ESS576/AA556

Space and Laboratory Plasma Physics

- This course is about Plasma Waves
- Temp=0: We start with the fluid equations (derived in ESS415/515 and AA405) and derive dispersion relationships for several wave modes (cold plasma modes)
- Temp>0: Use distribution function and derive Landau damping and growth along with a discussion of equilibrium and stability.
- Stability and Equilibrium; nonlinear waves

- **ESS576AA556 Course Outline**
- **A. Plane Wave Solutions of two fluid equations**
  - **Develop full set of equations**
  - **Electrostatic waves: electron plasma waves, ion acoustic waves**
  - **Electromagnetic waves with B=0**
  - **Then add B not = 0 and consider**
  - **Upper Hybrid waves**
  - **Electrostatic ion waves**
- **B. Intro to Vlasov Equation**
  - **review distribution function**
  - **Electrostatic dispersion relationship**
  - **Landau Damping**
  - **Susceptibility/CMA diagram**
  - **Stability (Nyquist and Penrose)**
  - **Two-stream instability**
  - **Generalized theory of linear Vlasov modes**
  - **Bernstein modes**
- **C. Use Vlasov theory to review all fluid modes and find new ones**
  - **Drift waves**
  - **ion acoustic solitions**
  - **parametric instabilities**

- **Grading: problem sets (70%) and final exam (30%)**

Main Source Material:

- **A. Kivelson & Russell**
- **B. Chapter 12 by Goertz and Strangeway**
- **B. Chapter 6 of Nicholson**
- **C. Chapter 7 of Nicholson**
- **Class Webpage:**
  http://earthweb.ess.washington.edu/bobholz/ess576aa556/

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Why Study Plasma Waves?

1. Waves tell you about the state of a plasma - density, temperature, stability

2. Waves, or field fluctuations, can exert major control over plasma dynamics, energy transport, and can change the distribution function

