

The amplitude-ratio and the cross-phase methods to automatically identify FLR in the SuperDARN VLOS data

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Outline:

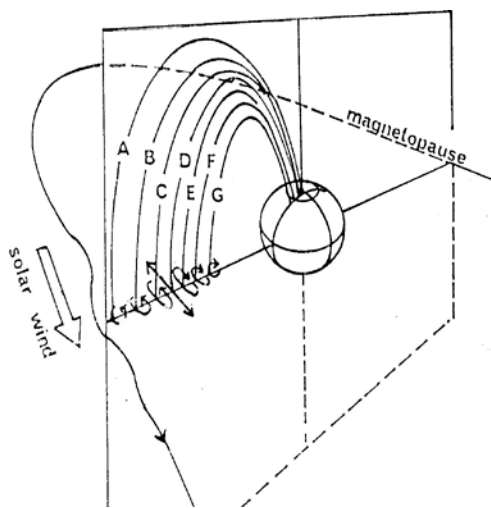
- Importance of the magnetospheric region identification, through the density estimation, from the ground by SuperDARN
- **Field-line resonance (FLR)** enables estimating the plasma density in the magnetosphere
- **Gradient method** (= **amplitude-ratio method** and **cross-phase method**) could clearly and automatically identify FLR

Field-Line Resonance (FLR)

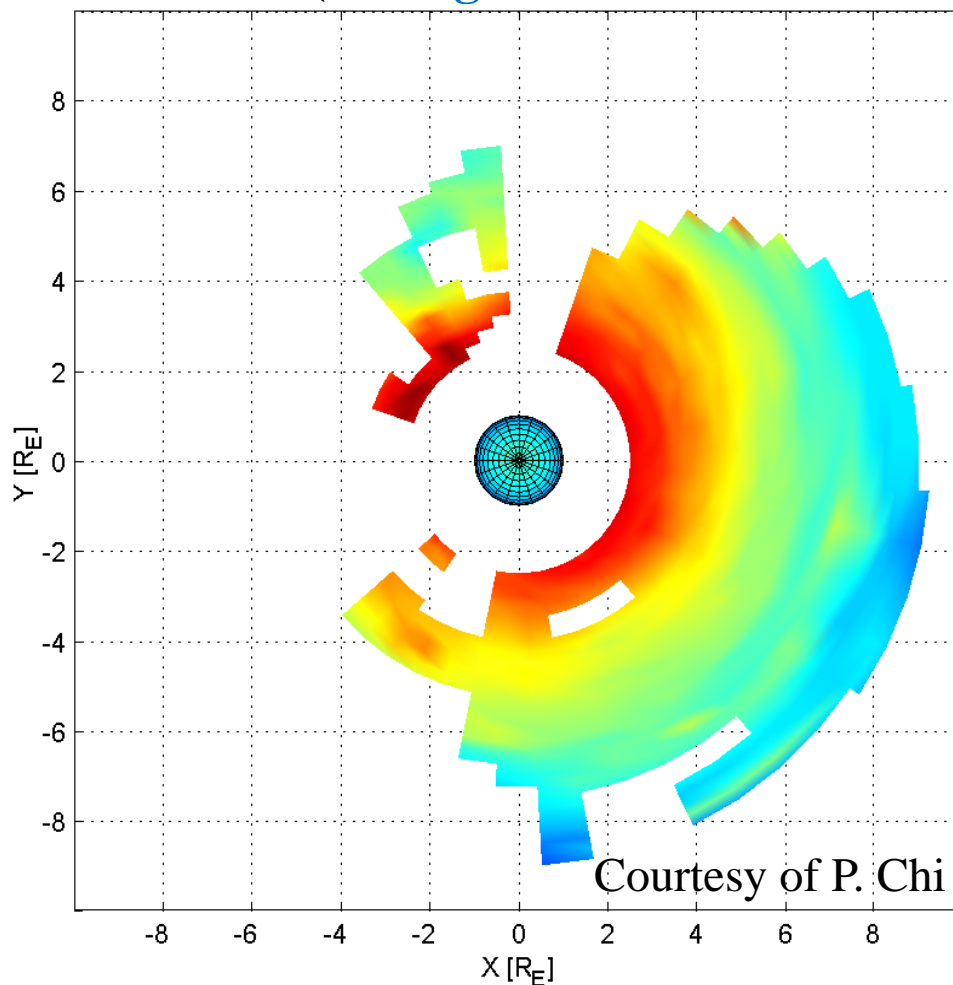
- Frequency of the field-line eigen-oscillation
- Magnetospheric Density

An incoming wave and a magnetospheric field-line eigen-oscillation resonates where the field line's **eigen-period** matches the **incoming-wave period**.

Eigen-period $\propto l, \rho^{1/2}$,
 where l : field-line length,
 $\rho^{1/2}$: plasma density



Equatorial magnetospheric densities thus estimated by using **ground magnetometers** (average of a few weeks' data)

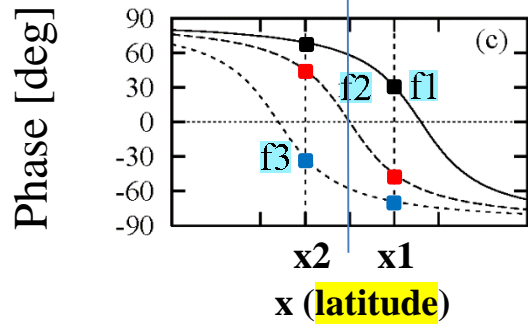
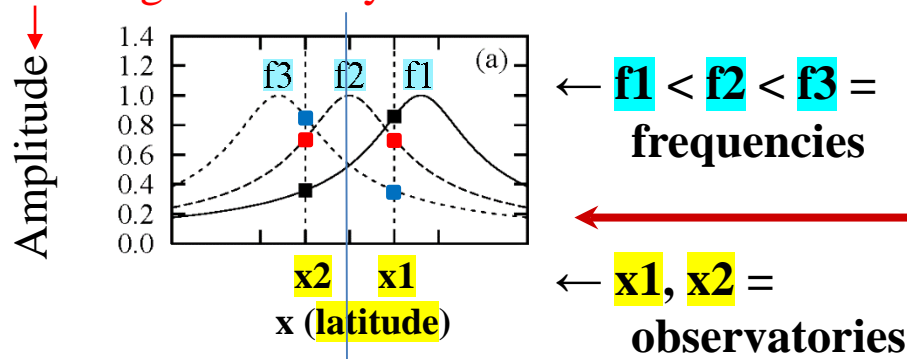


○ What is (to be) seen by SuperDARN

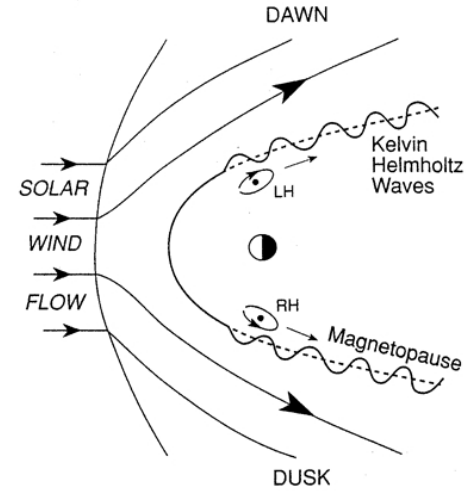
- FLR-driven field-line eigen-oscillations also cause oscillations of VLOS. The FLR can thus be identified in VLOS data, not only in ground-magnetometer data.
- SuperDARN, making **two-dimensional** observations, could make a (two-dimensional) map of equatorial magnetospheric plasma-density **at any given time**.

Perturbations in the magnetic field or VLOS generated by the FLR

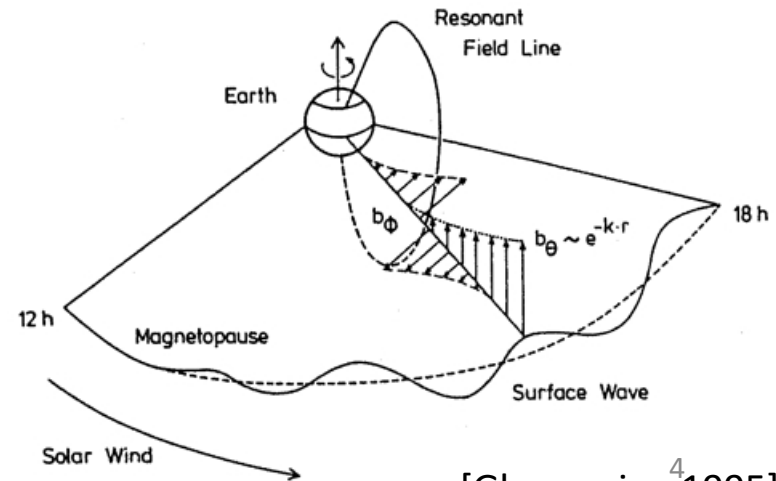
Typical pattern of the FLR



FLR

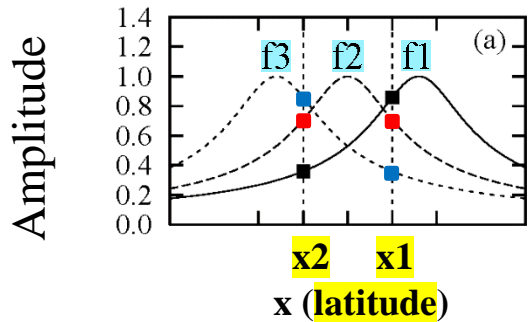


[Hughes, 1994]



