Observations of E-region scatter with the Iceland SuperDARN radars

Mark Lester and Steve Milan
University of Leicester

University of Leicester

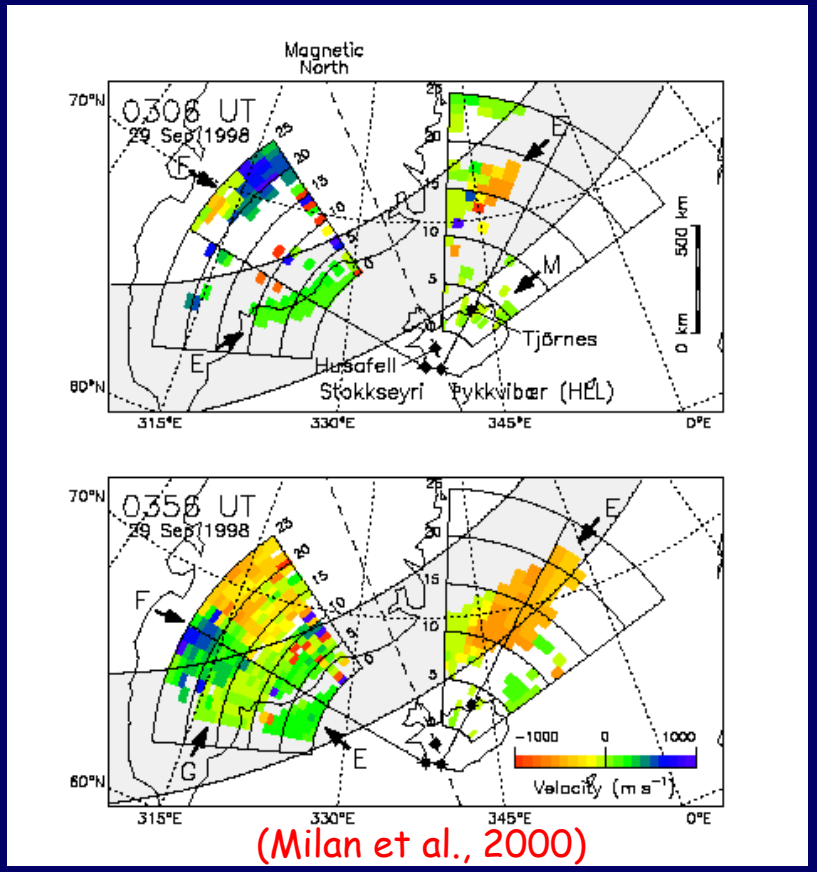
Introduction and background

- An overview of work undertaken with the Iceland radars on E-region scatter
- An interest of Jean-Paul Villain who contributed to the work that has been done with the Iceland radars
- Over 10 papers published on this topic with data from the Iceland radars
- Many have involved optical observations by NIPR (see also Hosokawa et al. presentation on Tuesday at 11.10)

University of Leicester

Example Observations

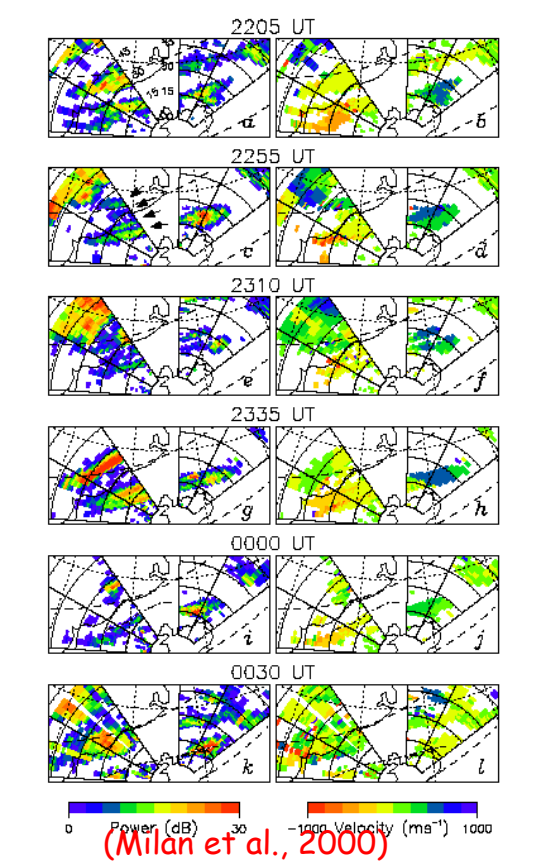
- An early paper (Milan et al. 2000) presented results from both radars and an auroral imager at Husafell.
- Introduction of a new mode – Myopic – to study E-region scatter.
- This was 75 x 15 km range gates
- Example demonstrates the Iceland radars are well suited for E-region studies
- Here E-region, F-region, Ground and Meteor scatter are observed in the radars



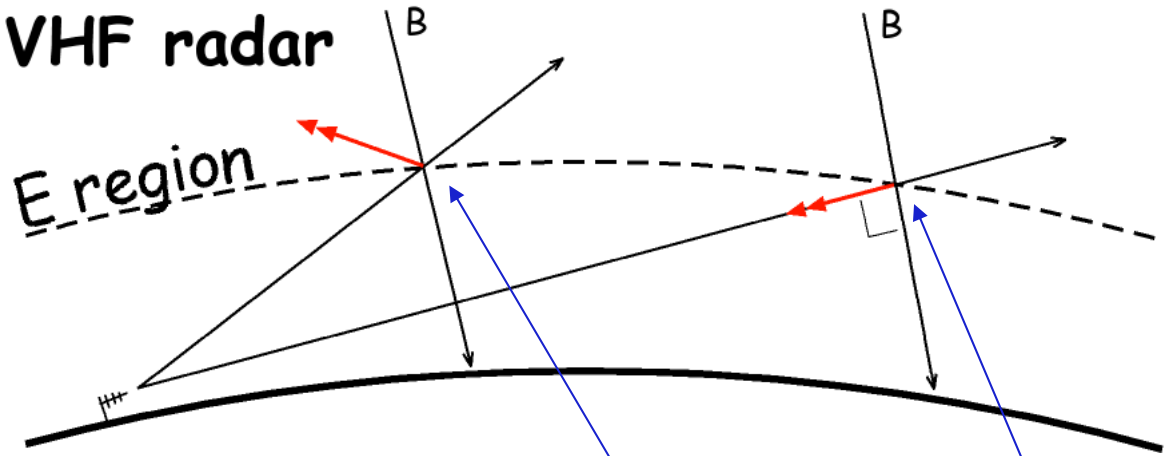
(Milan et al., 2000)

