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# Early Years of HF radar studies of the ionosphere

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# Some historical elements …

+ Development of VHF radars in 1960s by NOAA group. Observations of the equatorial electrojet and Spread F.
+ First HF radar experiment in 1973 in Chad by LSEET. Joint HF / VHF observations.
+ Multifrequency HF observations in Ethiopia and Djibouti from 1974 until 1980.

+ From mid 1970s, incitation for high-latitude observations in relation with the development of EISCAT.
+ First test campaign in summer 1978 from Uppsala and Lycksele (Sweden).
+ Installation of SAFARI (Swedish And French Auroral Radar Investigations) radar in Lycksele. Later extension with a second station in Oulu (Finland).

# How Jean-Paul became involved in radars …

+ PhD thesis at CERGA in Grasse (1978):
  'Determination of thermospheric gas density from CACTUS accelerometer data'

+ JPV was looking for postdoc and future position,
  he was advised by F. Barlier to visit LSEET in Toulon

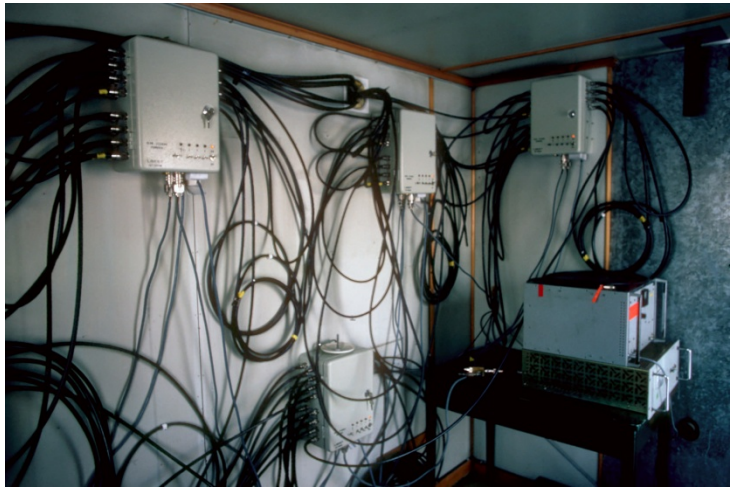
+ He was put in contact with Ray and went to Lindau to work on STARE

+ Later came back to Toulon ( ~ 1980-81) in order to work on SAFARI
  for his 'Doctorat d'Etat', which was passed in June 1985:
  'Coherent HF studies of ionization irregularities in auroral and polar F region'

+ Then to APL and work on Goose Bay / Schefferville radars …….

# The SAFARI radars

**+ Installed at Lycksele (Sweden) in 1978**
**+ Extension to Oulu (Finland) in 1982**
(4 antennas moved)



GEOPHYSICAL RESEARCH LETTERS, VOL. 8, NO. 10, PAGES 1083-1086, OCTOBER 1981

# SPECTRAL STUDIES OF F REGION IRREGULARITIES IN THE AURORAL ZONE

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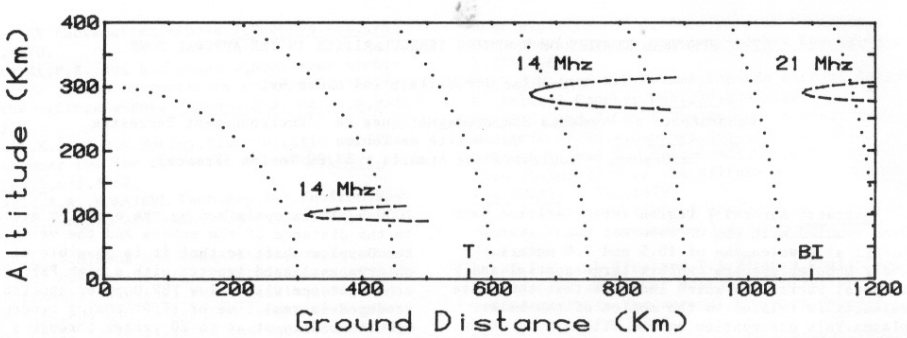


Fig. 1..Distance from Lycksele at which the radio rays are perpendicular to the magnetic field when refraction is included (dotted curves).The model is based on two parabolic layers of respective parameters $F_{oE}$=3.6 MHz,$H_E$=105 Km,$Y_E$=15 Km,$F_{oF}$=6.0 MHz,$H_F$=300 Km and $Y_F$=50 Km.Also indicated are the locations of Tromsö (T) and Bear Island (BI).

