It remains for us to see what sustains the electric field E_x which we presupposed was there. As $\mathbf{E}_1$ fluctuates, the ions' inertia causes them

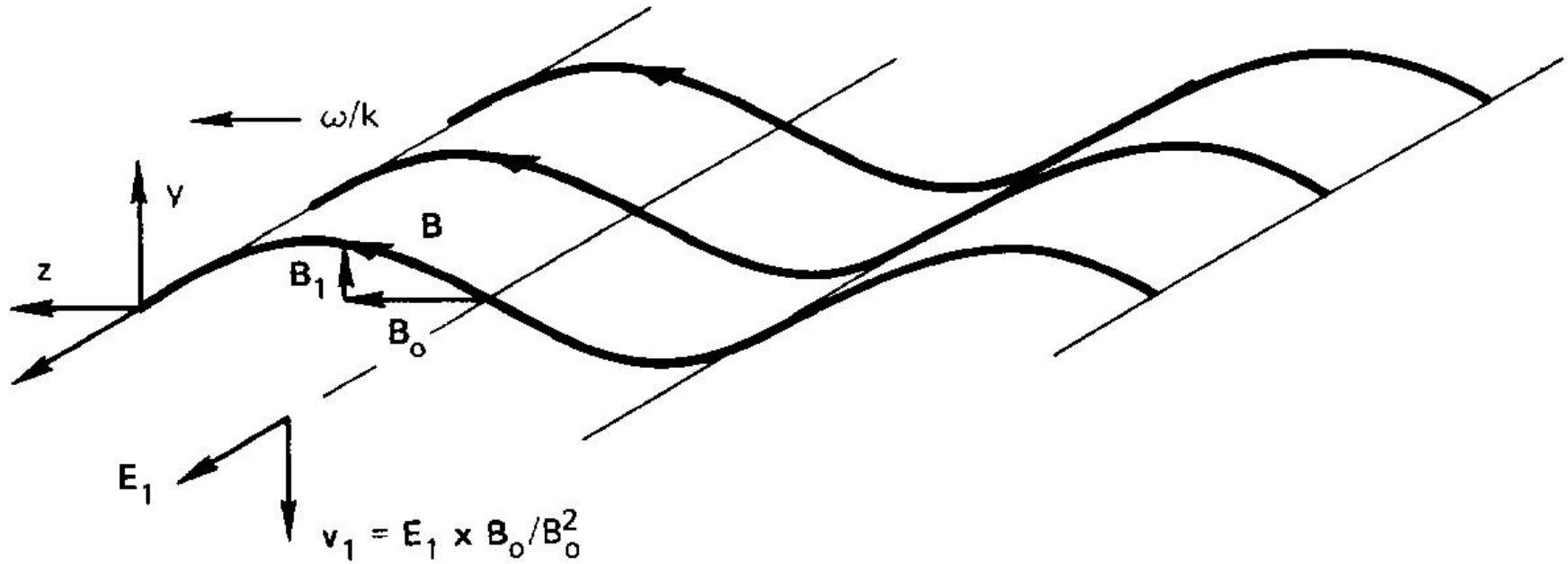


FIGURE 4-46 **Relation among the oscillating quantities in an Alfvén wave and the (exaggerated) distortion of the lines of force.**

Chen, p. 139

given by

$$\nabla \times \mathbf{E}_1 = -\dot{\mathbf{B}}_1 \qquad E_x = (\omega/k)B_y \qquad [4\text{-}128]$$

