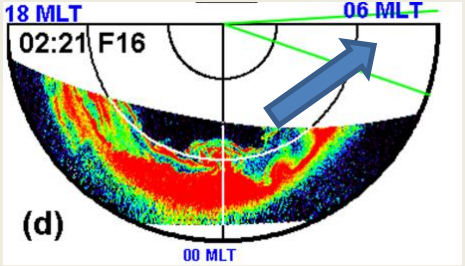
Fast moving auroral structures as a cause for large GIC



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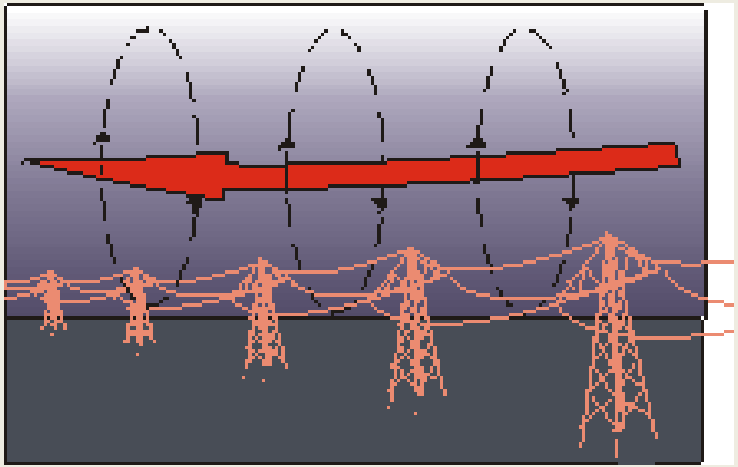
Geomagnetically Induced Currents (GIC)

- Currents in the ionosphere / magnetosphere
- dB/dt at the Earth's surface
- **E** and currents in long conductors

$$rot\, \boldsymbol{B} = \mu_0 \boldsymbol{J} + \mu_0 \varepsilon_0 \frac{\partial \boldsymbol{E}}{\partial t}$$

$$rot\, \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$$

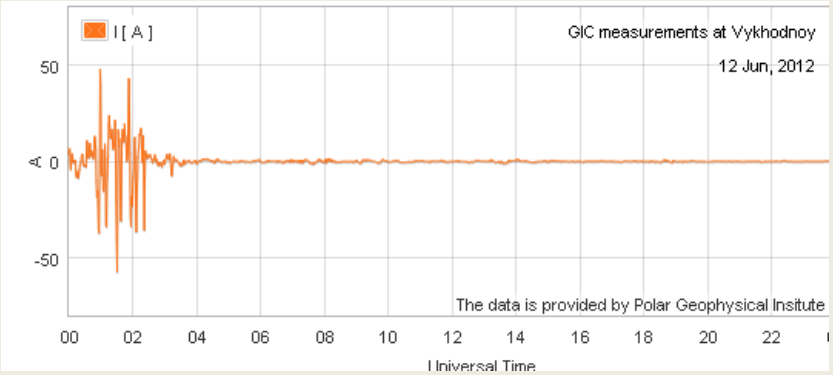


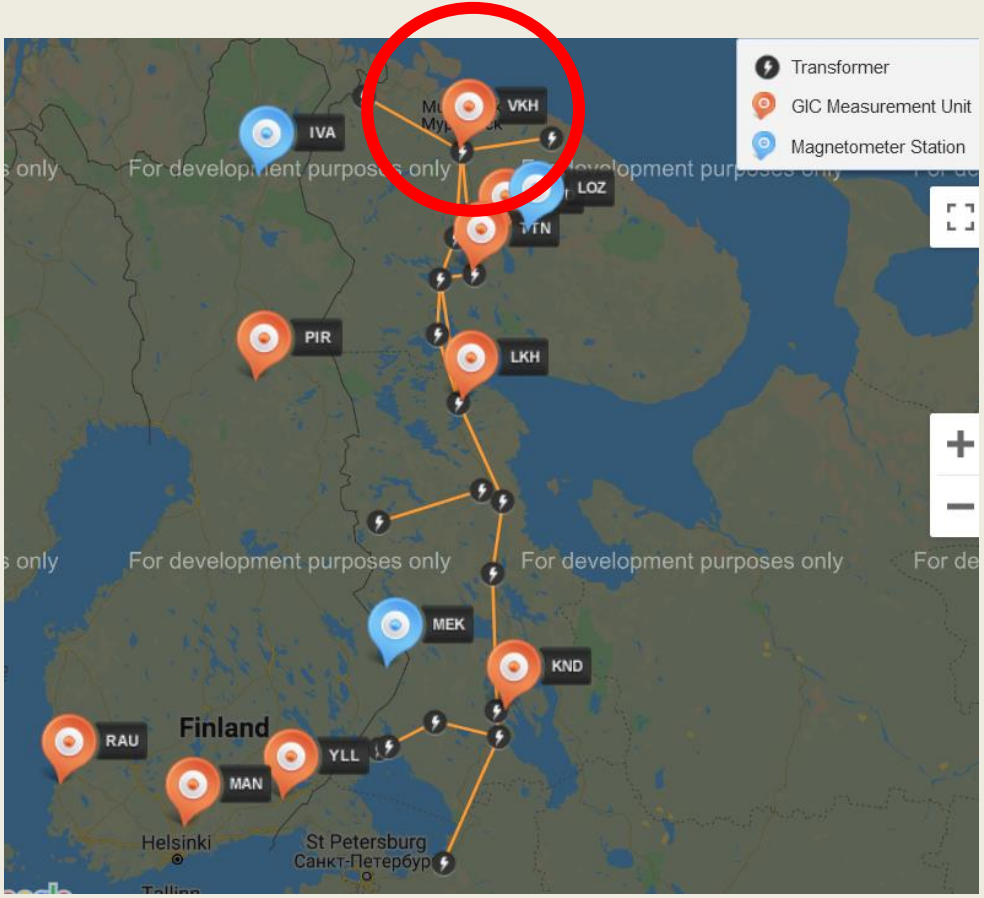
from spaceweather.gc.ca

Why and when
large dB/dt (GIC) found?

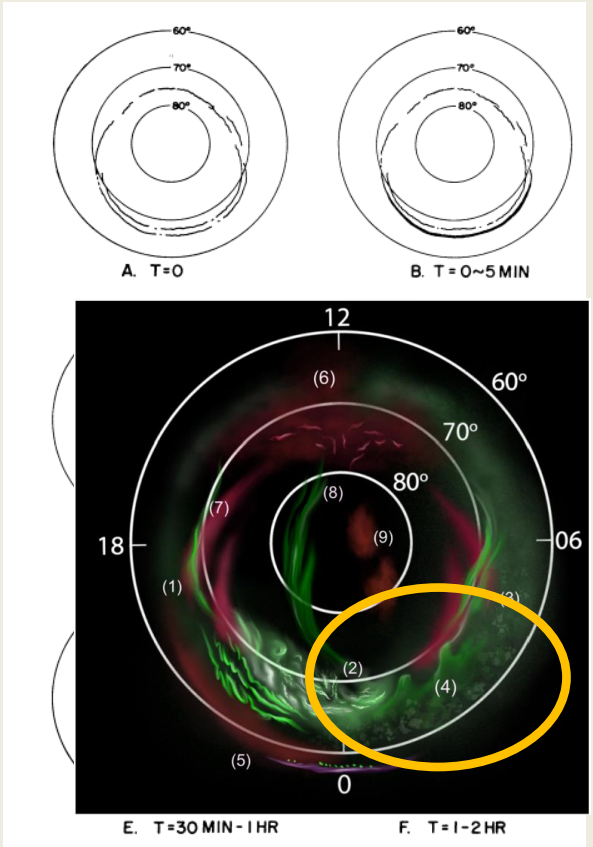
140 largest GIC at Vykhodnoy transformer, 2012-2018

