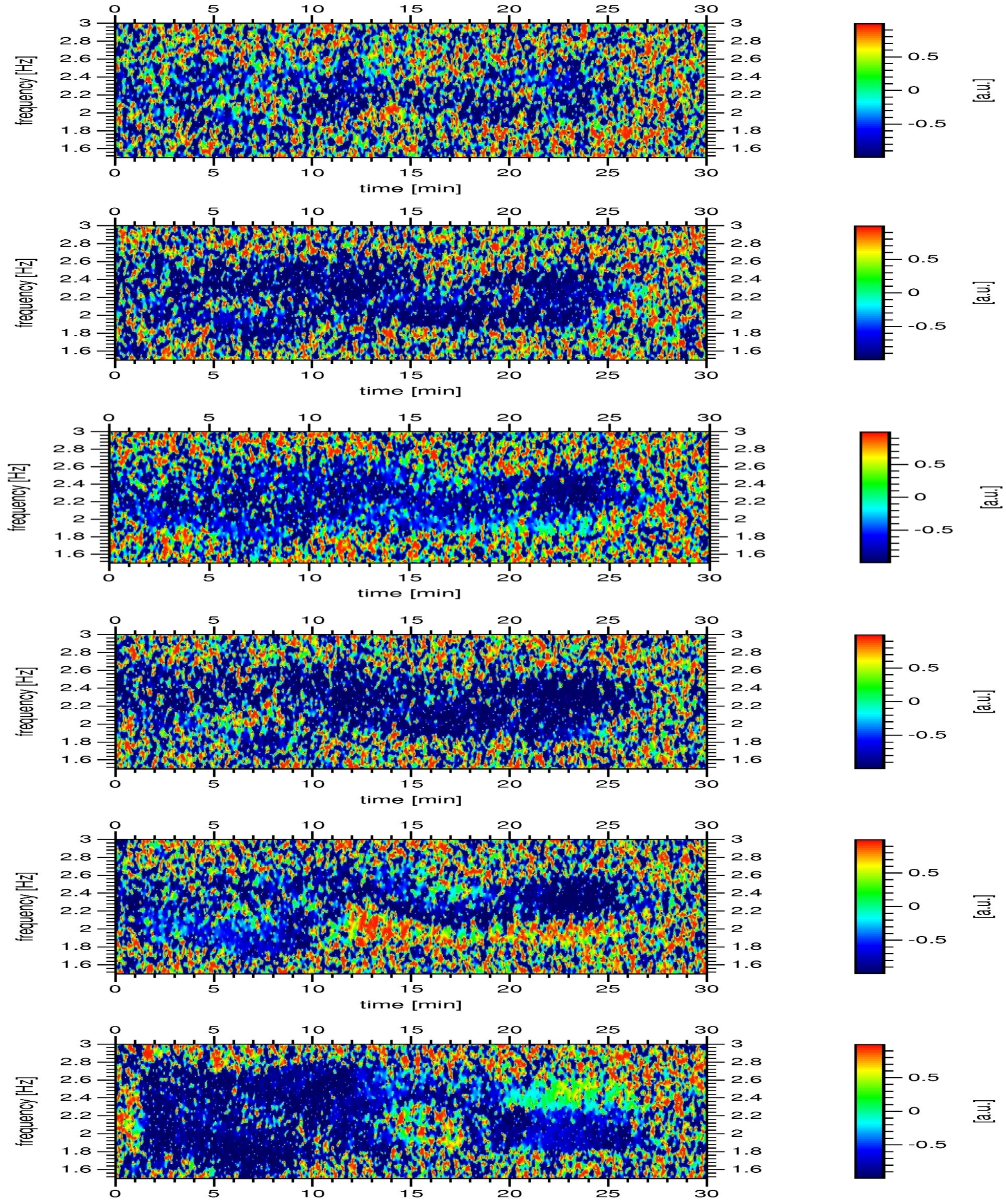
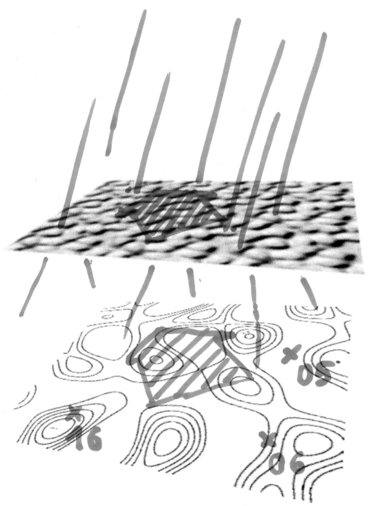
$$\begin{bmatrix} |\hat{b}_x(\omega)|^2 & \hat{b}_x(\omega)\hat{b}_y(\omega)^* \\ \hat{b}_y(\omega)\hat{b}_x(\omega)^* & |\hat{b}_y(\omega)|^2 \end{bmatrix}$$

$$|\hat{b}_x(\omega)||\hat{b}_y(\omega)|(\cos\delta + i\sin\delta)$$





Dispersion



$$\psi(\boldsymbol{r},t) = \int d\boldsymbol{r}' L^t(\boldsymbol{r}-\boldsymbol{r}')\psi(\boldsymbol{r}',0)$$

$$\psi(\boldsymbol{k},t) = \psi(\boldsymbol{k},0)e^{\Omega(\boldsymbol{k})t}$$

$$\mathbb{E}[\psi(\boldsymbol{r}_1,t_1)\psi(\boldsymbol{r}_2,t_2)] = \int d\boldsymbol{k}P(\boldsymbol{k})e^{\Omega(\boldsymbol{k})\tau}e^{i\boldsymbol{k}\cdot\boldsymbol{\zeta}} = C(\boldsymbol{\zeta},\tau),$$

$$\boldsymbol{\zeta} = \boldsymbol{r}_2 - \boldsymbol{r}_1,\ \tau = t_2 - t_1$$

$$P(\boldsymbol{\zeta},\omega) = \int d\tau C(\boldsymbol{\zeta},\tau)e^{i\omega\tau} = \int d\tau e^{-i\omega\tau}\int d\boldsymbol{k}P(\boldsymbol{k})e^{\Omega(\boldsymbol{k})\tau}e^{i\boldsymbol{k}\cdot\boldsymbol{\zeta}} =$$

