PHYSICS AND ENGINEERING PHYSICS

Real space considerations and the study of EEJ irregularities

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Meter-scale observations for strong EEJ near or at the vertical

(What can we learn from the spectral shape and aspect angle behavior of vertical type I echoes in the EEJ?)

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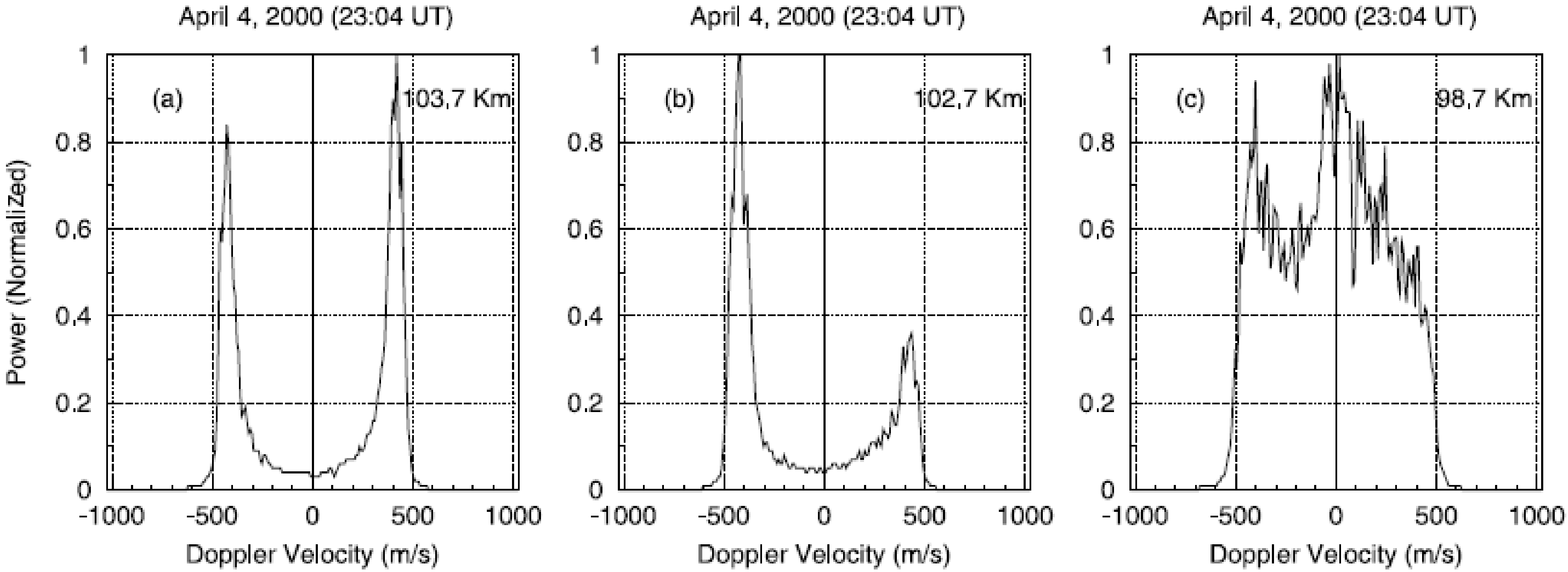
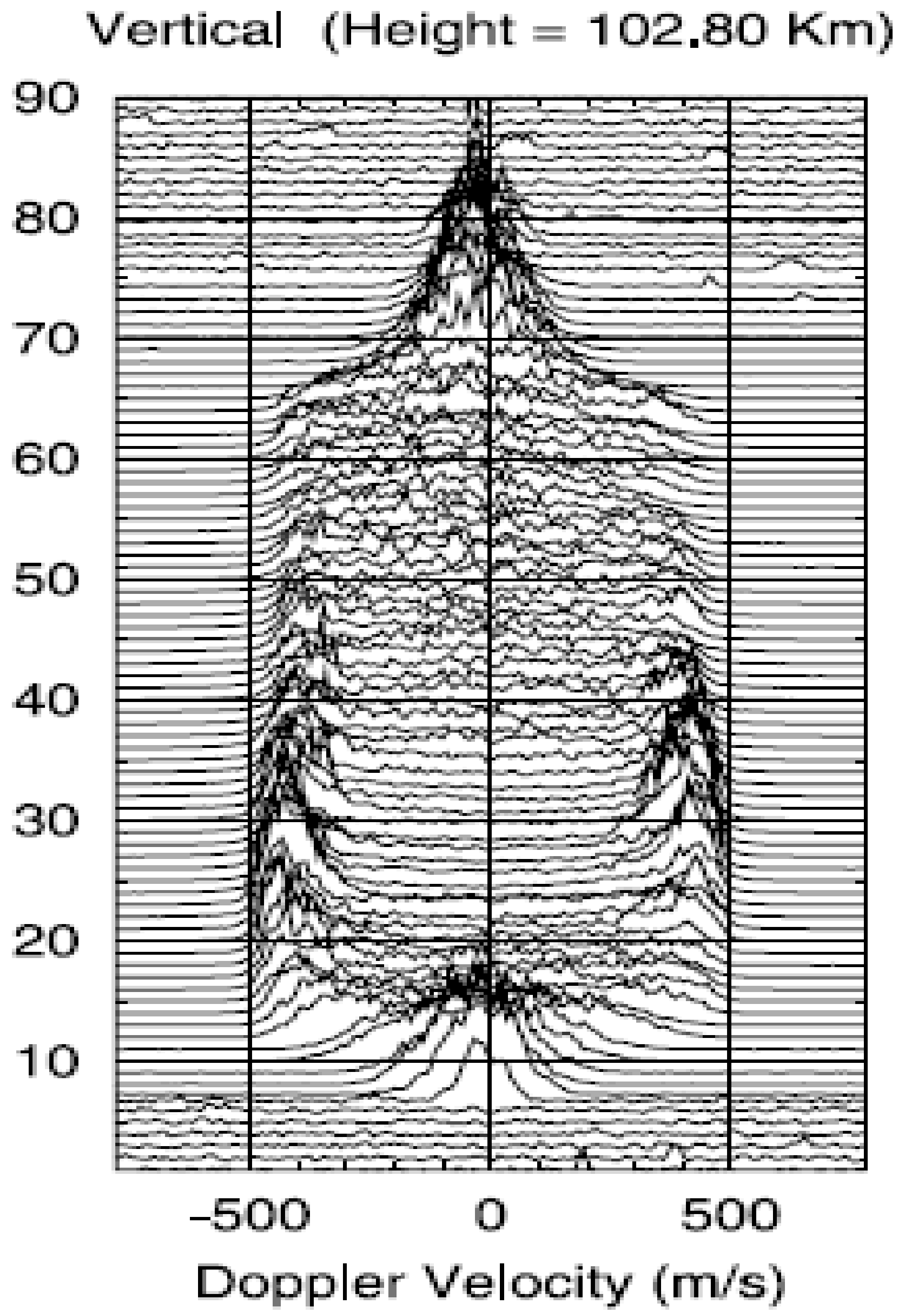


Figure 1. Examples of the kind of spectra that were observed with the vertical beam of the Pohnpei radar during strong electrojet conditions observed on April 4, 2000.

Under rather exceptional conditions, find strong peaks in the vertical near plus or minus Cs. The peaks are strongest at some intermediate altitude.

The spectrum evolves in time and exhibits 2 strong peaks for a fairly short-lived interval.