Example of motion of scatter

- Examples of both backscatter power (left) and Doppler velocity (right)
- Note the location of the statistical average auroral oval
- Note also the location of an equatorward moving auroral arc observed by Husafell all sky camera in the bottom 4 panels
- E-region scatter extends over some 3 hours of local time

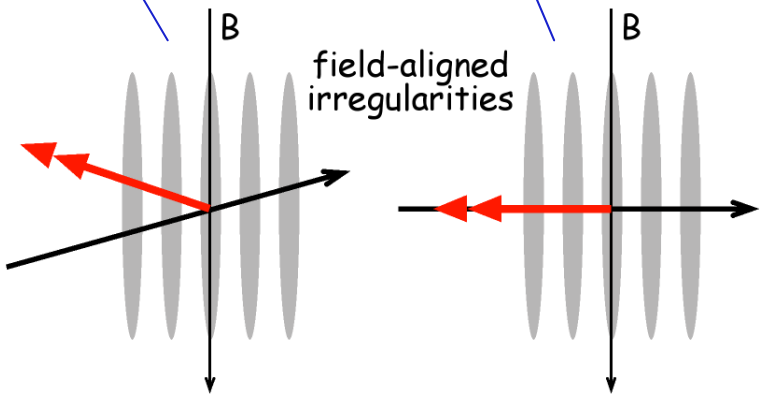


(Milan et al., 2000)

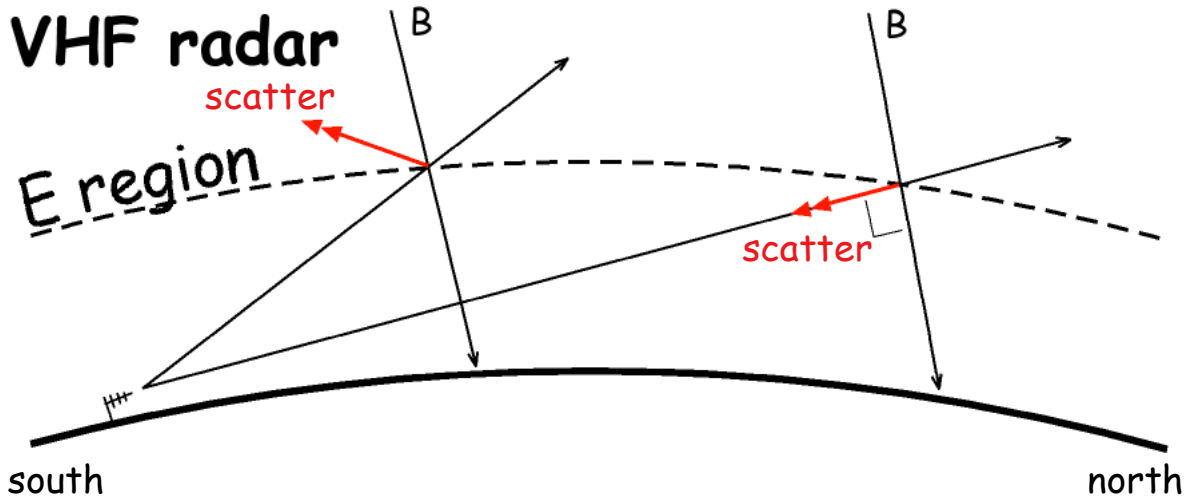


- Coherent scatter (**Bragg** scatter) from field-aligned irregularities

- Most plasma instability theories predict that irregularities have low aspect angles ($\alpha < 1°$)