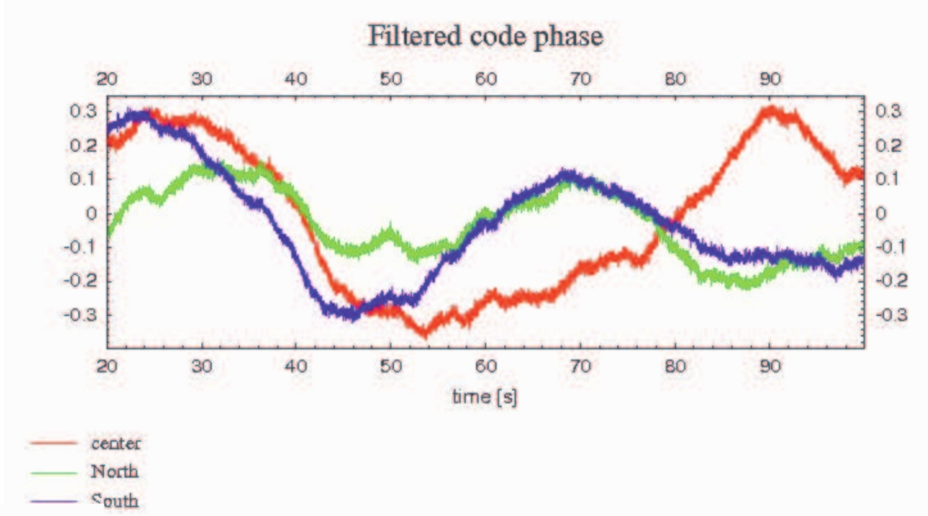
$$\int d\boldsymbol{k}P(\boldsymbol{k})e^{i\boldsymbol{k}\cdot\boldsymbol{\zeta}}\delta(\omega-\Omega(\boldsymbol{k}))$$

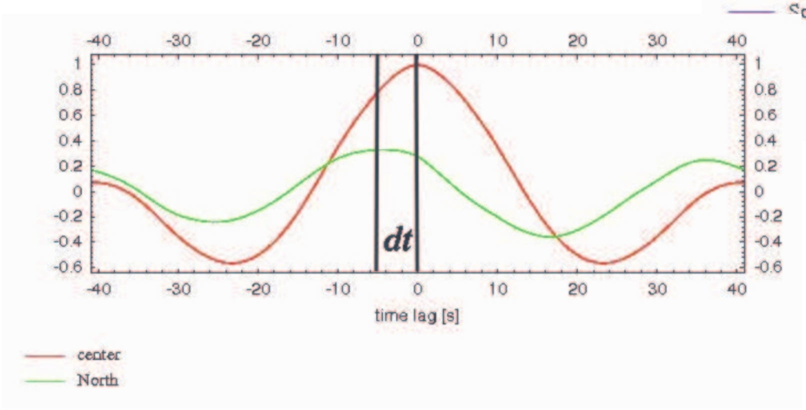
$$\frac{\partial\psi}{\partial t} - \boldsymbol{v}\cdot\nabla\psi = 0$$

$$<\boldsymbol{\zeta}> = \frac{\int d\boldsymbol{\zeta}\boldsymbol{\zeta}C(\boldsymbol{\zeta},\tau)}{\int d\boldsymbol{\zeta}C(\boldsymbol{\zeta},\tau)}$$

$$\frac{\partial}{\partial\tau}<\boldsymbol{\zeta}> = \nabla_{\boldsymbol{k}}\Omega(\boldsymbol{k})|_{\boldsymbol{k}=0}$$

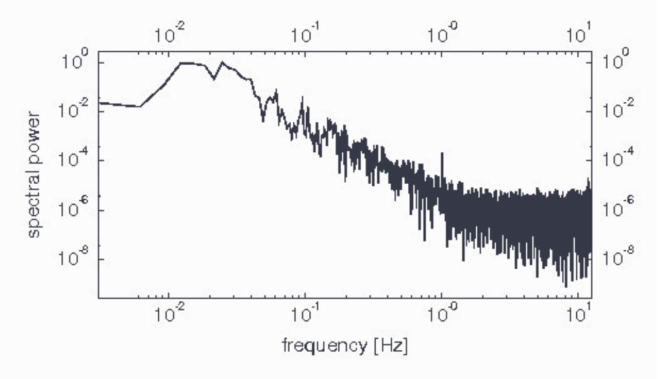
Dispersion cont.

