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Radar measurements

FYS 3610

RADARS

- RADAR (RAdio Detection and Ranging)
- A radar transmits a radiopulse and detects and analyzes the backscatter or echo some time later
- **Incoherent scatter radars (IRS)** detect scatter from single electrons
- **Coherent scatter radars (CSR)** detect scatter from gradients in the electron density

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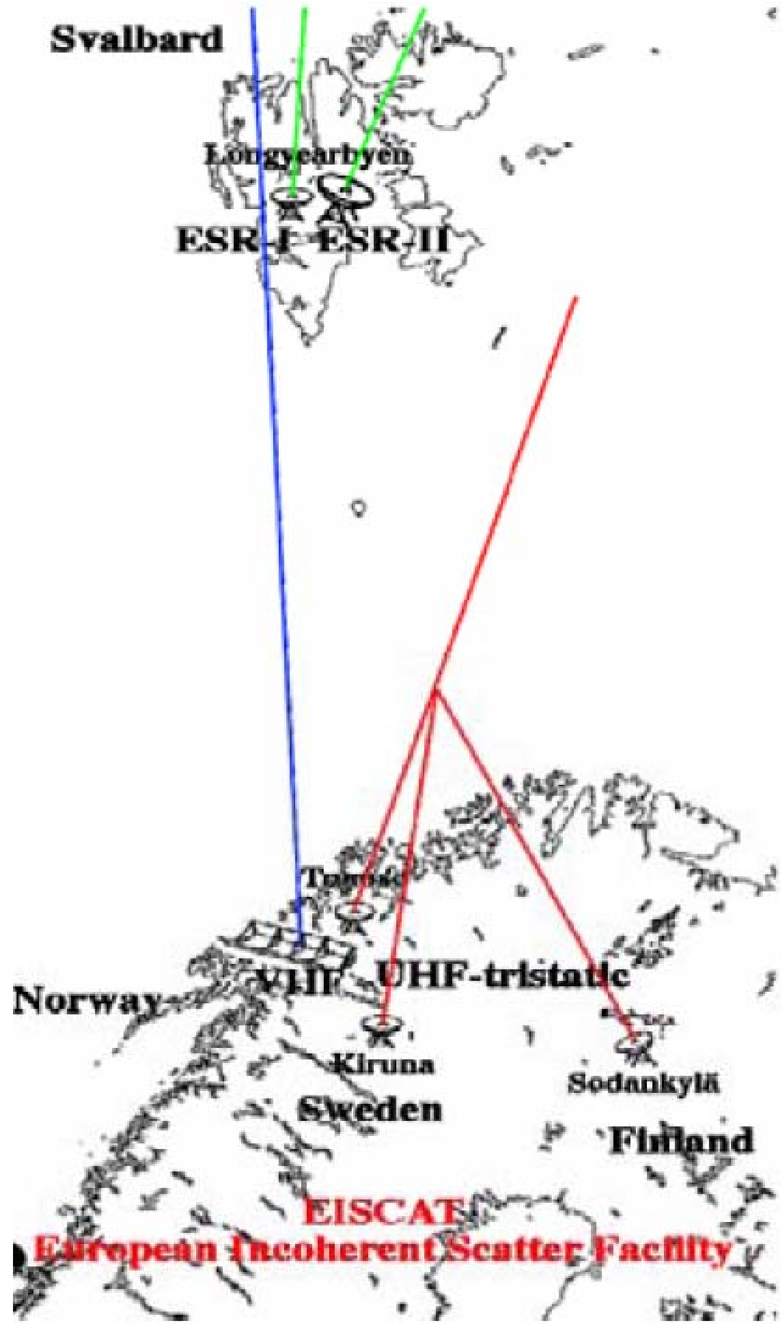
Incoherent scatter radars: EISCAT Scientific Association

Three Incoherent Scatter Radar Systems:

- **Tromsø VHF (224 MHz)**
- **Tromsø UHF (933 MHz)**
- **EISCAT Svalbard Radar (500 MHz)** - dual antenna system