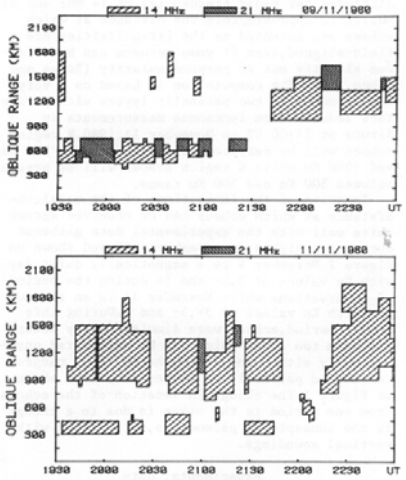


Fig. 2. Range of E and F layers backscattered echoes observed on 14.3 and 21.4 MHz on November 9 and November 11,1980.The two sets of echoes do not overlap and can be unambiguously recognized as their range agrees with the results shown on figure 1.

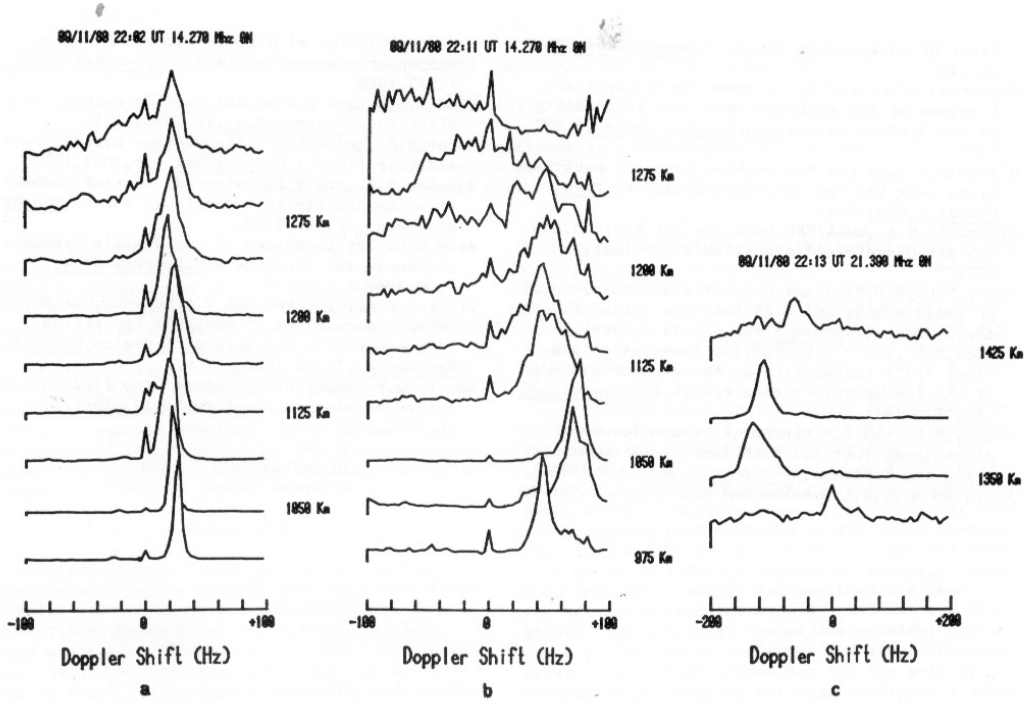


Fig. 3. Doppler spectra from F region irregularities observed northwards from Lycksele on November 9,1980 on a frequency of 14.3 MHz at 22:02 UT (3a) and 22:11 UT (3b) and a frequency of 21.4 MHz at 22:13 UT (3c).Note the large spatial and temporal variations and the reversal in radial component at greatest ranges.Peaks with a zero Doppler shift are due to transmitter coupling.Each spectrum is normalized to unity on a linear scale.