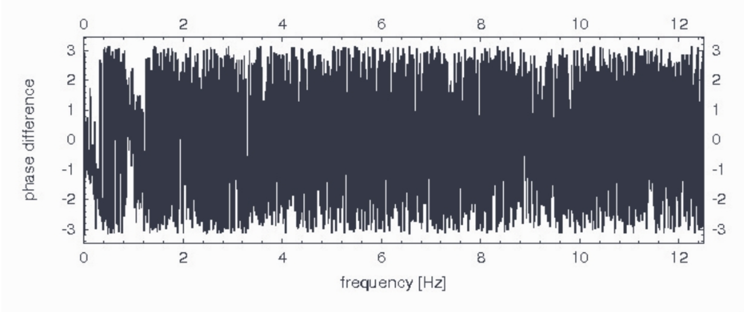




$$E\{\psi(r,t)\,\psi(r+d,t+\tau)\} = C(d,\tau)$$

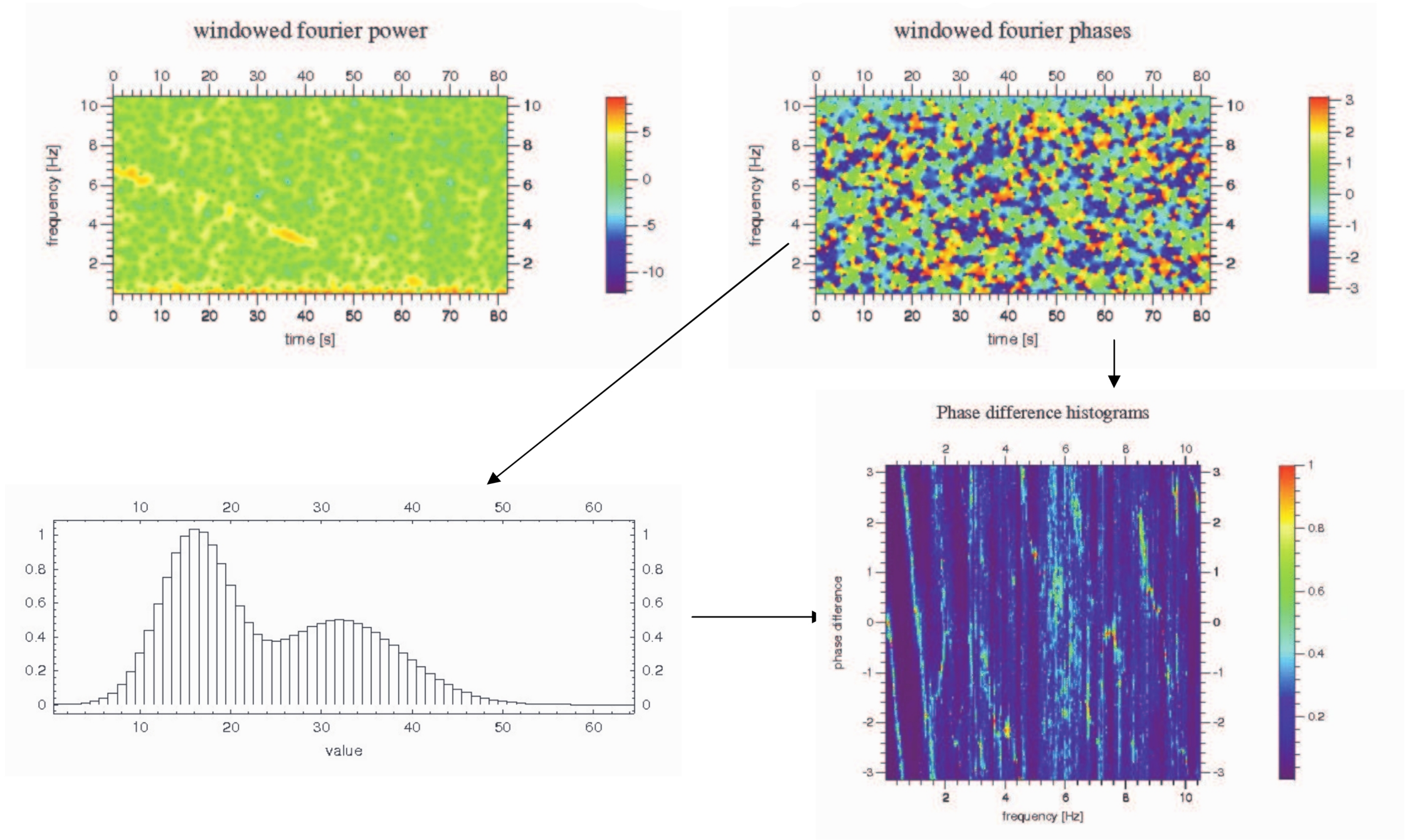
$$\mathbf{v}_d = \frac{\delta}{dt}$$





$$\int d\tau\, C(d,\tau) \sim P(\omega)\, \exp\left\{ i \frac{d}{v_d} \omega \right\}$$

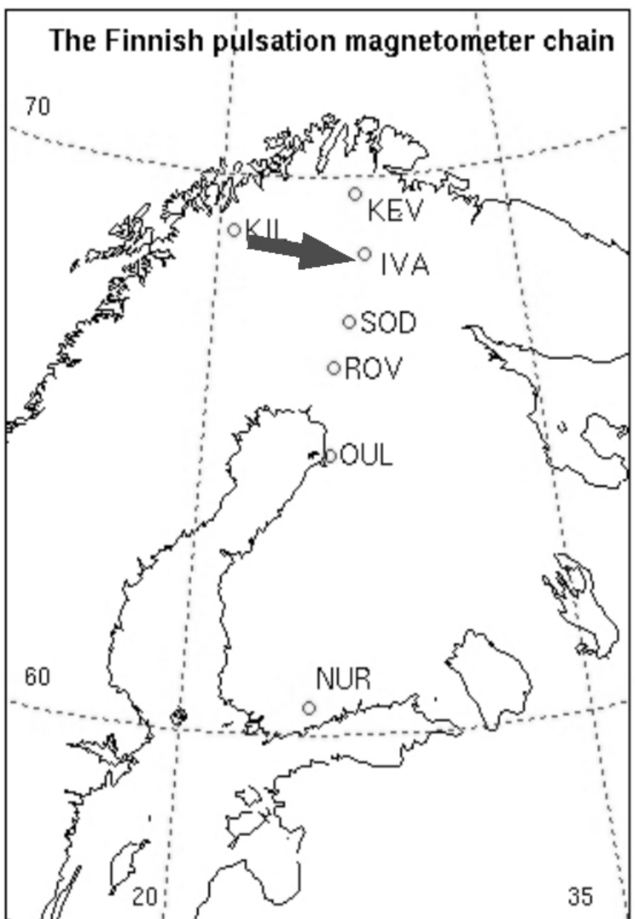
Dispersion cont.