The small component B_y, when added to $\mathbf{B}_0$, gives the lines of force a sinusoidal ripple, shown exaggerated in Fig. 4-46. At the point shown, B_y is in the positive y direction, so, according to Eq. [4-128], E_x is in the positive x direction if ω/k is in the z direction. The electric field E_x gives the plasma an $\mathbf{E}_1 \times \mathbf{B}_0$ drift in the negative y direction. Since we have taken the limit $\omega^2 \ll \Omega_c^2$, both ions and electrons will have the same drift v_y, according to Eqs. [4-120] and [4-121]. Thus, the fluid moves up and down in the y direction, as previously indicated in Fig. 4-45. The magnitude of this velocity is $|E_x/B_0|$. Since the ripple in the field is moving by at the phase velocity ω/k, the line of force is also moving downward at the point indicated in Fig. 4-46. The downward velocity of the line of force is $(\omega/k)|B_y/B_0|$, which, according to Eq. [4-128], is just equal to the fluid velocity $|E_x/B_0|$. Thus, the fluid and the field lines oscillate together *as if the particles were stuck to the lines*. The lines of force act as if they were mass-loaded strings under tension, and an Alfvén wave can be regarded as the propagating disturbance occurring when the strings are plucked. This concept of plasma frozen to lines of force and moving with them is a useful one for understanding many low-frequency plasma phenomena. It can be shown that this notion is an accurate one as long as there is no electric field *along* $\mathbf{B}$.

It remains for us to see what sustains the electric field E_x which we presupposed was there. As $\mathbf{E}_1$ fluctuates, the ions' inertia causes them

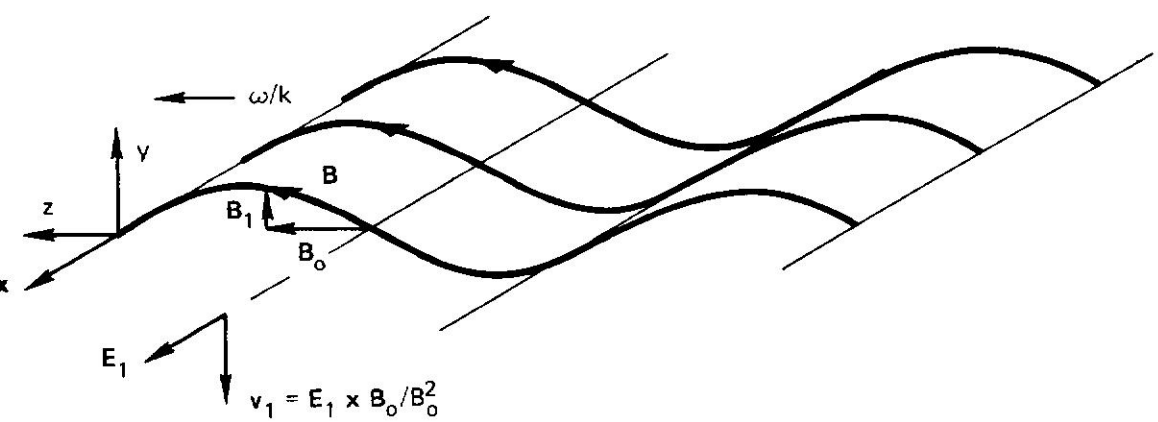


FIGURE 4-46 **Relation among the oscillating quantities in an Alfvén wave and the (exaggerated) distortion of the lines of force.**