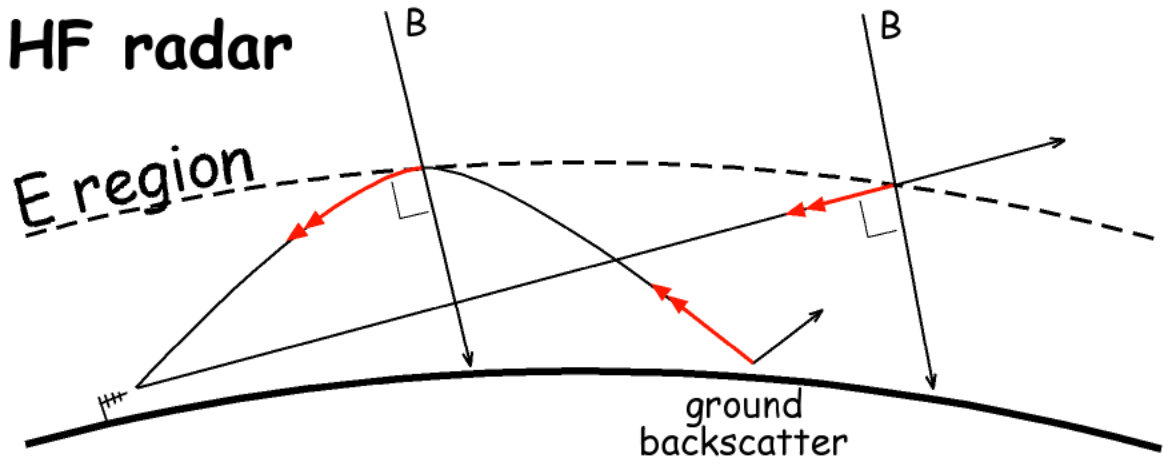


University of Leicester

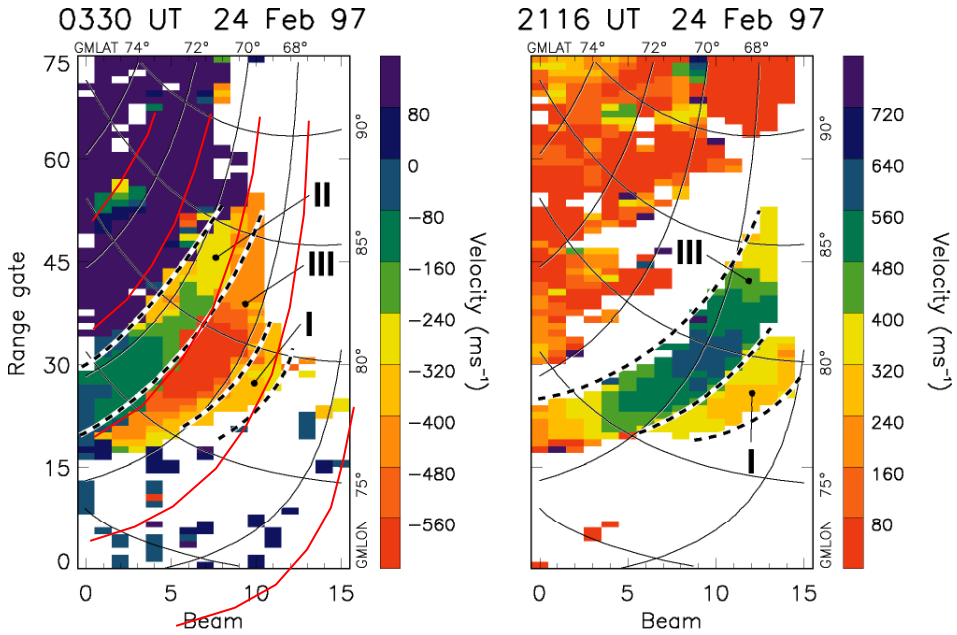


- Radar frequency exceeds E region plasma frequency ($f_p^2 = \frac{N_e e^2}{4\pi^2 \varepsilon_0 m_e}$)
- Very little refraction of radar signals
- Orthogonality with magnetic field is governed by line-of-sight geometry
  - *only in the E region*

University of Leicester



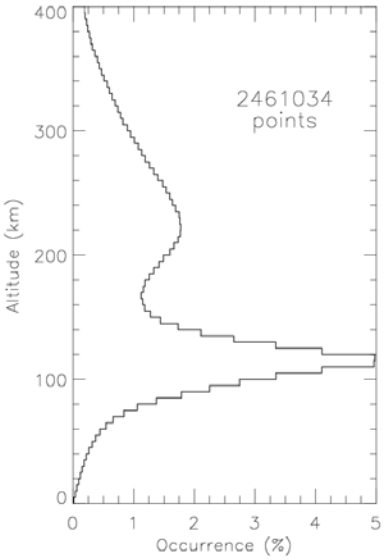
- Radar frequency comparable to E region plasma frequency
- Significant refraction and possibly reflection, especially where electron density is enhanced
- Orthogonality can be achieved in E and F regions, and geometry is not so limited

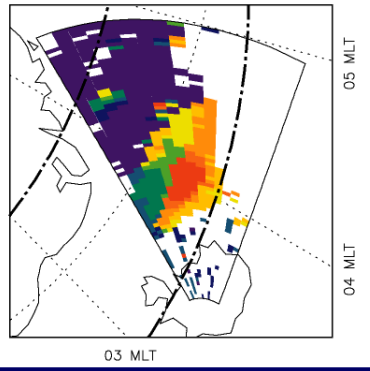


Myopic

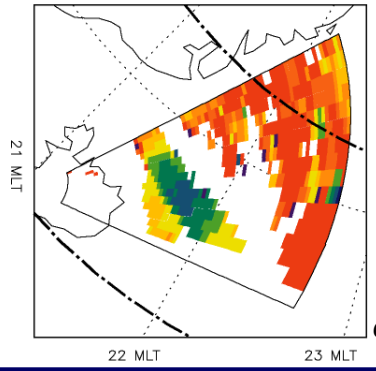
E region experiment

180 km range to first gate,
15 km range gates
3 s dwell, no synchronization
10 MHz transmissions