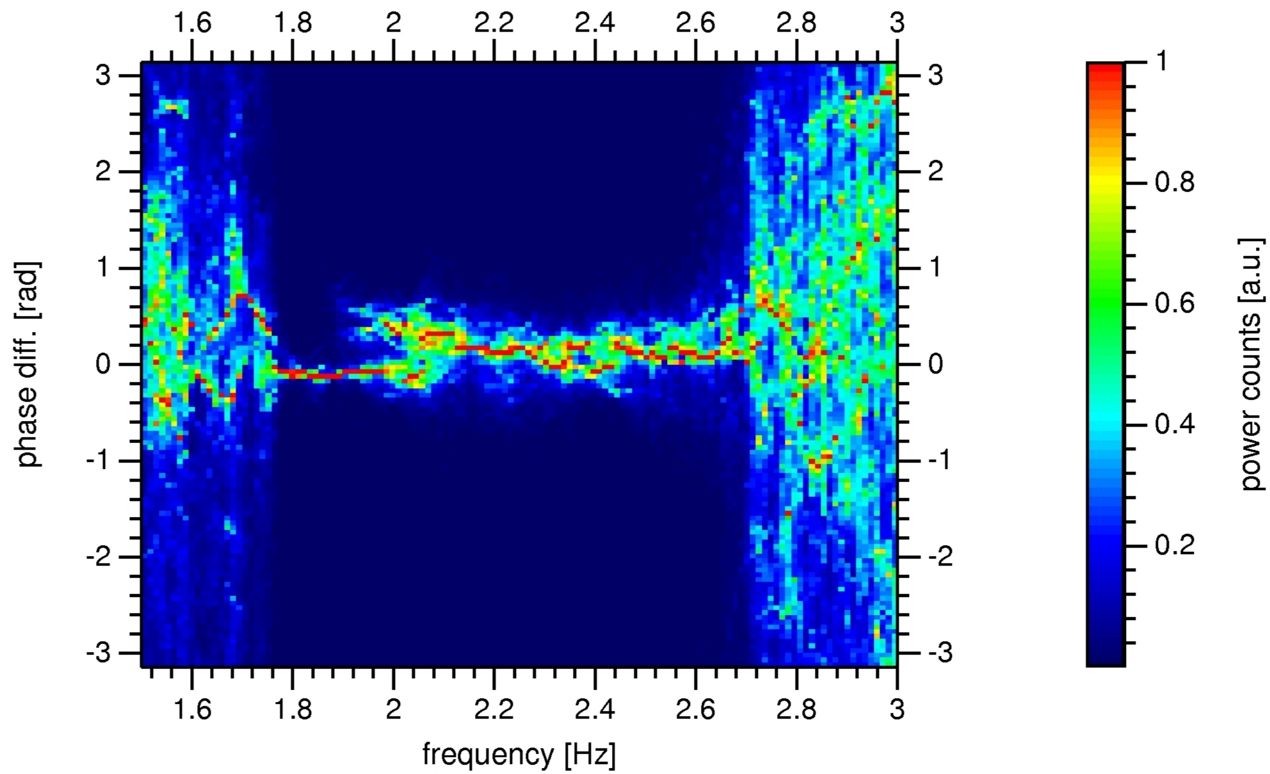


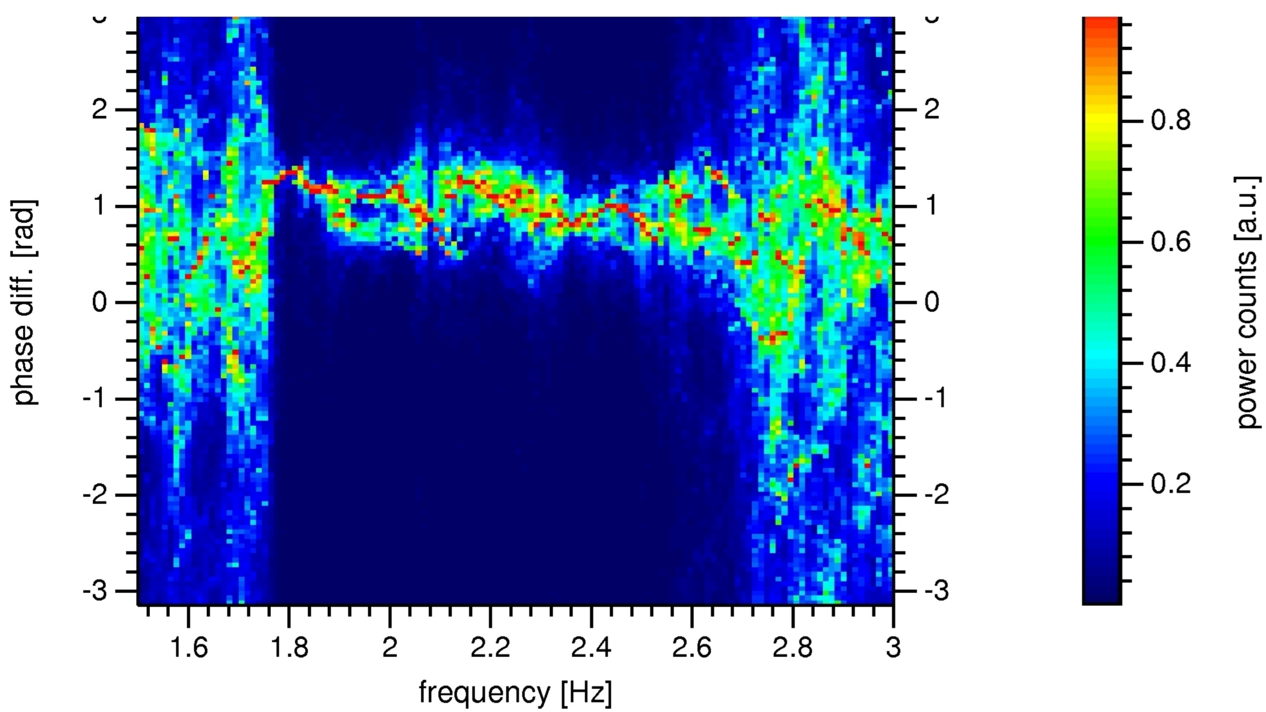
$$\mathbf{b} = b_L \mathbf{e}_L + b_R \mathbf{e}_R$$

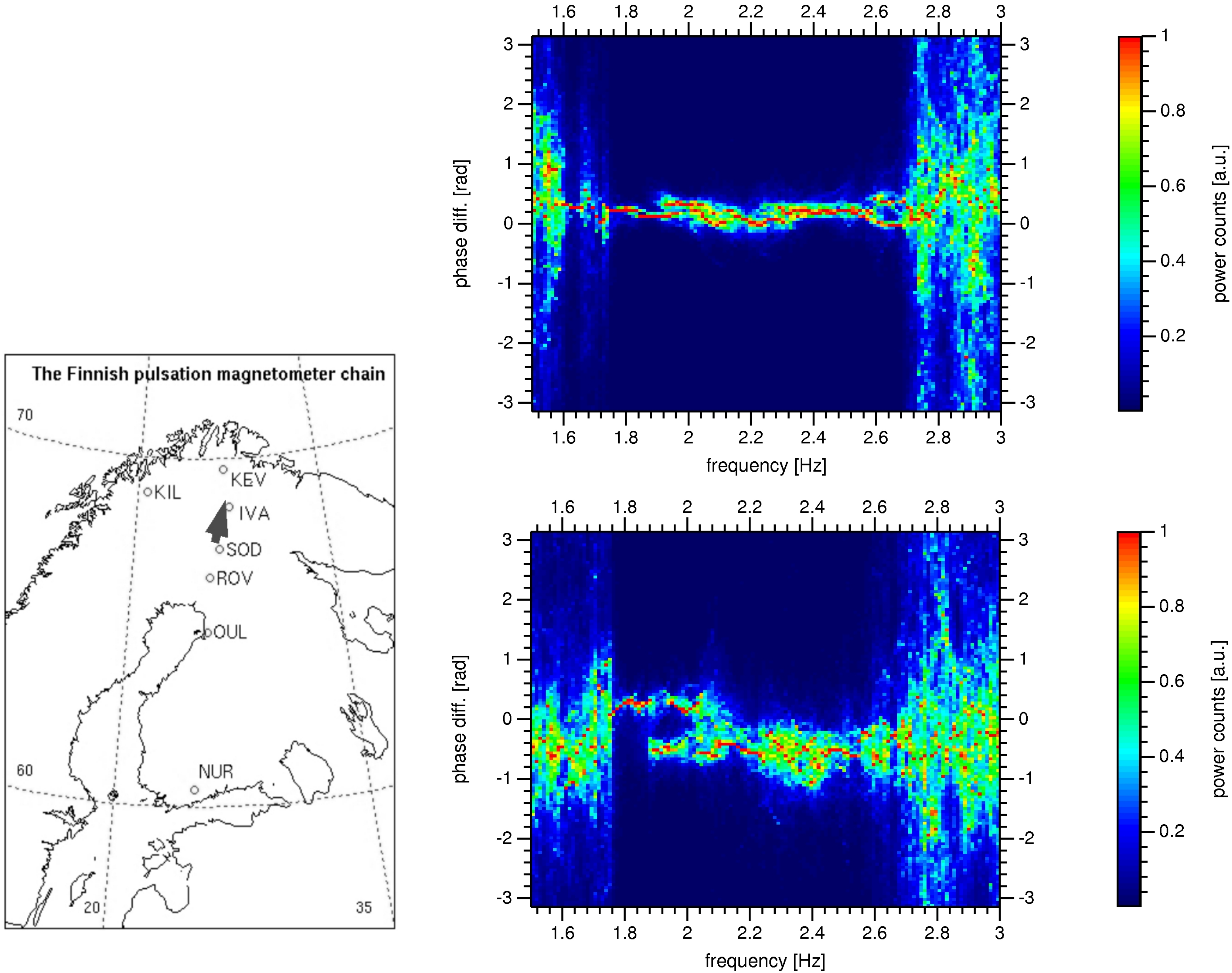
$$b_L = \frac{1}{\sqrt{2}}(b_x - i b_y)$$