3. Observers need to know how wave modes couple to EM waves even to make the measurements

4. Lab and space plasmas have to satisfy the same equations, just the scale and boundary values may be different.

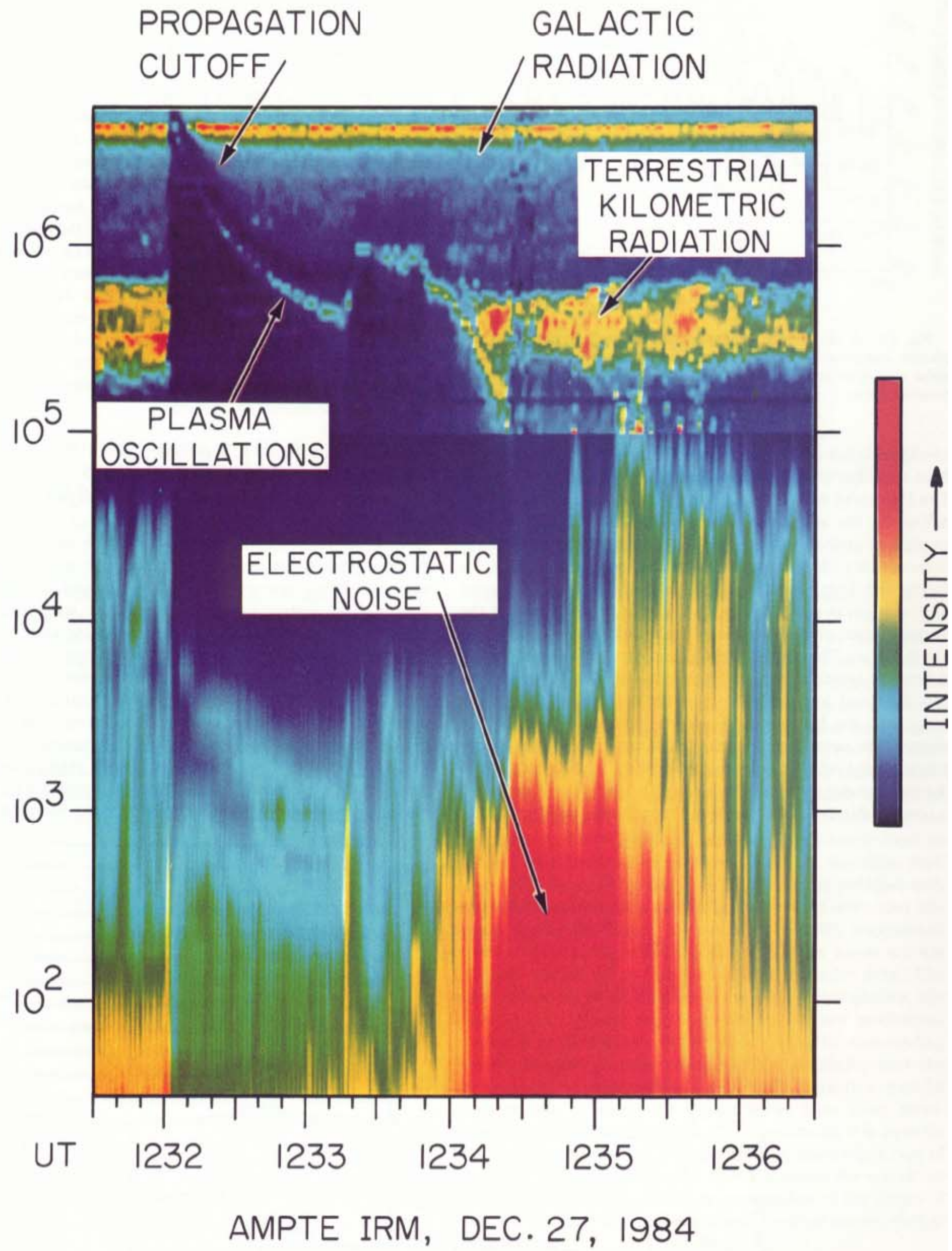


Plate 1. A frequency-time spectrogram from the high-frequency sweep-frequency receiver. The intensity scale is adjusted as a function of frequency so that the dynamic range extends from the instrument noise level (blue) to the saturation level (red). The dense plasma cloud formed by the explosion at 1232:00 blocked the galactic and terrestrial radio noise and produced depressed noise intensities for about 2 min as the cloud expanded over the spacecraft. The electron number density N_e can be determined from the electron plasma oscillation line, which is at the local electron plasma frequency f_{pe}, $= 9000\,(N_e)^{1/2}$ Hz, where N_e is in cm^{-3}.