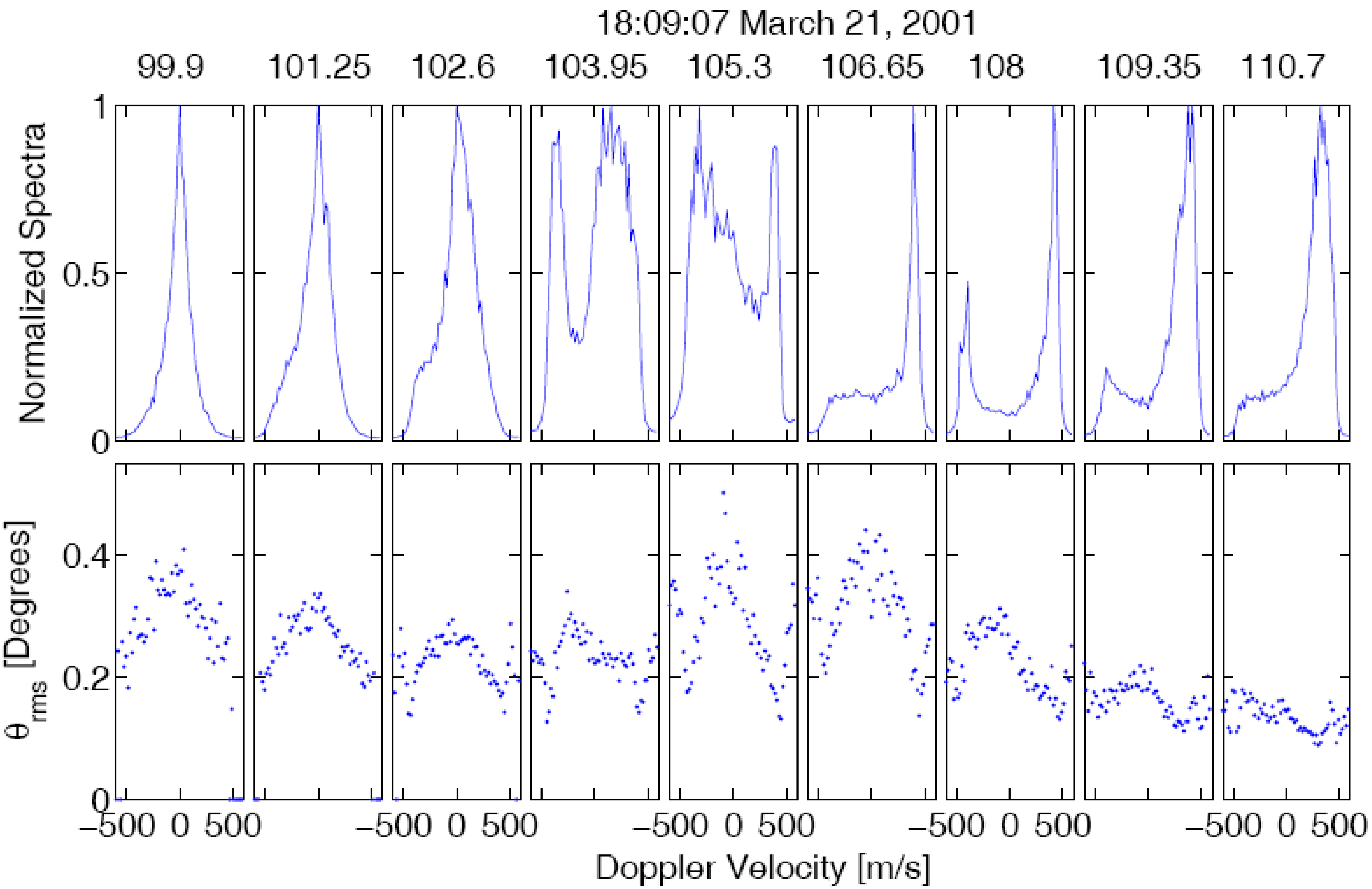
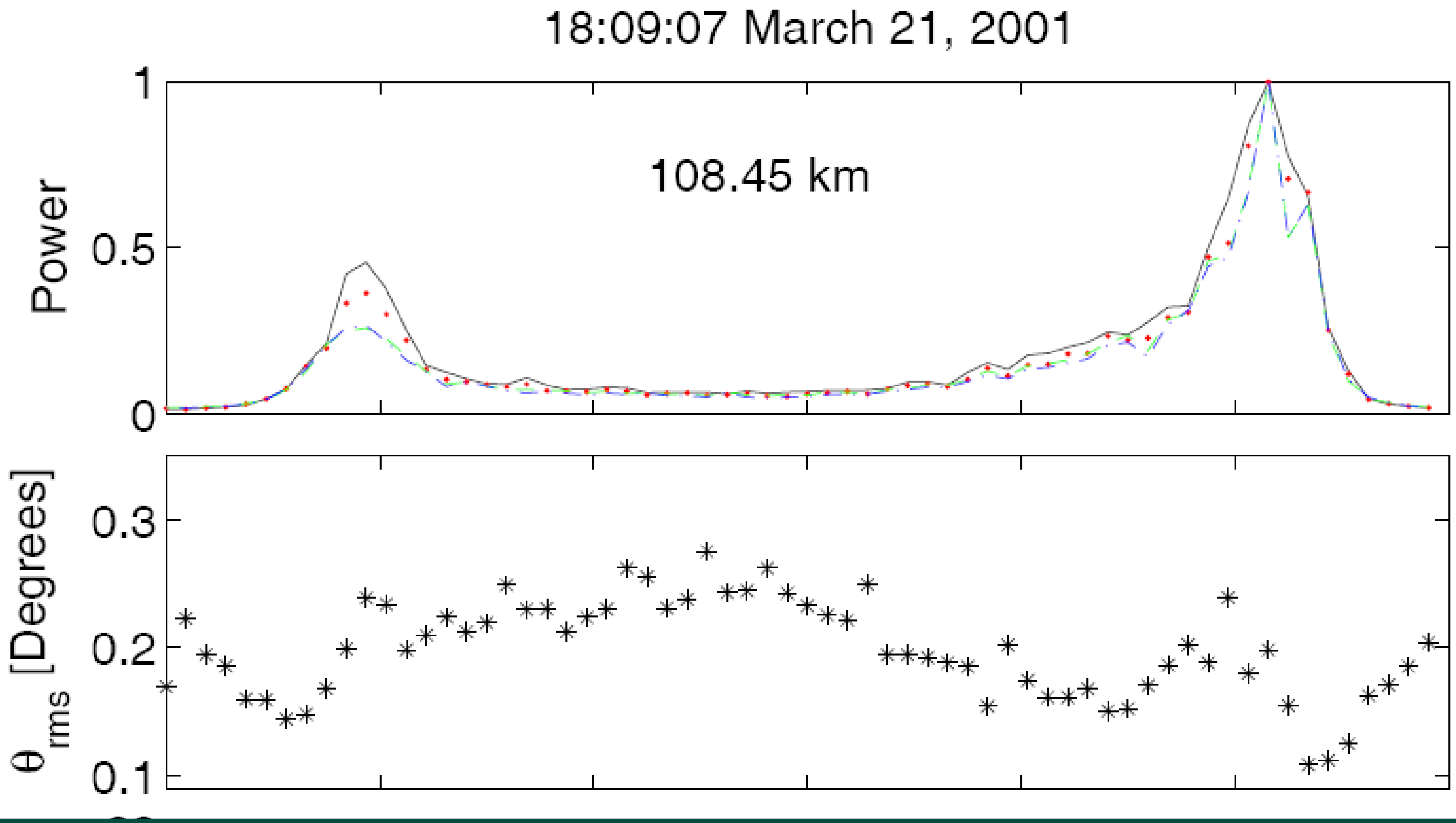


Figure 7. Power spectra and $\theta_{\rm rms}$ observations during a late afternoon period (18:09 Local Time) on March 21, 2001 with strong type 1 echoes extending to the highest altitudes



The aspect angle is smallest at speeds somewhat faster than those at which we have a spectral peak.

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Summary: for the relatively rare « vertical type 1 » spectra

- Sometimes see strong peaks near plus or minus Vthreshold. The stronger the echoes,
  - the closer to Vthreshold the peaks are (not shown here)
  - The stronger the Vthreshold peaks are
- Aspect angle observations by Lu et al show
  - Largest aspect angles near zero frequency
  - A minimum in aspect angle BEYOND the Vthreshold peaks.

Theoretical framework

1. Rotation
2. « Mode-coupling »
3. Aspect angle evolution
4. FB structures within GD structures

ROTATION: the polarisation field is due to the electron ExB drift, which is normal to the *total* field, not the ambient field.

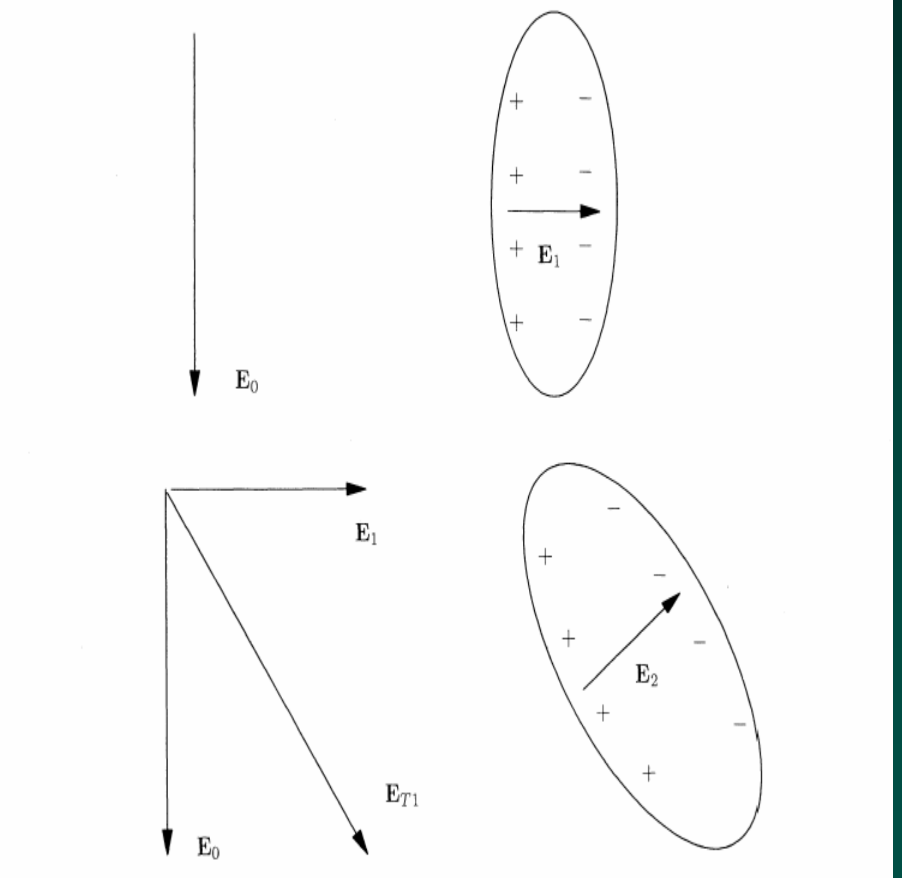

Figure 2. Sketch illustrating how the field created by electron polarization must rotate in response to the net electric field, which is the sum of the ambient field, $\mathbf{E}_0$, and the first-order field $\mathbf{E}_1$.