- VKH near Murmansk
- 65 deg Mlat – auroral zone
- Select top 140 GIC in 2012-2018
- 1h data
- GIC are 17-140 Ampere



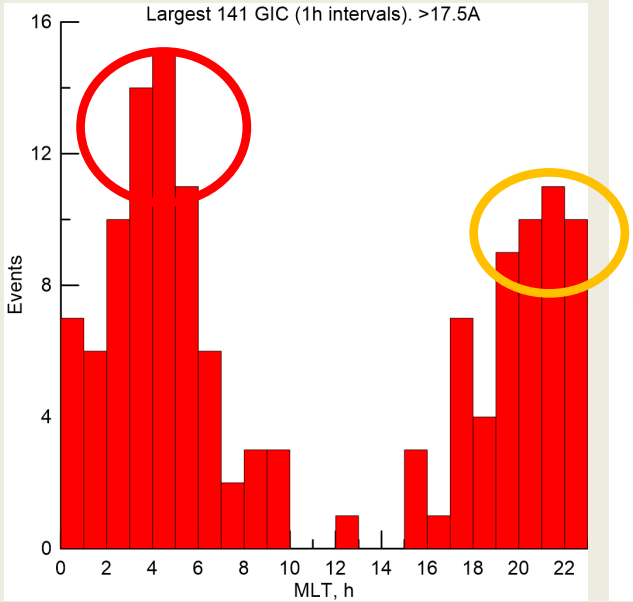


Substorms and GIC versus LT

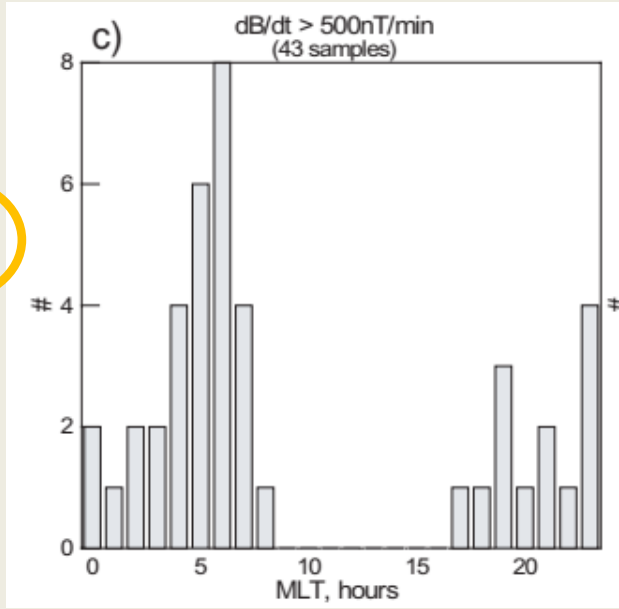


Akasofu aurora development

Premidnight and morning maxima

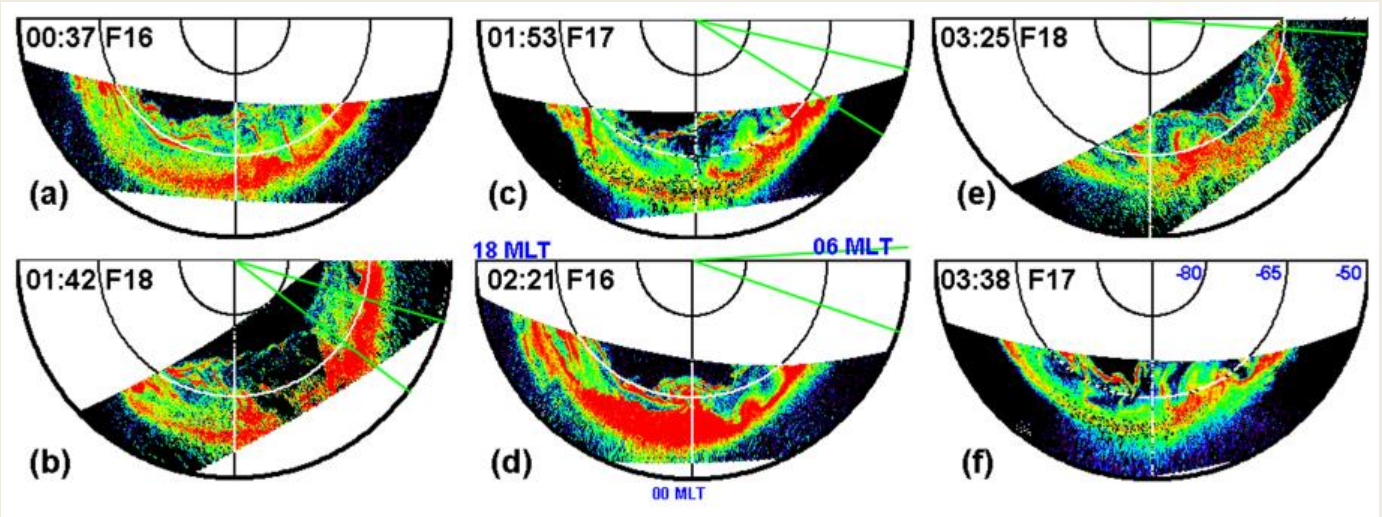


Large GIC vs LT
140 events

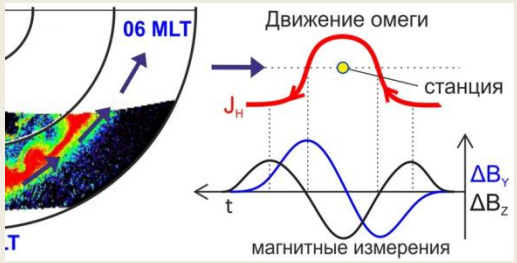


Large dB/dt vs LT
5years stat
Apatenkov et al 2004

Highest ever recorded GIC at VKH



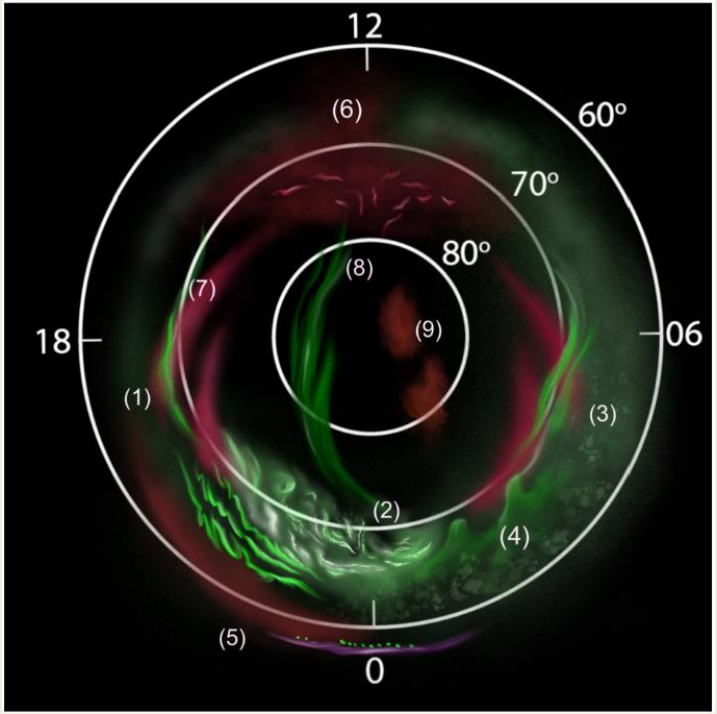
Auroral omega bands, move 0.1 – 2 km/s eastward