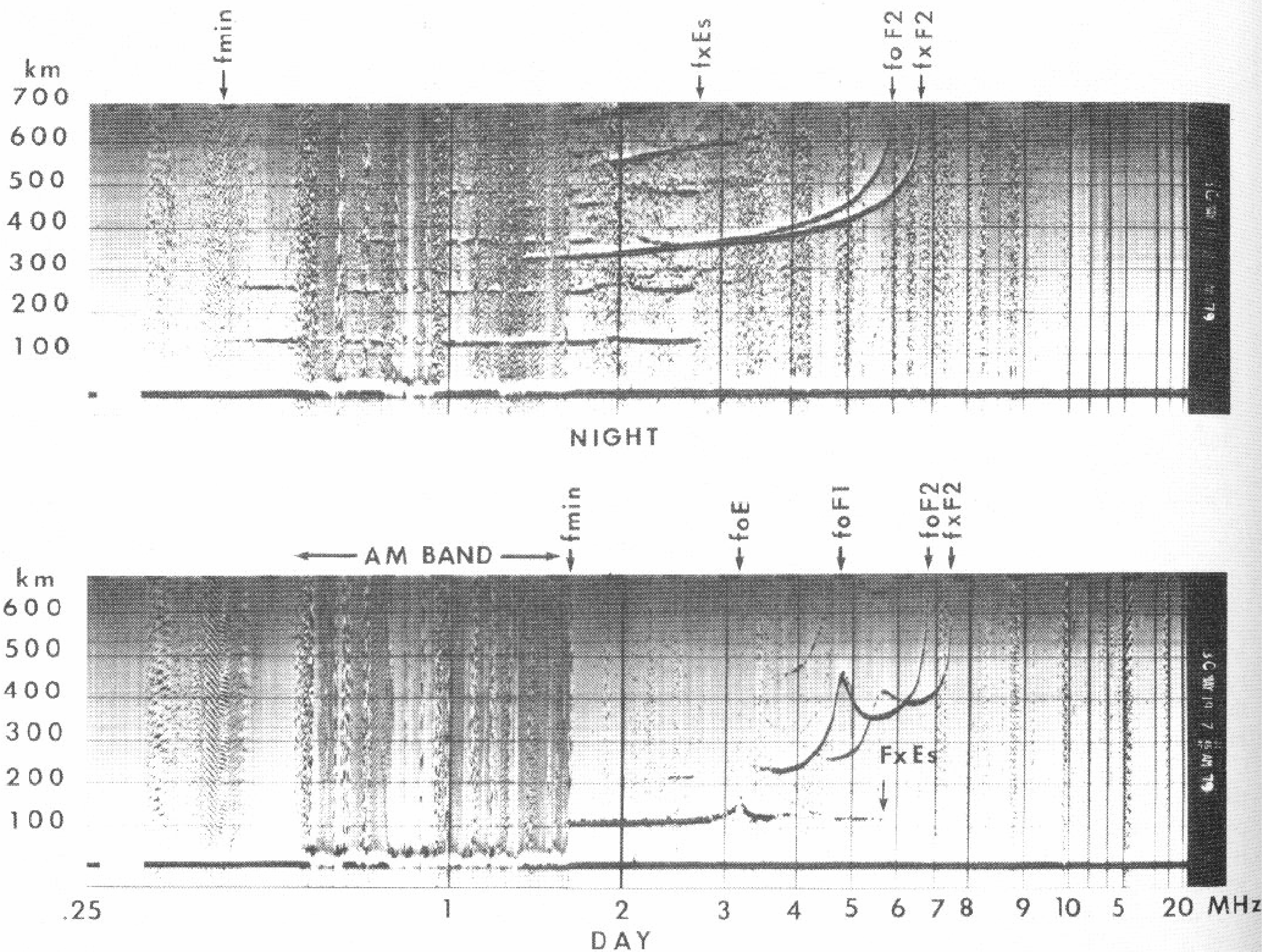