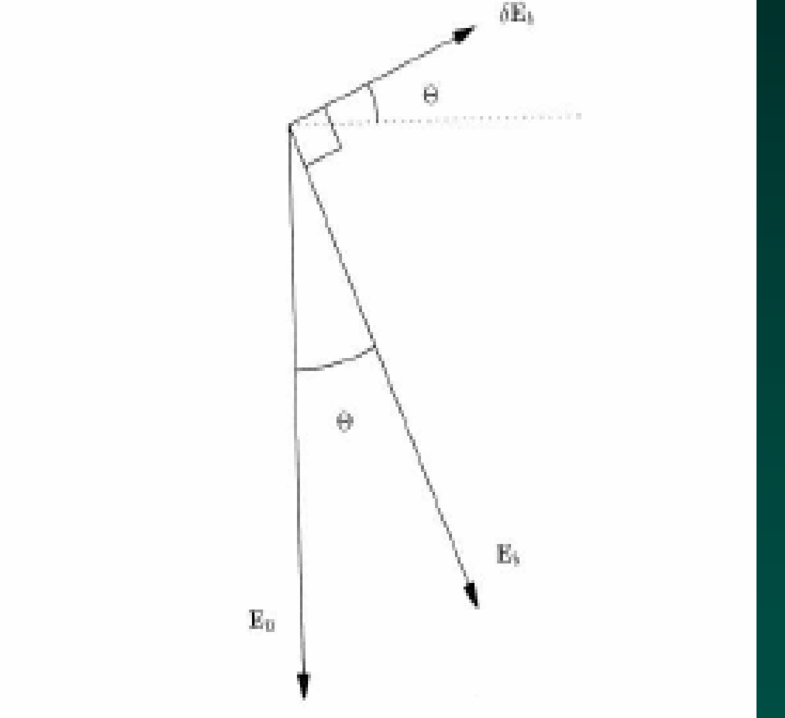

Figure 3. Geometry of electric field inside a blob.

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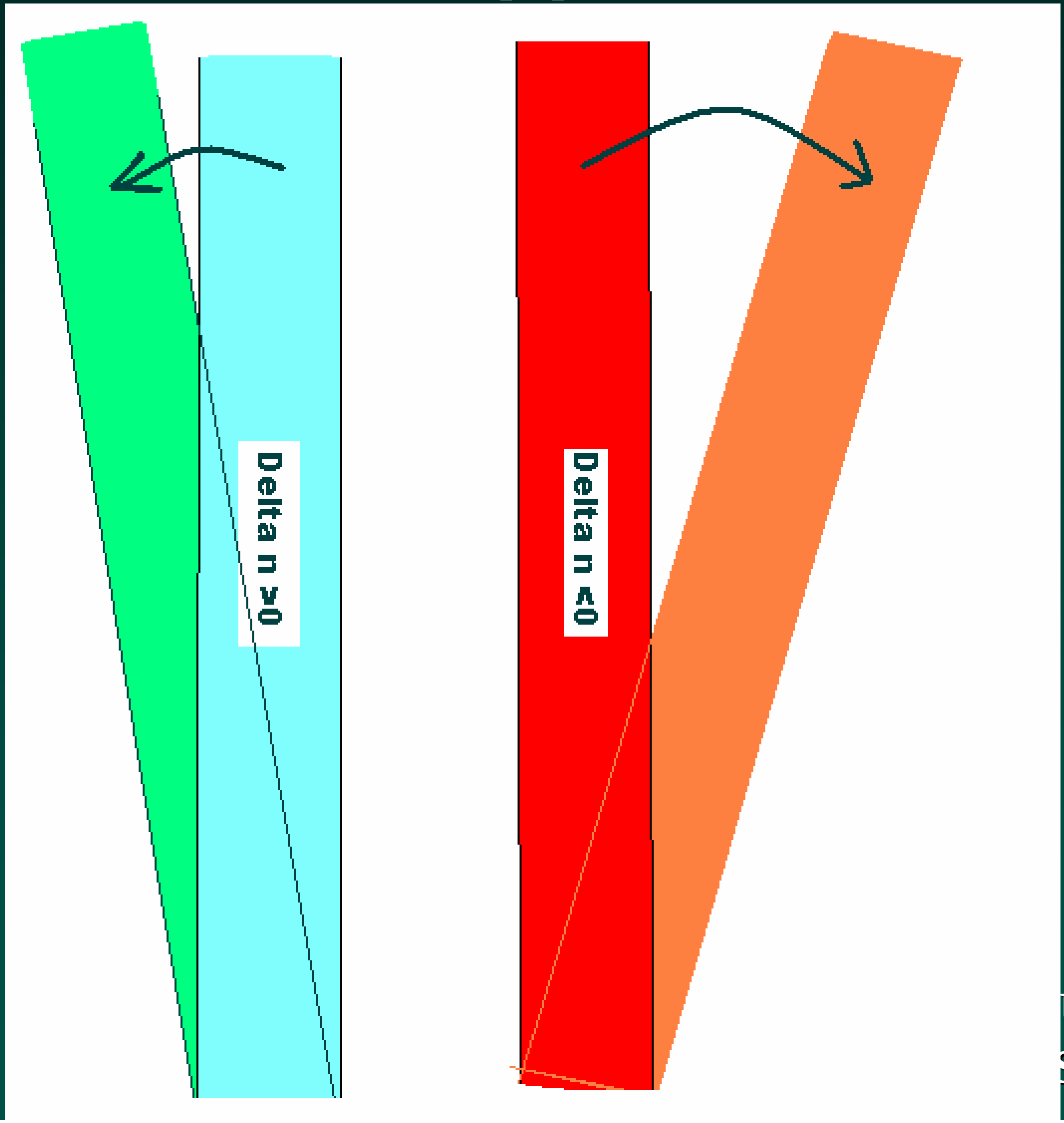
Fact: crests and troughs must rotate as the amplitude increases, but rotation is in opposite directions.



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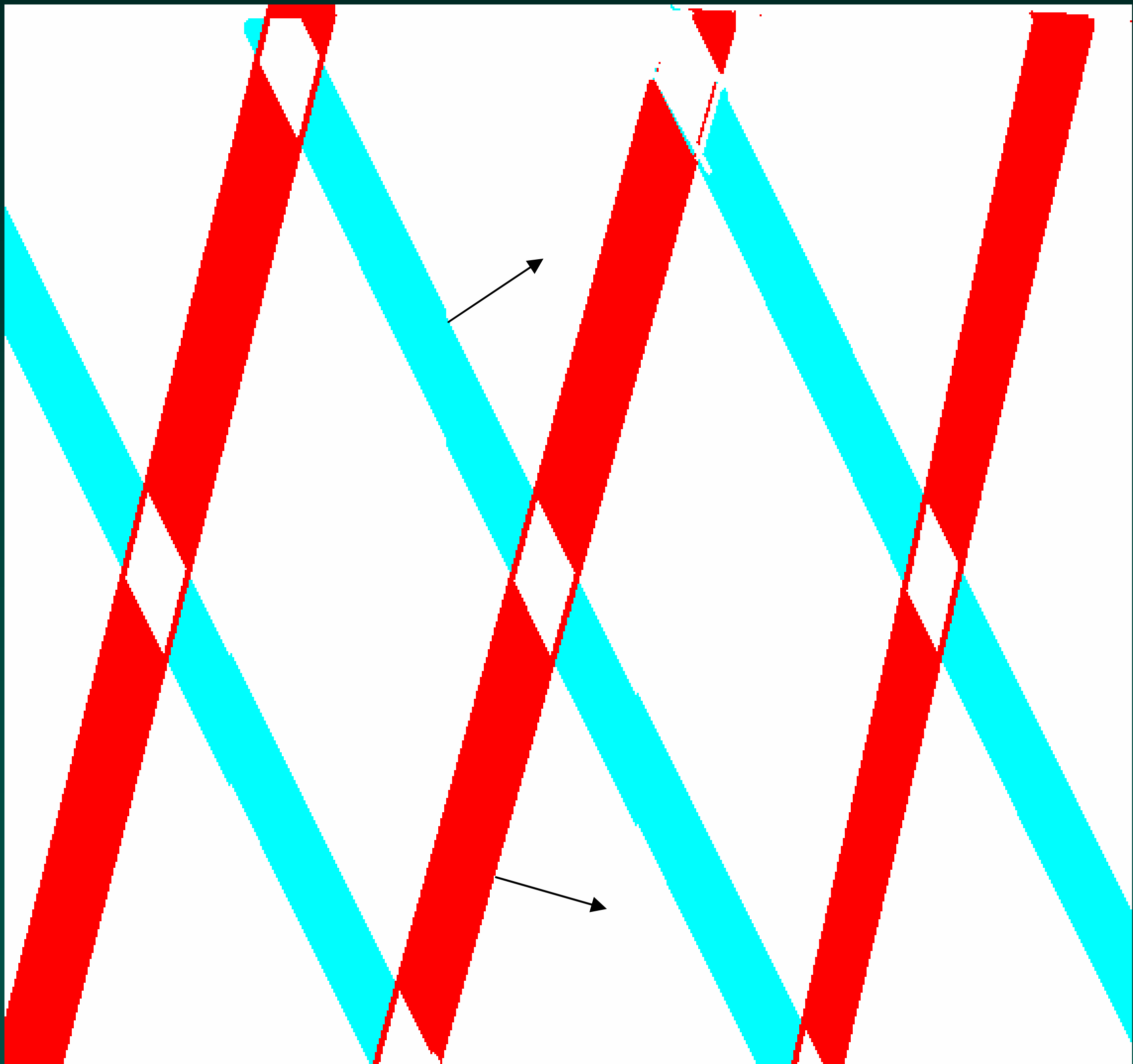
Is this an example of what we would call mode-coupling?



Now we get periodicities from much more than the original left to right direction.