$$b_R = \frac{1}{\sqrt{2}}(b_x + i b_y)$$









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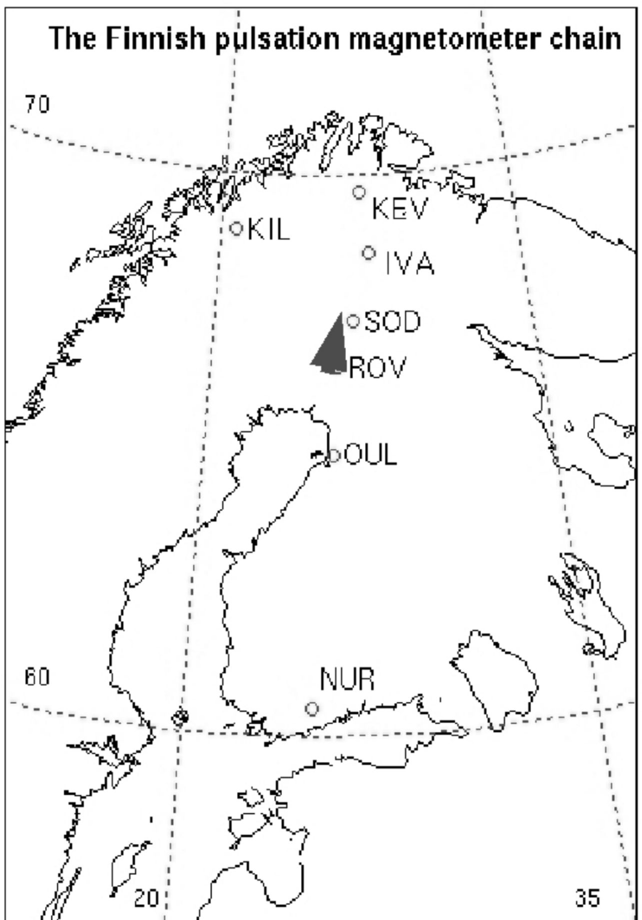
phase diff. [rad]
frequency [Hz]
power counts [a.u.]
phase diff. [rad]
frequency [Hz]
power counts [a.u.]