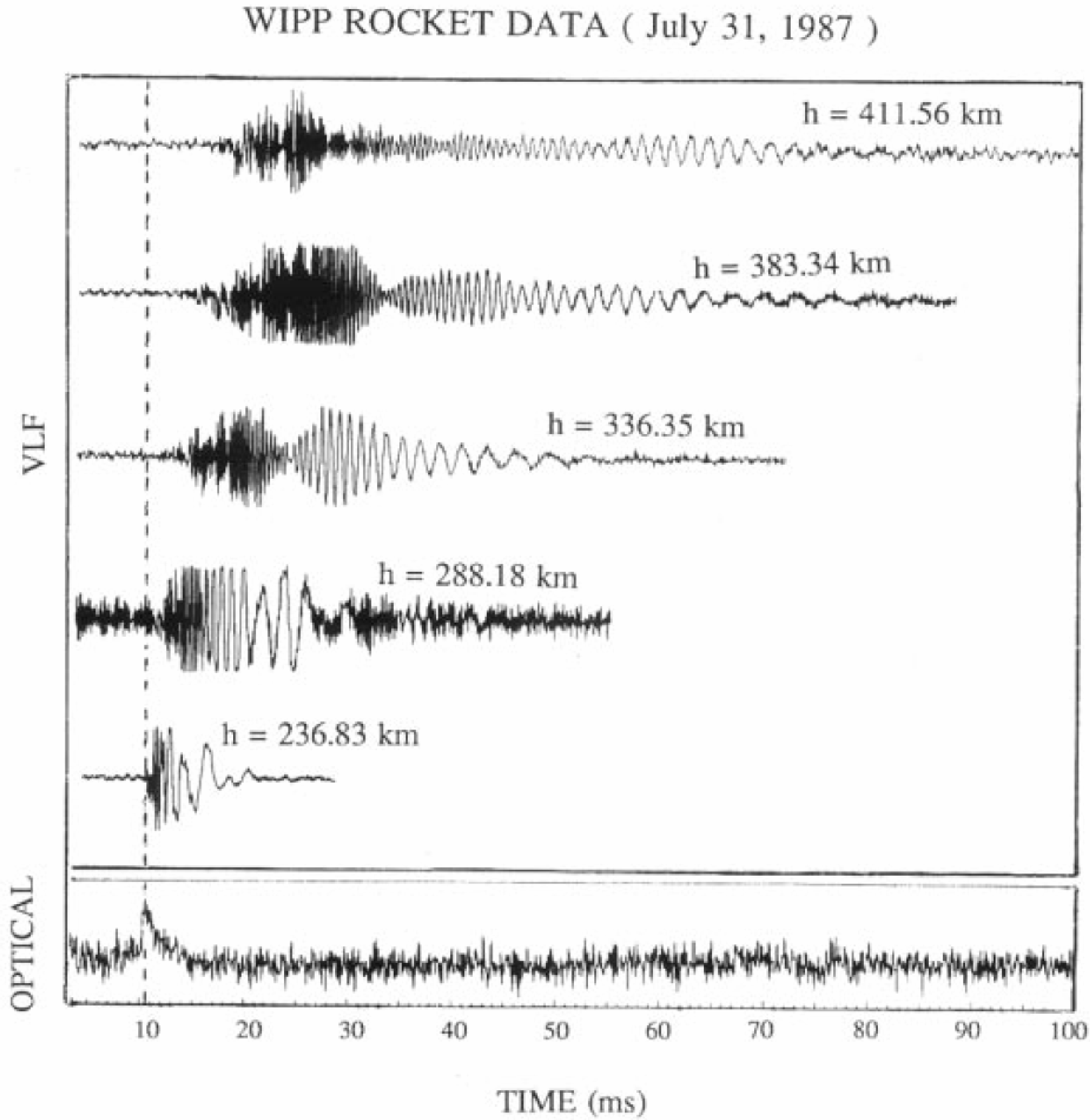