Intermittency

- With amplitude modulation along the troughs and crests, the rotation will induce individual elongated structures with edges at their ends
- The larger enhancements grow faster than the rest. Ditto for deepest depletions.
- Conclusion: the largest structures dominate. *Individual structures control the evolution of turbulence.*

1) First crack at dealing with the intermittent structures

1. Use nonlinear relation between E and perturbed densities to determine
   1. The <u>direction</u> of the elongated structures
   2. The <u>phase speed</u> of the structures
2. For growth rates and aspect angle effects, use usual linear-like dispersion relation
3. Assume that all directions produce roughly same scattering power

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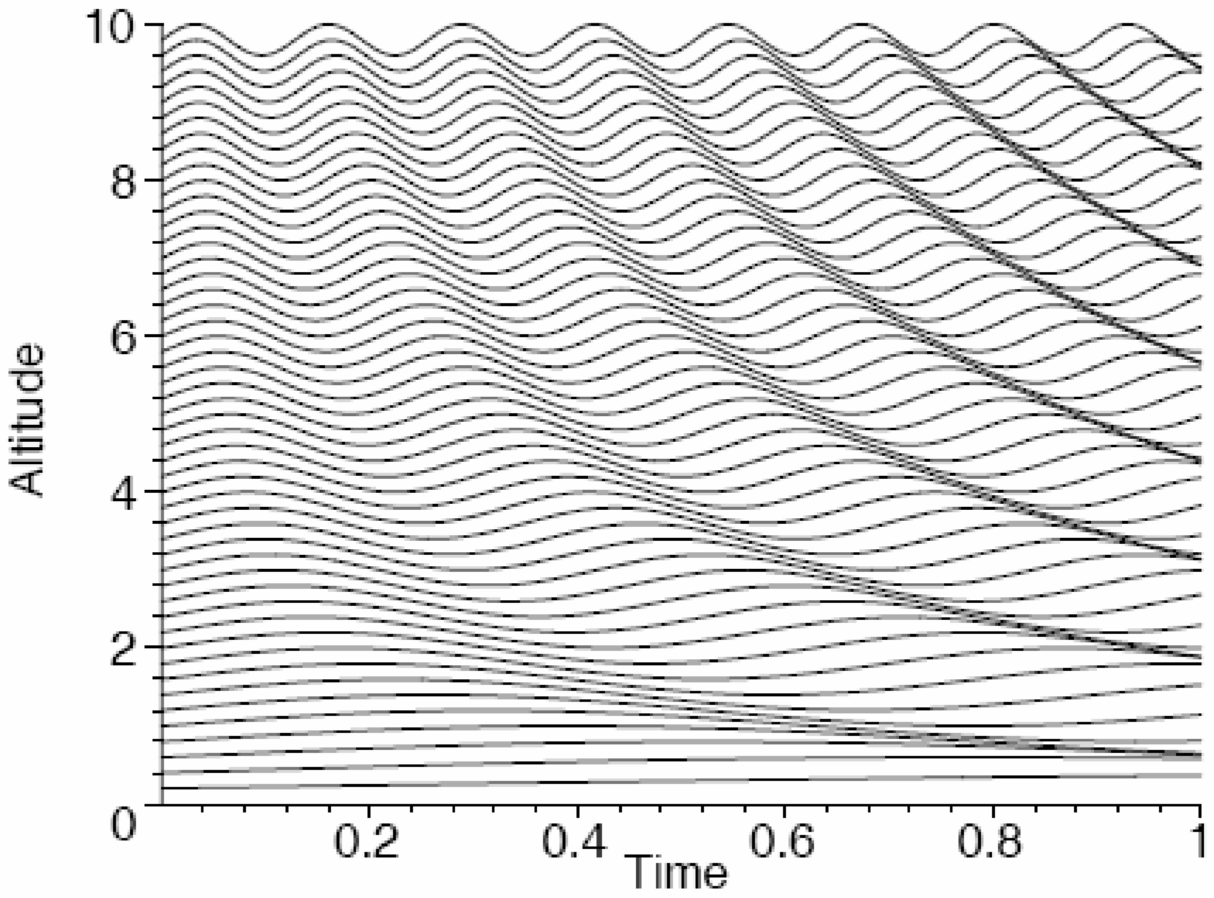

Fig. 1. Phase changes with time and space for a frequency that increases with altitude. All altitudes are assumed to be in phase initially.

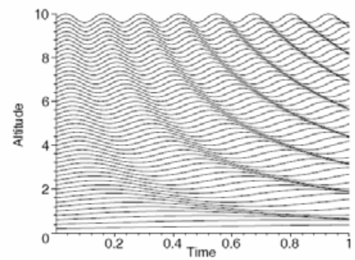
Fig. 1. Phase changes with time and space for a frequency that increases with altitude. All altitudes are assumed to be in phase initially.

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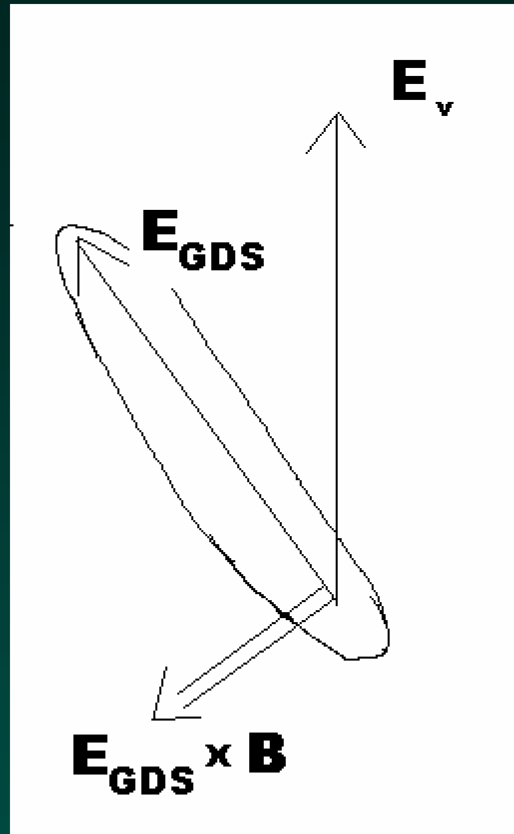
How rotation and aspect angle growth control the evolution of FB irregularities

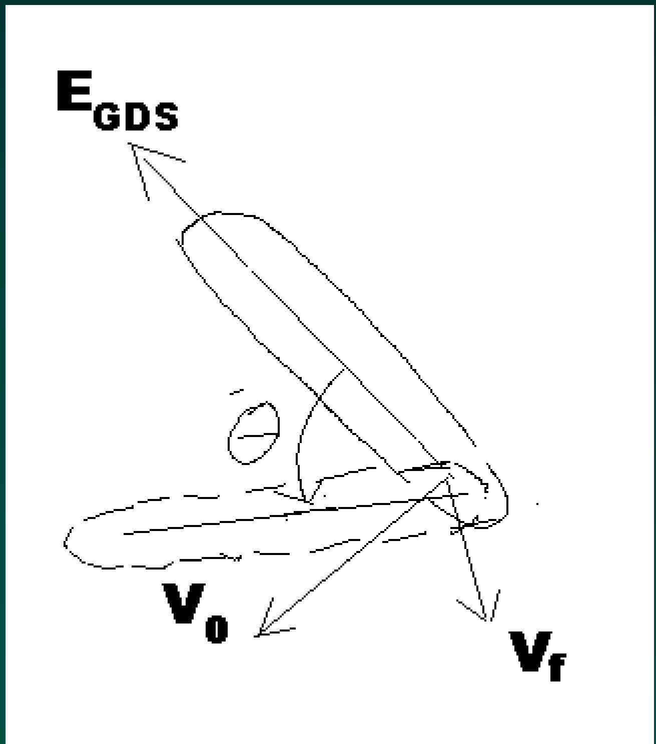
1. For a given density fluctuation level there can be only one perturbed electric field vector. Therefore, for a given density level (amplitude)
   - Direction of the K-vector is known
   - Phase speed is known
2. Aspect angle changes everything
   – Without it the large amplitude structures would stop evolving: delta function spectra
   – With an increasing angle, the structures rotate back to the original direction, decay, and slow back down.

3) The role played by gradient-drift waves

- GD crests and troughs must also rotate (same physics as FB waves)
- As they rotate, the ***total*** E field inside GD structures becomes more horizontal, though it also becomes smaller in magnitude.
- FB waves are born inside the fields of GD structures.
  – The more horizontal the GD field is, the easier it is to obtain vertical FB waves,
  – However the triggering fields weaken as they become more horizontal.

The field that excites FB structures is the vector sum of the vertical field plus that of the GDS (panel on the right)





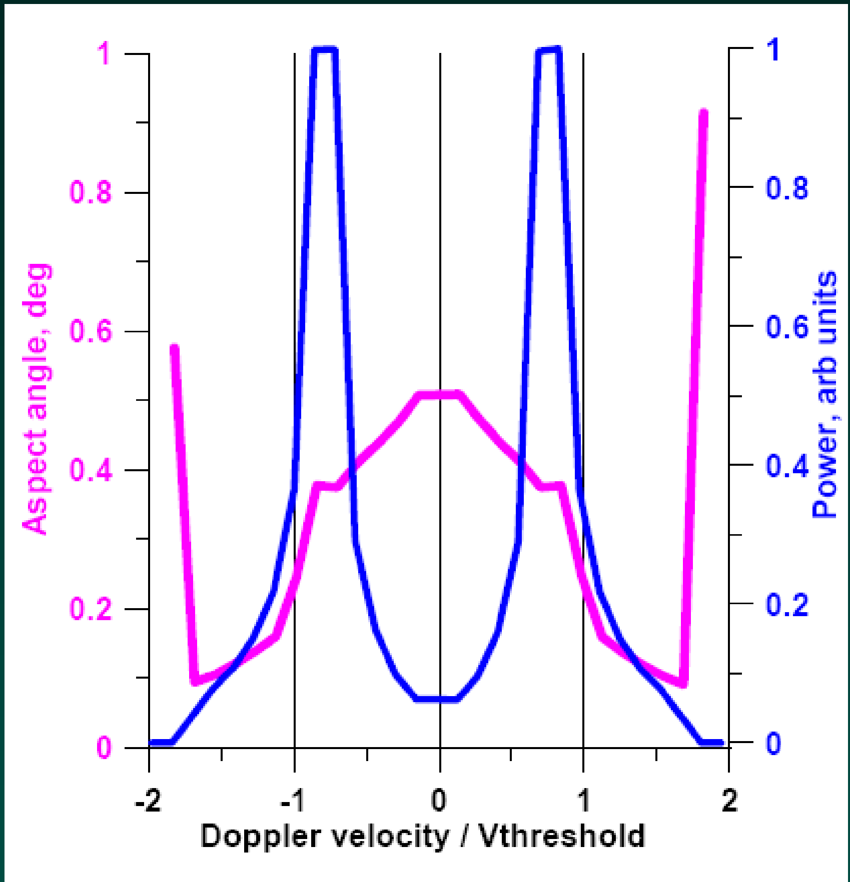
FBS are initially produced in the **E**$_{GDS}$ direction, but they rotate while growing and slowing down (left panel)