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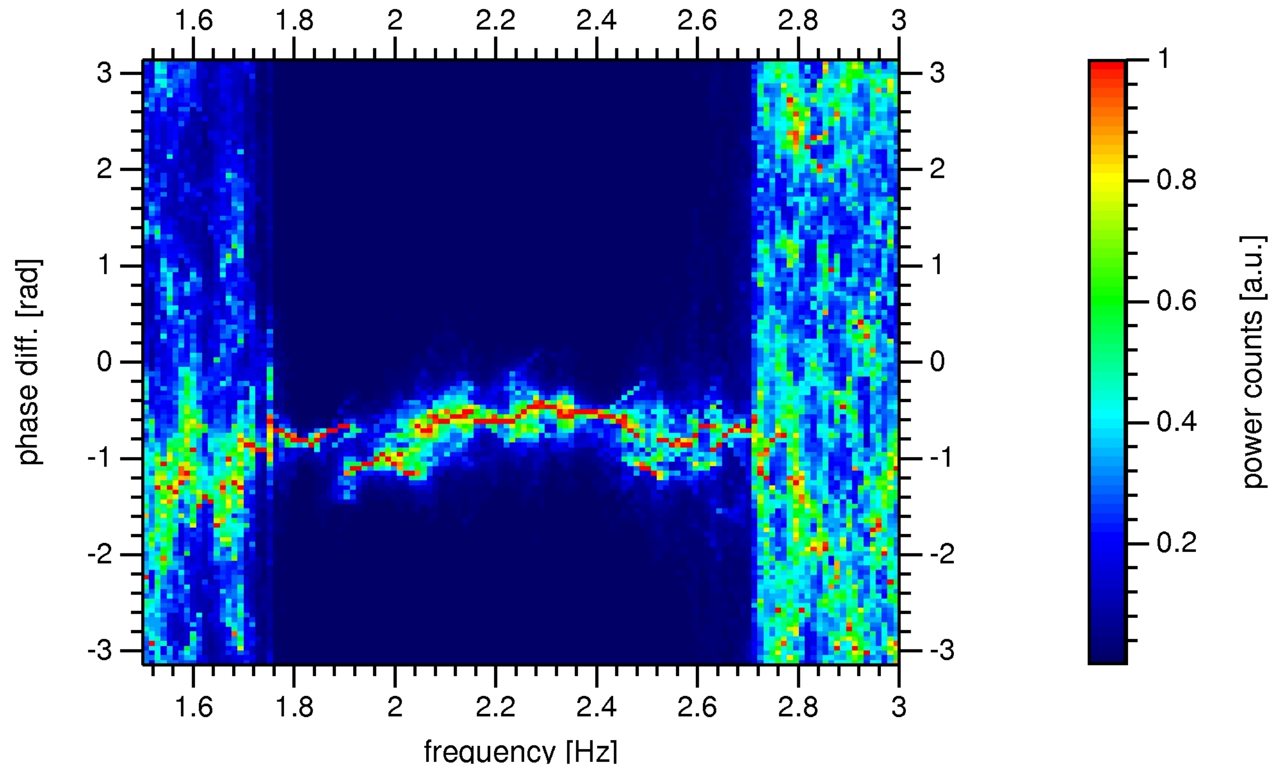
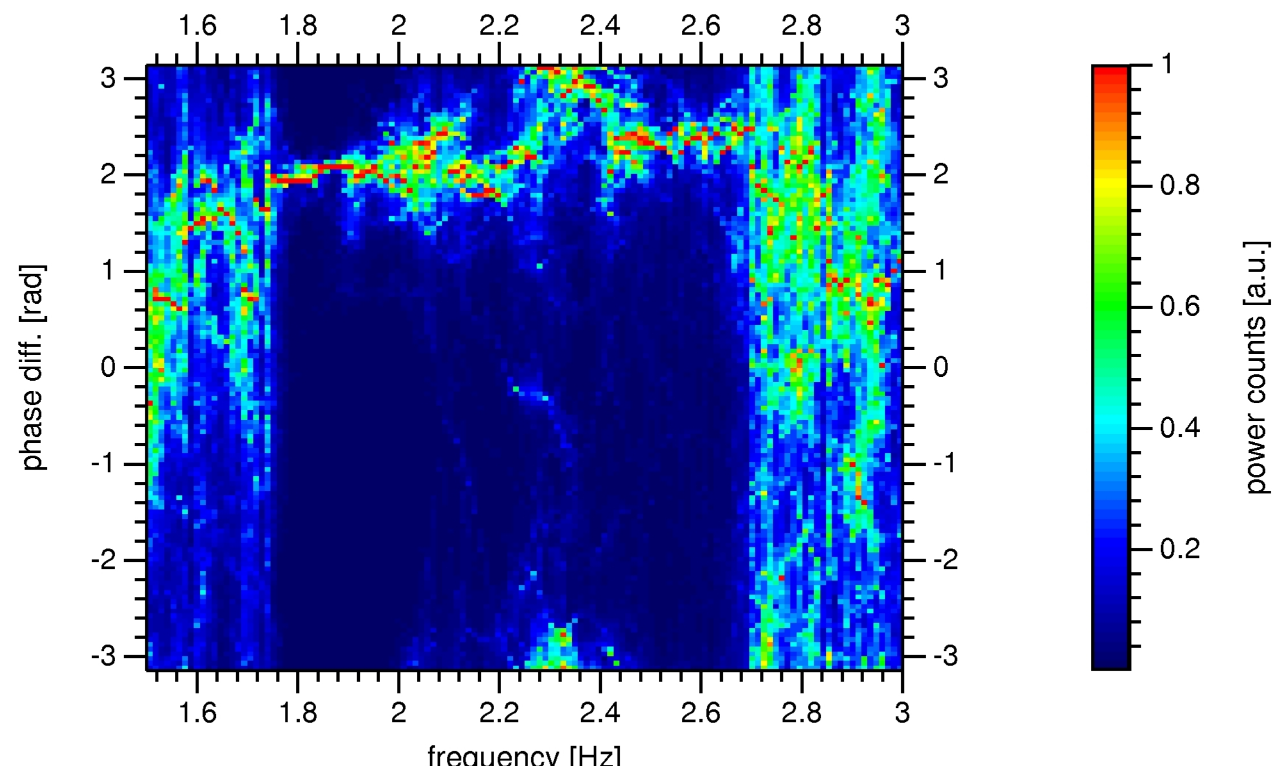


phase diff. [rad]
frequency [Hz]
power counts [a.u.]



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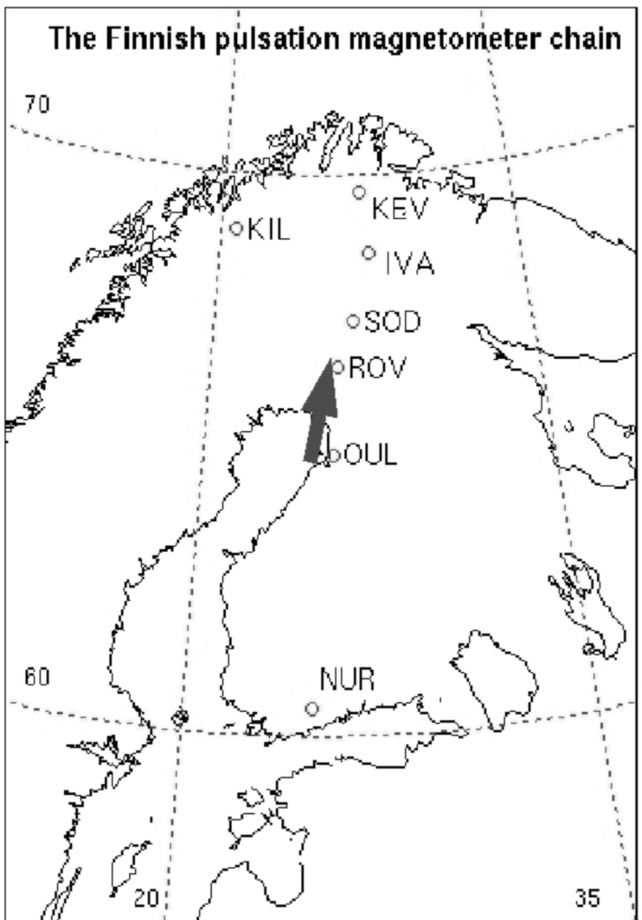
frequency [Hz]
power counts [a.u.]