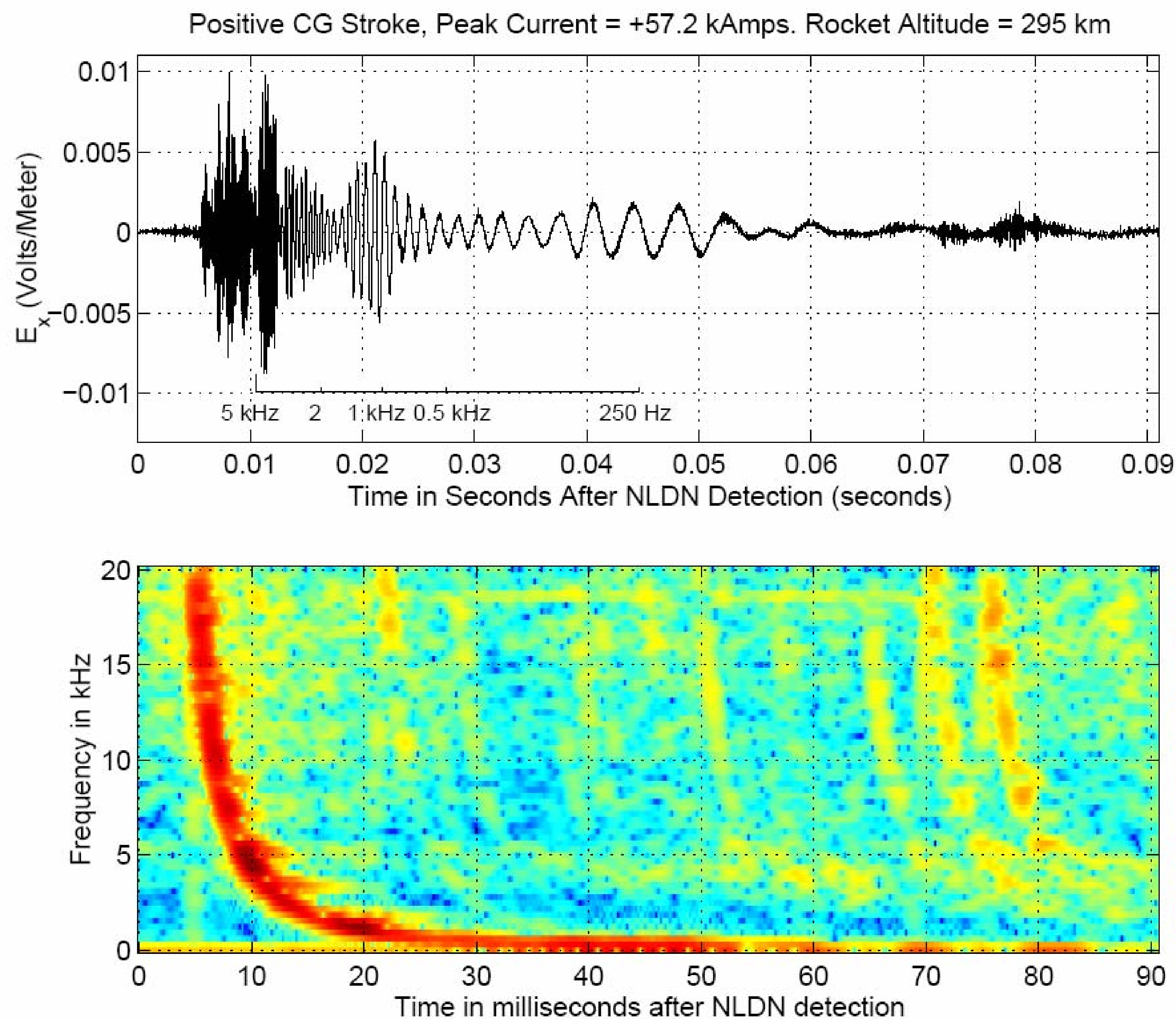