Associated countries:
Germany, France, Finland, Japan, Norway, Sweden, UK, China



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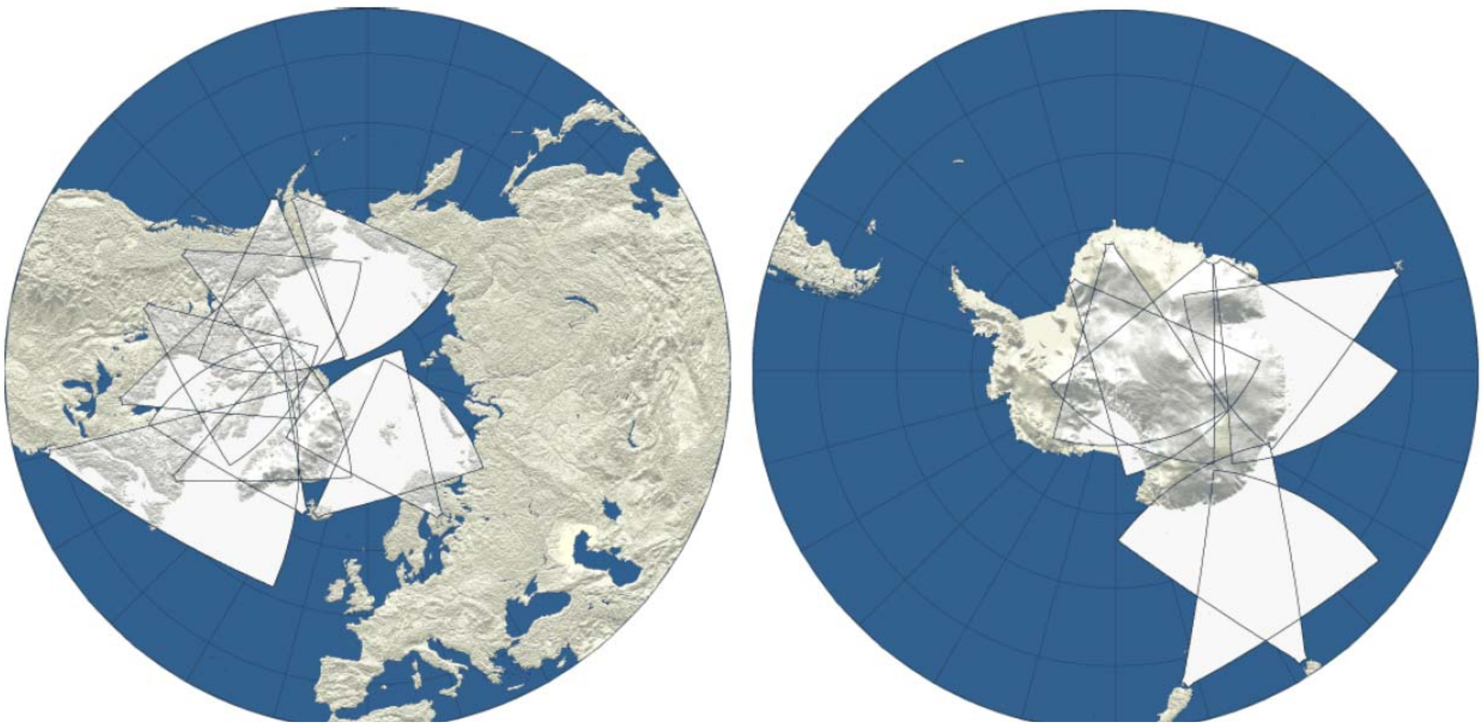
Coherent scatter radars: SuperDARN network



Monostatic and Multistatic radars

- Monostatic radars: The same radar transmits and receives the signal
- Multistatic radars: One radar is the transmitting radar, and one or more other radars act as receivers
- EISCAT UHF is an example of a tristatic system with one transmitter in Tromsø and two receivers in Sondankyla and Kiruna respectively
- Advantage of multistatic radars: possibility of receiving height profiles with real 3-D vectors

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Incoherent scattering

- The IS radar transmits a wave at a certain frequency
- Typical frequencies used are from 50 MHz and up (to 2 GHz).
- The electric field in the transmitted wave causes the electrons encountered by the radar pulse to oscillate, resulting in radiaton of a signal at almost the same frequency (Thomson scattering).
- The power in the returned signal is proportional to the electron concentration in the volume irradiated. This stems from the fact that each electron incoherently radiates back a small amount of the incident energy.
- The backsacttered signal is very weak (some pikowatt), and multi-megawatt transmitters ($P_T \sim 10^6$ W, $P_R \sim 10^{-15}$ W), large high gain antennas and sensitive receivers (effect ~$1000 m^2$) are needed.

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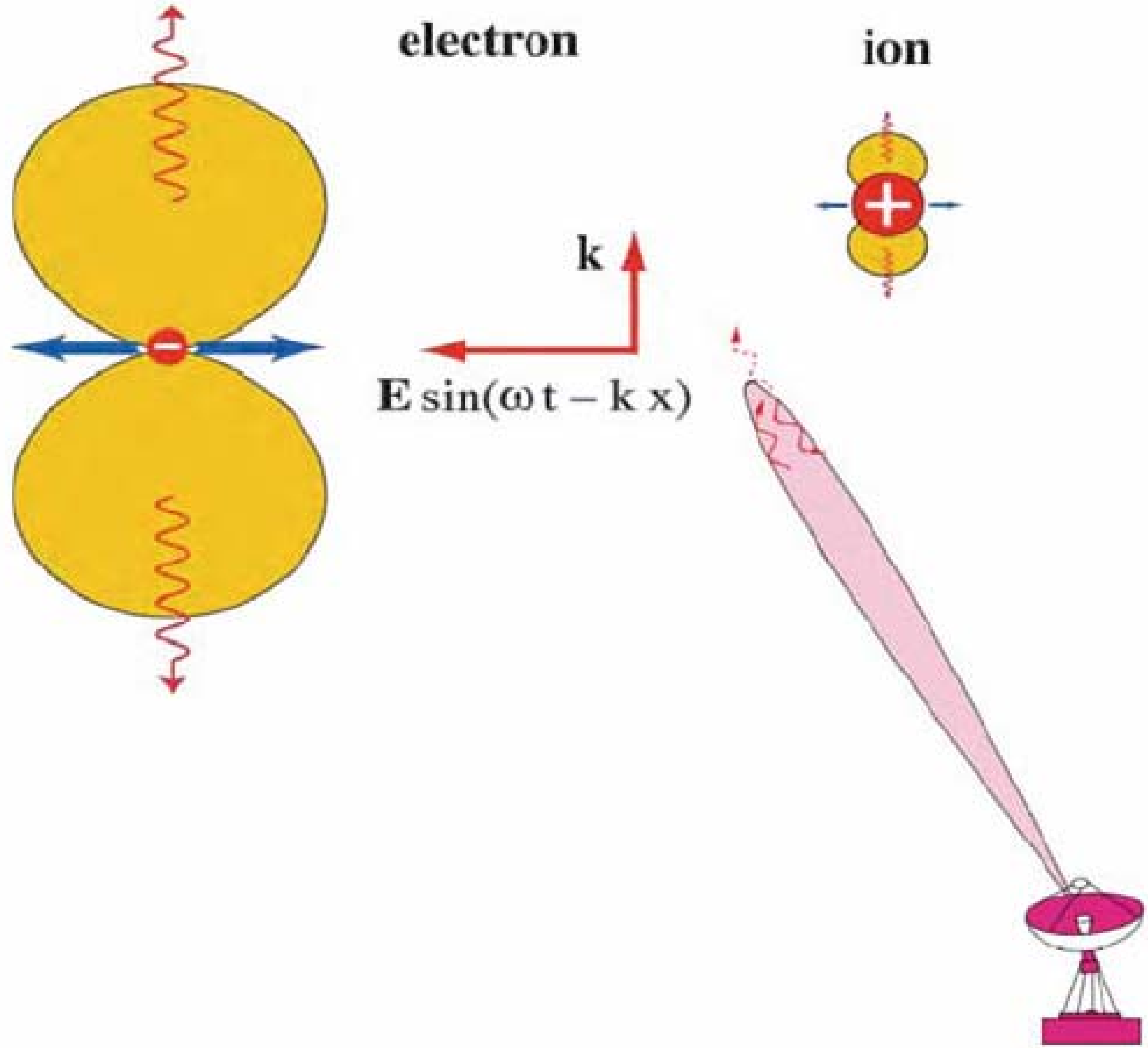
Incoherent scattering