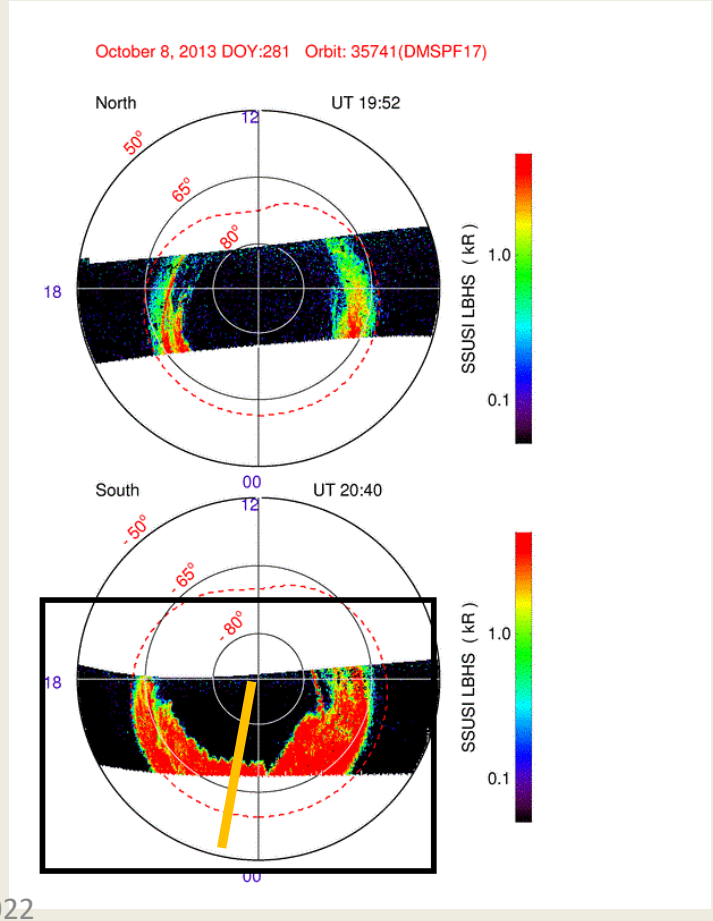


- CASE study, Apatenkov et al 2020, GRL. GIC 140A - 29/06/2013
- STAT: Use DMSP/SSUSI images GIC events 2012-2018