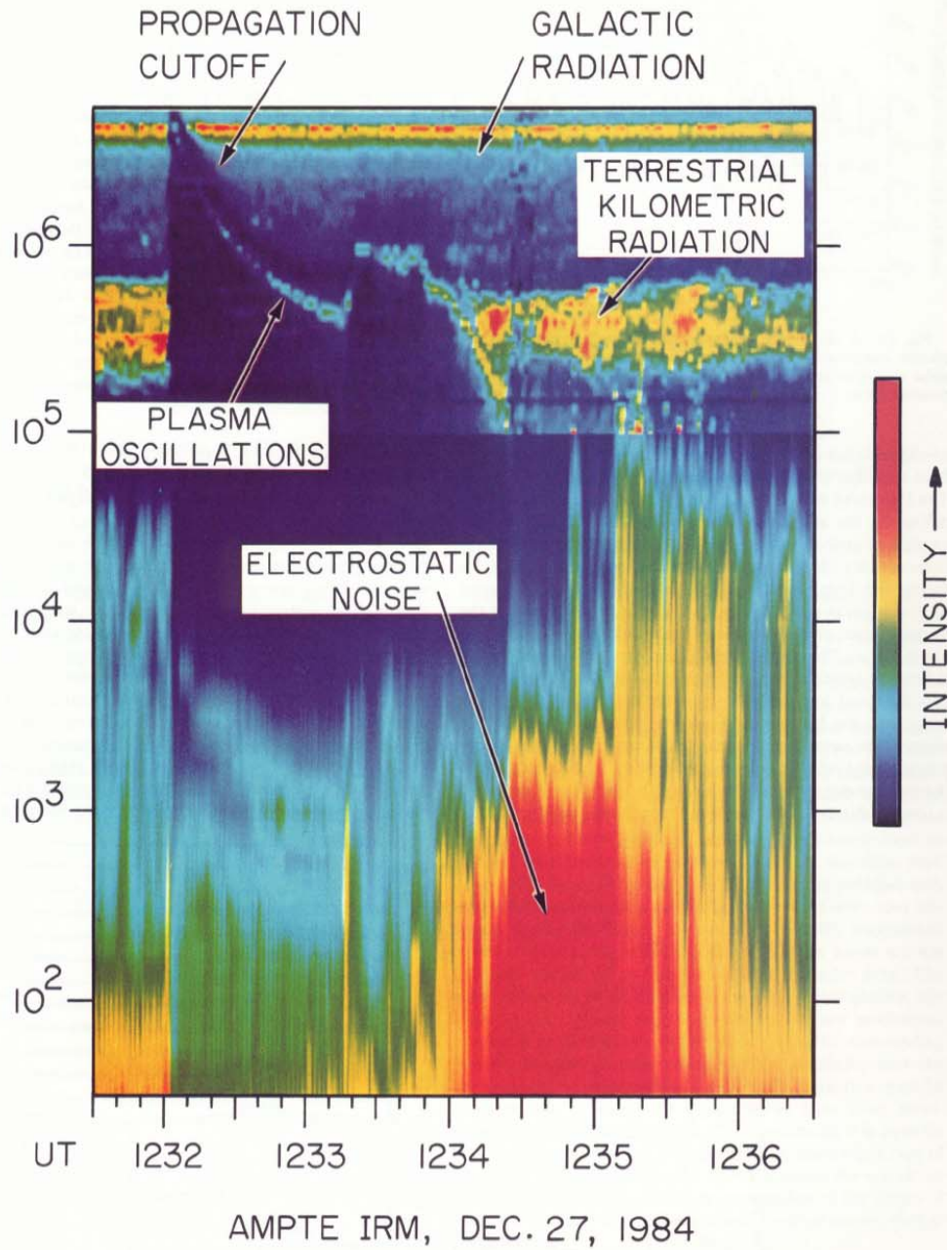


Plate 1. A frequency-time spectrogram from the high-frequency sweep-frequency receiver. The intensity scale is adjusted as a function of frequency so that the dynamic range extends from the instrument noise level (blue) to the saturation level (red). The dense plasma cloud formed by the explosion at 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}.