Free electrons? Quasi-coherent scattering

- Due to the electrostatic forces in a plasma between the ions and electrons it is not corret to assume that the electrons are ”free” as first assumed by Thomson
- Electrons form a ”shielding layer” around each ion, the size of the layer is given by the debye length
- The debye length in the ionosphere is typically 10^{-3}m
- If the transmittet wavlength is much smaller then the debye length, it is correct to assume scattering from free electrons.
- If the transmitted wavelength is larger, as in IS experiments, electrons cannot be considered free.
- Electron motion is then controlled by the ions


SWAMP

Quasi-coherent scattering

- The random termal motion of the electrons induces ion- and electron accoustic waves, also called plasma waves (collective behaviour of the plasma)
- These wave exist over a wide spectrum of wavelength propagating in all directions
- The spectrum includes waves with frequency equal to half the transmittet frequency (Bragg criterion) which travel along and away from the beam.

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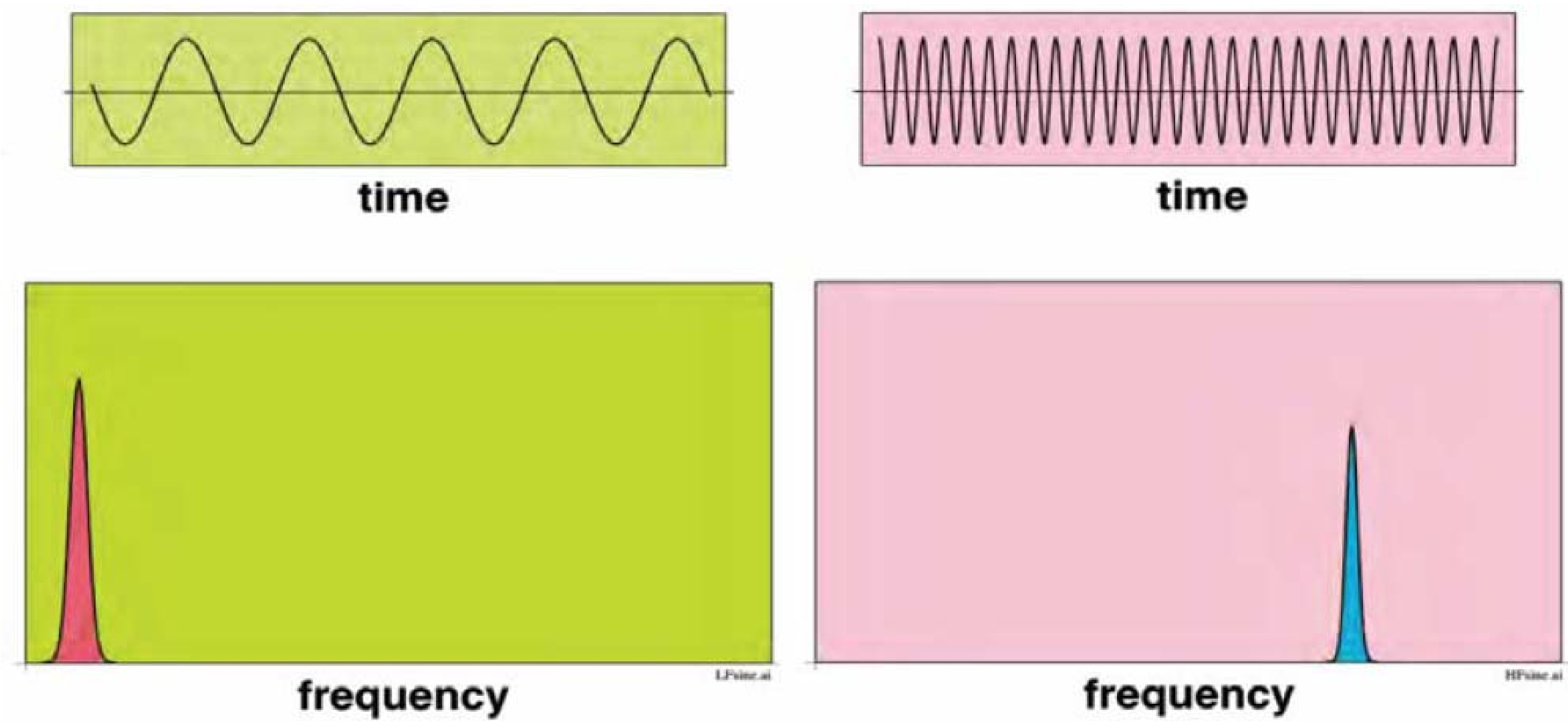
IS-spectrum