Auroral structures. Bulge

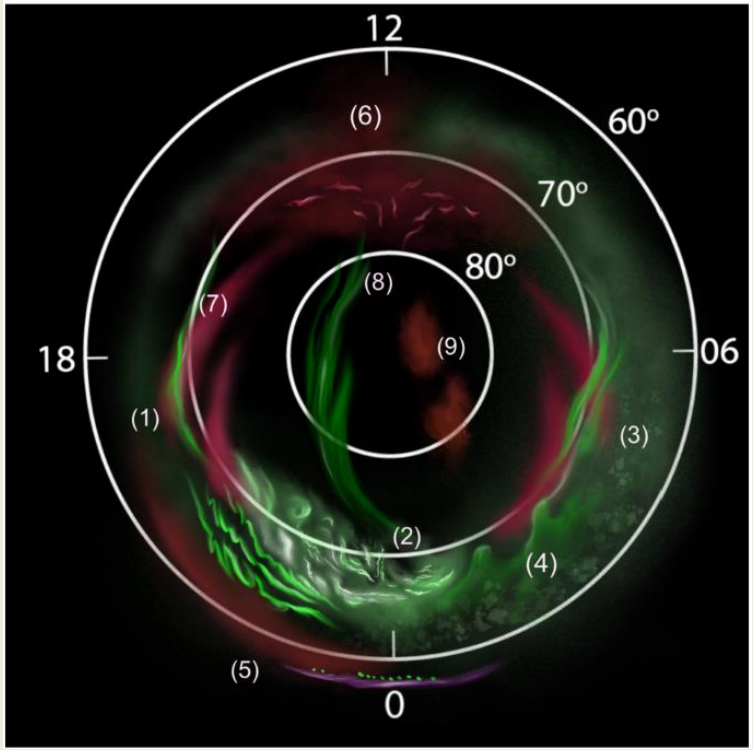
Auroral bulge – substorm onset

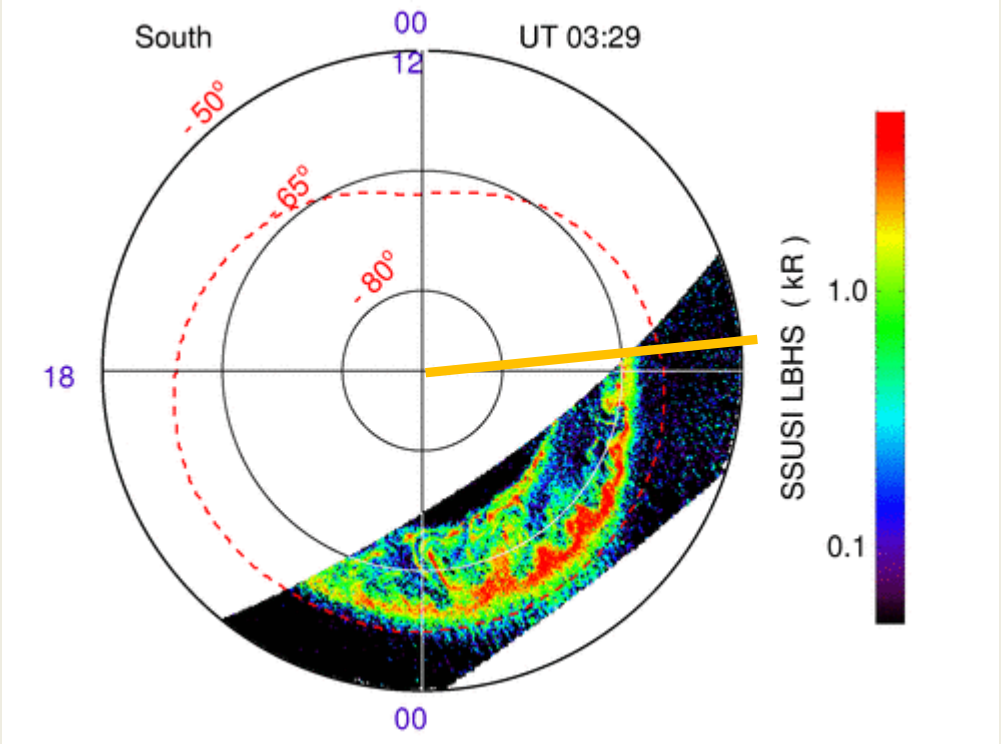




Auroral Physics, SSR, 2021

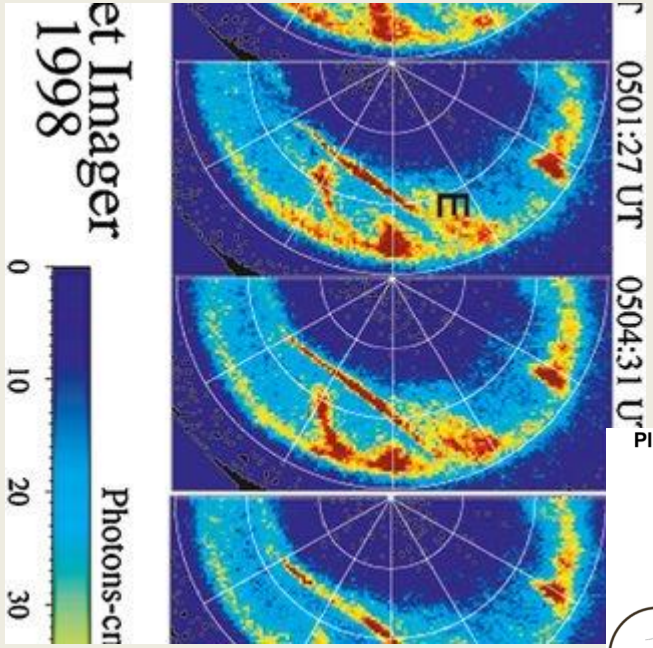
Auroral structures. Omega bands





Auroral structures. Streamers

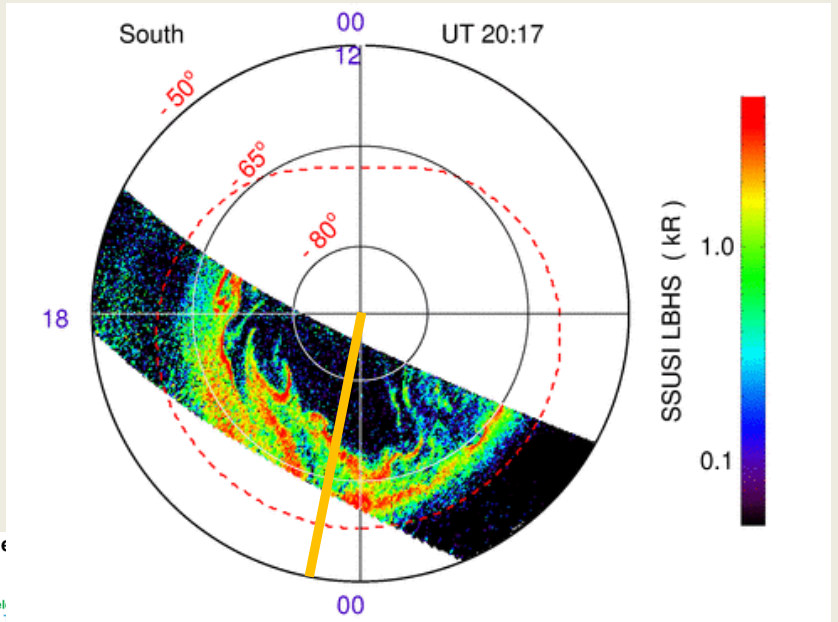
Auroral streamers

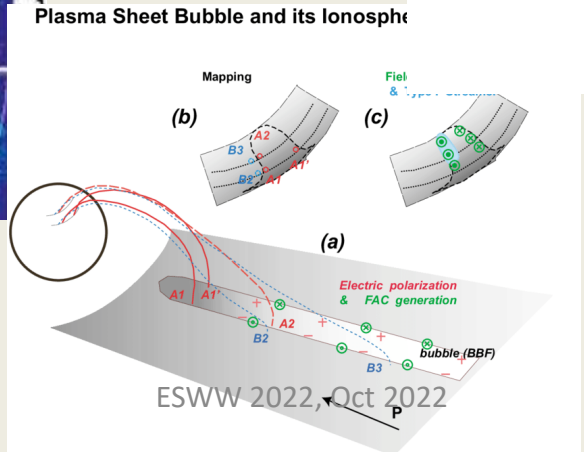


From Sergeev et al 2005

Streamers as
bursty bulk flow
ionospheric traces

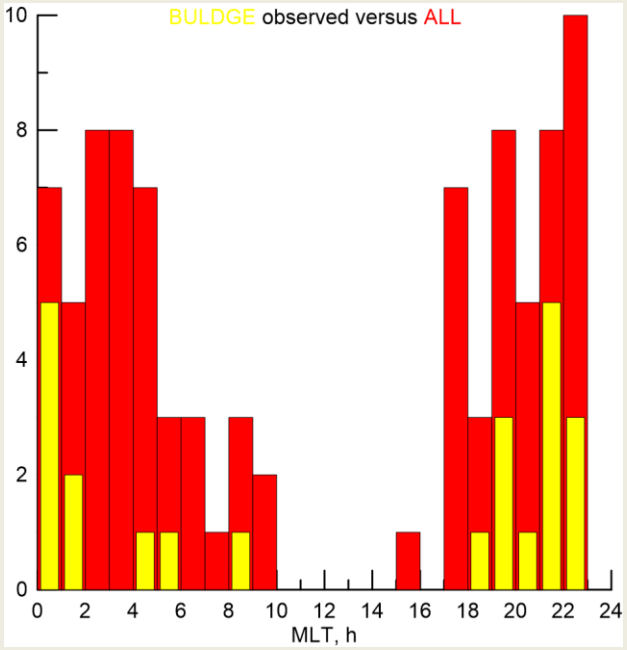
DMSP



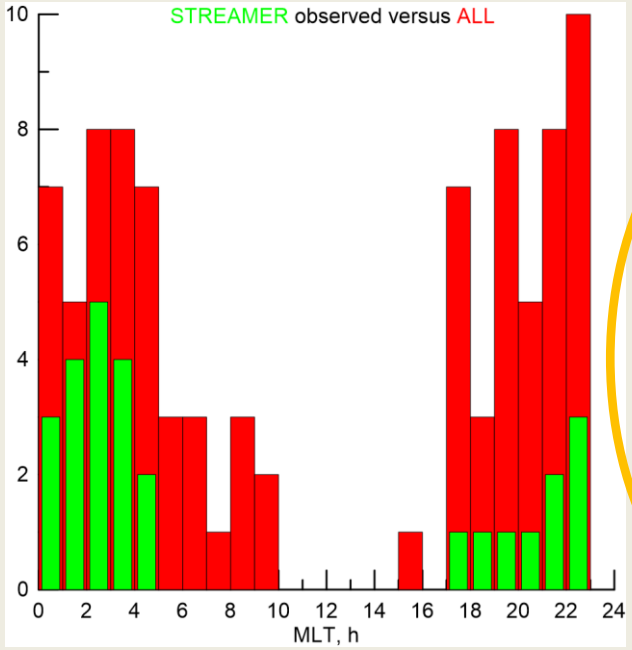


Aurora types for large GIC.
DMSP/SSUSI for 97 out of 140.