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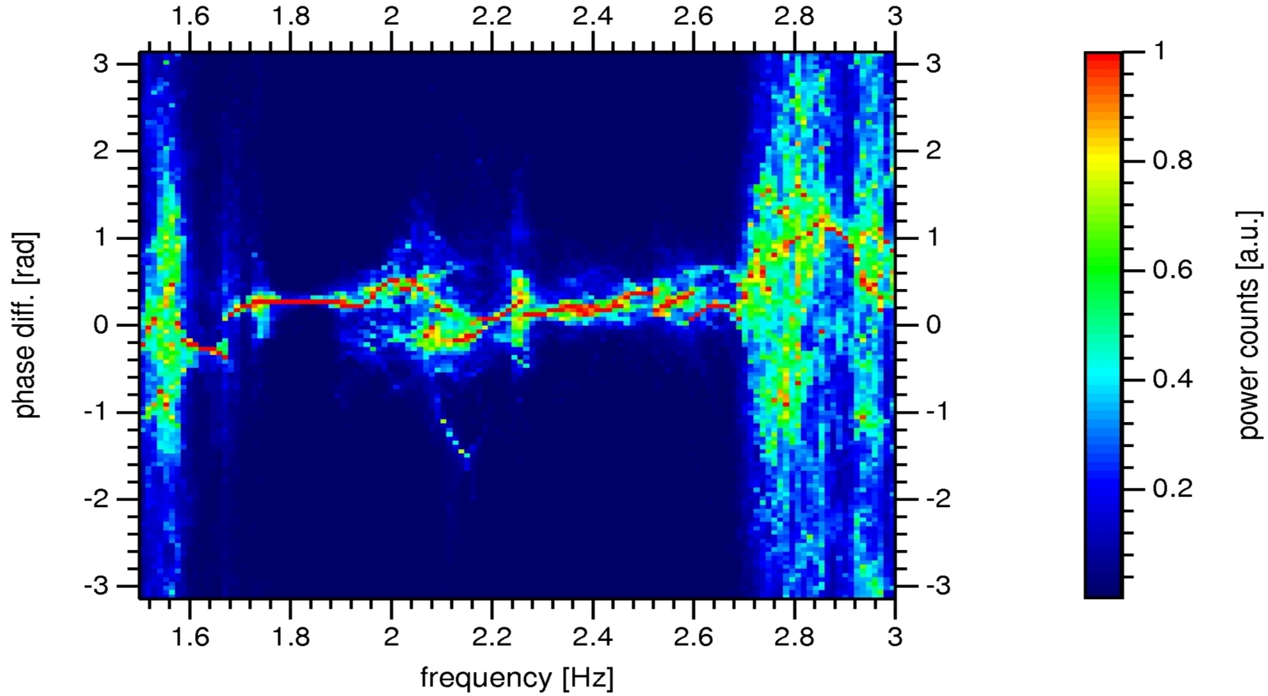
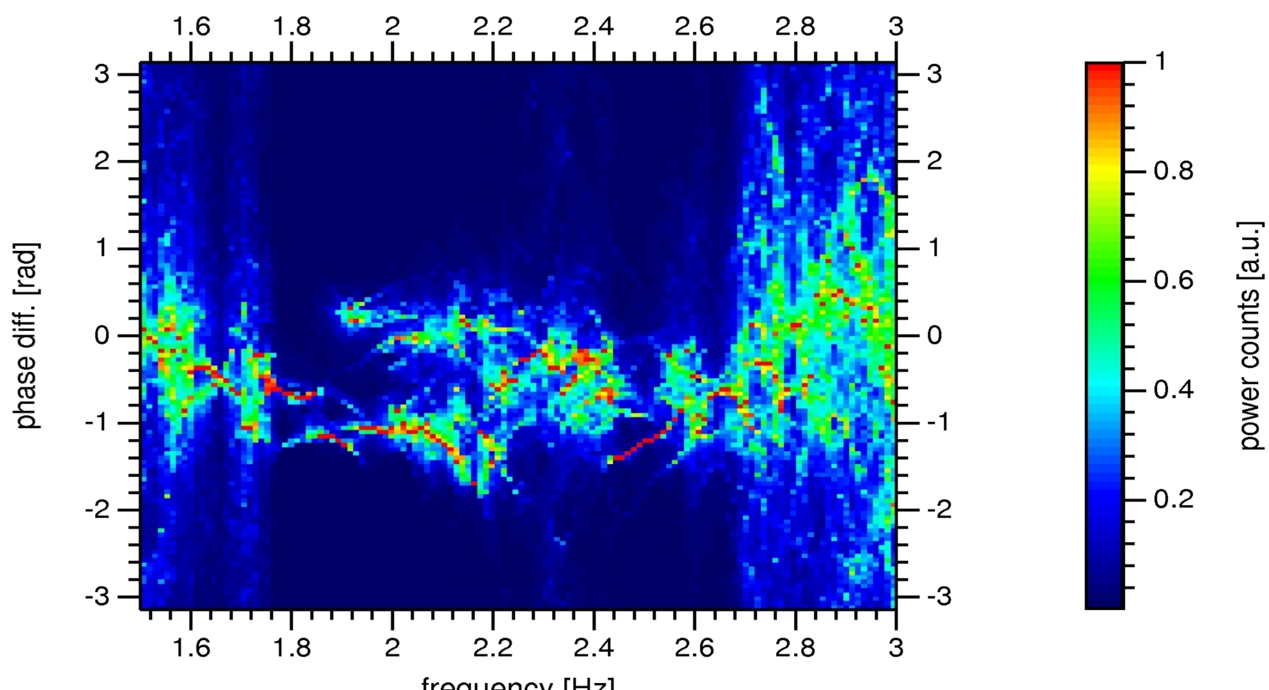


phase diff. [rad]
frequency [Hz]
power counts [a.u.]