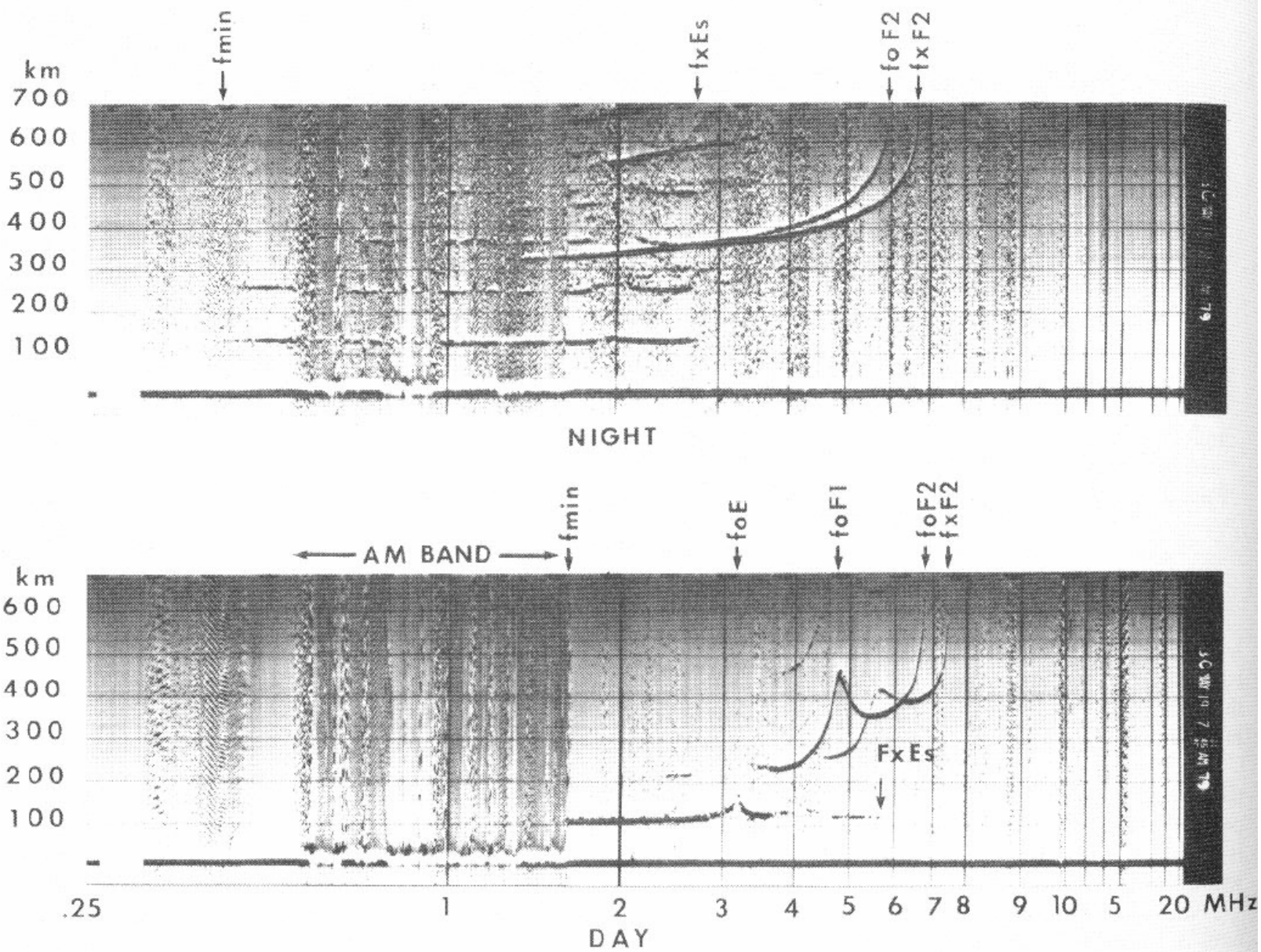