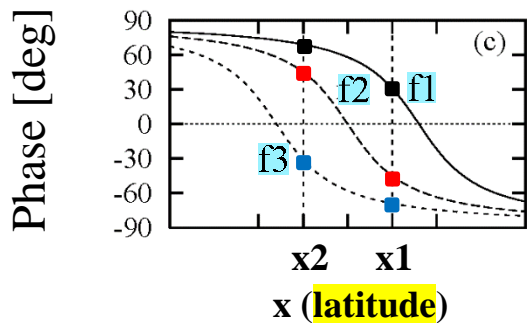
[Glassmeier, 1995]

The amplitude-ratio method and the cross-phase method (“gradient method” is their collective name)

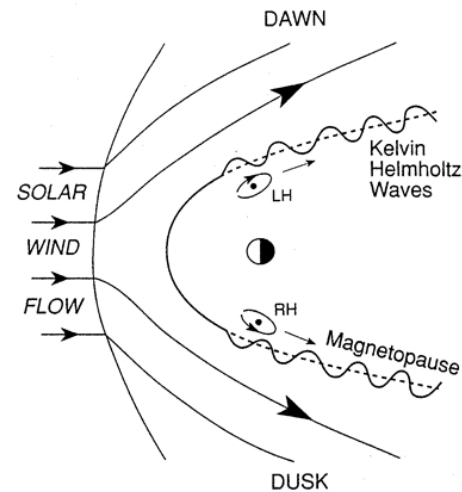


← $f_1 < f_2 < f_3 =$
frequencies

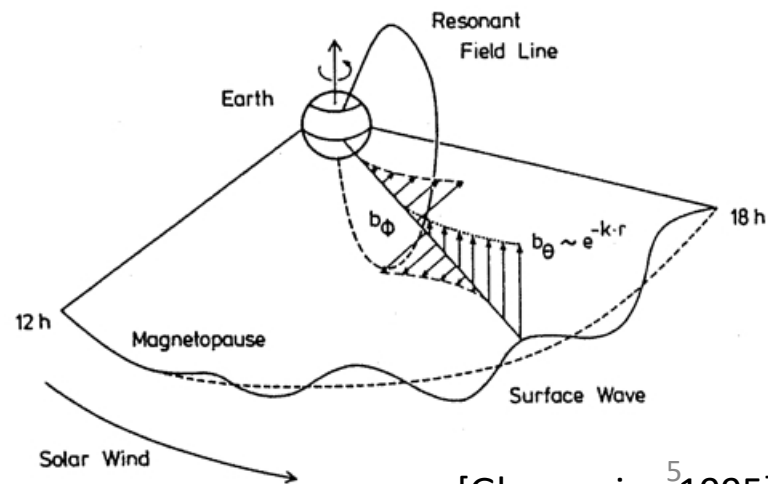
← $x_1, x_2 =$
observatories



FLR

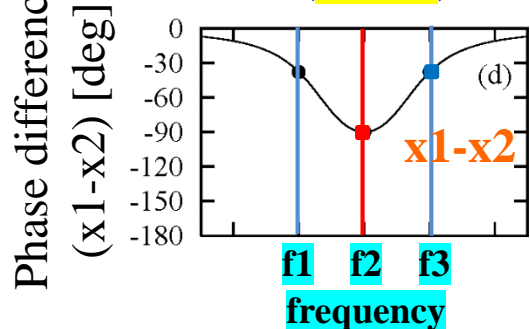
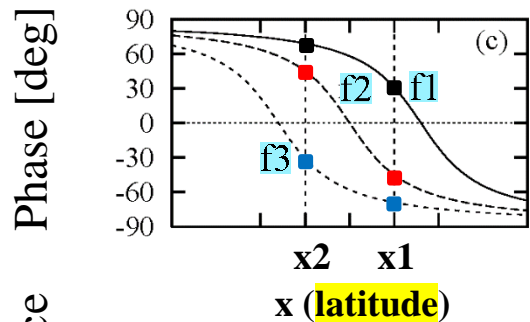
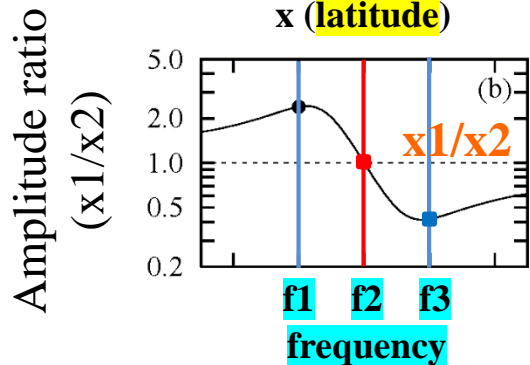
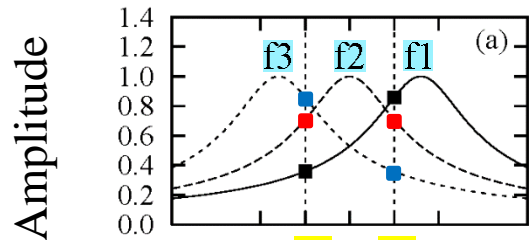


[Hughes, 1994]

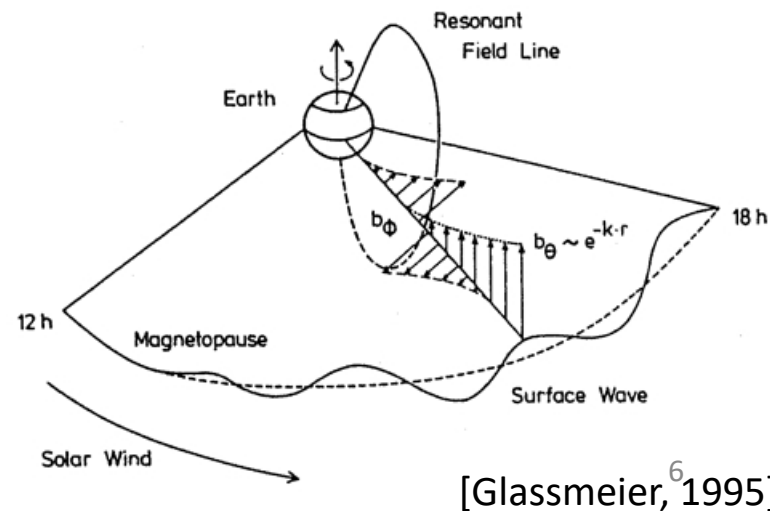
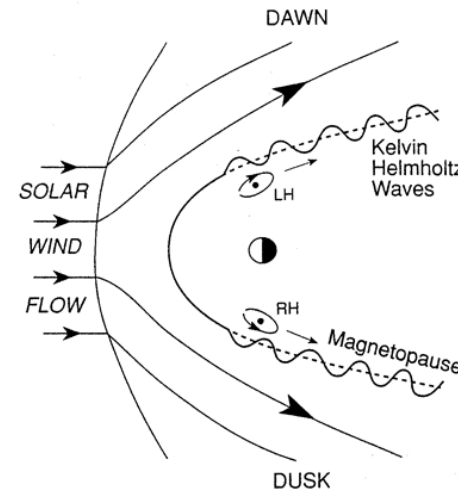


[Glassmeier,⁵ 1995]

The amplitude-ratio method and the cross-phase method (“gradient method” is their collective name)

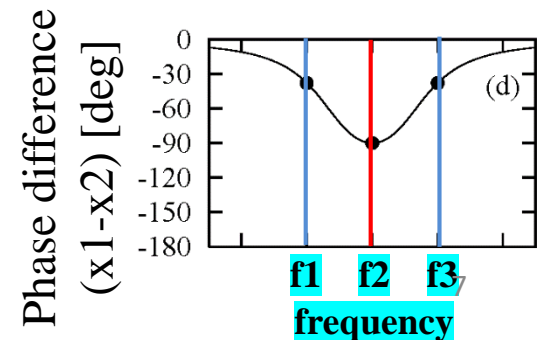
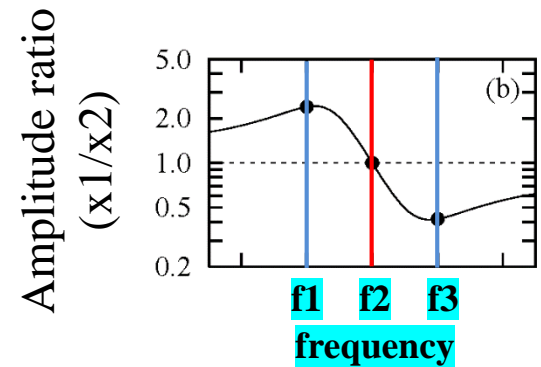