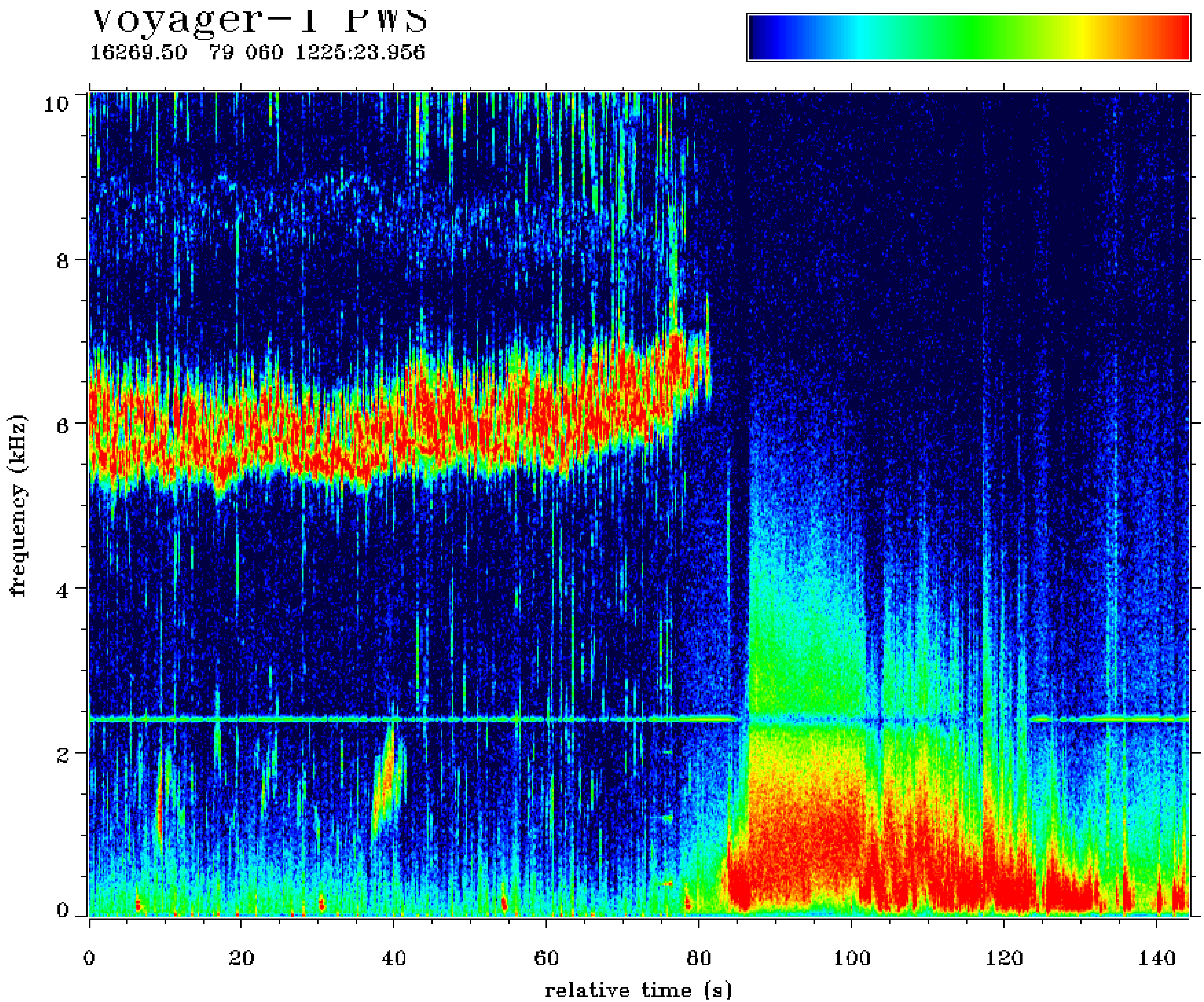