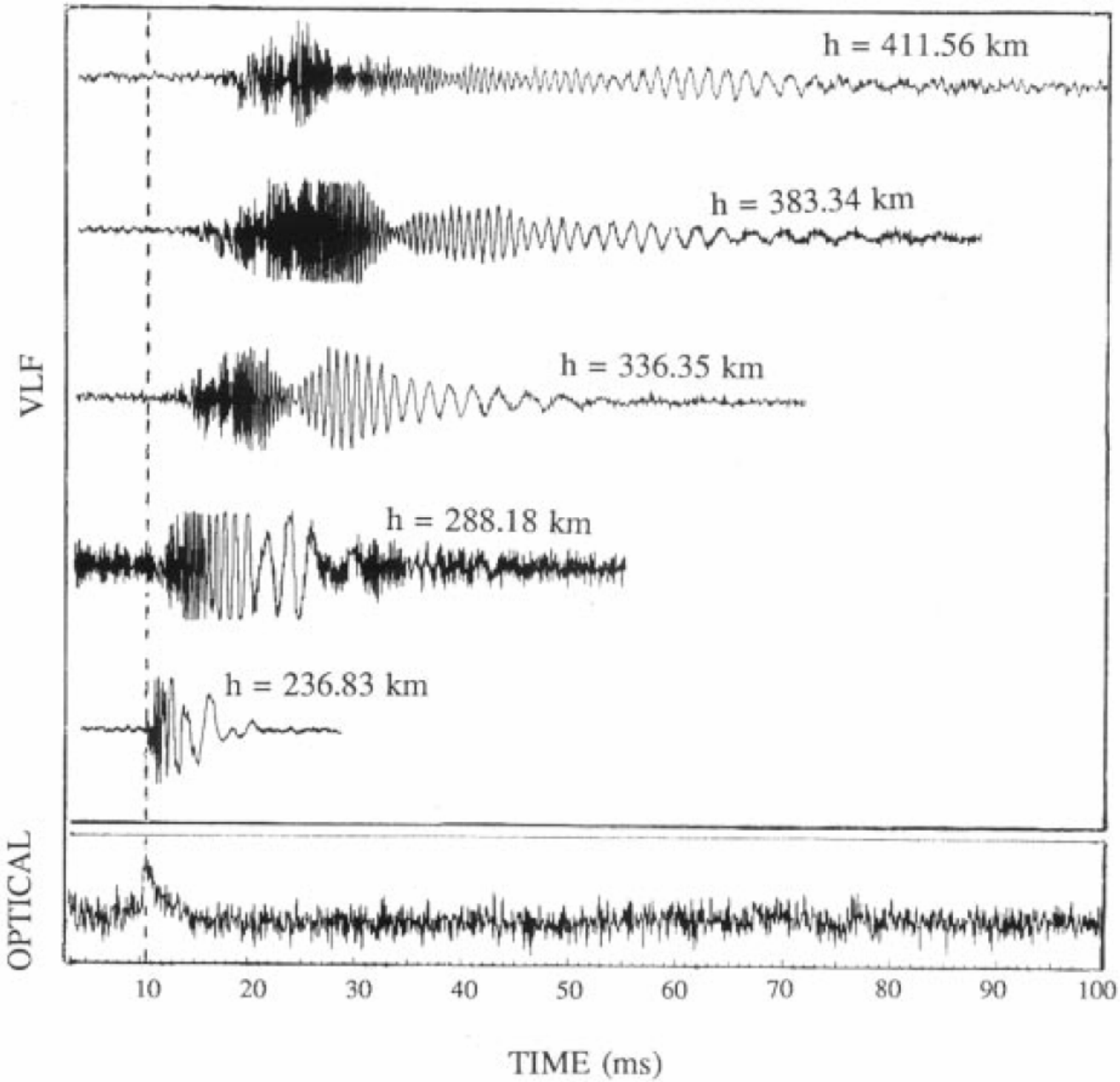