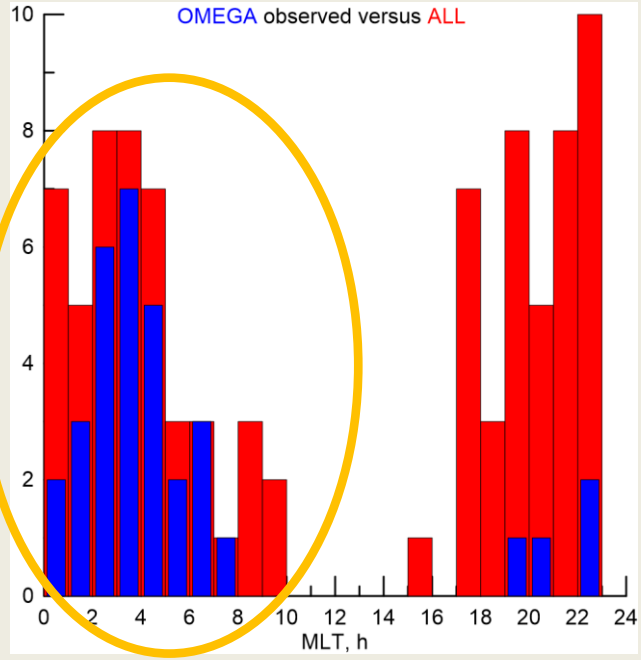
Buldges 27 / 97



Streamers 27 / 97



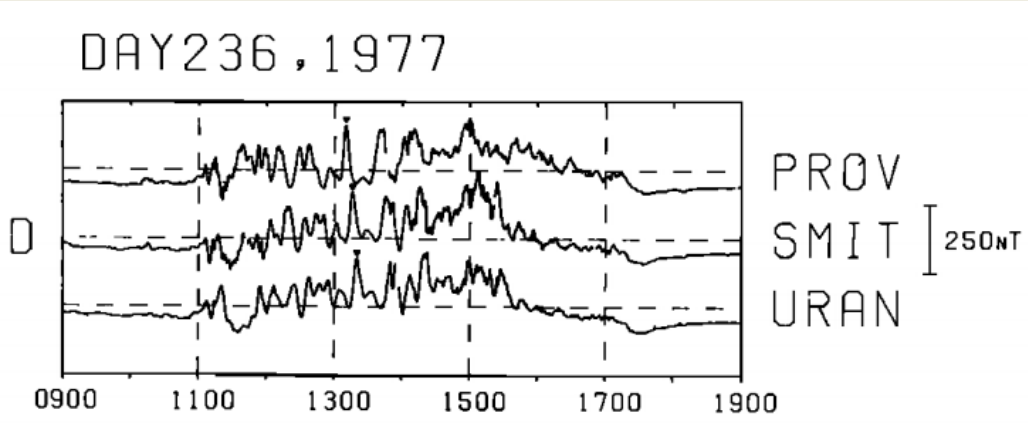
Omegas 31 / 97



30%.

80% in morning LT sector

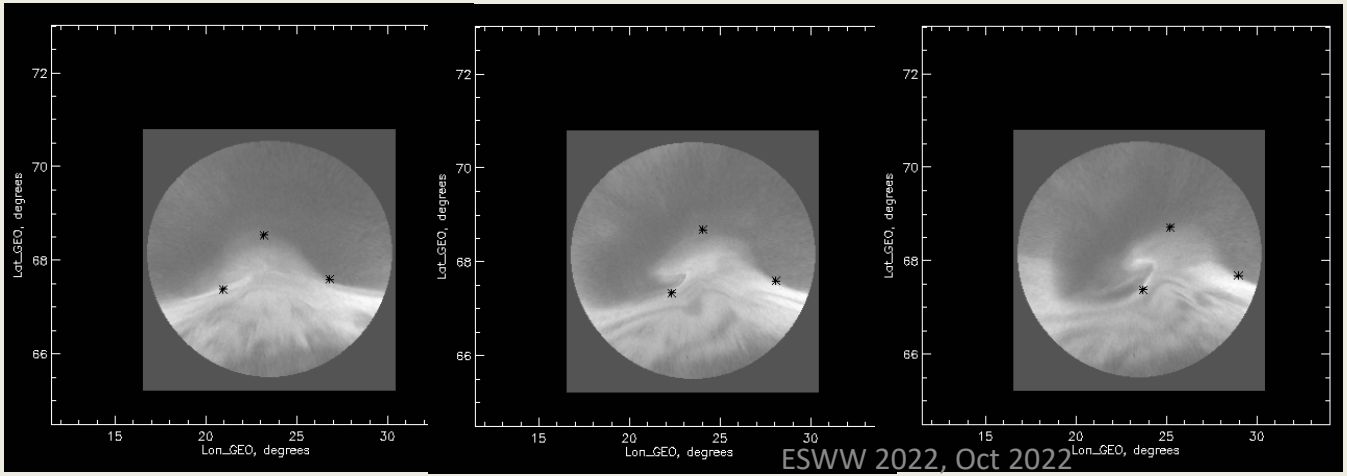
Spatial motion of omega bands. Two methods



Time shift in B_Y at west-east separated stations

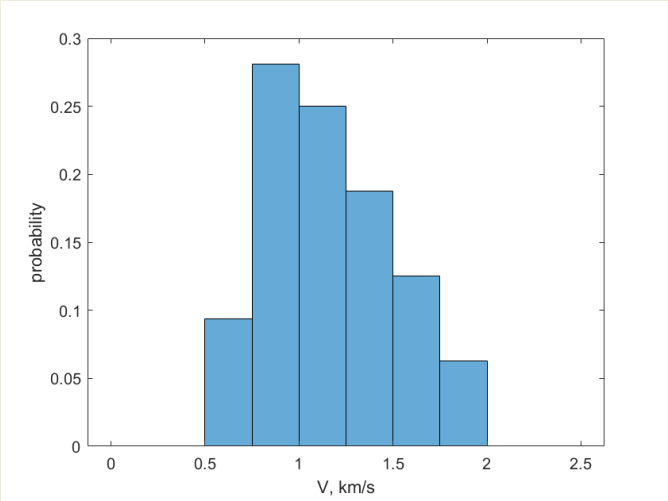
Kawasaki and Rostoker 1979 – magnetic data