Westward electrojet



Eastward electrojet

University of Leicester

Stereo Myopic

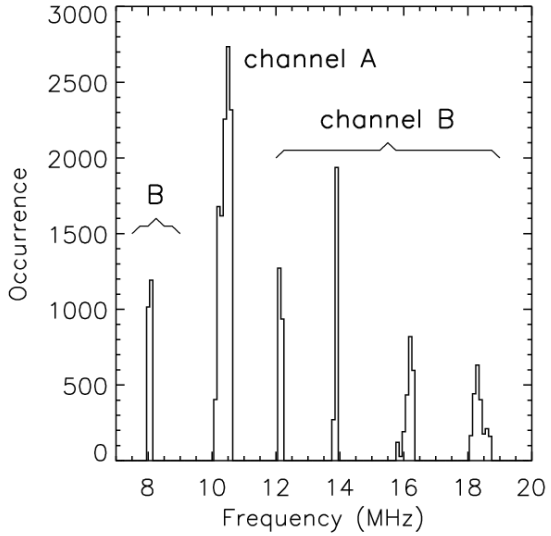
E region experiment

- **Myopic:**

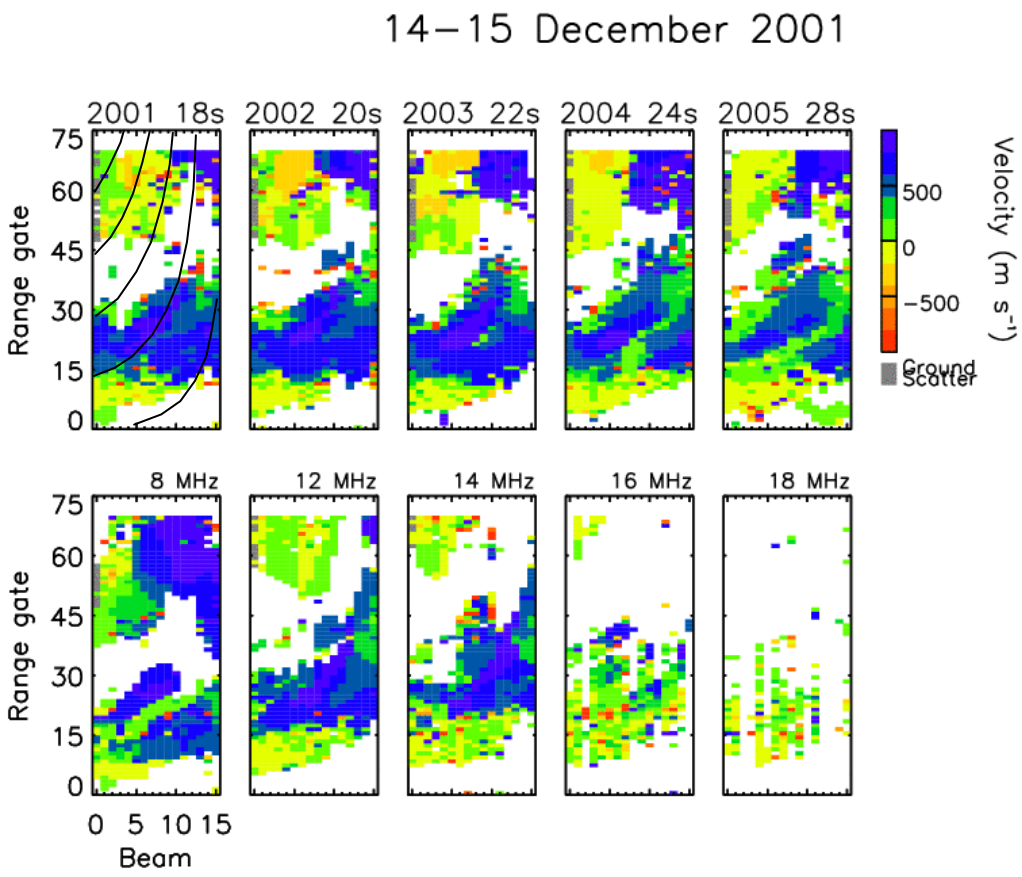
180 km range to first gate,
15 km range gates
3 s dwell, no synchronization
10 MHz transmissions

- **Stereo Myopic:**

channel A - 10 MHz
channel B - 8, 12, 14, 16, 18 MHz
one scan ≈ 1 min
one sweep ≈ 5 mins



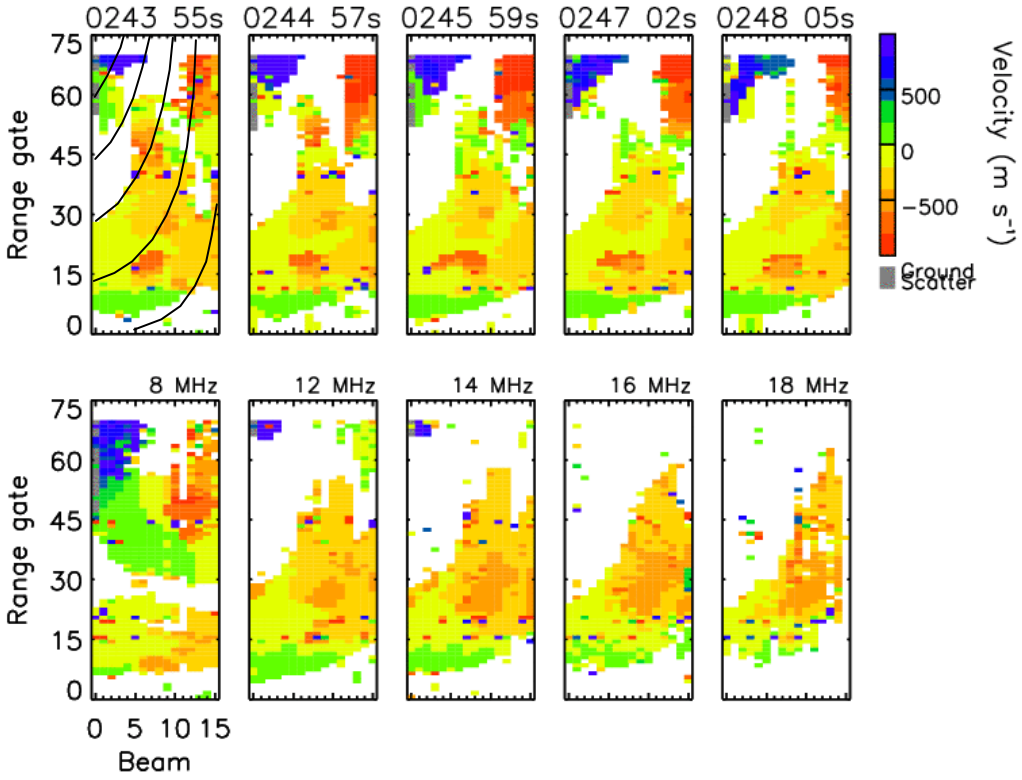
HAIR — high-aspect angle irregularity region



- Very near-range scatter has Doppler shifts opposite to the sense expected
- The demarcation between normal and reverse echoes is constant across beams
- The demarcation range depends on frequency

University of Leicester

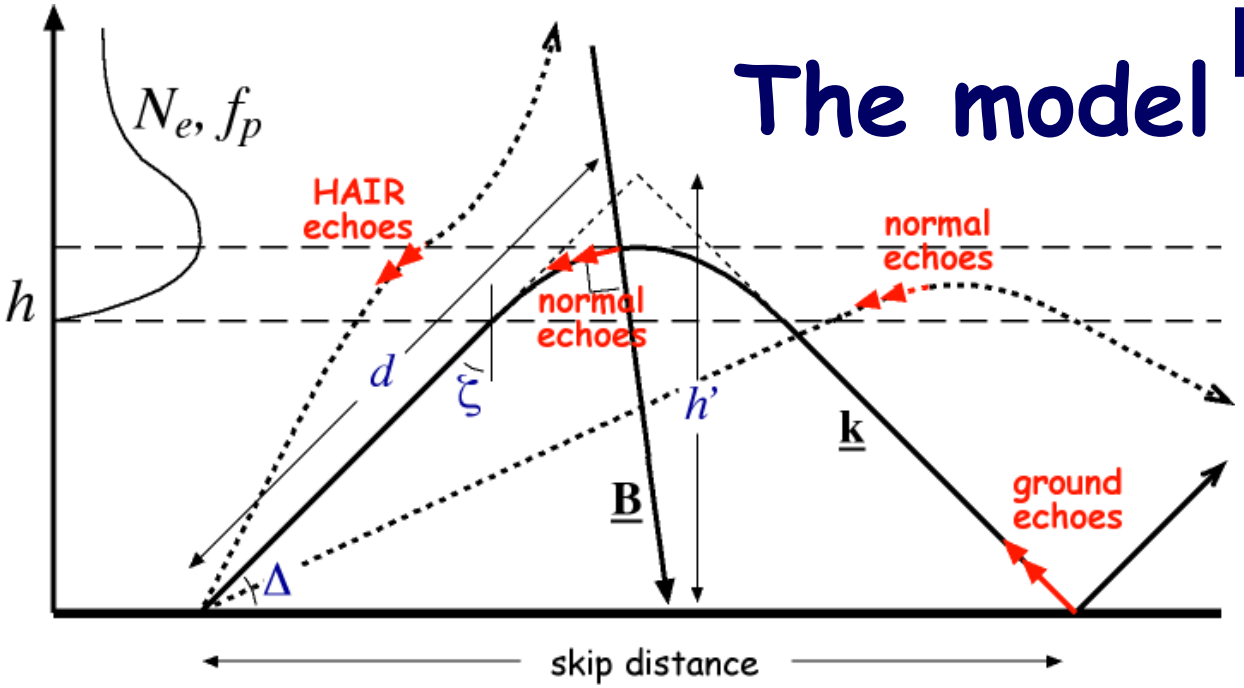
HAIR – high-aspect angle irregularity region