FLR



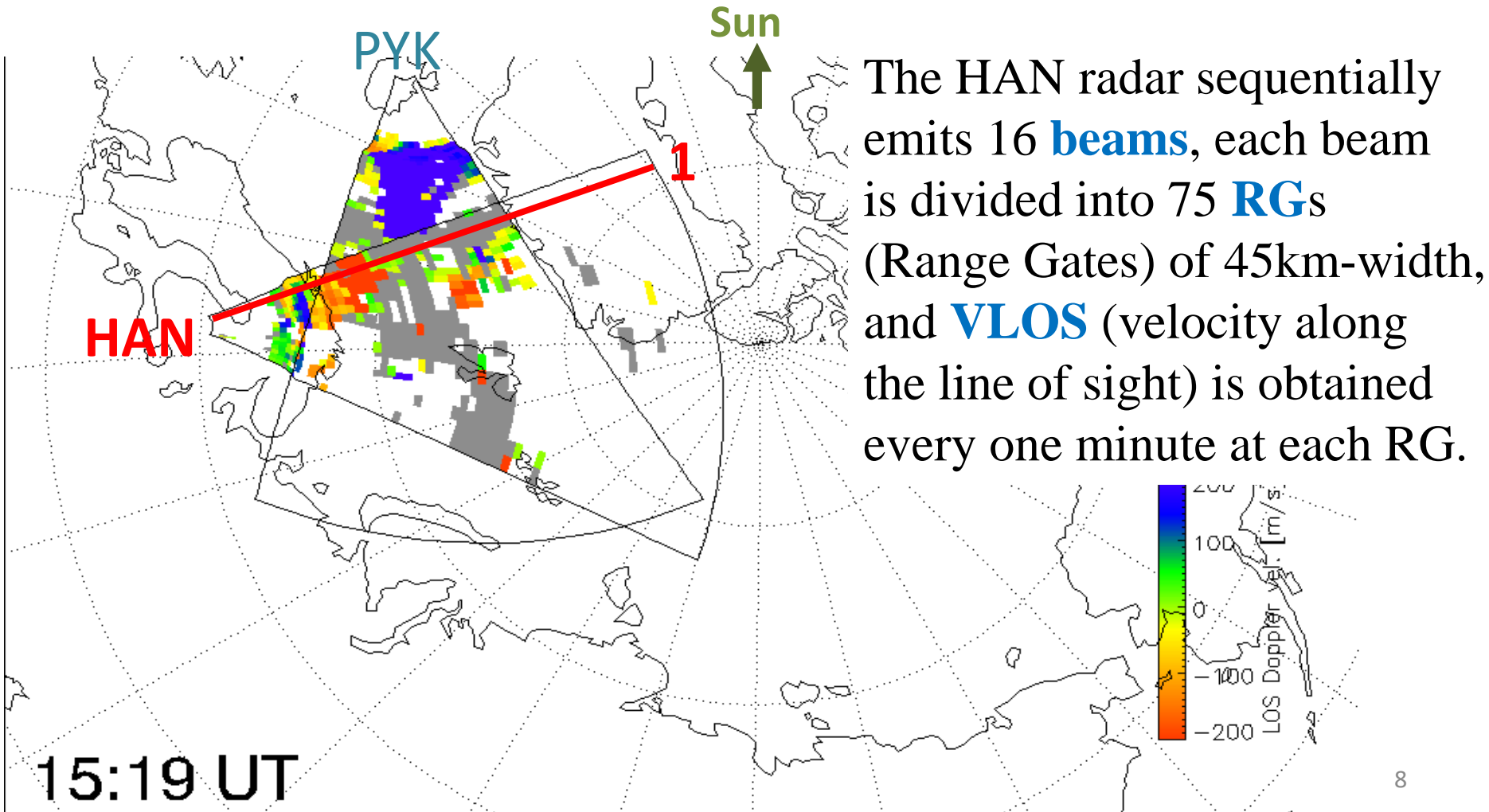
○ Advantages of the “gradient method” (the amplitude-ratio method and the cross-phase method)

- The FLR signal is quite often superposed by **global wave signals**, which makes it difficult to identify the FLR; the gradient method can **cancel out** the global wave signals.
- The gradient method are useful for **automatic identification** of the FLR: One can identify an FLR event if one peak in the phase-difference (**red vertical line**, right panels) lies between two peaks in the amplitude-ratio (**blue vertical lines**).

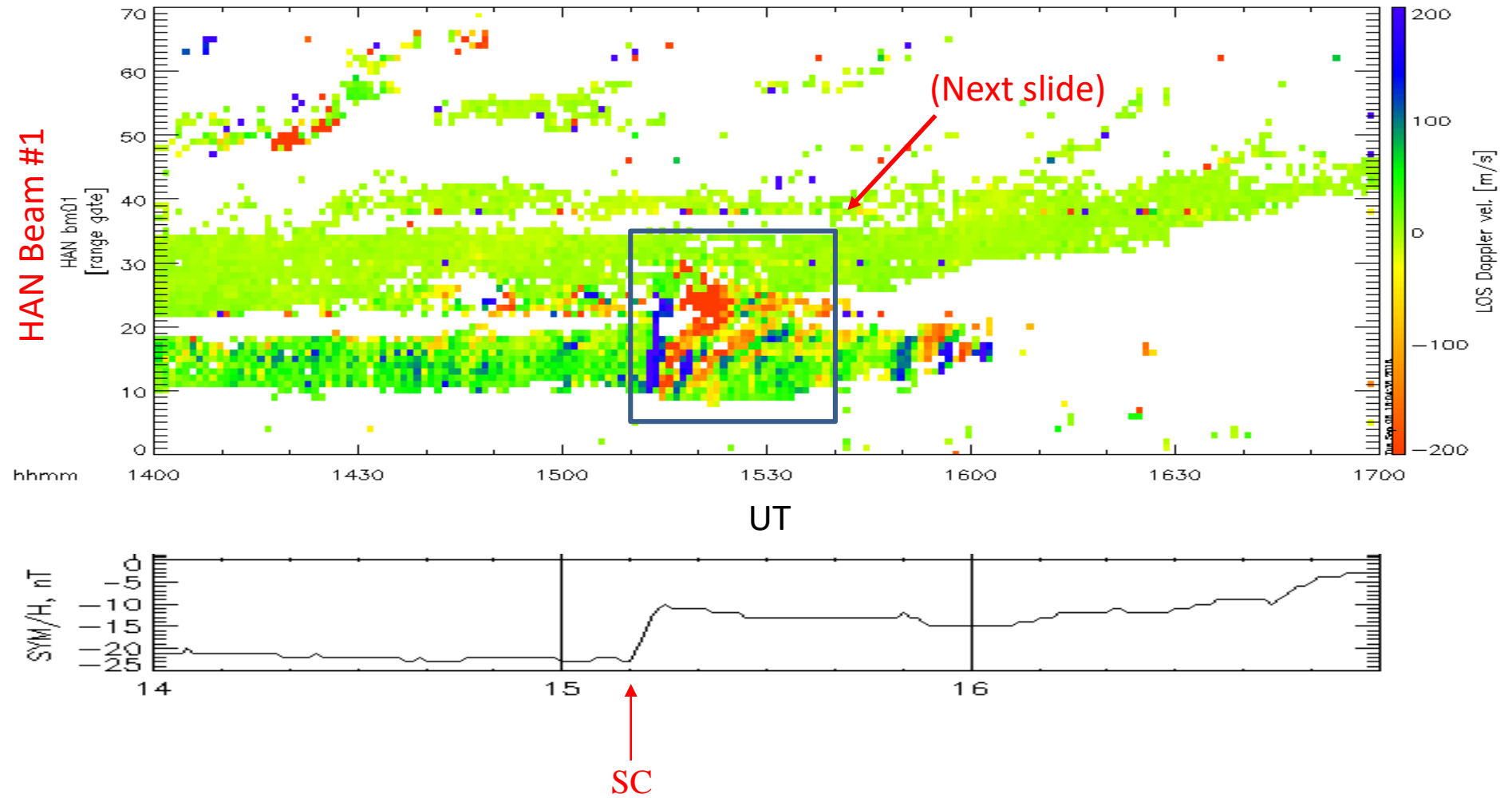


○ The event analyzed in this paper

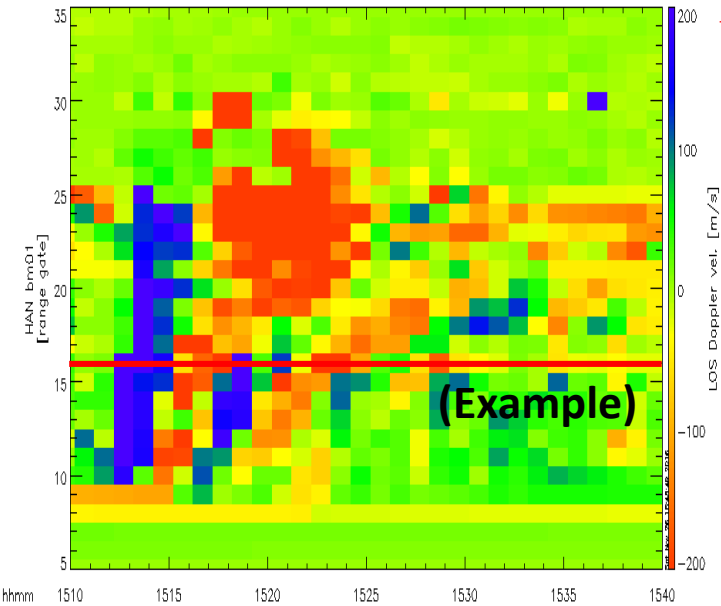
- As a feasibility study, we will apply the **gradient method** to the data from the **Beam #1** of **HAN** (Hankasalmi) during a **plasma-oscillation event** which started at the occurrence time of an SC (next slide)