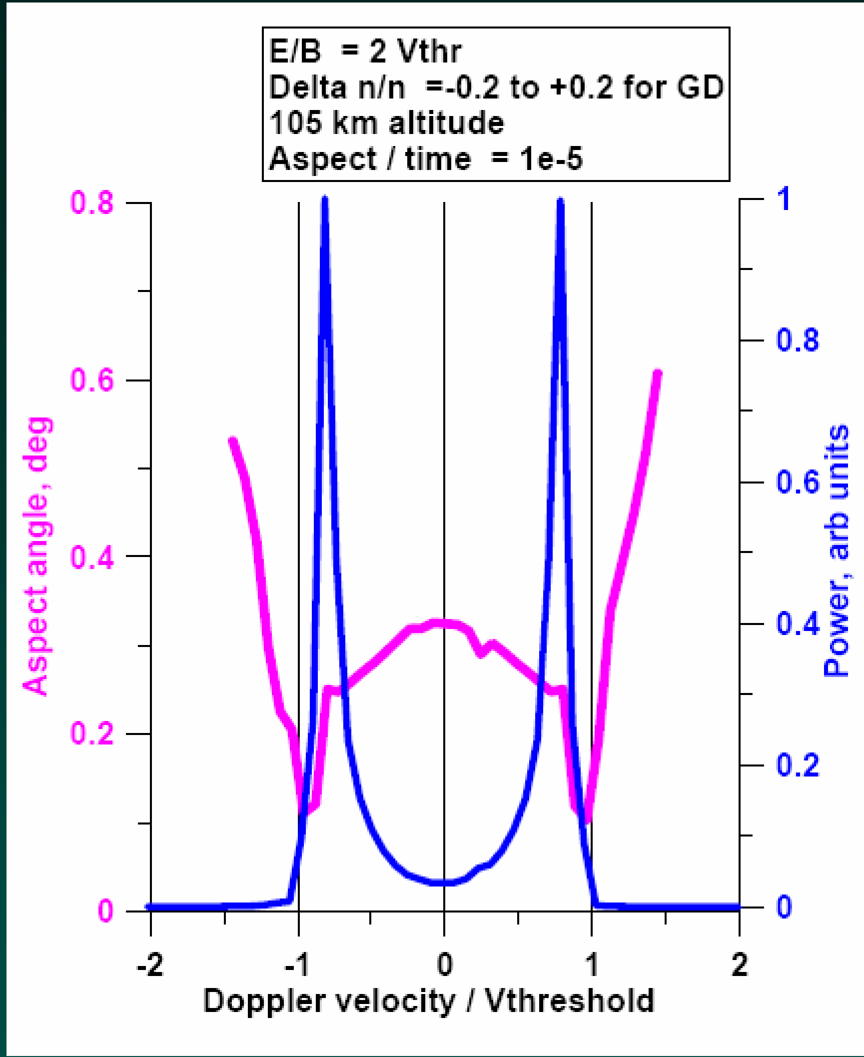
Algorithm

- Input ambient E field and threshold speed
- Sweep GD amplitudes from some minimum to some maximum (symmetry is the usual case)
- For each GD amplitude start with small value of FB amplitude and zero aspect angle
  - Find orientation and phase speed along the vertical
  - Store power, vertical phase speed, aspect angle
  - Compute the growth/decay rate and change the density.
  - Change aspect angle by a fixed amount.
  - Repeat until amplitude is small again

Results

(a) Symmetric GD situations





Same as on right but for E/B = 3.5 Vthr

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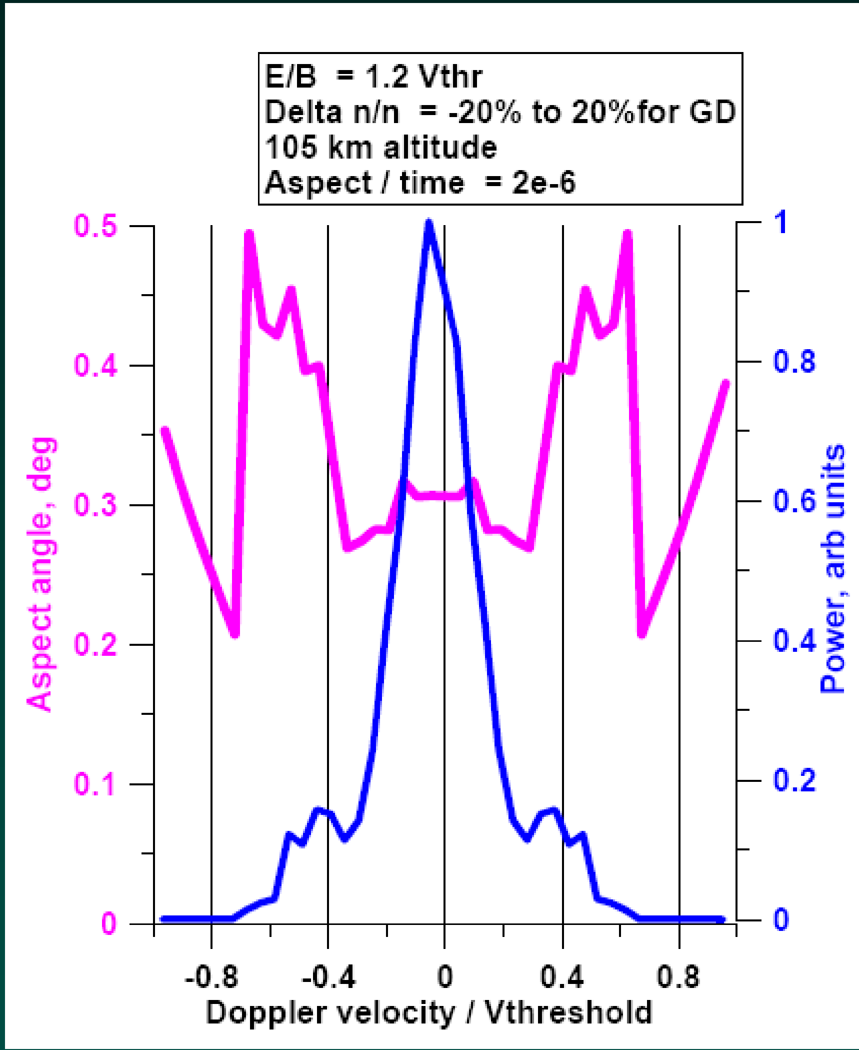

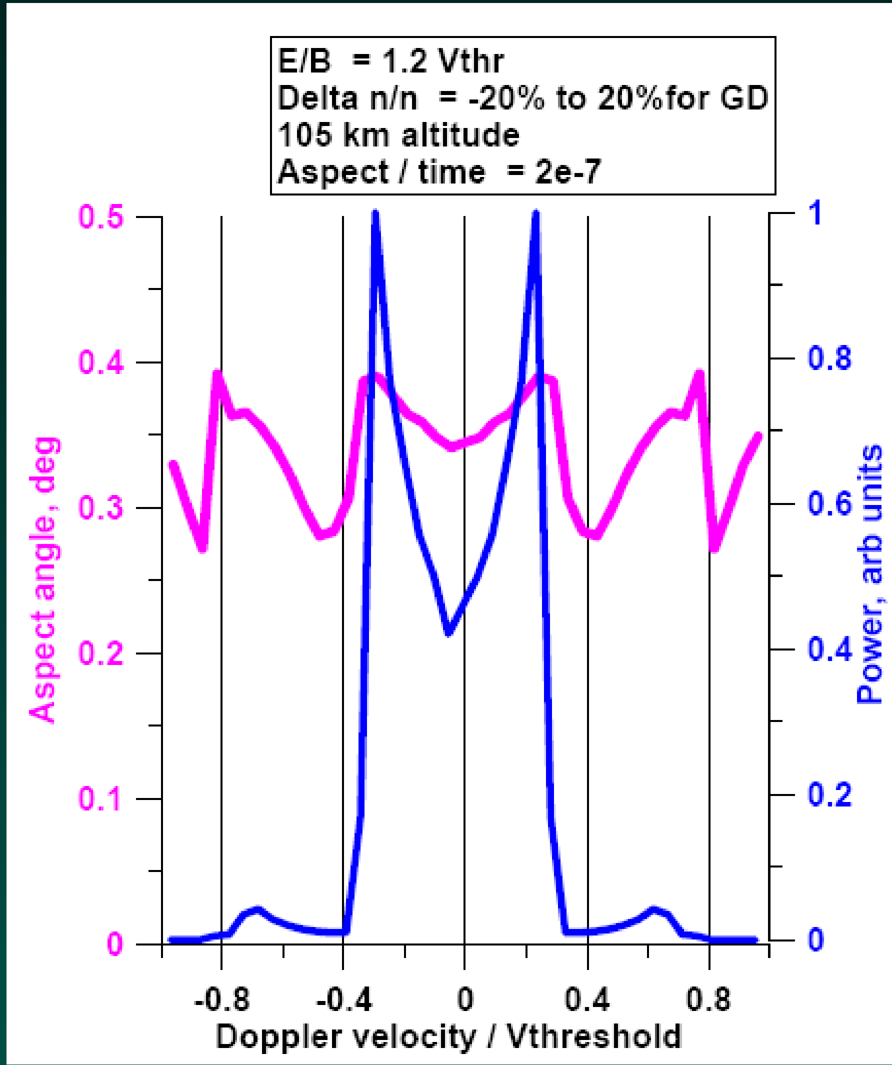

Faster aspect angle growth means a stronger central peak for weak cases.