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# A SAFARI-EISCAT COMPARISON BETWEEN THE VELOCITY OF F REGION SMALL-SCALE IRREGULARITIES AND THE ION DRIFT

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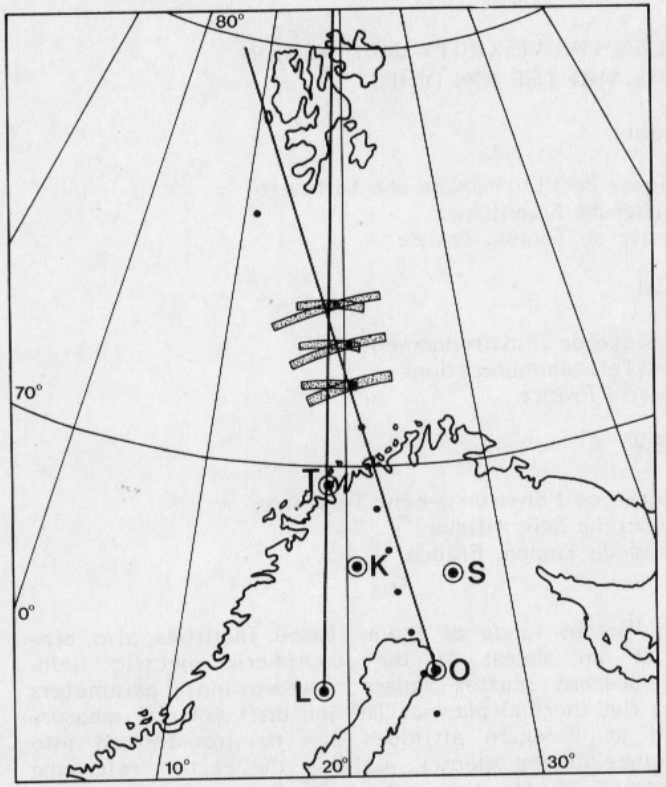


Fig. 1. Geographical configuration of the experiment over northern Scandinavia projected on an horizontal plane. The dots indicate the locations of the EISCAT plasma drift measurements during a meridian scan. The solid lines indicate the directions of the HF radar beams. The shaded areas are radar cells at different distances along the beam corresponding to EISCAT observations.

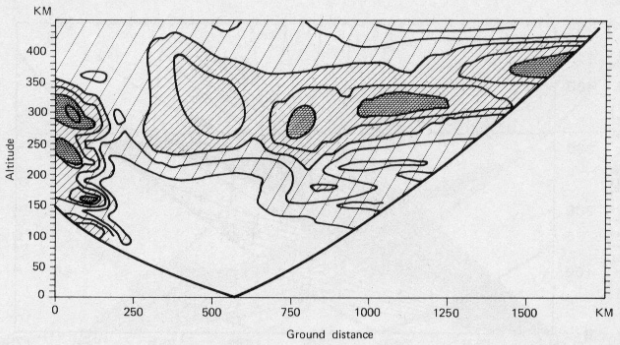


Fig. 2. Projection, on the initial azimuth of the radar beam, of the two-dimensional altitude-latitude map of electron density obtained during an EISCAT meridian scan. The zero location is located at the radar station. This electron density map was obtained on December 10, 1983, between 1800 and 1830 UT.

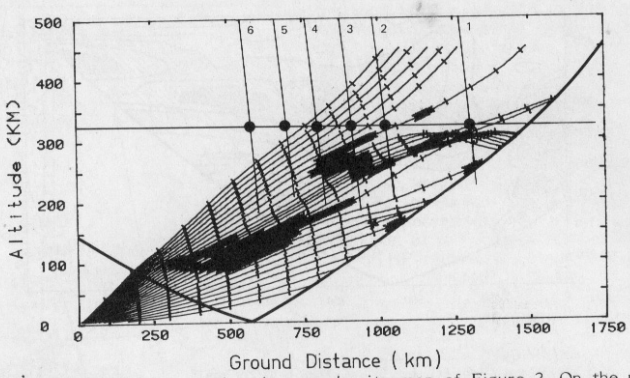


Fig. 3. Ray tracing calculated with the electron density map of Figure 2. On the ray paths, the dark segments correspond to the region where the electromagnetic wave is within 1° of perpendicularity to the earth's magnetic field B. Tick marks are plotted on each ray every 100 km in group path. The earth is considered as flat, so that straight line propagation appears curved. The dots on the horizontal line at 325-km altitude represent the EISCAT measurements. The almost vertical lines labeled 1-6 are the magnetic field lines intersecting the EISCAT measurement points. The angles appear distorted because of the different scales on the x and y axes.