Figure 10-1. Typical midlatitude day and nighttime ionograms, recorded by a C-4 ionosonde at Boulder, Colorado. The daytime ionogram shows reflections from E, Es, F1 and F2 layers; the nighttime ionogram those from Es and F2 layers.


WIPP ROCKET DATA (July 31, 1987)
h = 411.56 km
h = 383.34 km
h = 336.35 km
h = 288.18 km
h = 236.83 km
VLF
OPTICAL
10
20
30
40
50
60
70
80
90
100
TIME (ms)

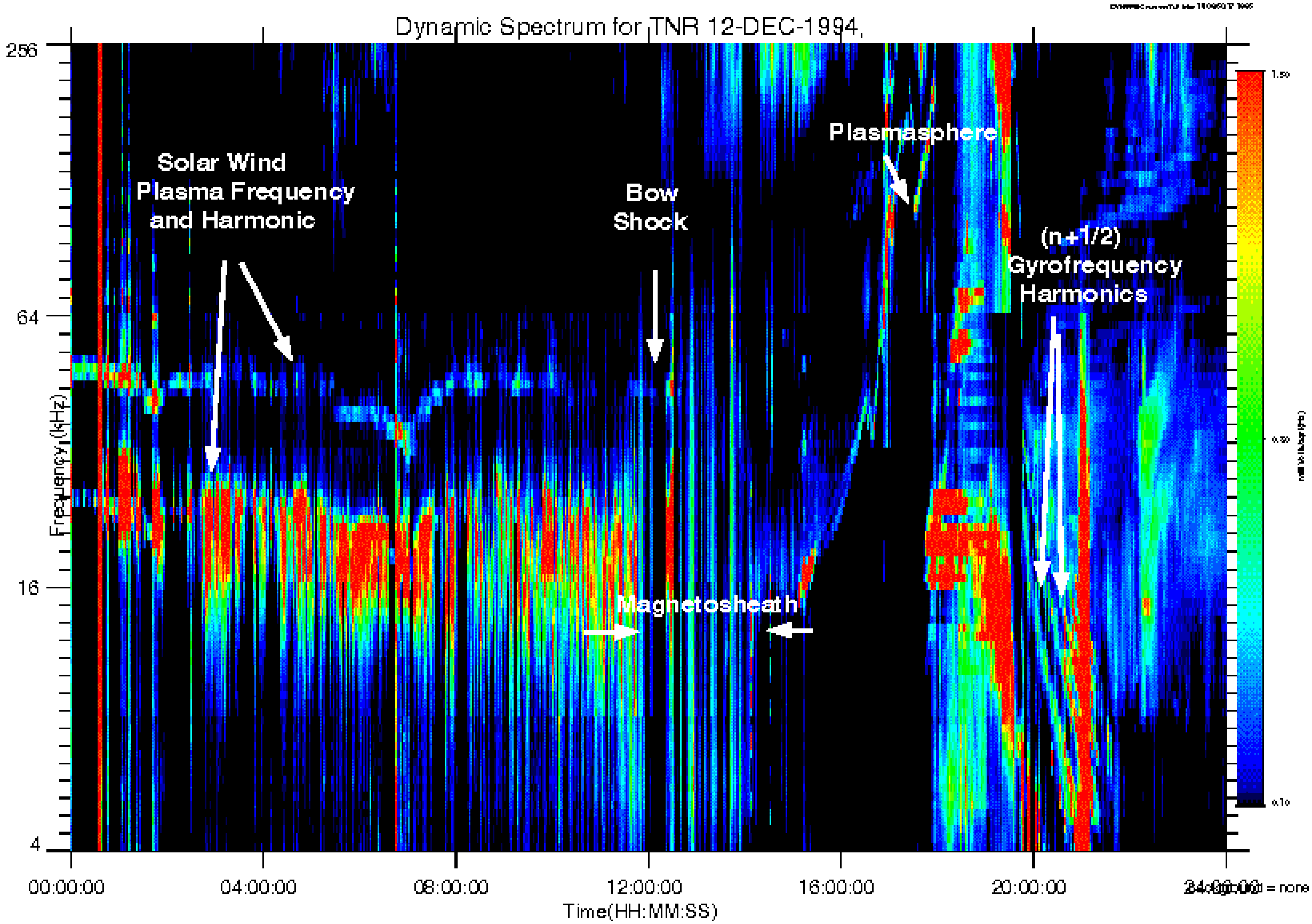


Positive CG Stroke, Peak Current = +57.2 kAmps. Rocket Altitude = 295 km
0.01
0.005
0
−0.005
−0.01
E_x (Volts/Meter)
5 kHz
2
1 kHz
0.5 kHz
250 Hz
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
Time in Seconds After NLDN Detection (seconds)
20
15
10
5
0
Frequency in kHz
0
10
20
30
40
50
60
70
80
90
Time in milliseconds after NLDN detection



Voyager-1 PWS
16269.50 79 060 1225:23.956
10
8
6
4
2
0
frequency (kHz)
0
20
40
60
80
100
120
140
relative time (s)

WAVES Thermal Noise Receiver (TNR)



Problem Set #1:

Goertz&Strangeway (K&R Chapter 12):

Problems 12.1-12.6

(due Jan 16, 2013)

Many more examples

- Why are you taking this class?
- (more examples see view graphs)
- Then: firehose instability example