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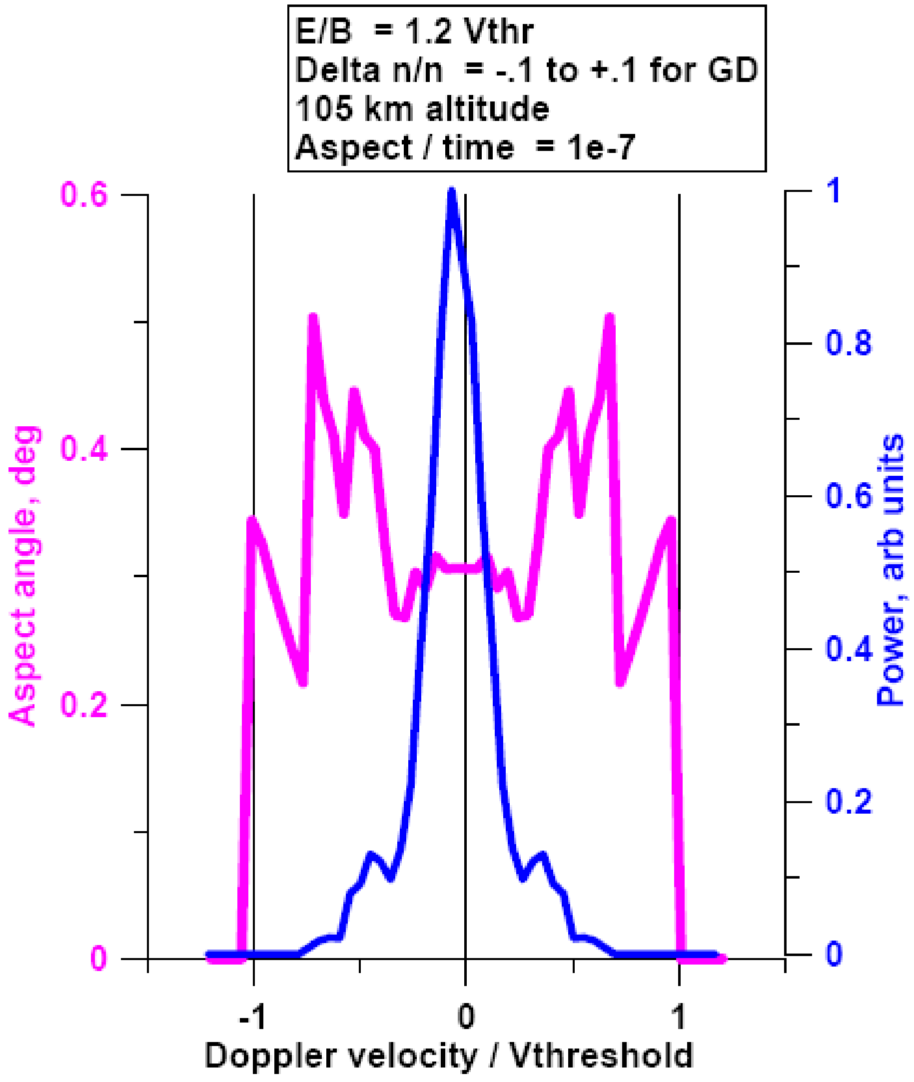
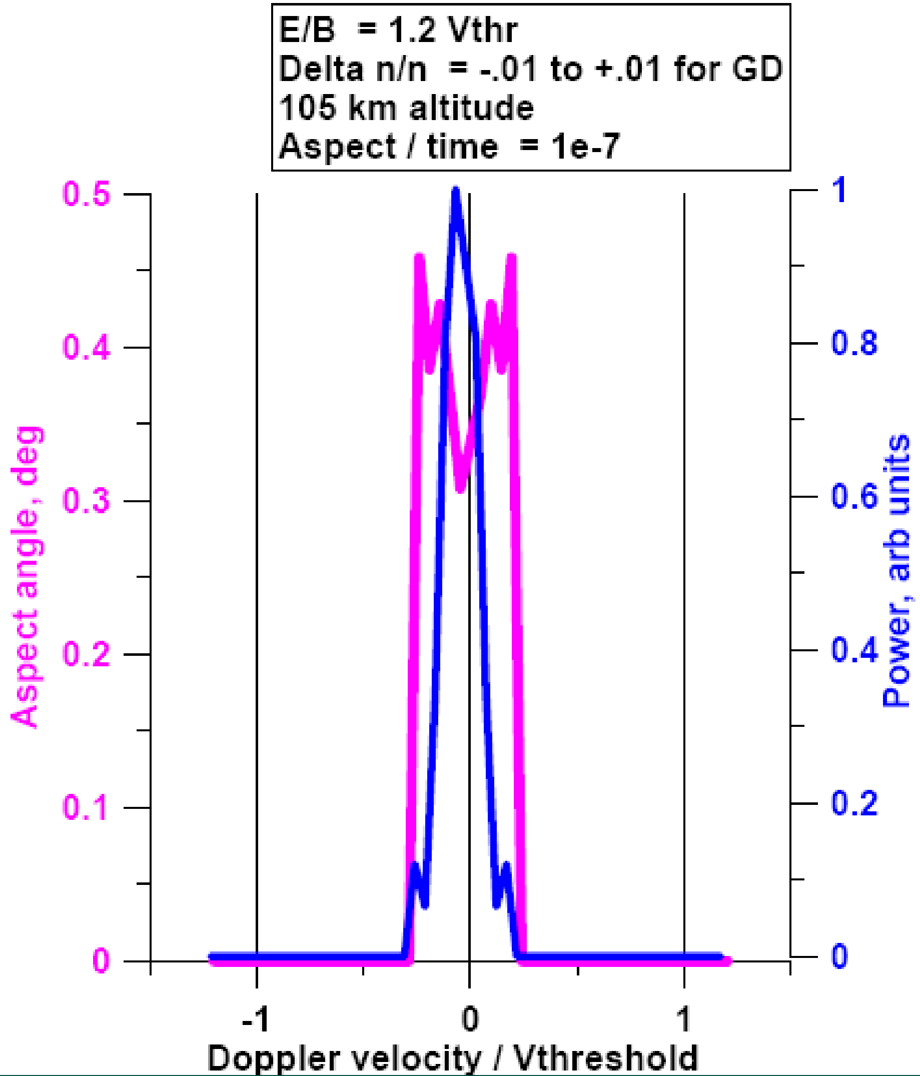
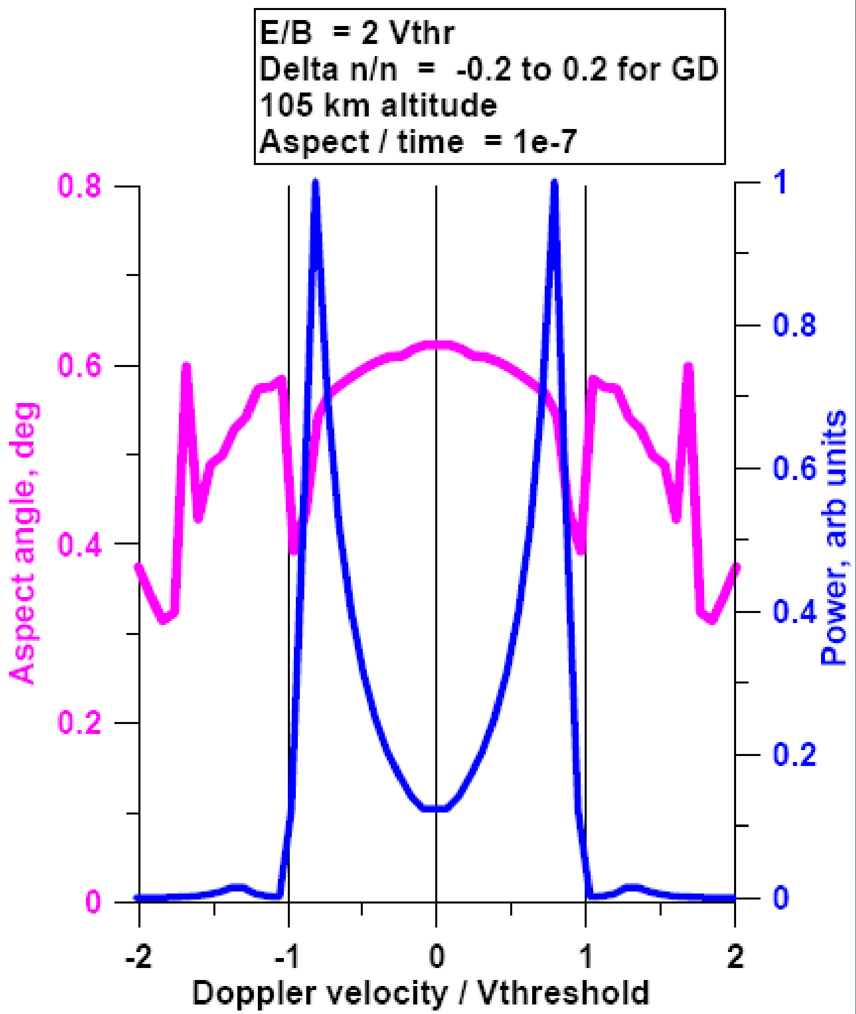
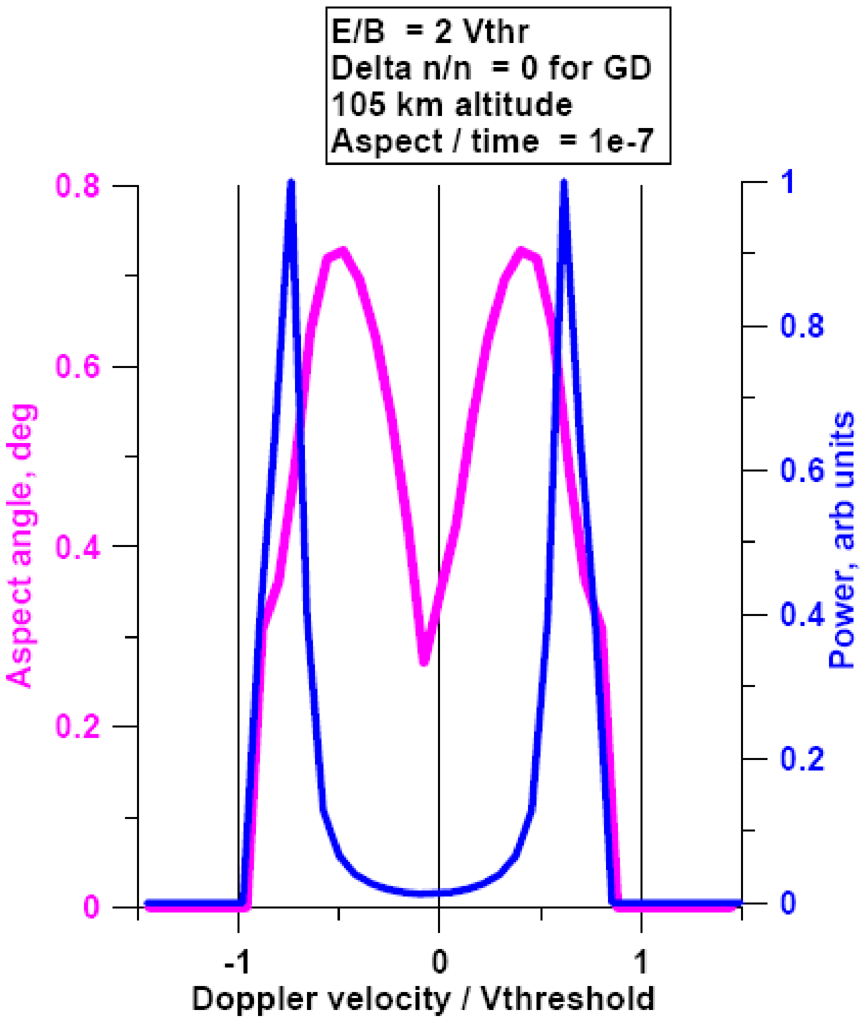
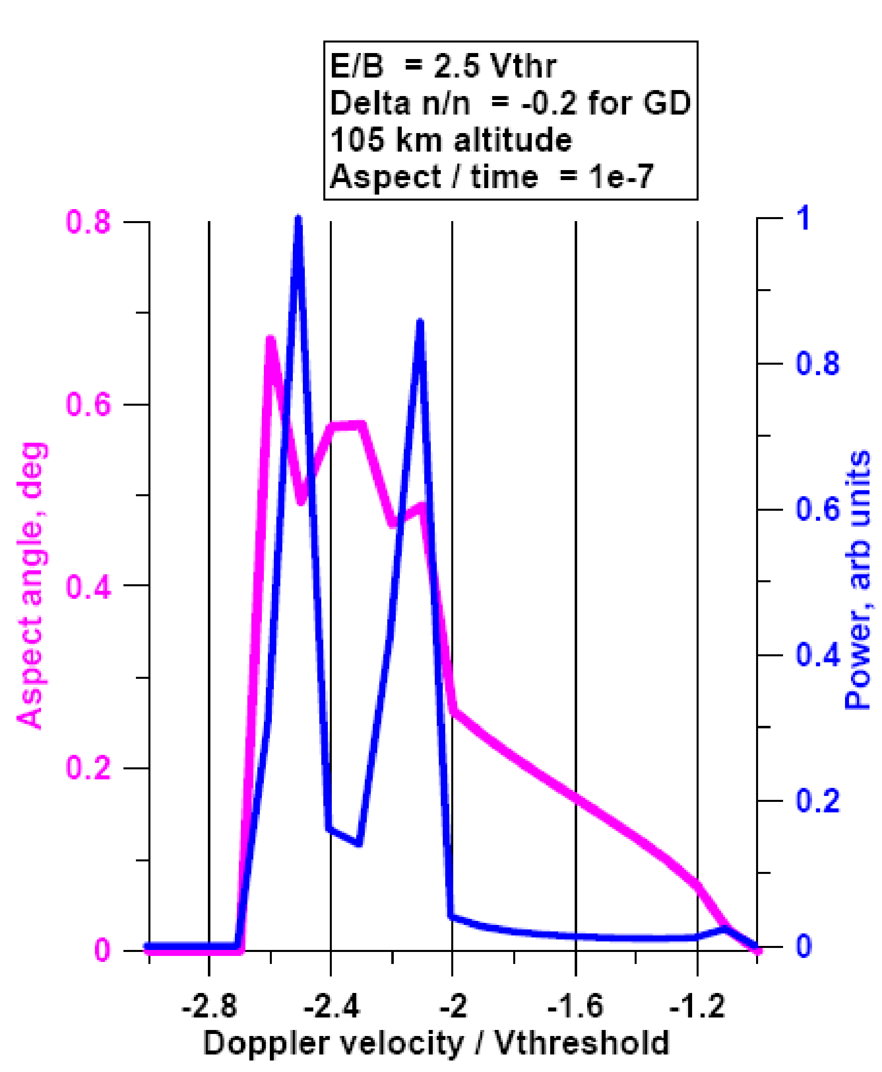