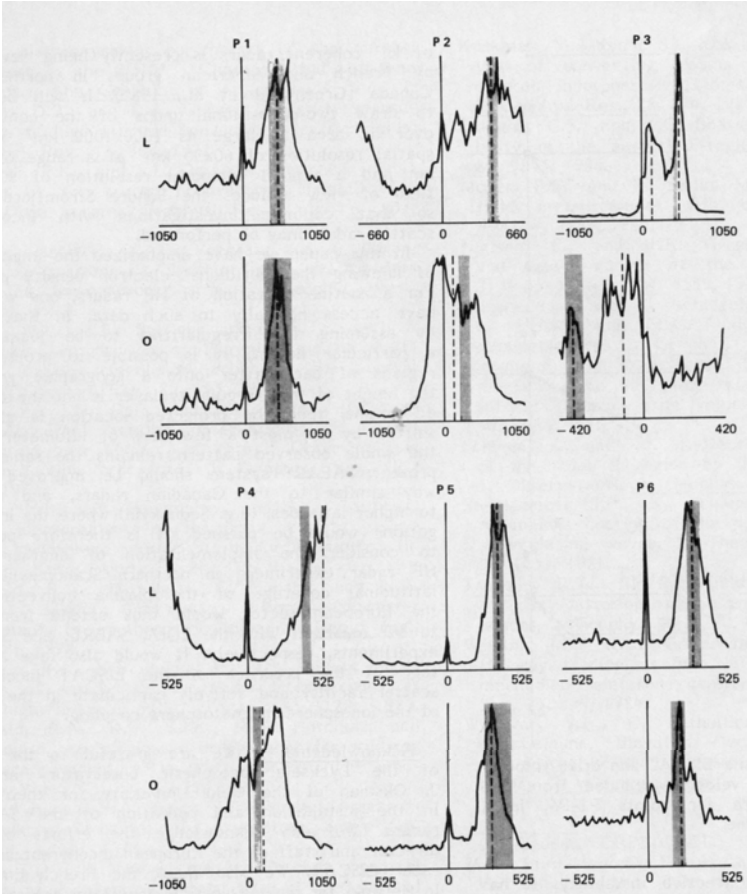


Fig. 10. Summary of the SAFARI Doppler spectra for the six points of comparison with EISCAT, P1-P6. The shaded area corresponds to the projection of the EISCAT ion drift velocity on the lines of sight of the SAFARI radar. The width of the shaded area corresponds to the error bars on the EISCAT measurements.

# ARCAD3-SAFARI coordinated study of auroral and polar *F*-region ionospheric irregularities

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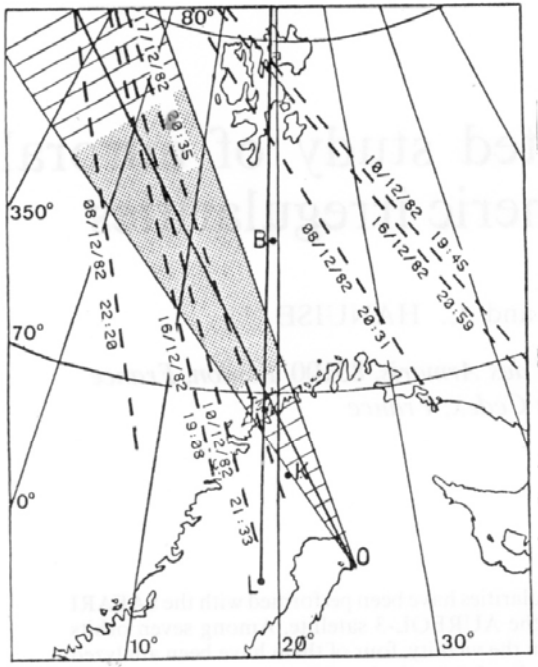


Figure 1

*Geographical configuration of the experiment over Scandinavia projected in the horizontal plane. The full lines indicate the radar beams directions. The hatched area corresponds to the beam width for the* HF *radar located at Oulu, and the darker area to the location in which the F-region echoes are generally observed. The dashed lines are projection on the ground of the satellite paths involved in this study.*