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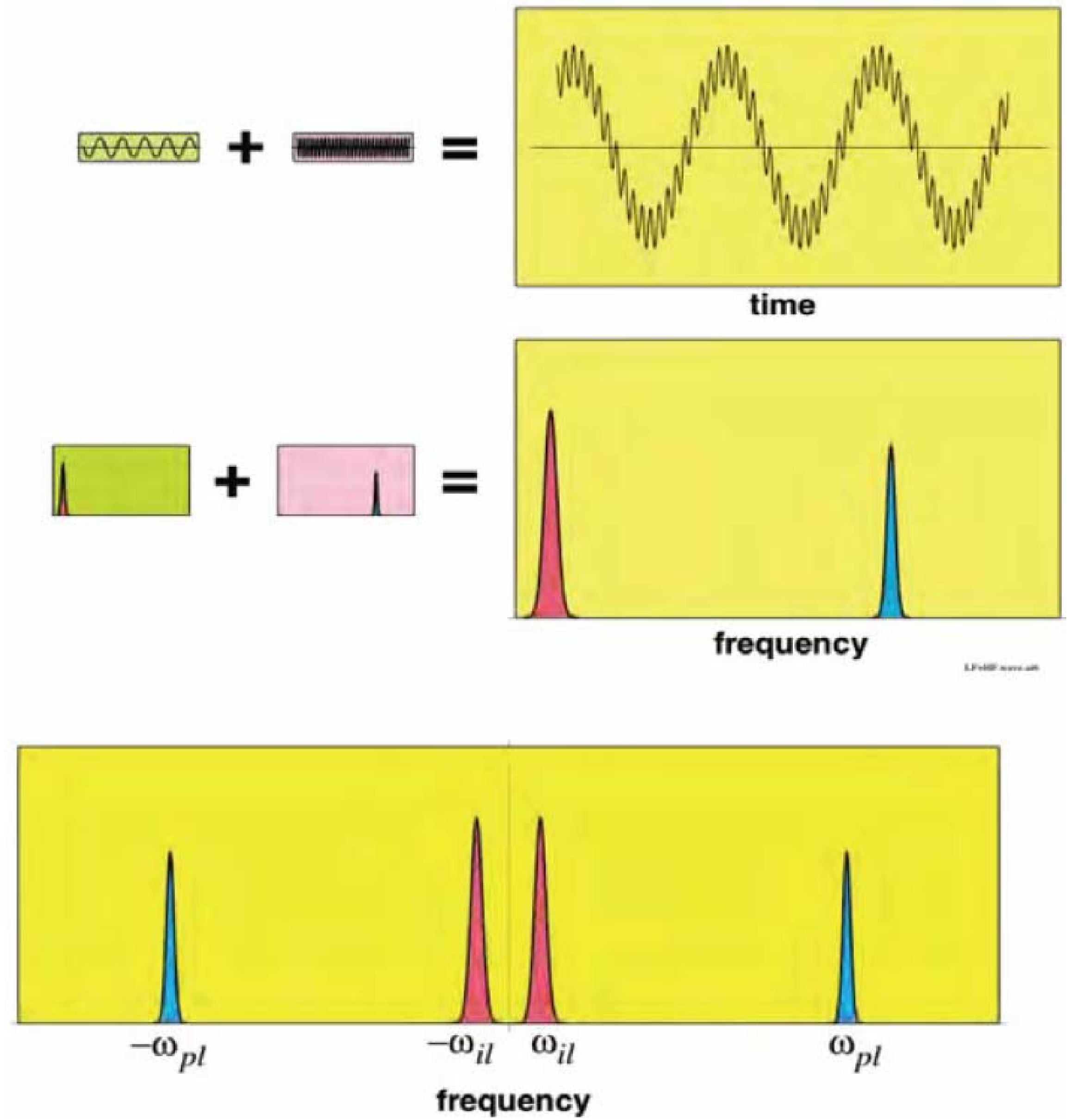
IS-spectrum