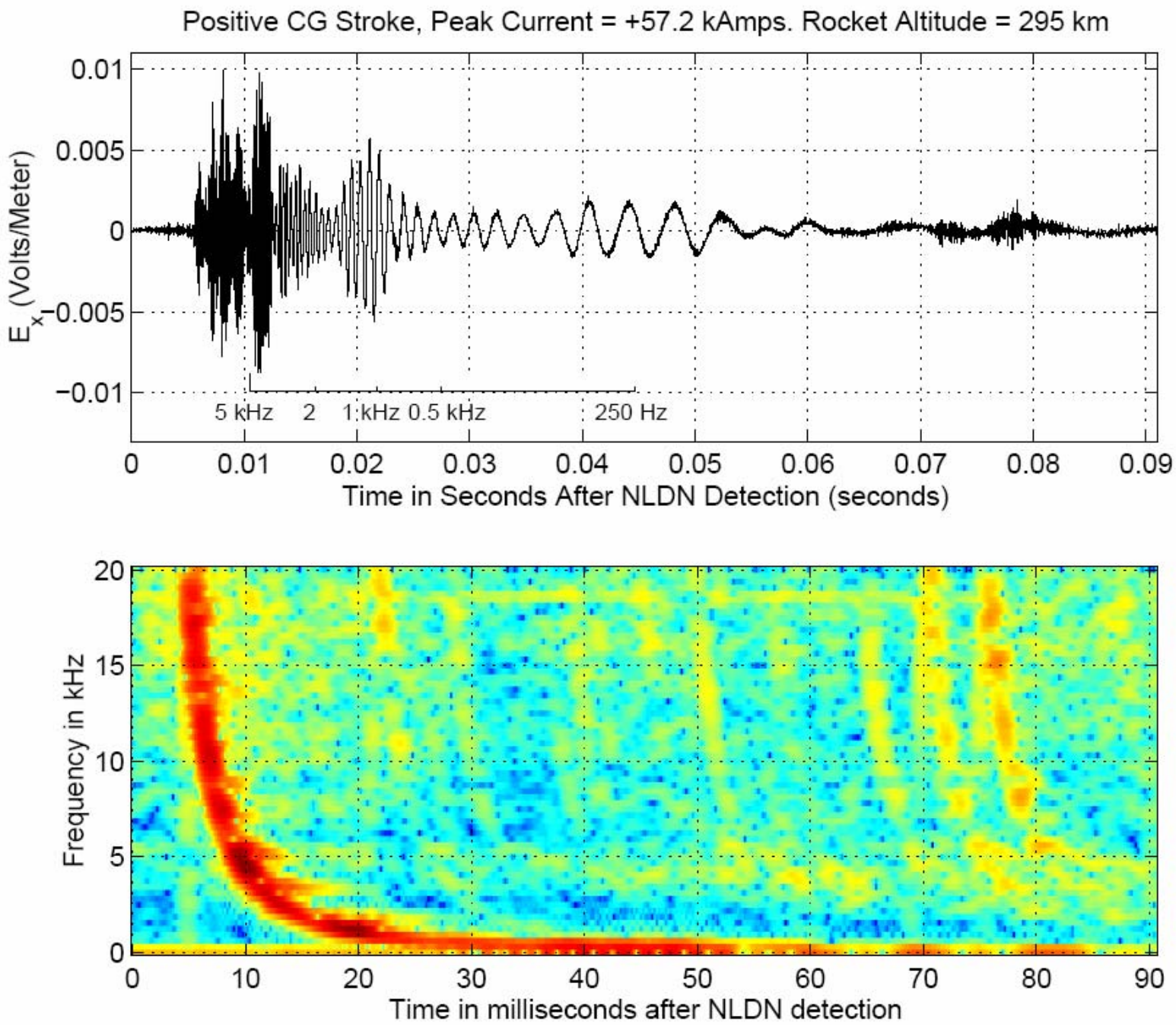