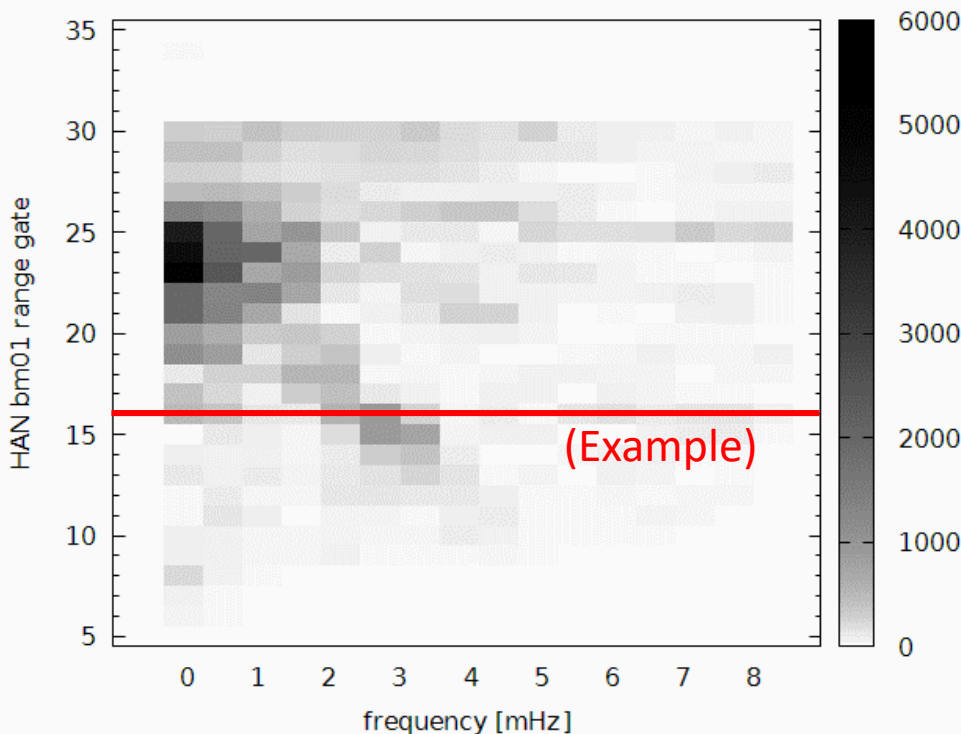
HAN Beam #1



HAN Beam #1

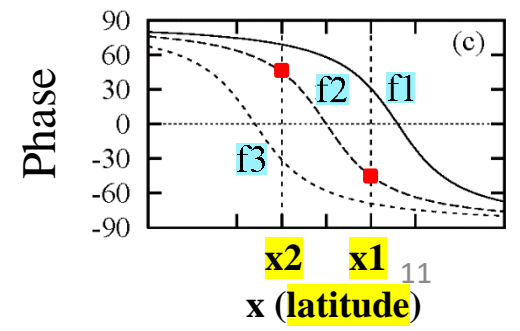
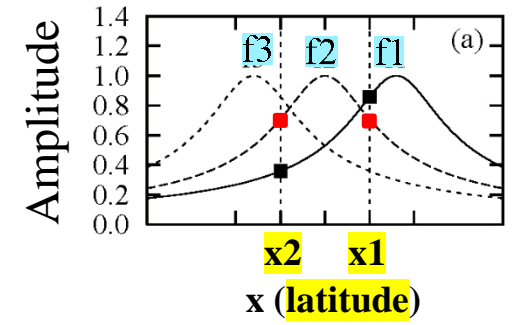
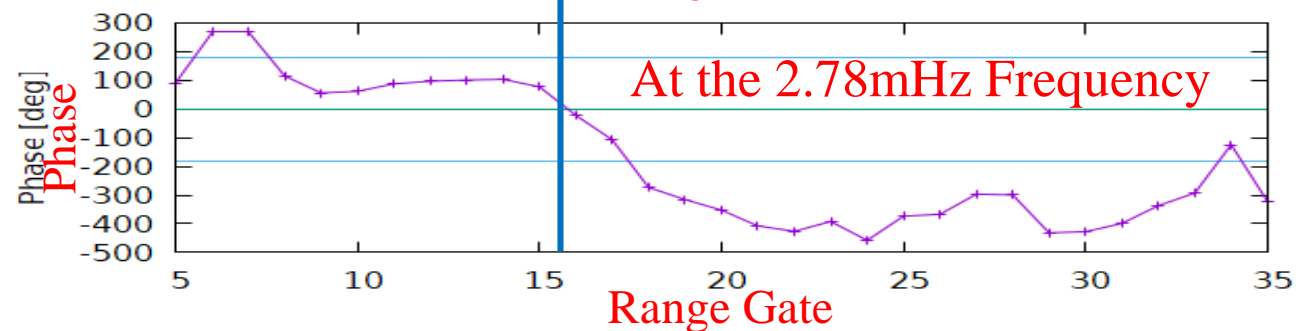
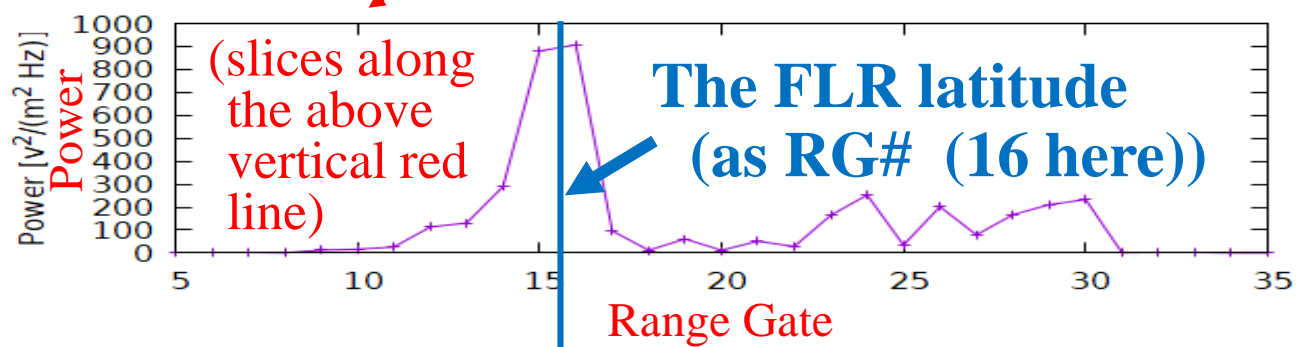
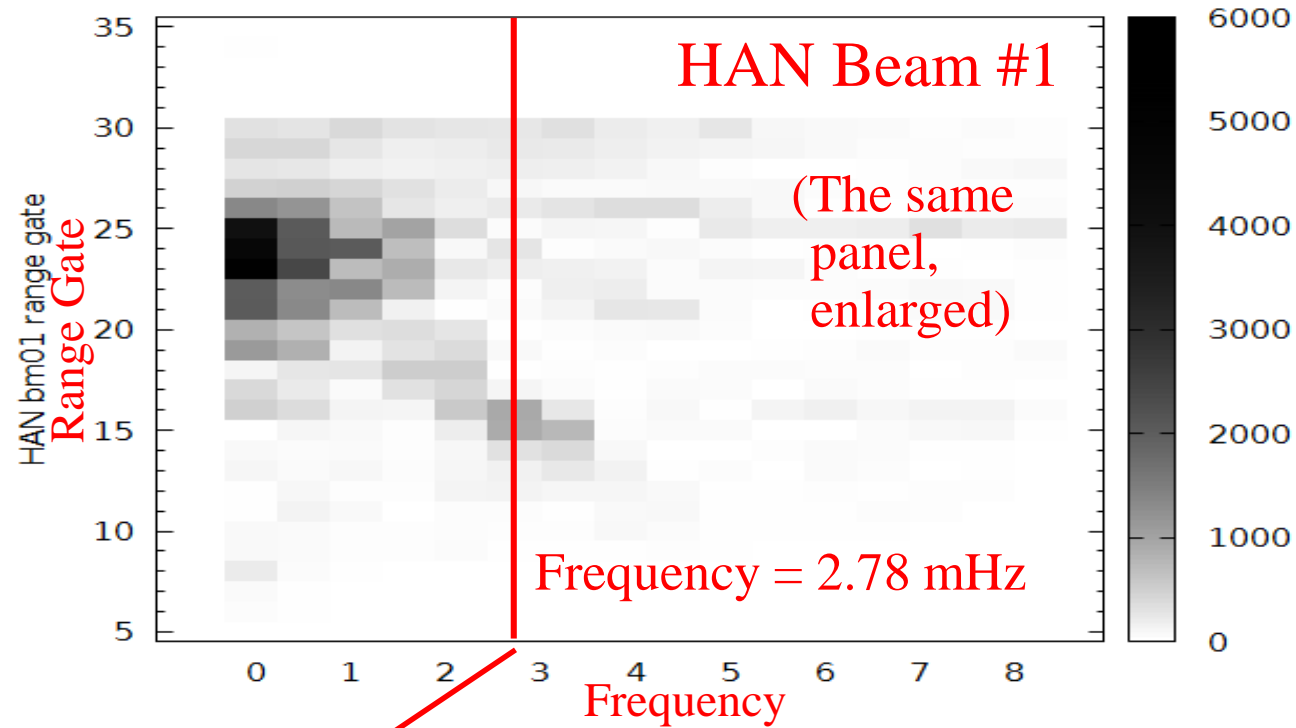