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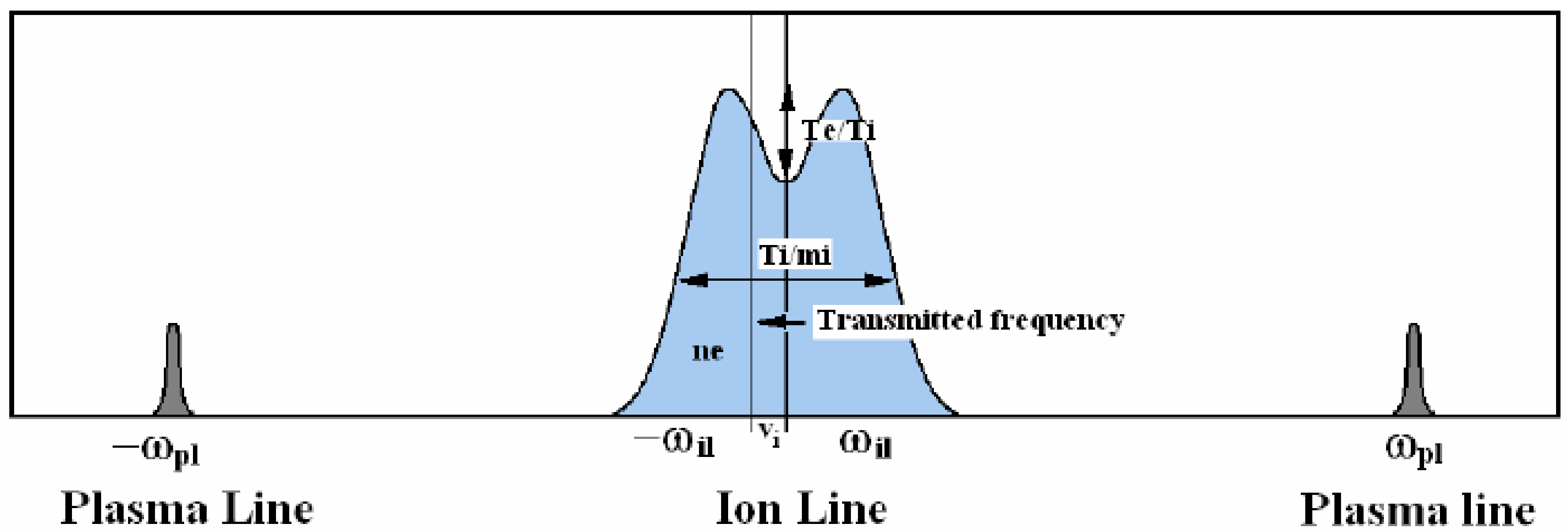
ICS spectrum "Double Hump"



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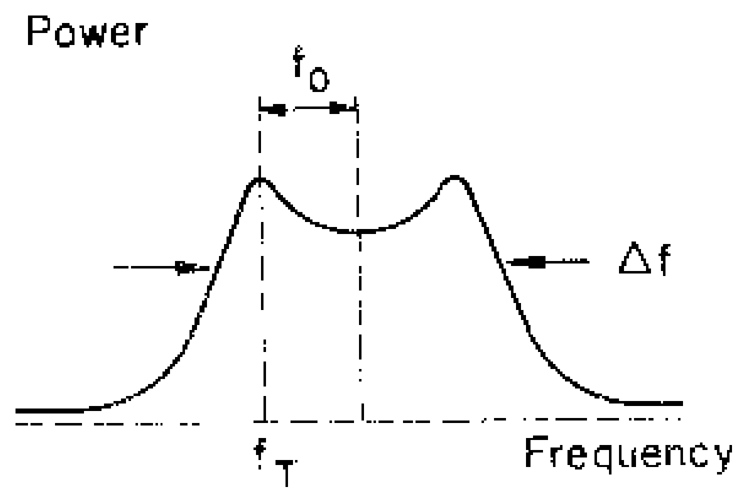
ISR – Doppler spectrum due to scattering from thermal fluctuations in the ion line

- Number density ~ power/area under the curve.
- The width Δf determines the ion temperature Ti.
- T_e / Ti determined from the intensity of the ”wings”/shoulders in the spectrum.
- The frequency shift f_o from the transmitt frequency f_T gives the mean ion velocity