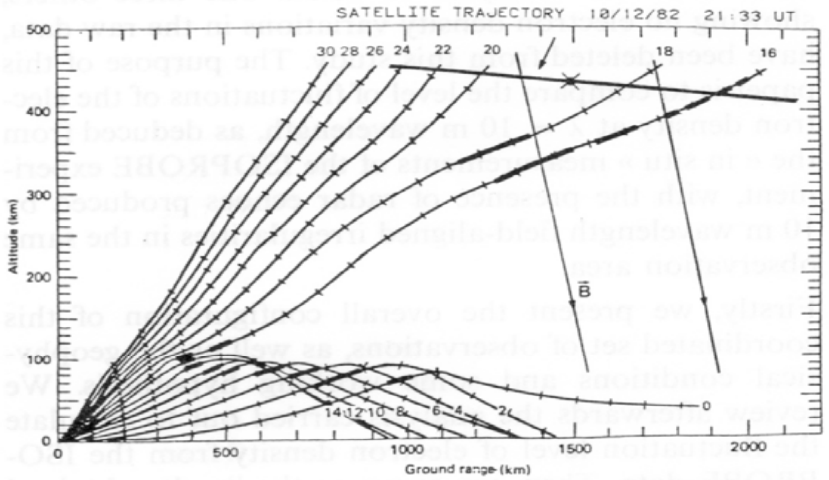


Figure 2

*Configuration of the experiment in a vertical plane. The zero location on the axes is located at the radar station. On the ray paths, the thick segments correspond to the region where the electromagnetic wave is within* 1° *of perpendicularity condition with the earth's magnetic field* $B_0$. *The angles appear to be distorted because of the different scale on the* X *and* Y *axes. The earth is considered as flat, so that straight line propagation appears to be curved.*

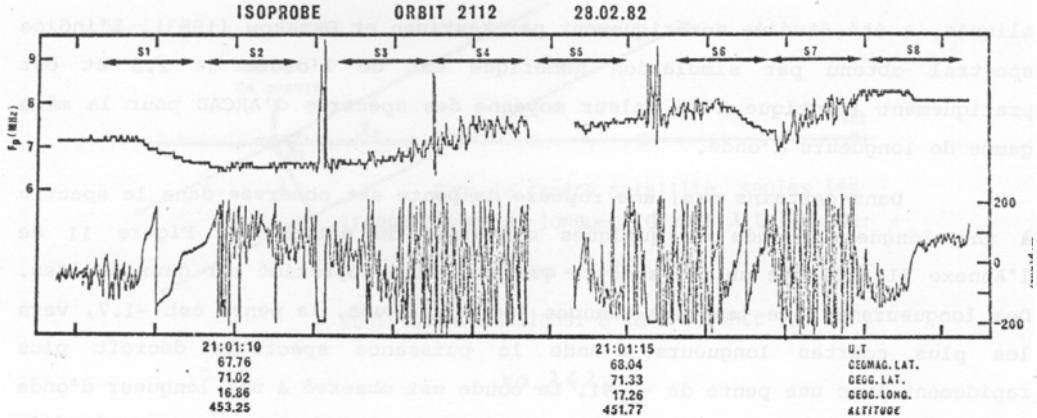


Fig.56 - Densité électronique mesurée par ISOPROBE le 28/02/82. Le panneau supérieur donne la fréquence plasma, et le panneau inférieur, les fluctuations dans une bande de 400 kHz autour de la valeur moyenne locale. On observe une corrélation entre le gradient de densité et l'amplitude des fluctuations.

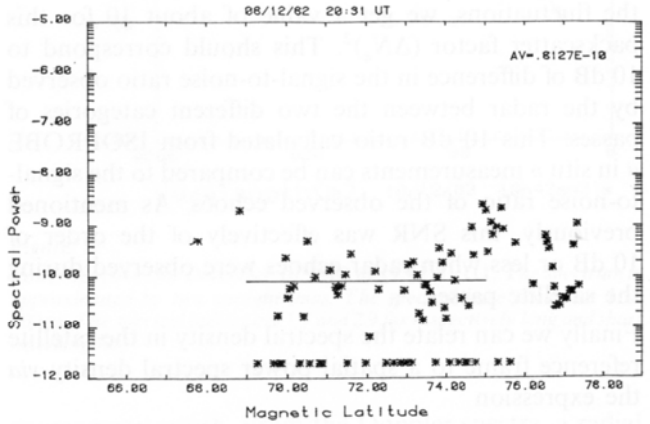


Figure 7

*Spectral power extrapolated at* 800 Hz ($\lambda$ = 10 m), *observed along the satellite trajectory for orbit* 5848, *December* 8, 1982 *at* 20:31 UT *and presented as a function of geomagnetic latitude. The straight line indicates the strip of latitude over which the spectral power is averaged. The value obtained is printed in the upper right corner of the frame. The eliminated data samples are plotted at the bottom.*