Andreeva et al, Vokhmyanin et al 2021 – optical data

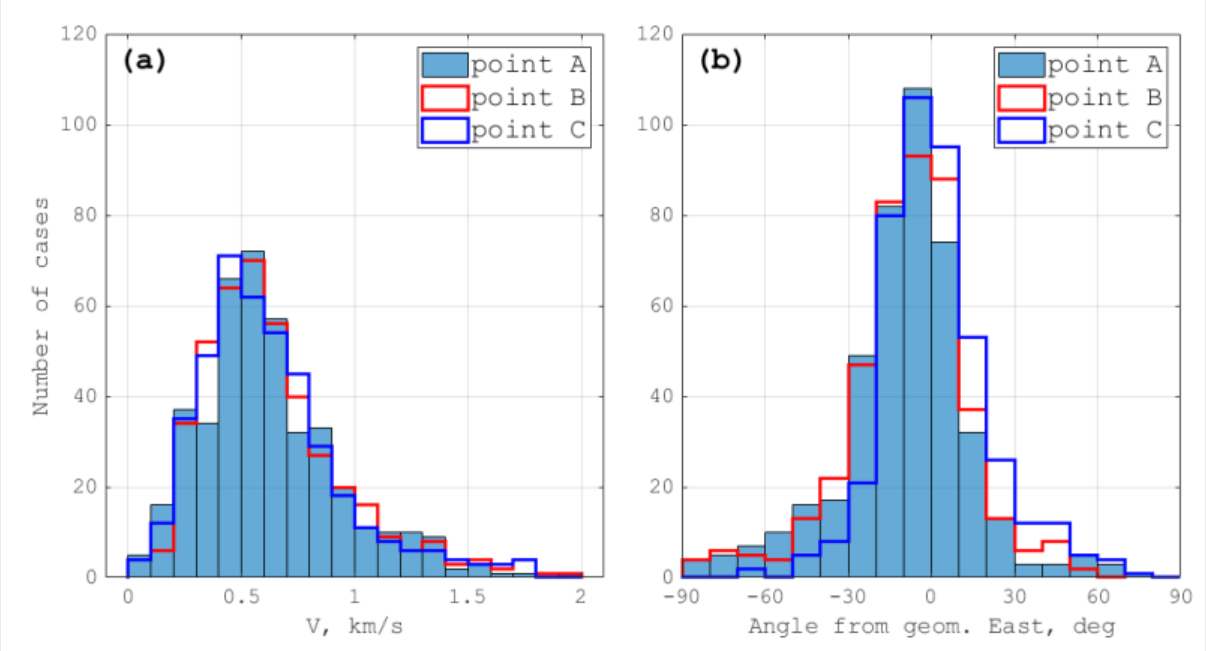


Spatial motion of omega bands

List of 400+ “normal” omegas, Partamies et al 2017



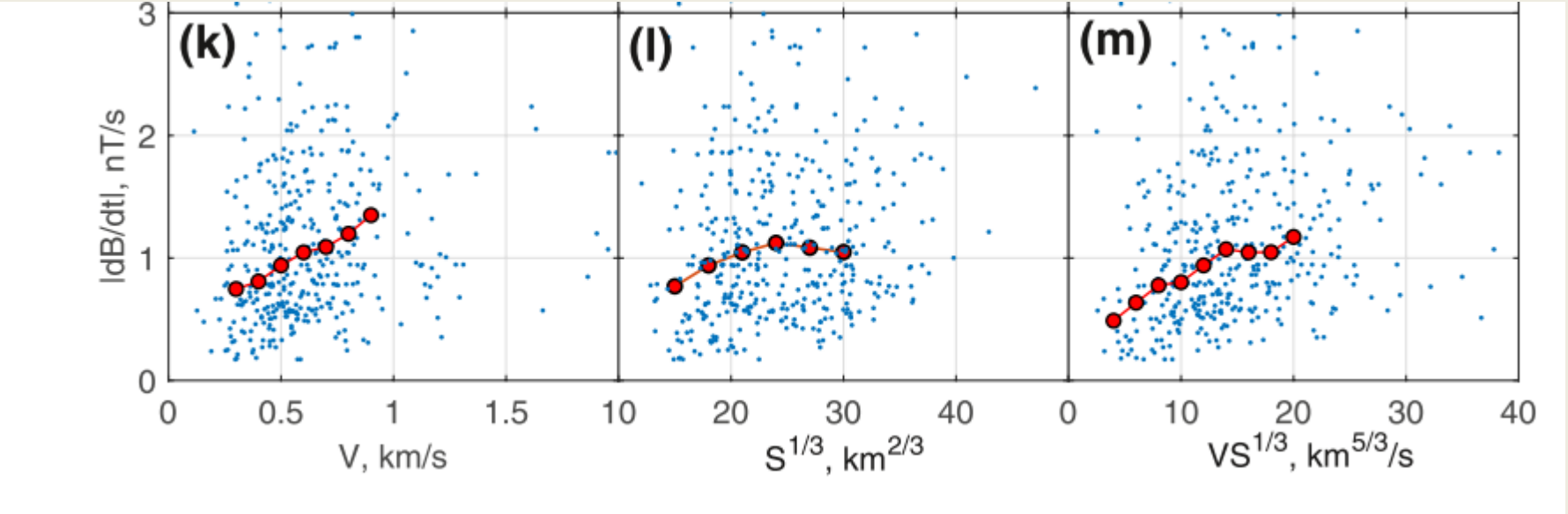
Kawasaki and Rostoker 1979 – magnetic data: 0.5-2 km/s



Vokhmyanin et al 2021 – optical data: 0.2 – 1.5 km/s, south-east direction

dB/dt vs speed and area

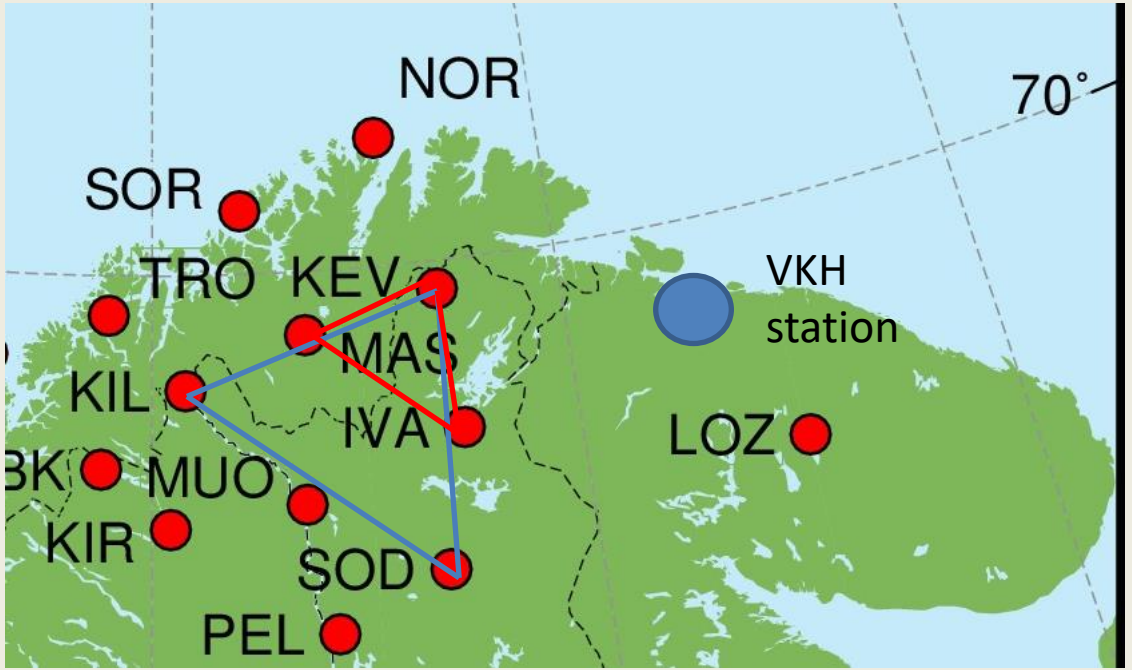
- Vokhmyanin et al 2021
  The larger and the faster an omega – the higher dB/dt



Spatial motion. Timing method

Omega bands are known to drift eastward

Small and large triangles
KEV – MAS – IVA 120km side
KIL – SOD – MAS 250km side
To apply “timing” and get **V**