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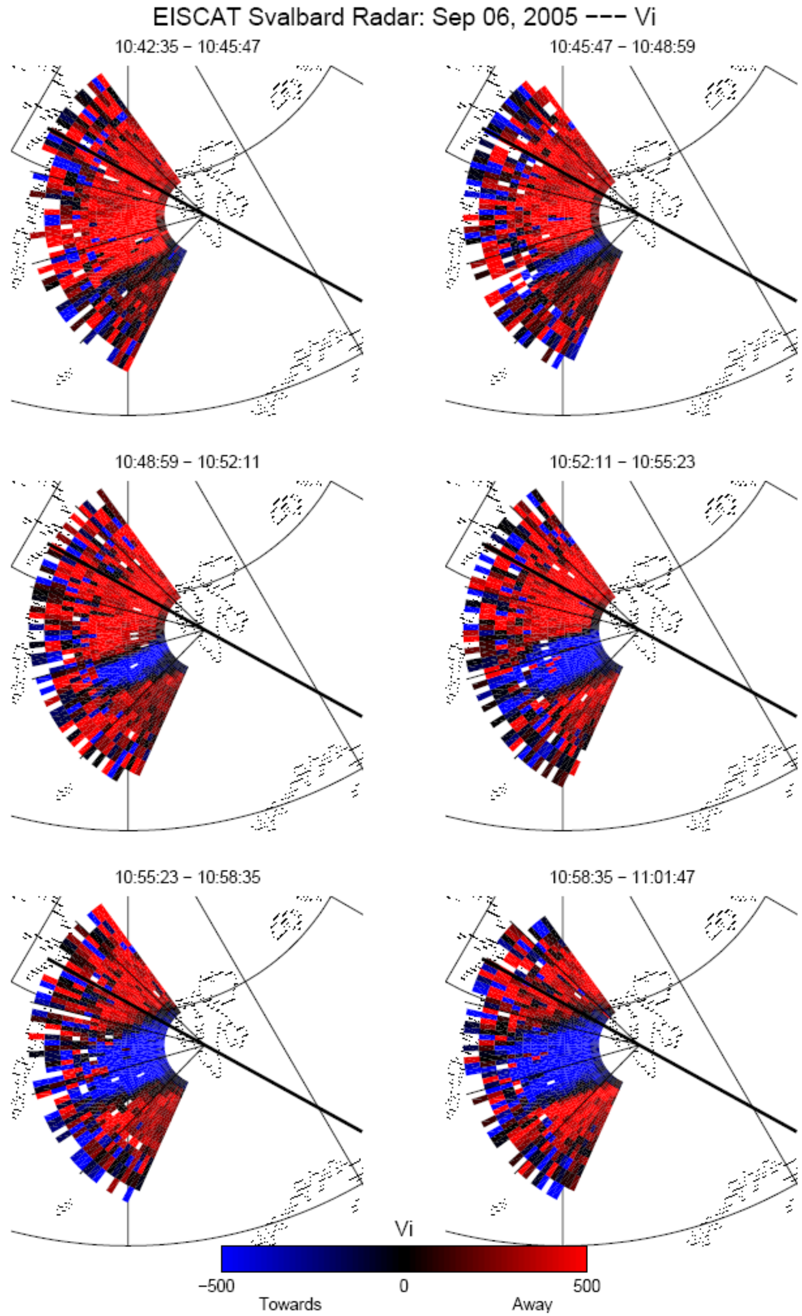
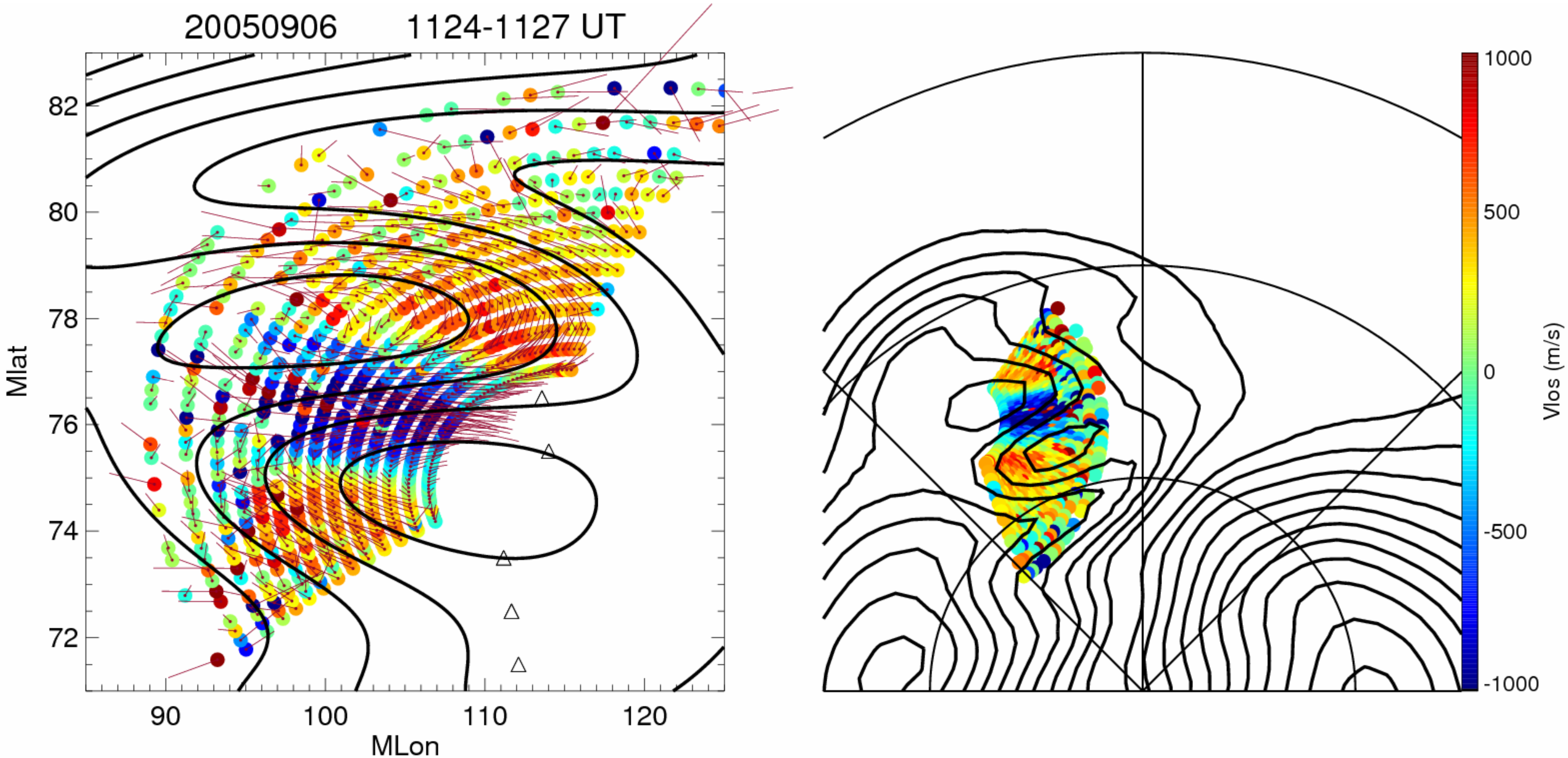
ESR research