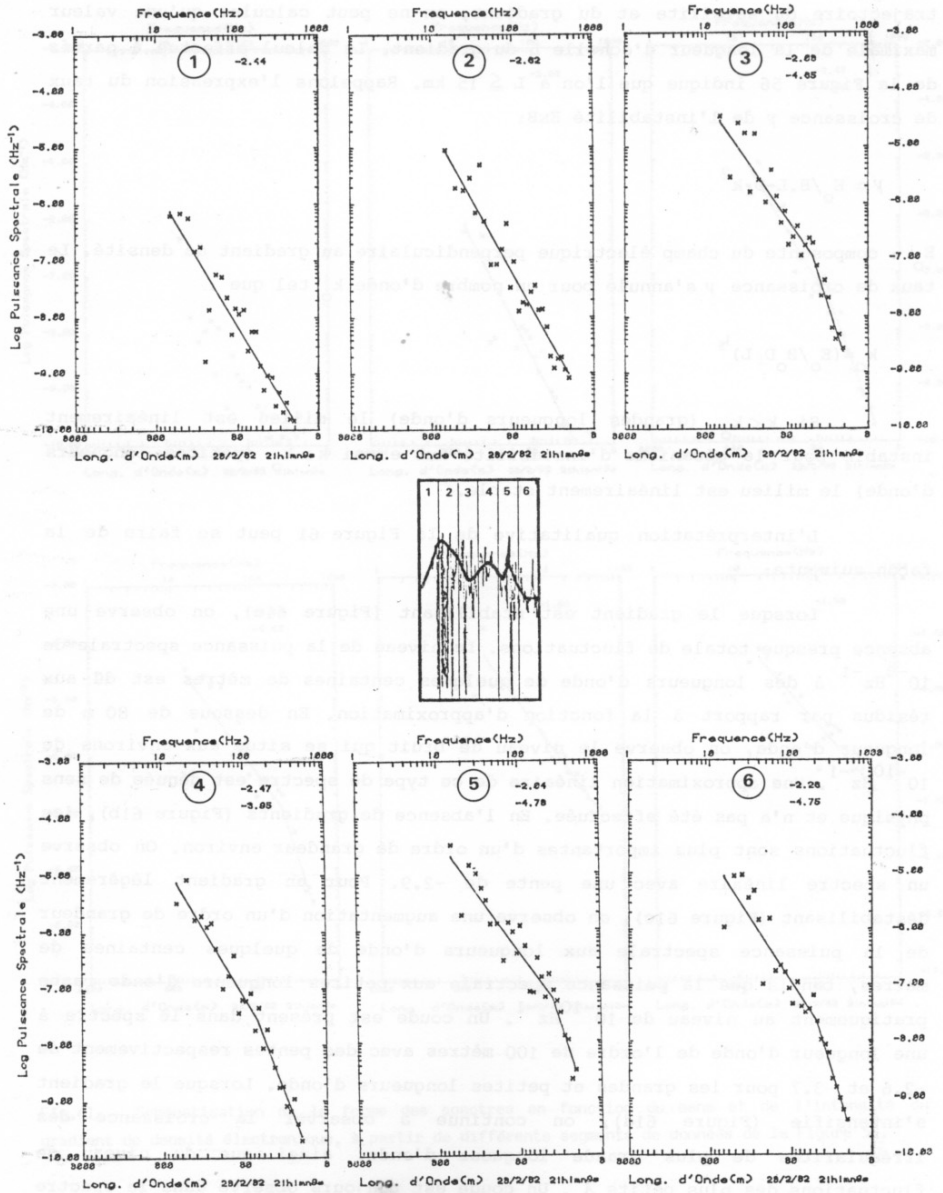


Fig.60 - Décomposition en éléments de 200 ms de la séquence 2 de la Figure 56. Le médaillon représente les fluctuations de la fréquence plasma avec la numérotation correspondant aux différents spectres. On note l'étroite corrélation entre le sens et l'intensité du gradient sur la forme du spectre (amplitude, pente) obtenu.









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