- Horizontal axis: UT (15:10 – 15:40 UT)
- Vertical axis: Range Gate (RG) number (RG#5 - #35);
a larger RG number corresponds to a higher latitude.



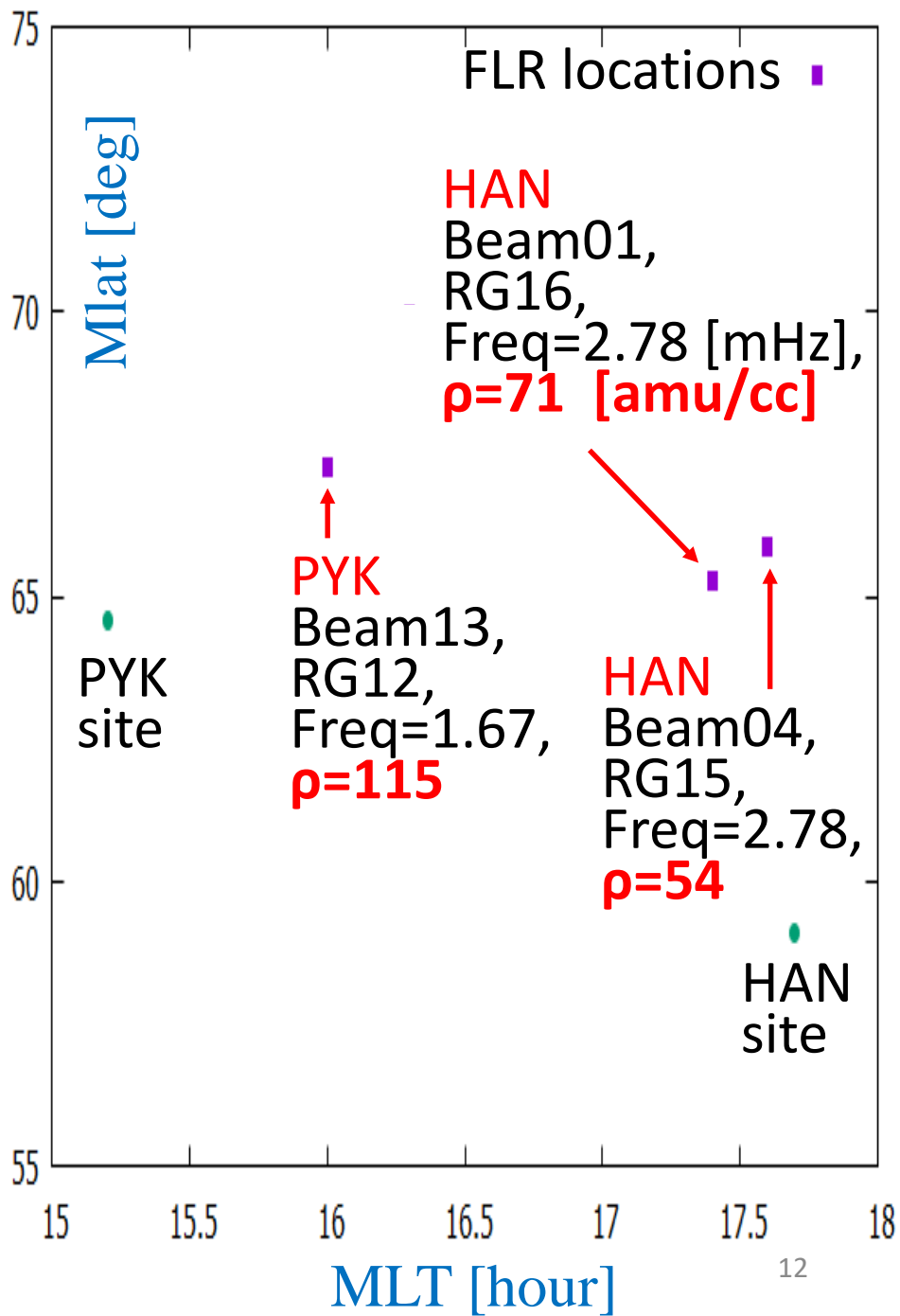
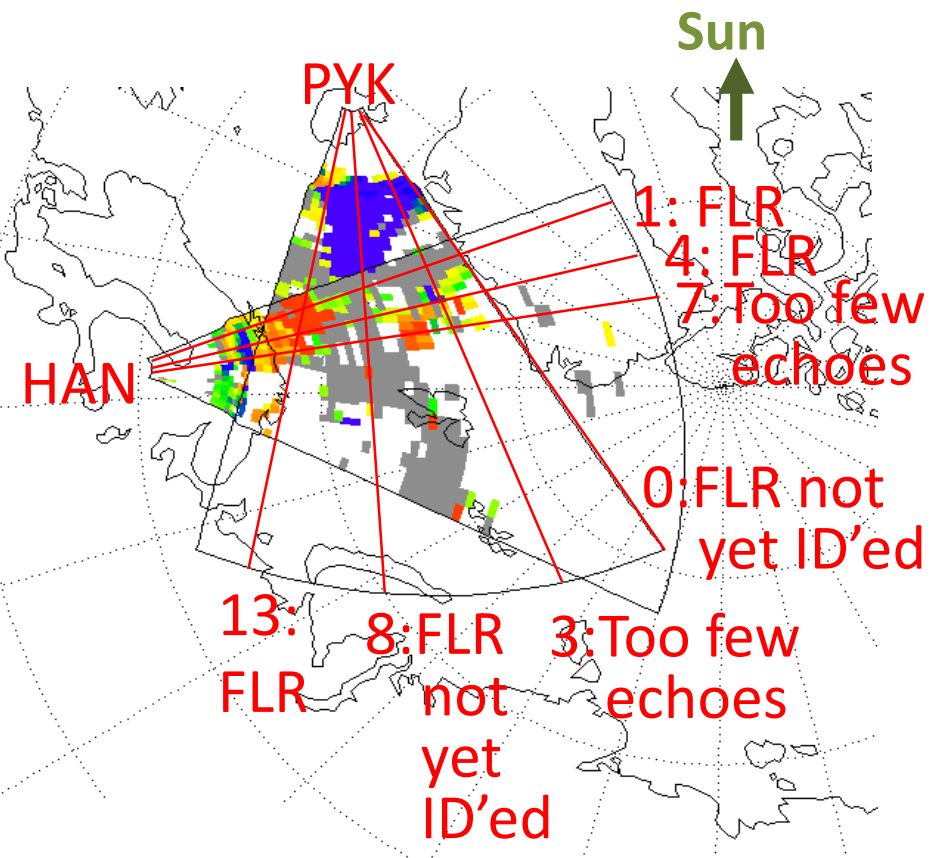
- For each RG, all the timeseries data in the top figure are Fourier transformed at once.
- The left figure shows the resultant **power** (a darker cell corresponds to a larger power)
 - Horizontal axis: frequency
 - Vertical axis: RG number
- In the next slide, this panel is analyzed in more detail.