- Developed fast sweep modes for mapping and tracking of density patches
- For both elevation and azimuth-sweeps the windshield-wiper motion is repeated every 128 seconds, and data is sampled every 3.2 seconds at a range resolution of 50 km.
- Steep density gradients may in a worst case scenario cause serious problems for GPS navigation



ESR research



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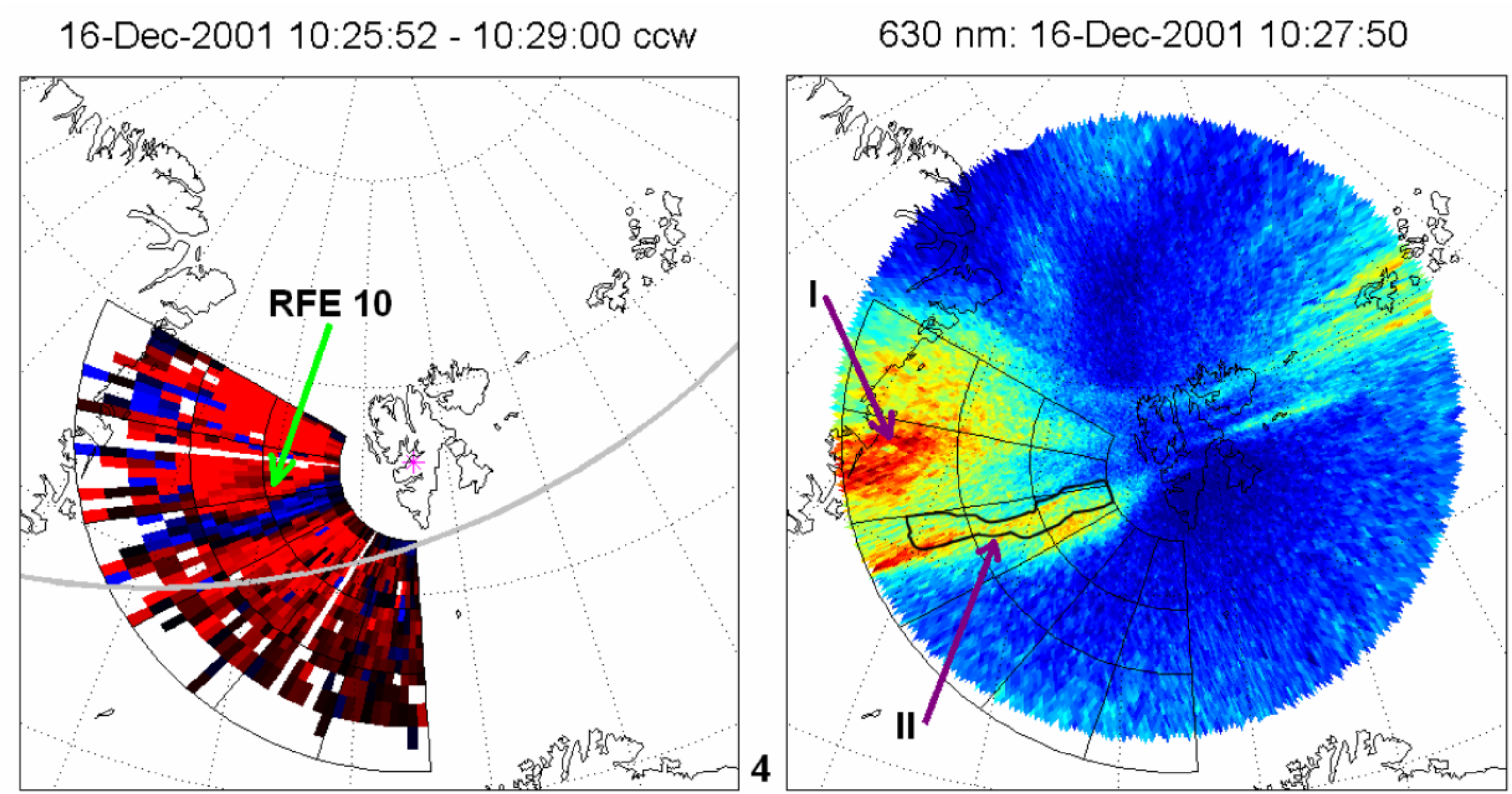
ESR research



Rinne et al. 2006

Coherent scatter radars

- Coherent scatter radars are sensitive to Bragg scattering from decameter electron density irregularities in the ionospheric plasma, which are aligned with the magnetic field and created by plasma instabilities
- Constructive interference occurs from plasma waves with frequency equal to half the transmitted frequency Only the backscatter from these waves is strong enough to produce a detactable echo

Coherent radar– backscatter targets

- The scattering wavelength is one half the transmitted wavelength, meaning that backscatter occures when the irregularities have a size of approximately on half the radar wavelength (constructive interference).
- Example:

A medium frequency radar operating at 10 MHz . This gives a wavelength of

$$\lambda = \frac{c}{f} = \frac{3 \cdot 10^8 m/s}{10 MHz} = 30m$$

This means that this radar will give backscatter when the irregularities are in the size of ~ 15 meters.