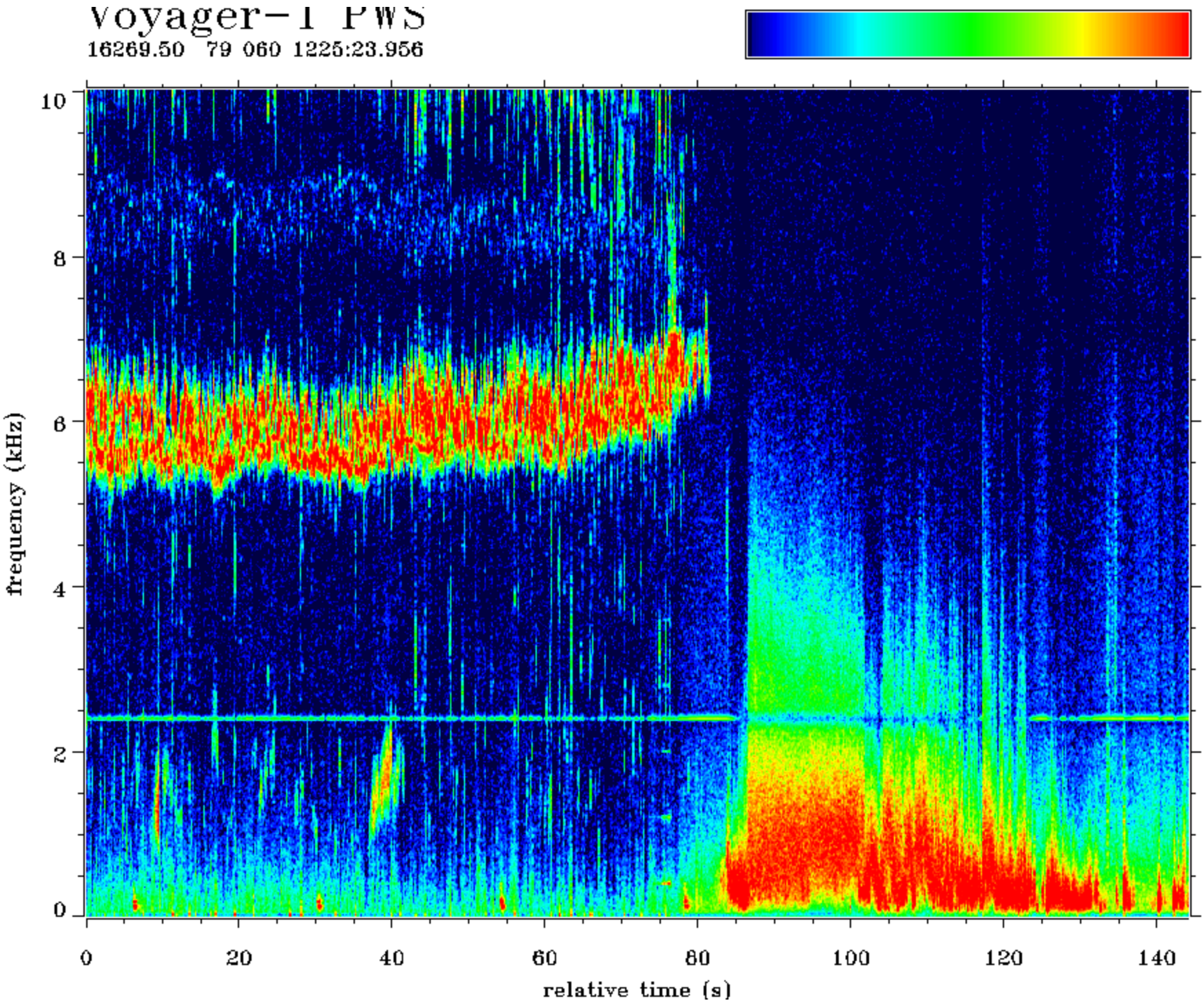