- “Direct” method to identify FLR

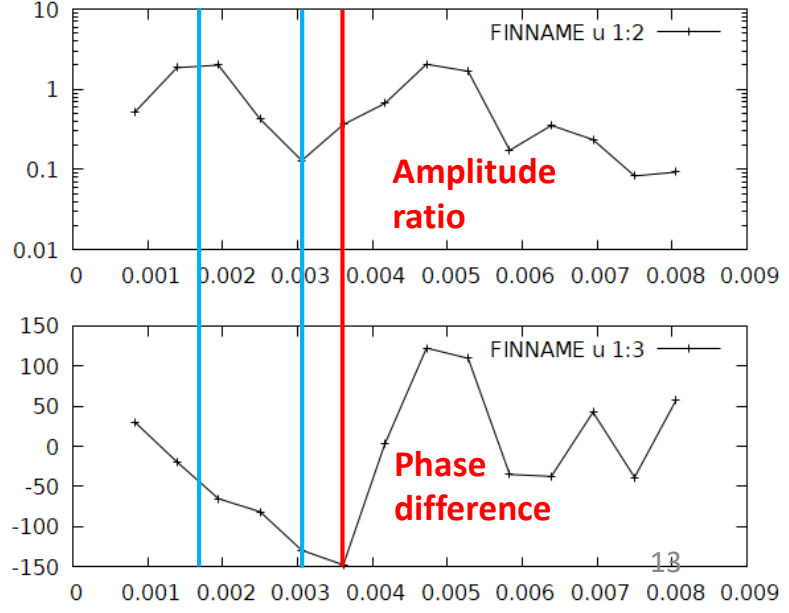
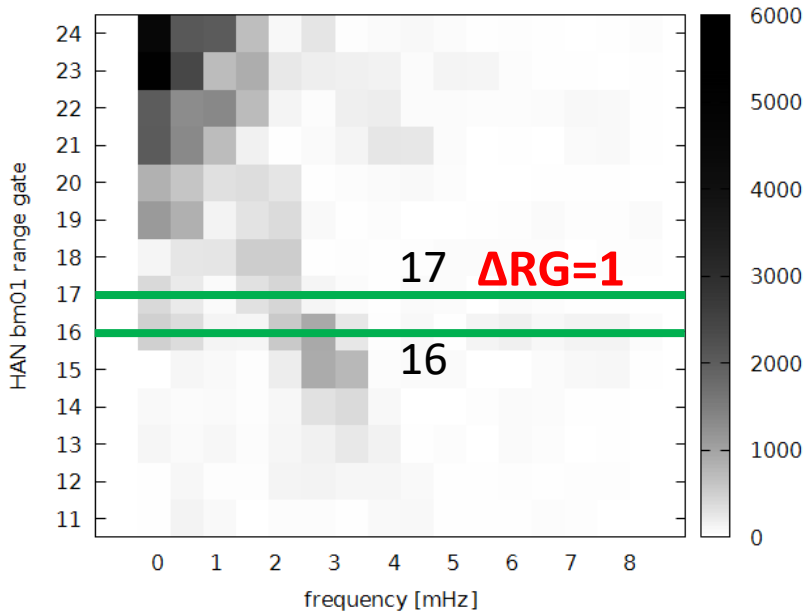
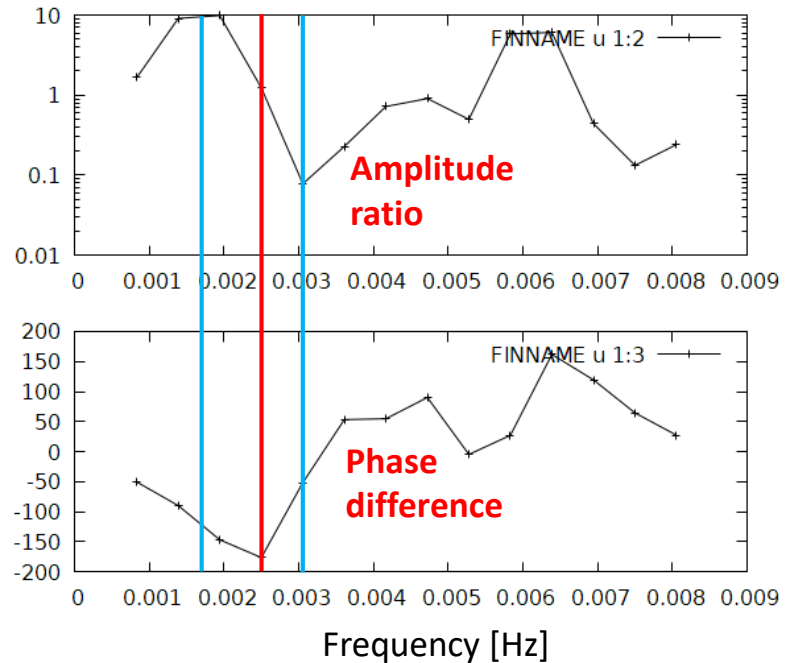
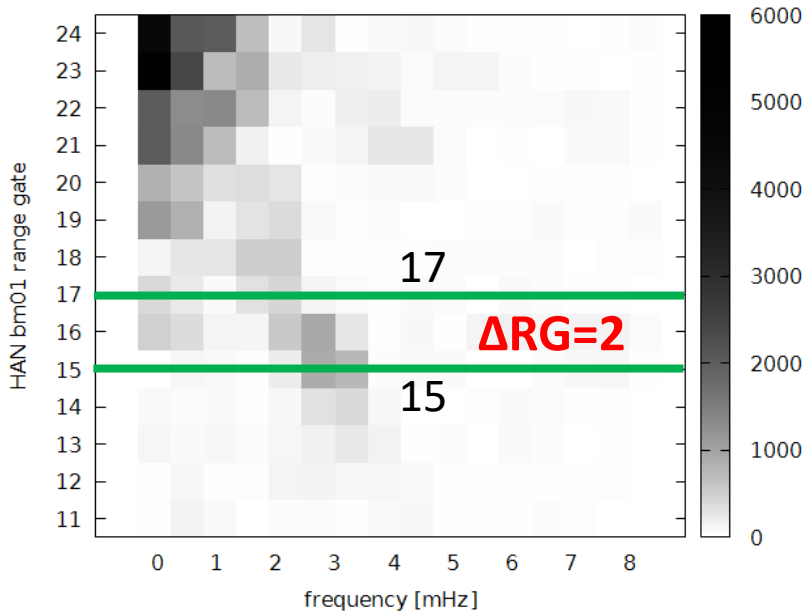


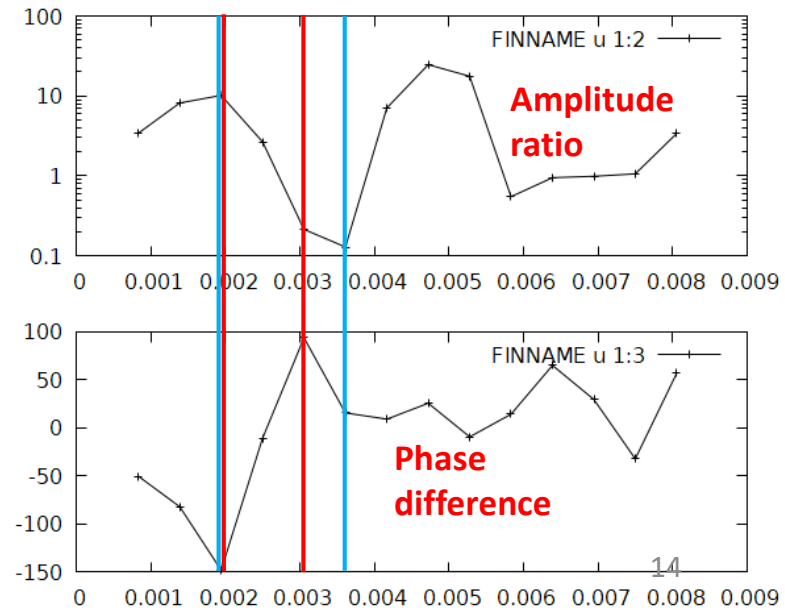
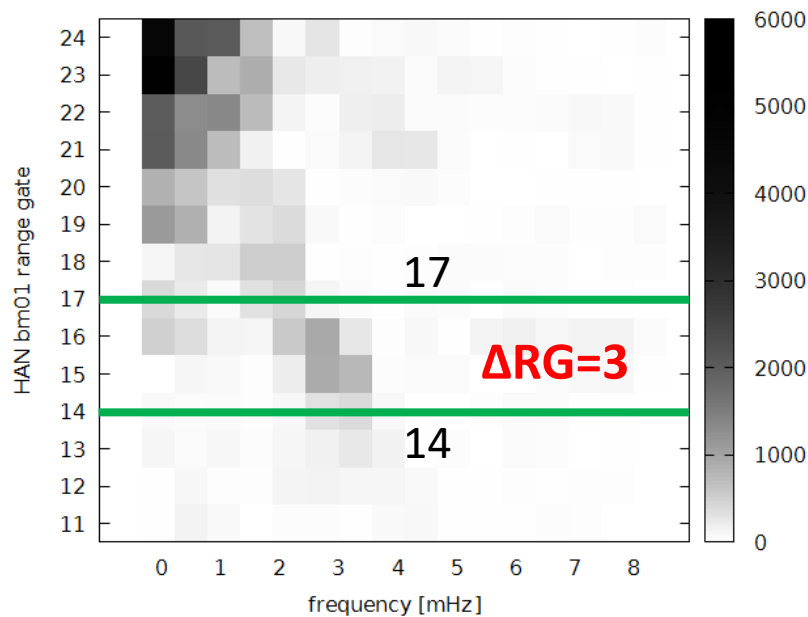
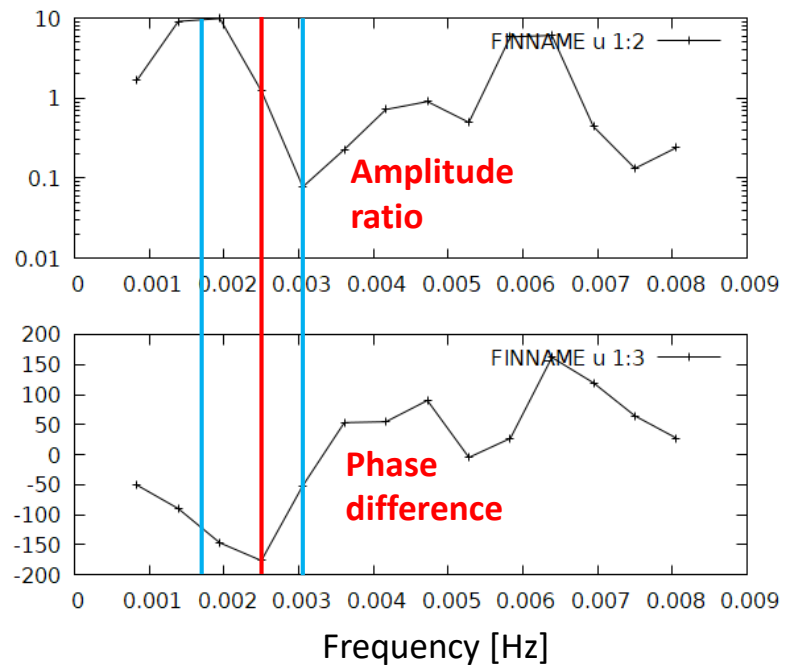
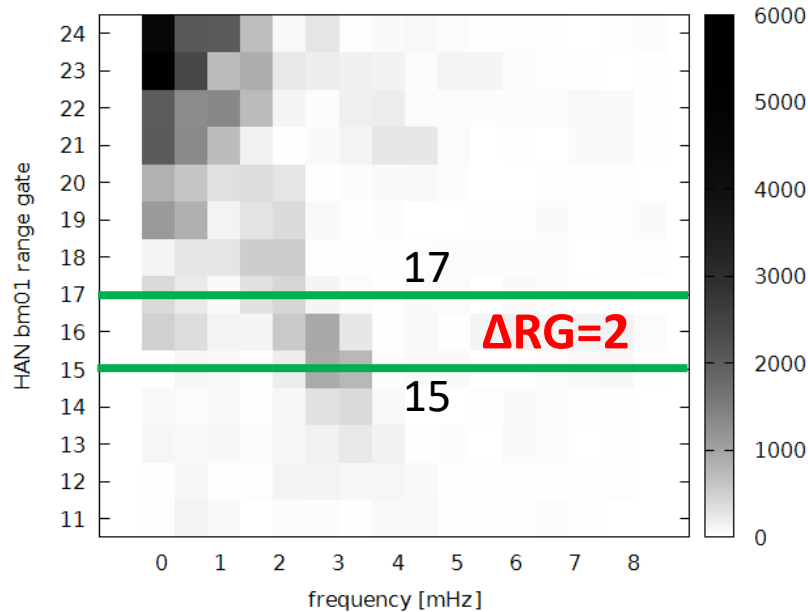
○ Results of the “direct” method