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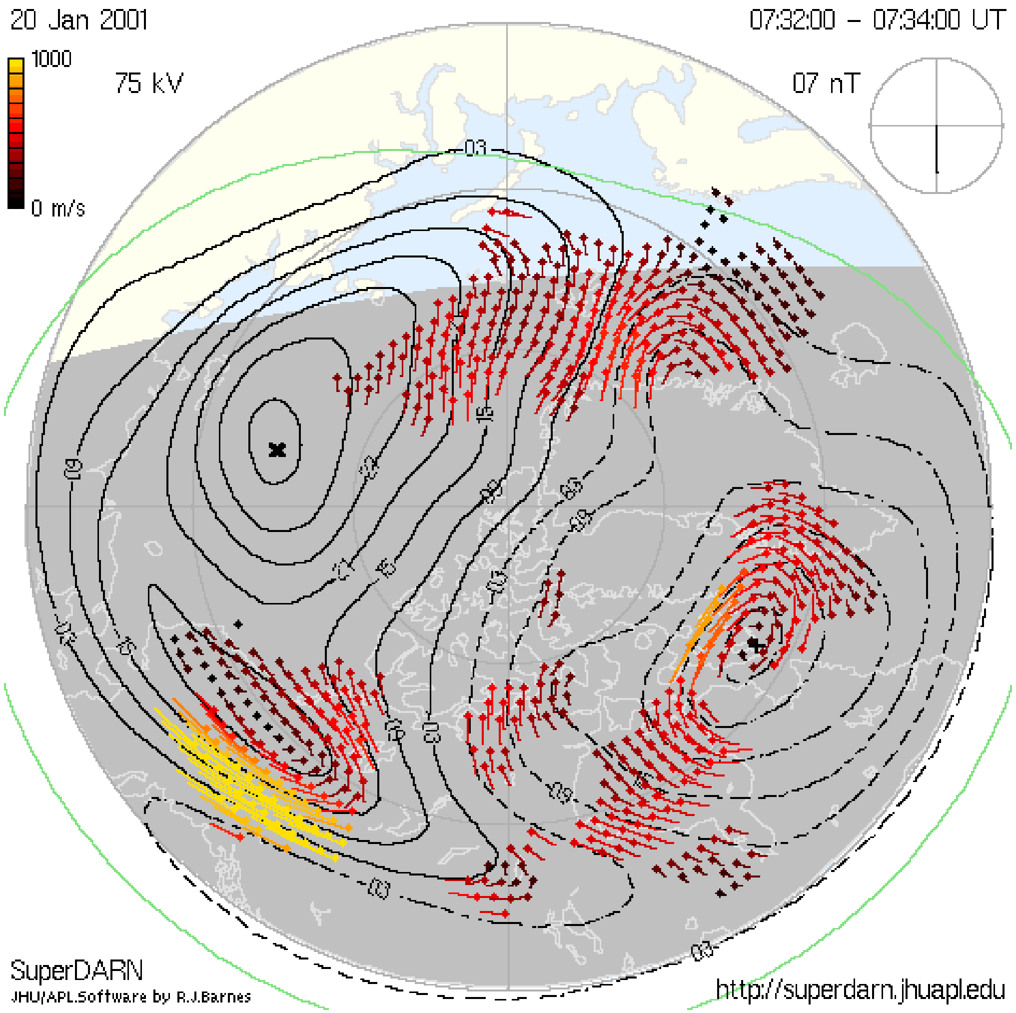
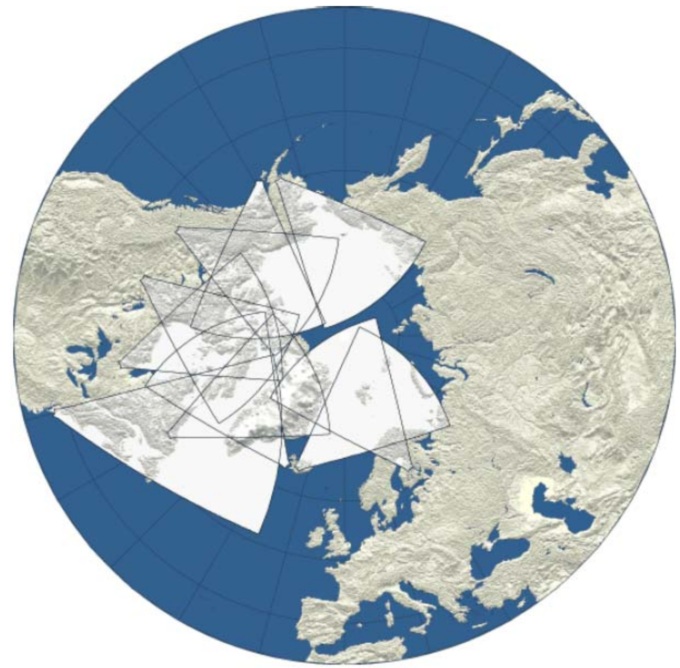
SuperDARN Radars





A network of HF radars that monitors the high-latitude ionosphere.