- Very near-range scatter has Doppler shifts opposite to the sense expected
- The demarcation between normal and reverse echoes is constant across beams
- The demarcation range depends on frequency

University of Leicester

The model



Secant Law $f_r = f_p \sec\zeta$

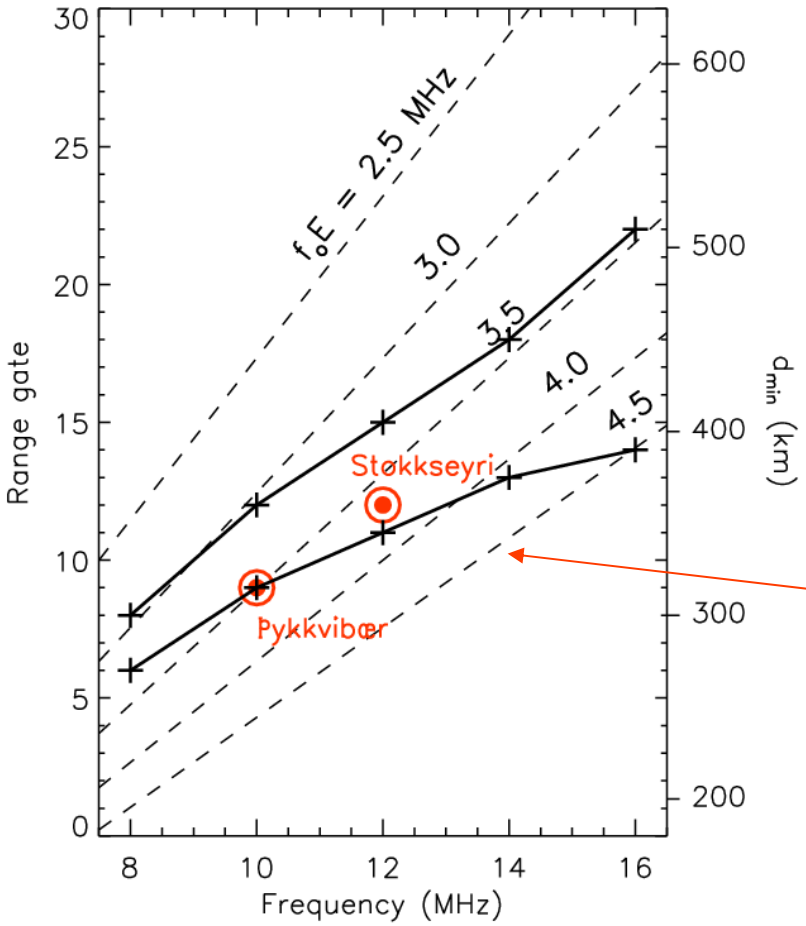
Path $h' = d\sin\Delta = d\cos\zeta$

$$f_p = f_r \frac{h'}{d}$$

$$d_{\min} = h' \frac{f_r}{f_o E}$$

$$f_o E = f_r \frac{h'}{d_{\min}}$$

The model

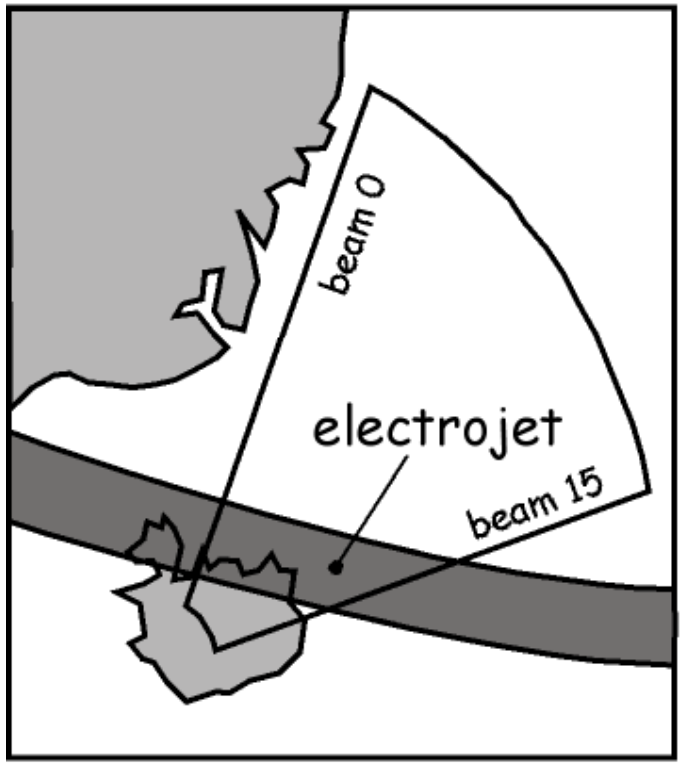


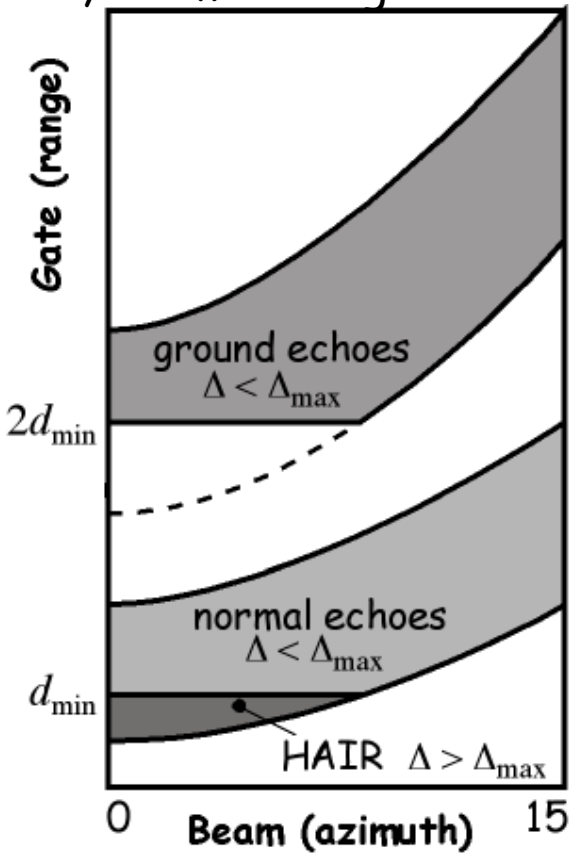
- Model expectations compare favourably with observations, suggesting foE values of 3-4 MHz, typical of nighttime auroral zone values