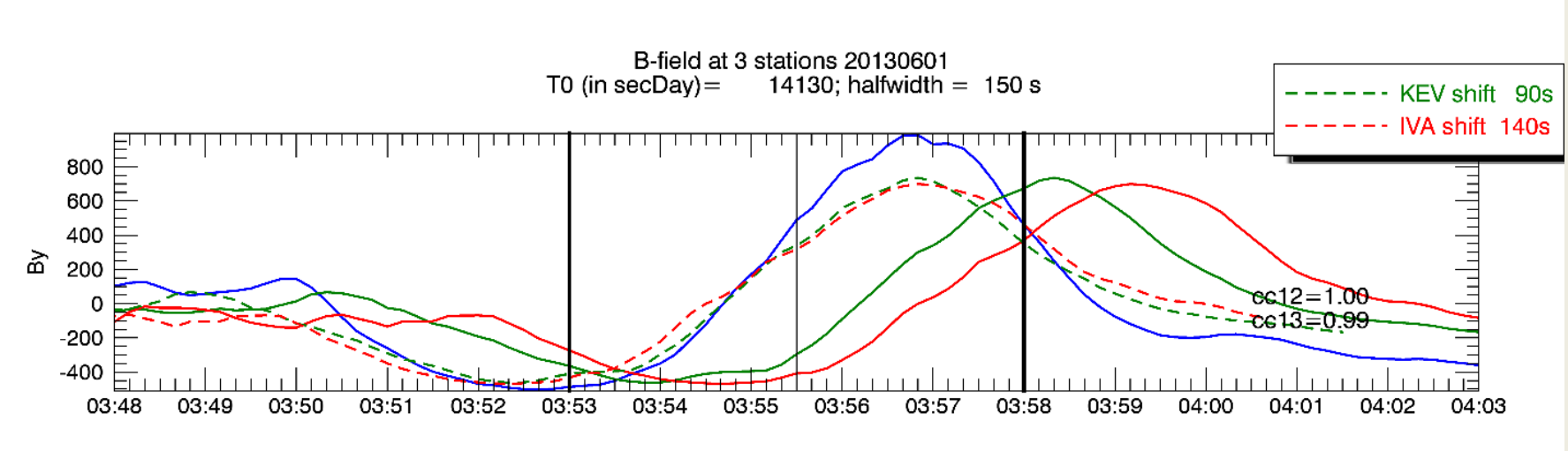
- Plane front assumption
- With 3 points
  we get velocity vector

$$(\boldsymbol{r}_\alpha - \boldsymbol{r}_4)\,\hat{\boldsymbol{n}} = V\,(t_\alpha - t_4)$$

$$\boldsymbol{m} = \frac{\hat{\boldsymbol{n}}}{V}$$

$$\boldsymbol{m} = \mathrm{D}^{-1}\boldsymbol{T}$$

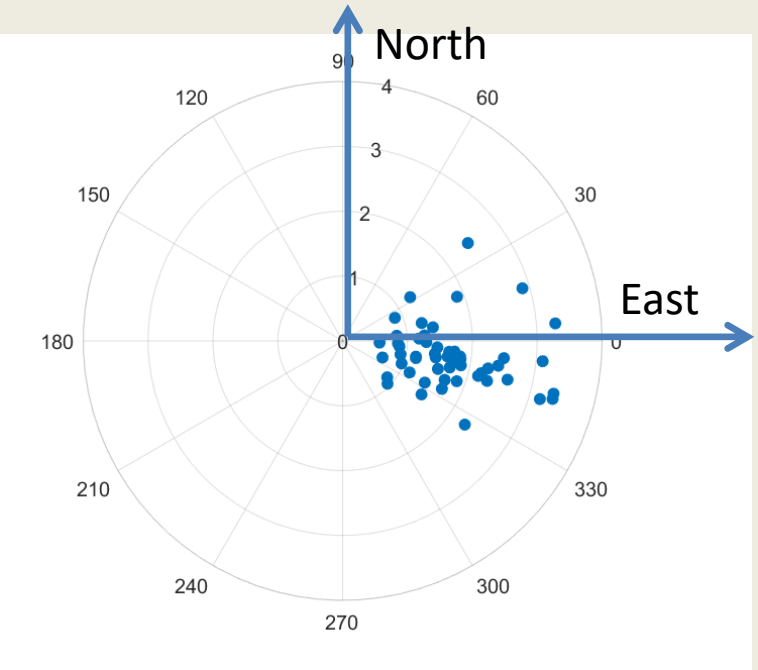
Timing method. Example

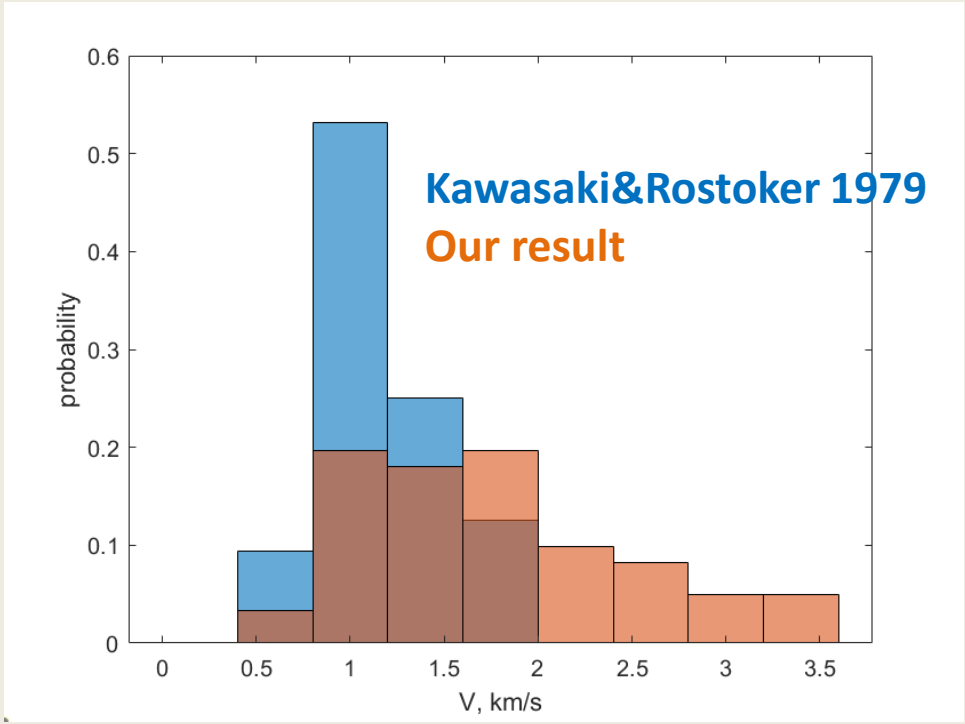


- V = 1.20 km/s
- Angle 111 deg, i.e. south-east (east is 90)

Spatial motion. Results

- V is larger then typical
- Eastern and equatorial direction





Conclusions

- 30 % of the highest GIC related to omega bands, 80% in morning LT sector
- High propagation speed of omega bands is responsible for large GIC

Thanks for your attention !

Acknowledgements:
FMI – IMAGE magnetometer data
JHU/APL – DMSP/SSUSI data
GIC - EURISGIC project
RSF grant 19-77-10016

Goals

- Auroral forms related to GIC ? Magnetospheric source?