phase diff. [rad]
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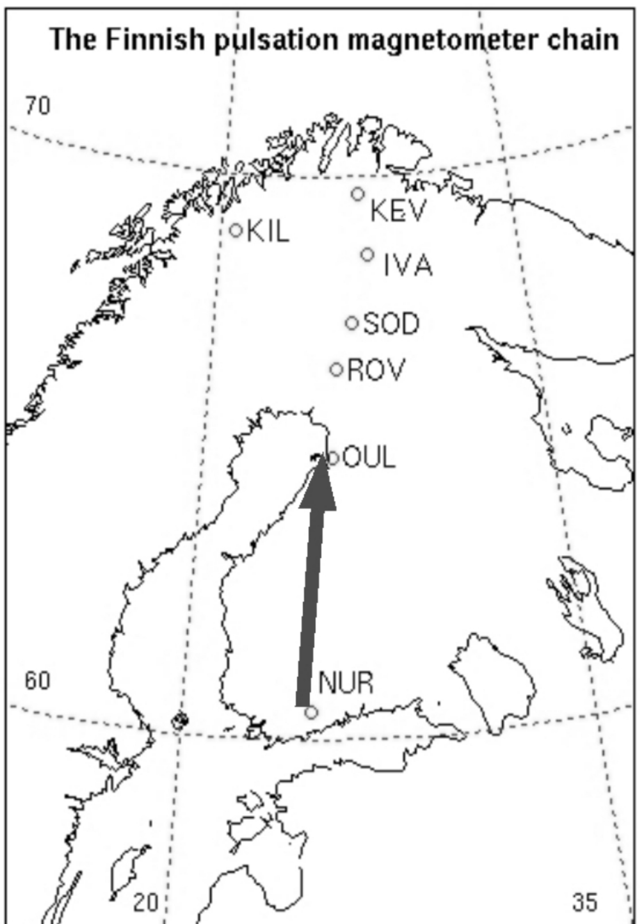
power counts [a.u.]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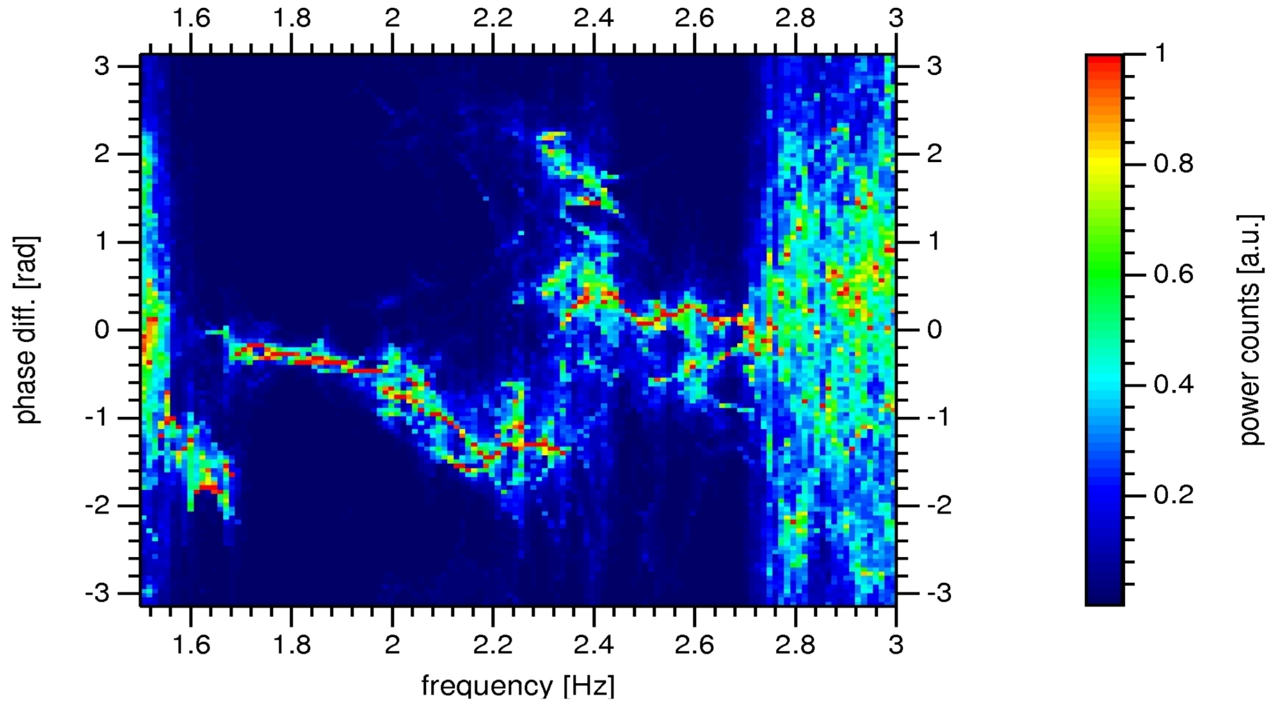
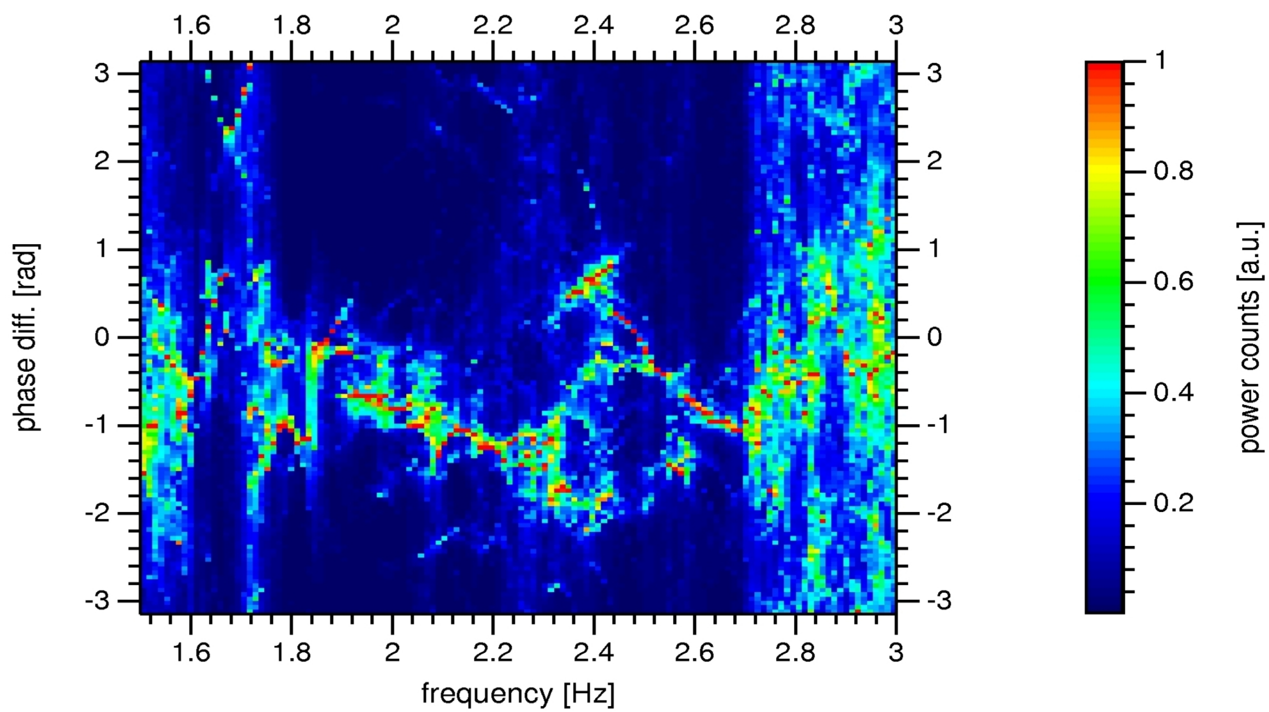

phase diff. [rad]
frequency [Hz]
power counts [a.u.]


phase diff. [rad]
frequency [Hz]
power counts [a.u.]

Conclusions

- pearl pulsations as observed on the ground are very beautiful phenomenon that reflects complex dynamics of Earth's magnetosphere and ionosphere during onset of magnetic storm
- polarisation properties are one of the main features describing their propagation
- the analysis of ground based observations suggests that the process has well localised source and polarisation properties distribution is an effect of different propagation for left and right polarised modes