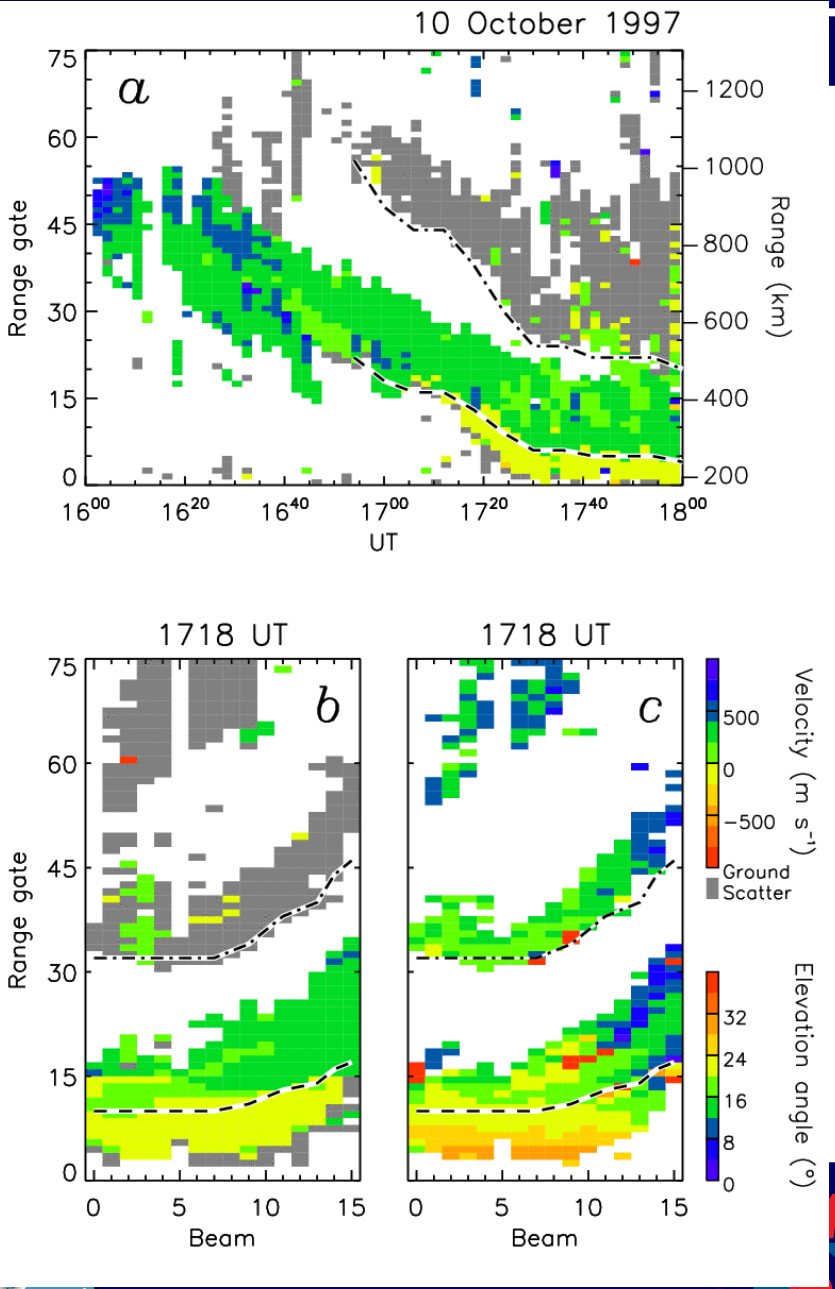
$$d_{\min} = h' \frac{f_r}{f_o E}$$

Other model predictions

- Expected elevation angle pattern in HAIR, normal and ground scatter



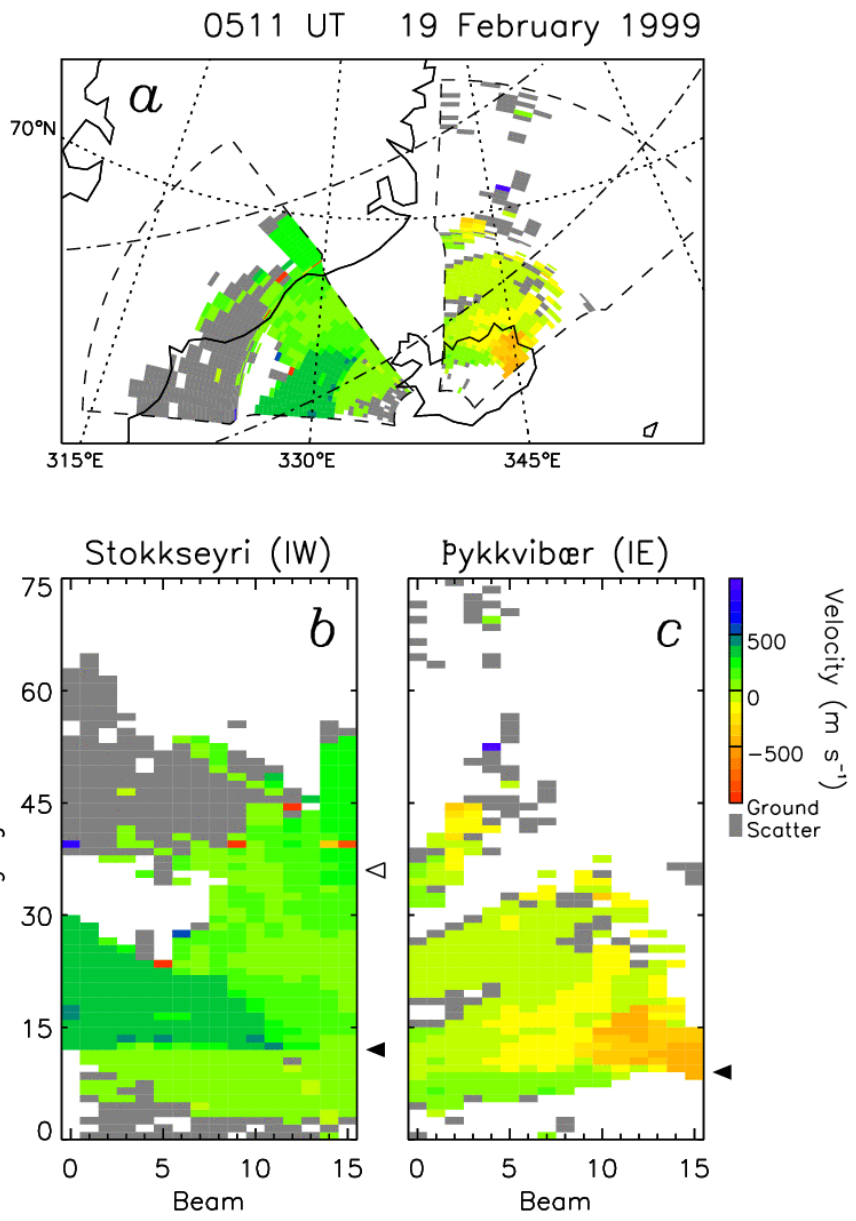




Other model predictions

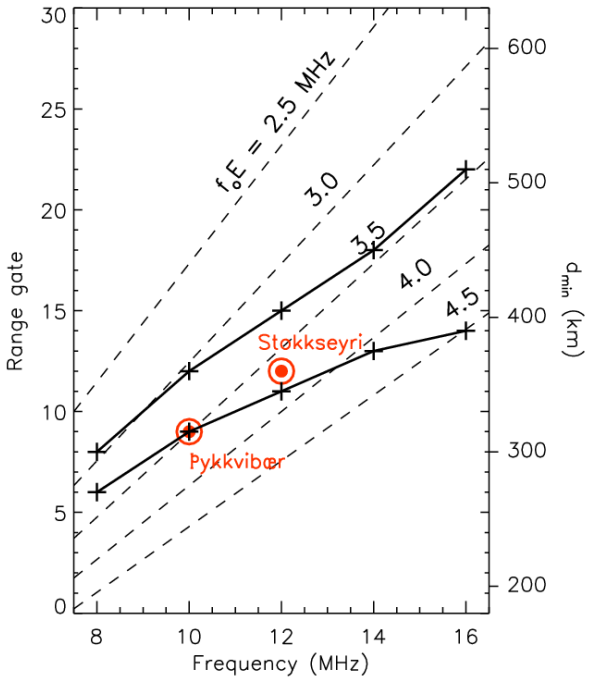
- Ground scatter should appear at twice the range of normal echoes ($2d_{min}$)