- FLR events were identified in the beams shown below → density, ρ , was estimated from the FLR frequency → mapped (right panel)
- ρ decreases with increasing MLT, possibly due to the compression associated with the SC.



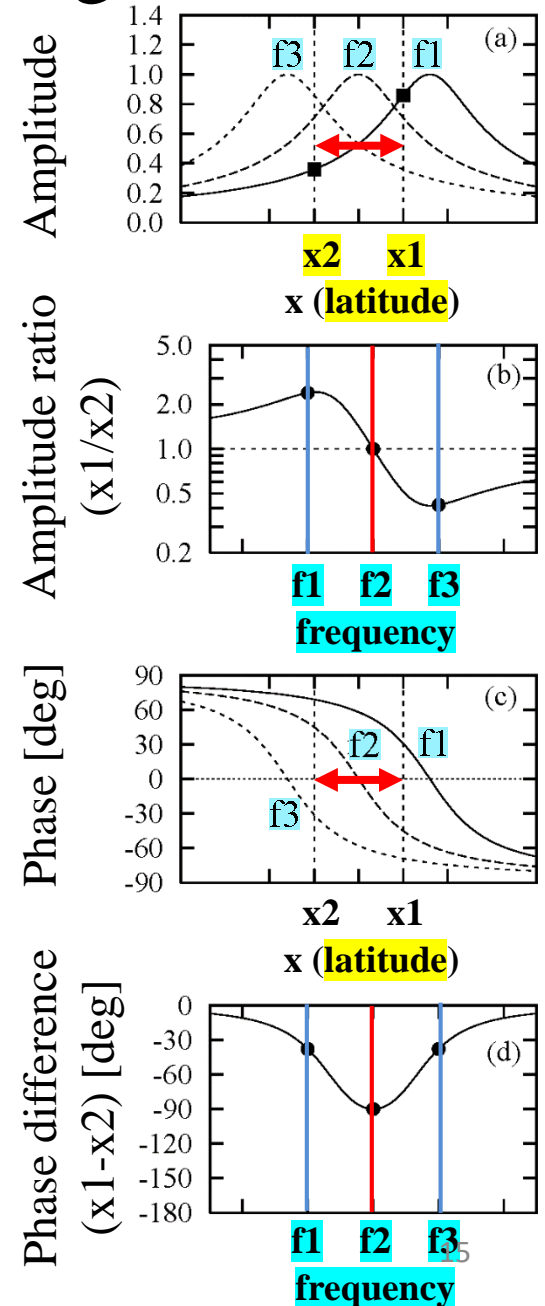
○ We could identify the FLR by the **gradient method** (for $\Delta RG=2$)





○ Interpretation of the results of applying the method

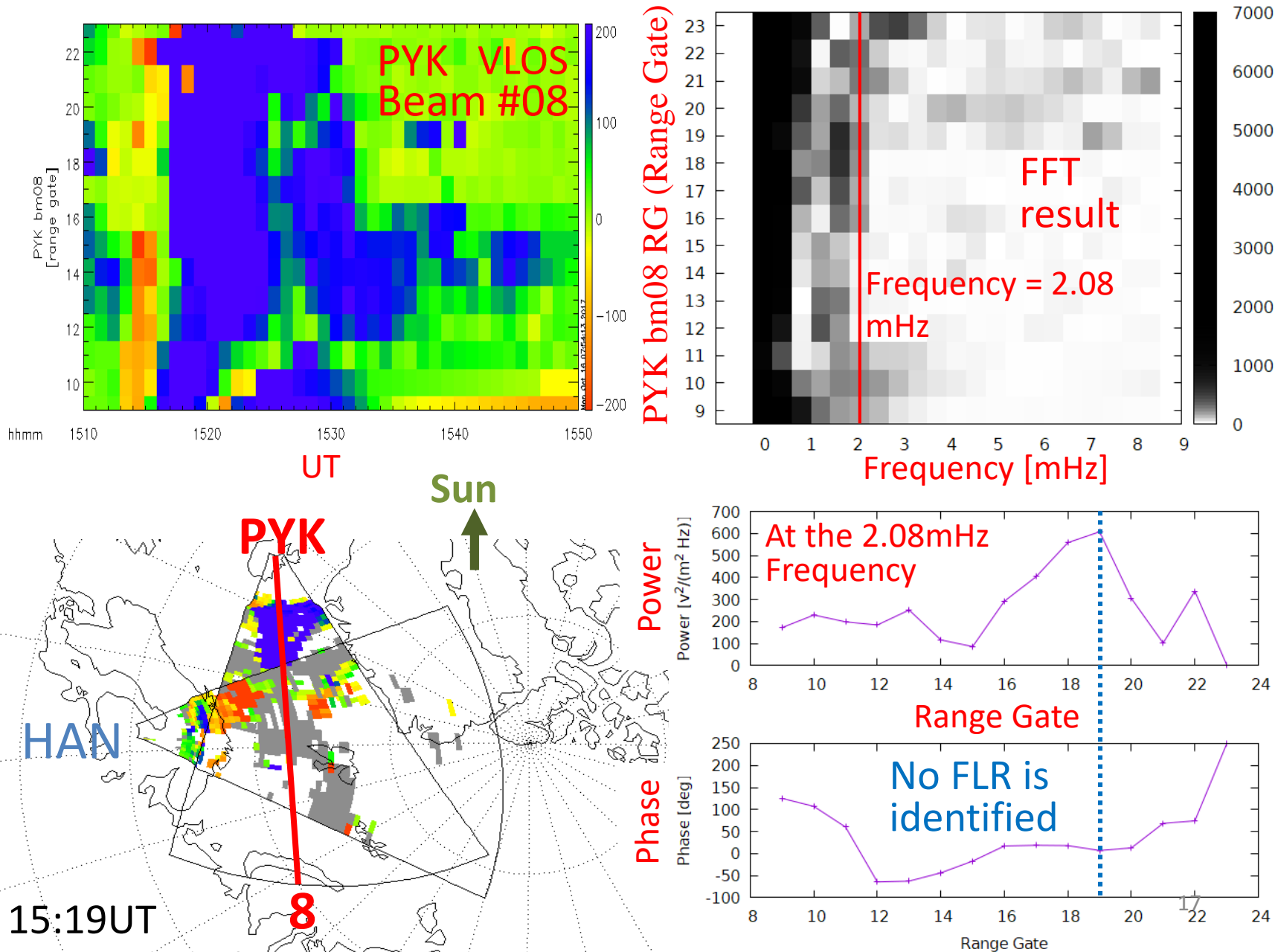
- The best distance between RGs (x1-x2 in the right figure) was 2. If we regard each RG as a “virtual observatory”, then the best distance between two “virtual observatories” was $\sim 80\text{km}$, because the RG latitudinal width was $\sim 40\text{km}$.
- This $\sim 80\text{km}$ can be regarded as the **resonance width**. It is an important physical quantity which reflects the FLR-energy dissipation near the resonance point and in the ionosphere.