Figure 10-1. Typical midlatitude day and nighttime ionograms, recorded by a C-4 ionosonde at Boulder, Colorado. The daytime ionogram shows reflections from E, Es, F1 and F2 layers; the nighttime ionogram those from Es and F2 layers.

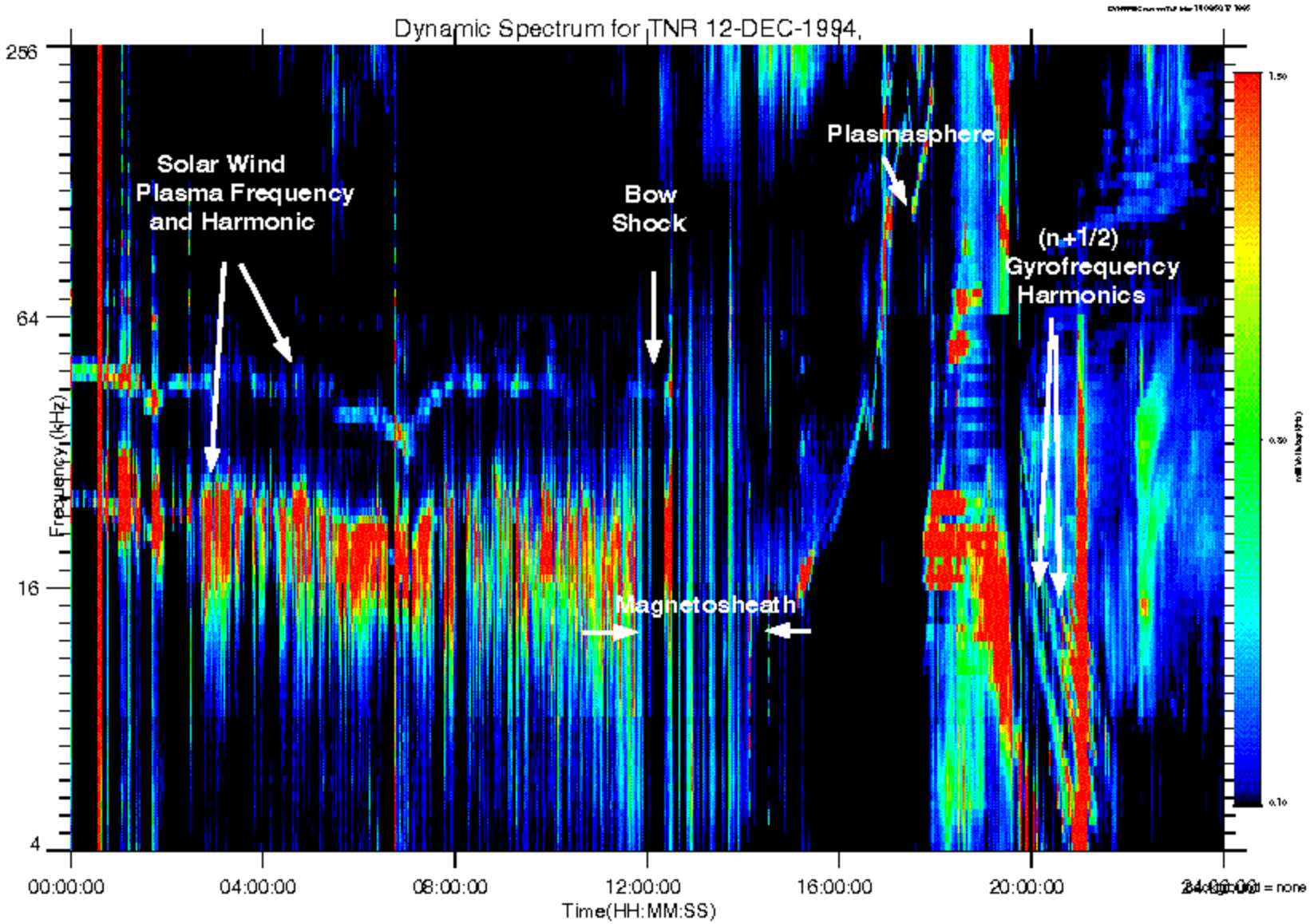
WIPP ROCKET DATA (July 31, 1987)




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
frequency (kHz)
10
8
6
4
2
0
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 12.1-12.11
(due in ~2 weeks)

Many more examples

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