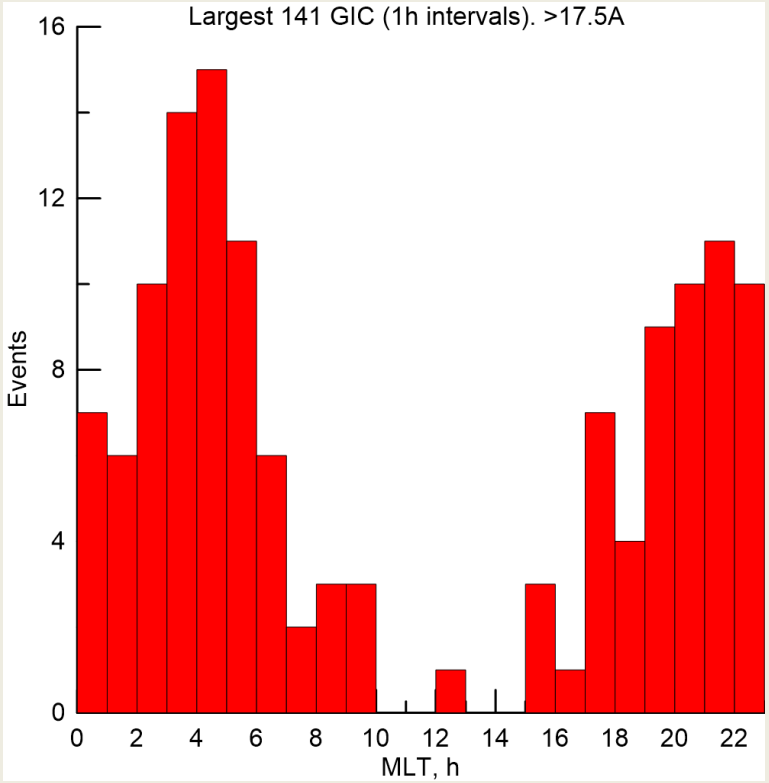
- Role of spatial motion in dB/dt

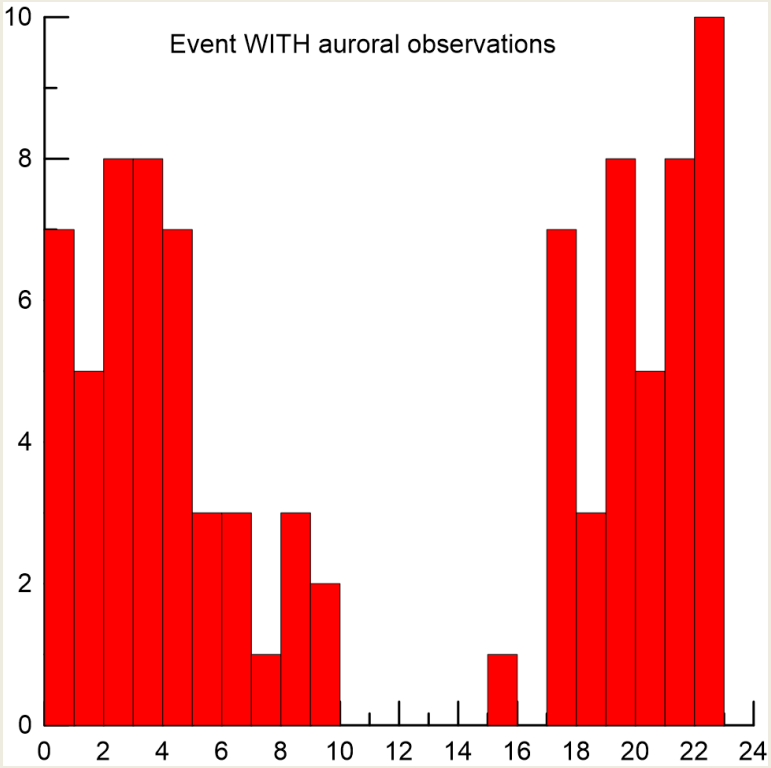
$$d\mathbf{B}/dt = \partial\mathbf{B}/\partial t + (\mathbf{V}\cdot\nabla)\mathbf{B}.$$

Ionospheric current
growth of motion?

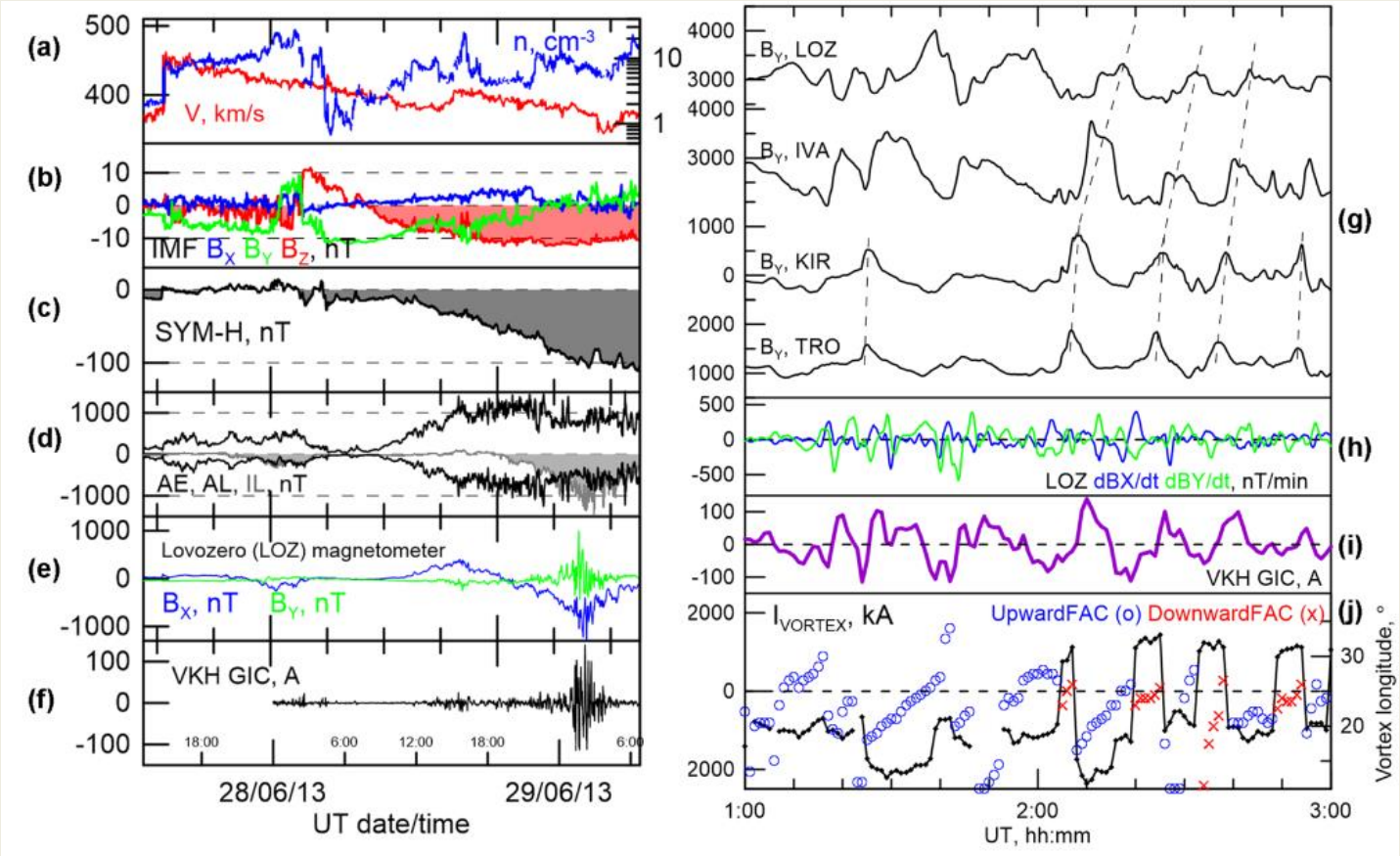
Top 140 GIC at Vykhodnoy transformer 2012-2018

97 out of 141 with DMSP images





Highest ever recorded GIC



max dB/dt 15nT/min

Temporal and spatial terms are comparable

Apatenkov et al 2020, GRL