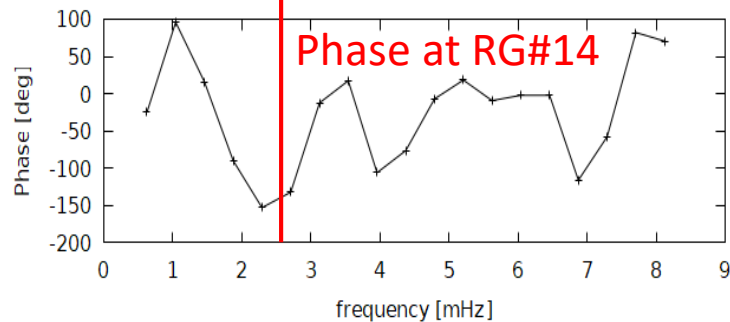
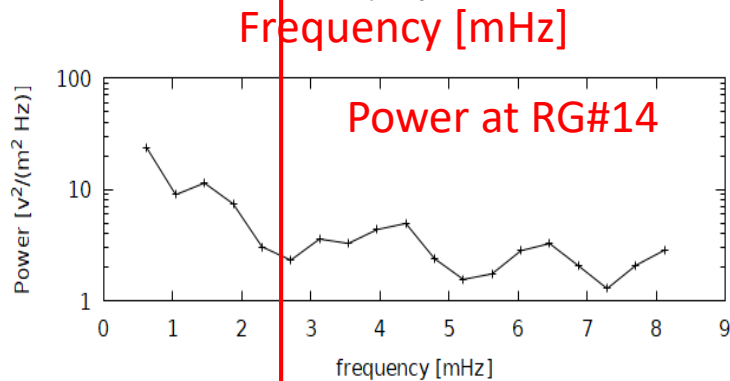
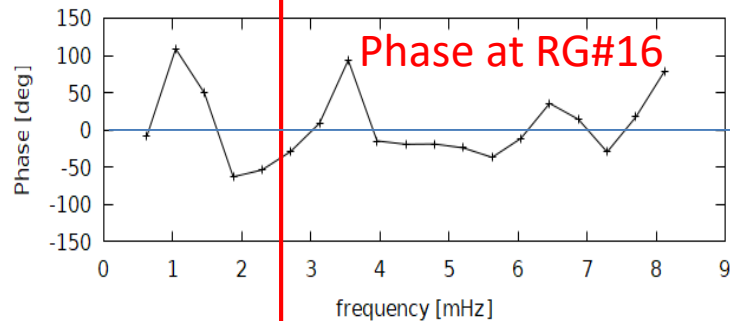
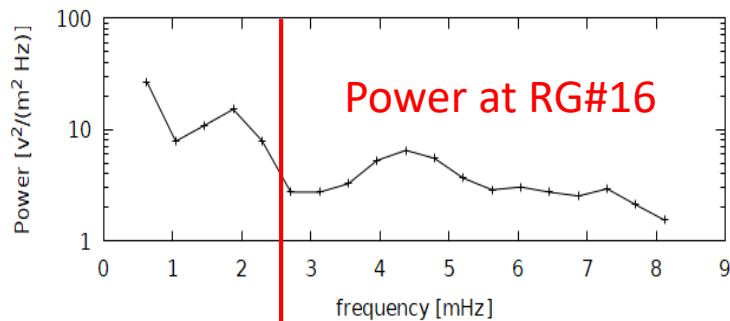


○ Summary and future subjects

- We could obtain an FLR frequency by applying the **gradient method** to VLOS from HAN beam #1.
- From that FLR frequency we estimated the **magnetospheric equatorial density**. It was similar to that estimated by using the “direct” method (not shown in this presentation).
- If we regard each RG of the SuperDARN as a “virtual observatory,” they are aligned along a beam with the same spacing; from that, we could estimate the **resonance width**.
- We are now developing computer codes to use the gradient method and **automatically identify FLR** events. So far they have succeeded in reproducing the visual-inspection results in the previous slides for $\Delta\text{RG} = 1, 2, \text{ and } 3$.
- “Hidden” FLR events, masked by global wave signals? → 16

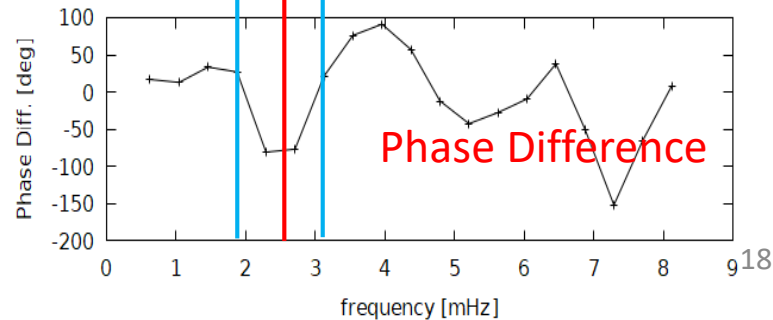
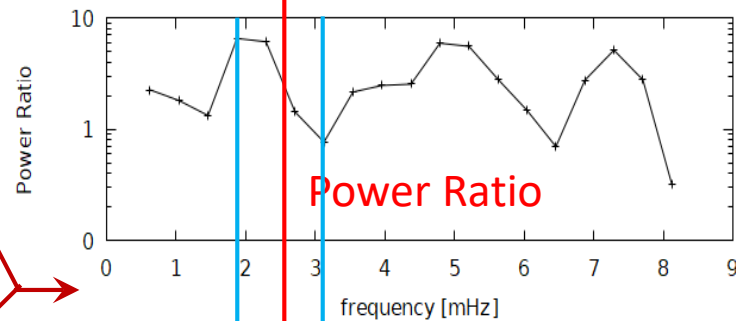
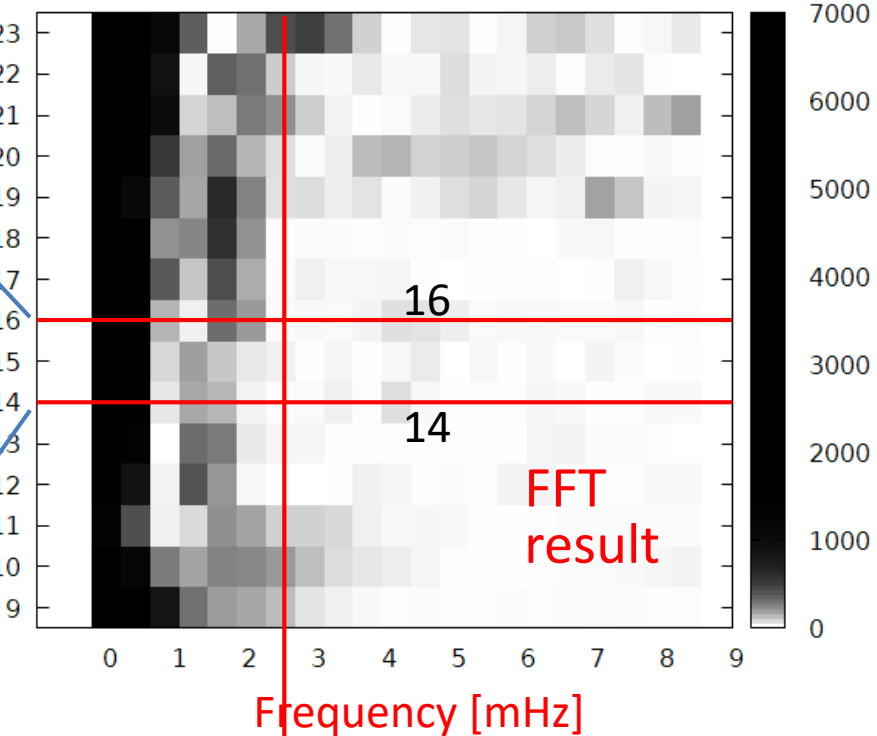
A possible “hidden” FLR event





Gradient
Method

PYK bm08 RG (Range Gate)



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- A possible “hidden” FLR event has been found.

END