- Ground scatter should not be associated with HAIR echoes

University of Leicester

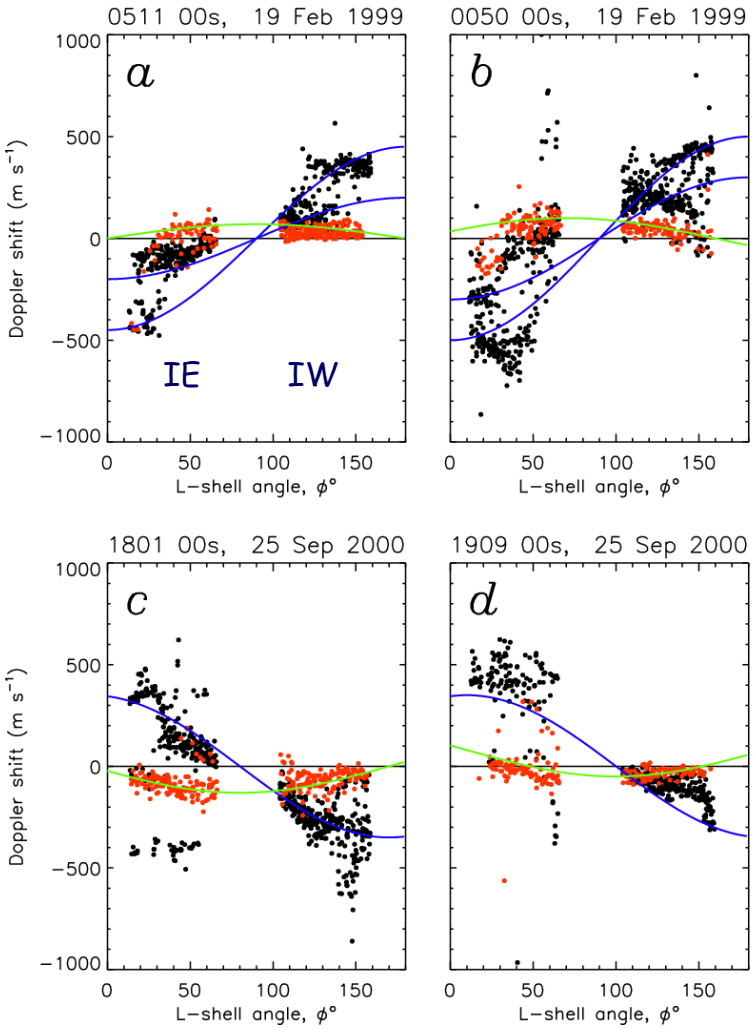


Flow angle dependence

- HAIR can be observed simultaneously by two radars



University of Leicester



Flow angle dependence

- Normal echoes have Doppler shifts that are consistent with the line-of-sight component of **E**x**B** drift