E/B = 1.2 Vthr
Delta n/n = -.1 to +.1 for GD
105 km altitude
Aspect / time = 1e-7
Aspect angle, deg
Power, arb units
0.6
0.4
0.2
0
1
0.8
0.6
0.4
0.2
0
-1
0
1
Doppler velocity / Vthreshold

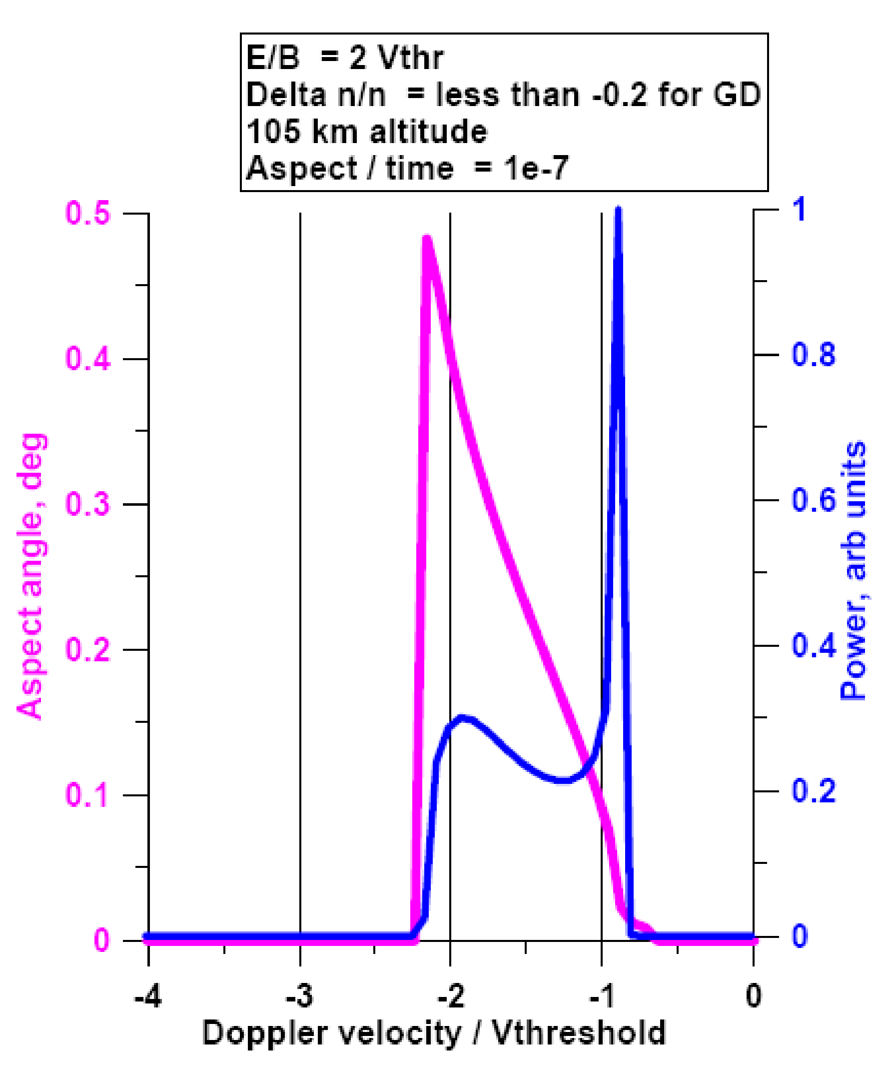

E/B = 1.2 Vthr
Delta n/n = -.01 to +.01 for GD
105 km altitude
Aspect / time = 1e-7
Aspect angle, deg
Power, arb units
0.5
0.4
0.3
0.2
0.1
0
1
0.8
0.6
0.4
0.2
0
-1
0
1
Doppler velocity / Vthreshold


E/B = 2 Vthr
Delta n/n = -0.2 to 0.2 for GD
105 km altitude
Aspect / time = 1e-7
Aspect angle, deg
Power, arb units
Doppler velocity / Vthreshold


E/B = 2 Vthr
Delta n/n = 0 for GD
105 km altitude
Aspect / time = 1e-7
Aspect angle, deg
Power, arb units
Doppler velocity / Vthreshold