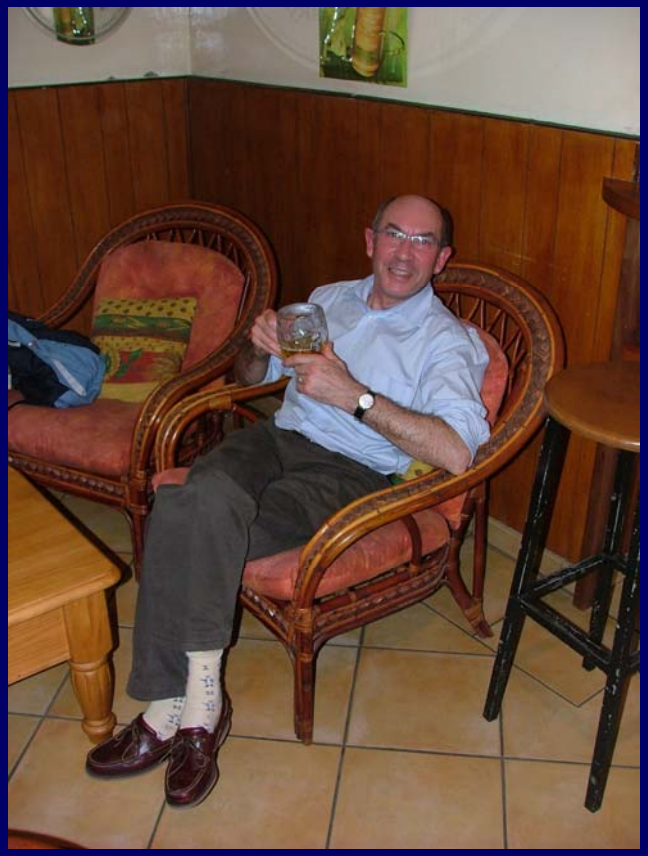
- HAIR echoes have Doppler shifts that appear to be the line-of-sight component of a drift directed in the **E** direction, with a magnitude ~10% of ***E/B***
  - possibly related to ion drift

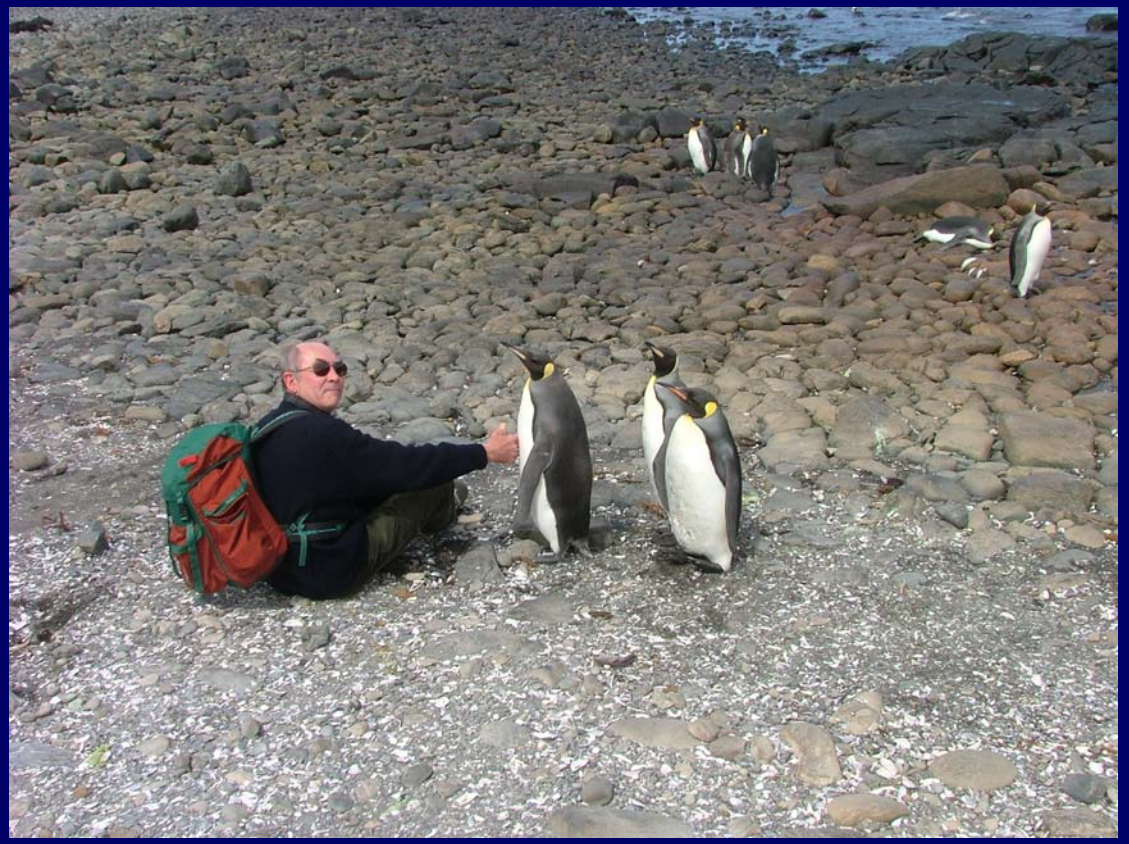
University of Leicester

HAIR - Conclusions

- Normal E region echoes arise from field-aligned irregularities, in regions where the radar beam achieves orthogonality with the magnetic field
- Where powerful normal echoes are not present (orthogonality is not achieved), high aspect angle scatter is seen
- HAIR echoes have Doppler shifts ~10% of the electron drift and a direction consistent with **E** not **ExB**
- Observations suggest an aspect insensitivity of ~1 dB deg-1, not ~10 dB deg-1 reported at VHF
- Possibly related to the "non aspect sensitive" irregularity generation mechanism proposed by Robinson and Schlegel (2000)
- Stimulated further theoretical work (see Jean-Pierre's talk)

University of Leicester





University of Leicester