(b) Asymmetric GD situations





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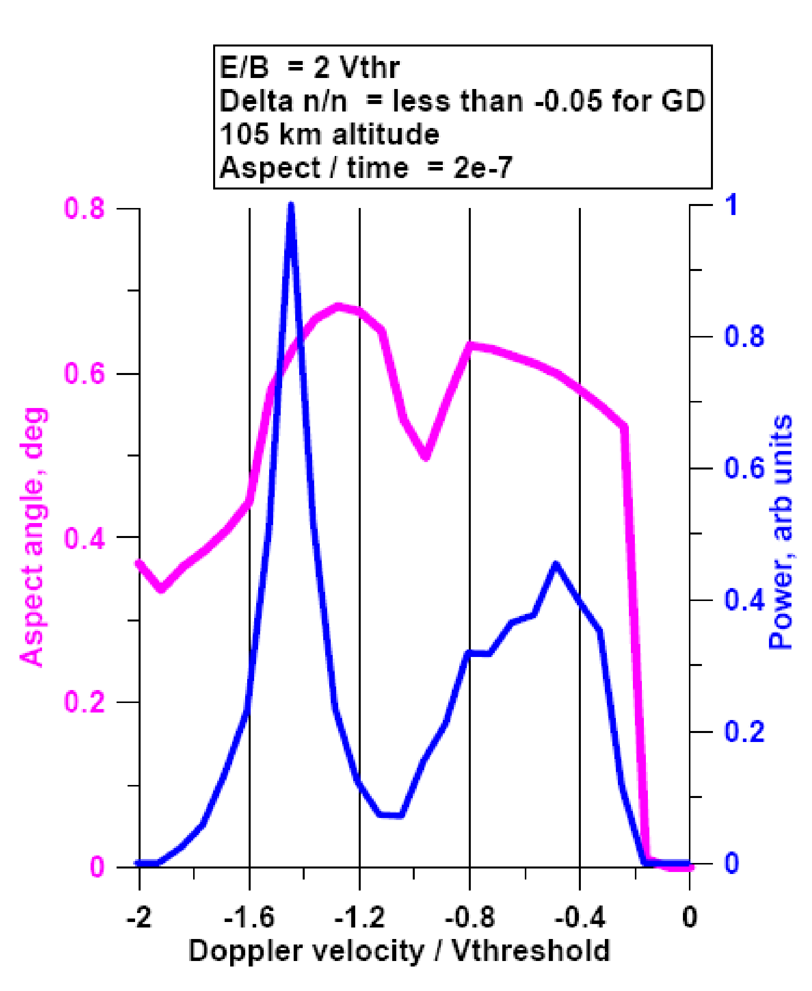

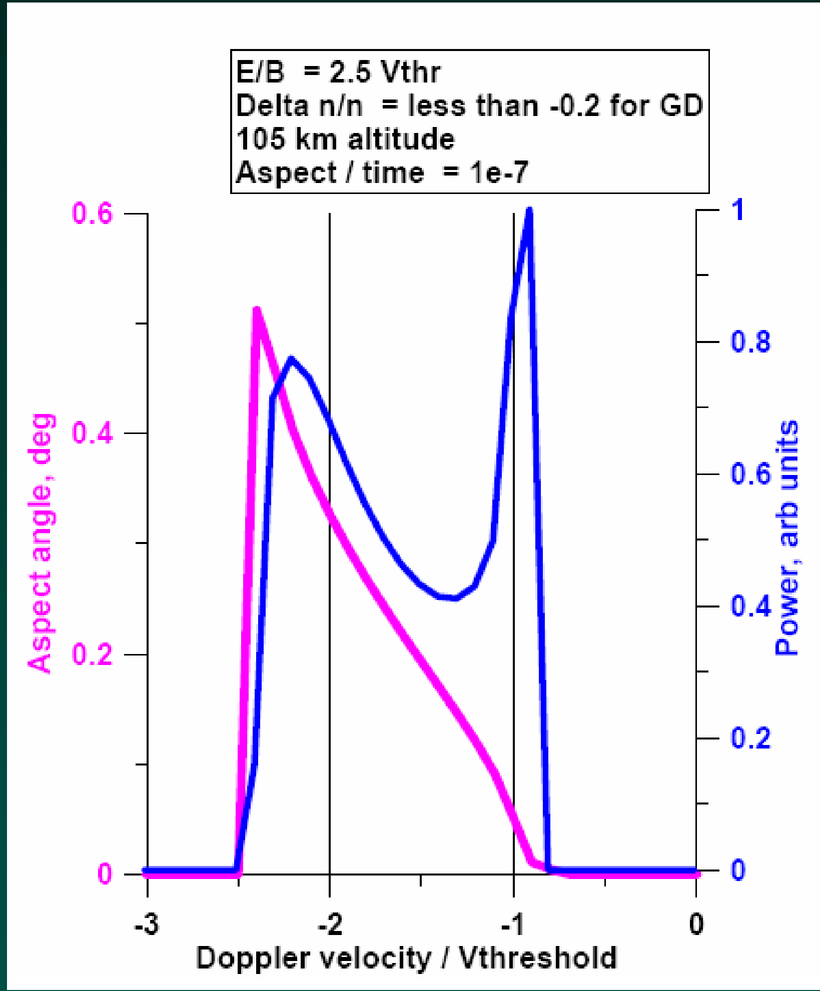

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Summary (1)

- Controlling parameters are
  - E/B / Vthr
  - Rate at which the parallel wave vector is changing
  - Amplitude (and phase) of GD waves

Summary (2)

- For symmetric spectra with strong peaks at plus and minus Vthr
  - Require E/B / Vthr ratio of order 2 or more
  - Get a peak in aspect angle at zero frequency only if
    - GD waves have large enough amplitude
    - Aspect angle growth is large enough

Summary (3)

- Spectra with central peaks
  - we require a small E/B / Vthr ratio
  - and/or a relatively fast aspect angle growth. (A relatively slow aspect angle growth produces a double peak).
  - The spectrum broadens if we increase the GD amplitudes

Summary (4)

- Asymmetric spectra
  - Are the result of asymmetric GD structures
  - If GD is limited to strong positive or strong negative values they are
    - Weak
    - Multi-peaked
    - Not necessarily related to Vthre
    - Unpredictable in shape

Conclusions: interpreting vertical « Type I » waves

- The aspect angle signature at strong E fields is explained by the slightly nonlocal character of the instability in the EEJ.
- Doubly peaked spectra are not a GD signature. However, the peak in aspect angle at zero frequency is due to presence of GD waves.
- It may well be that GD waves still exist at the altitudes for which the spectrum is narrower
- The narrowing of the spectrum as the altitude increases is due to a decrease in the vertical E field. Decrease in GD amplitude makes the spectrum narrower still.
- For strong E fields the spectral peaks are only approximately at the threshold speed. In general, they are at smaller speeds than threshold.
- For high time resolution and strong E/B, multiple peaks beyond the threshold speed can be found. However, the power is then weak.

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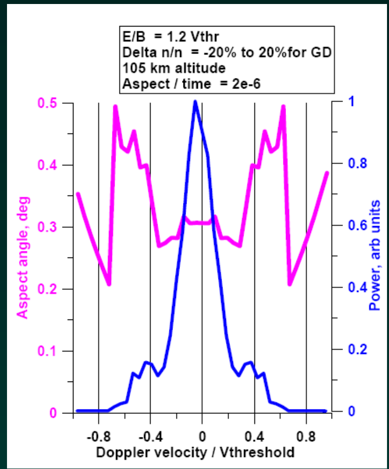
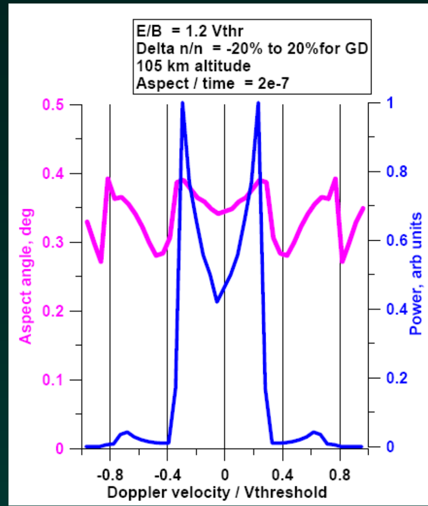
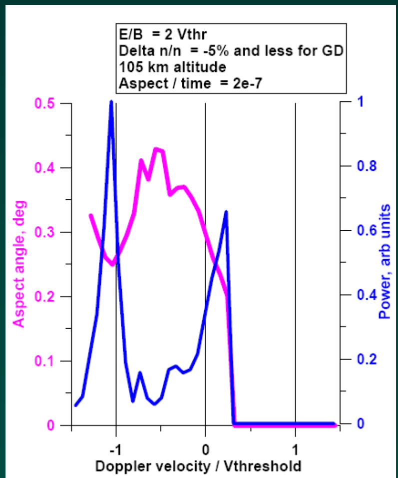
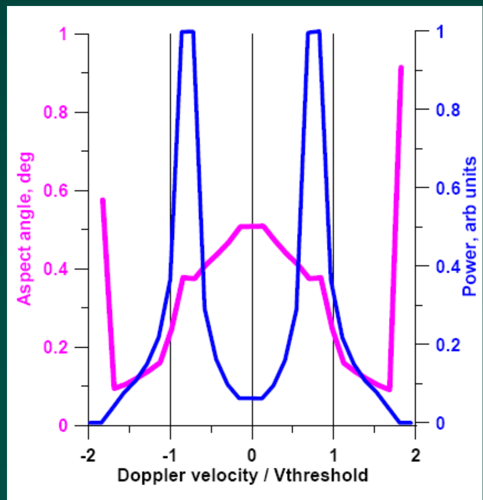
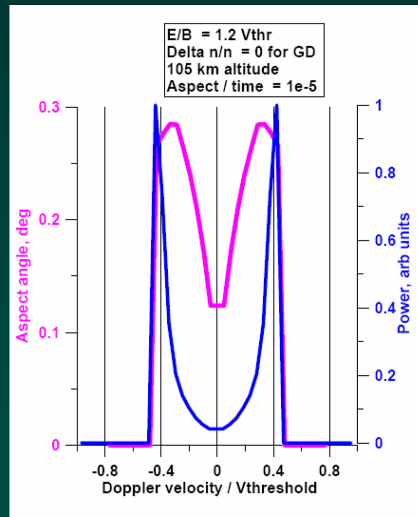






The End





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