Challenges in the Understanding of Auroral Acceleration Physics

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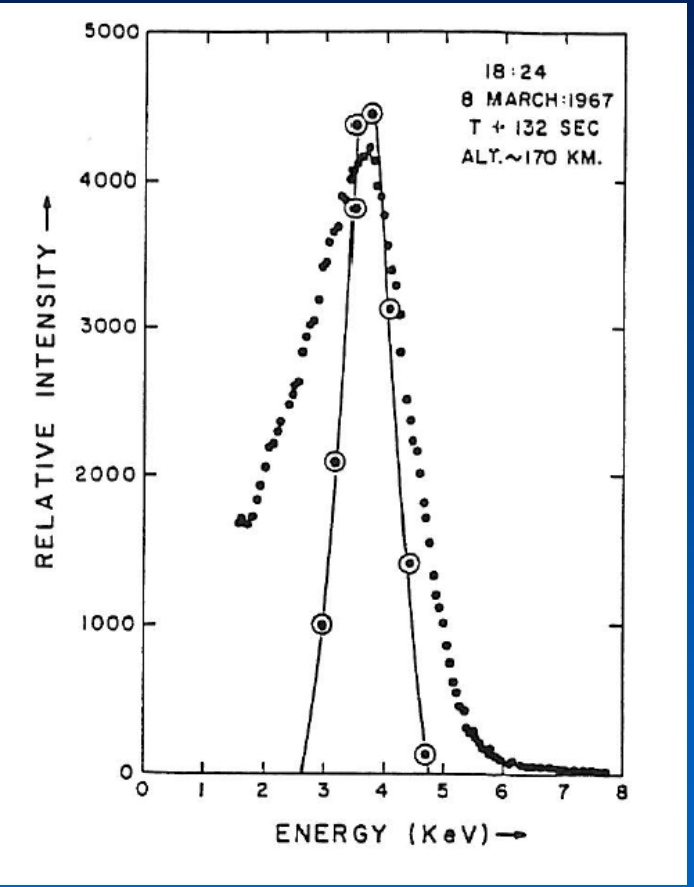
What We Do Know – A Lot!

- ‘Mono-energetic’ electron precipitation causes the aurora.
- Parallel current plus converging field lines requires a potential drop.
- Both upward and downward currents play a role, but the two regions are different.
- Background parameters: both ionospheric and plasma sheet source populations.
- Alfven waves play a key role.

Early Measurements

- From McIlwain, 1960: “The presence of monoenergetic electrons strongly suggests an electrostatic acceleration mechanism."



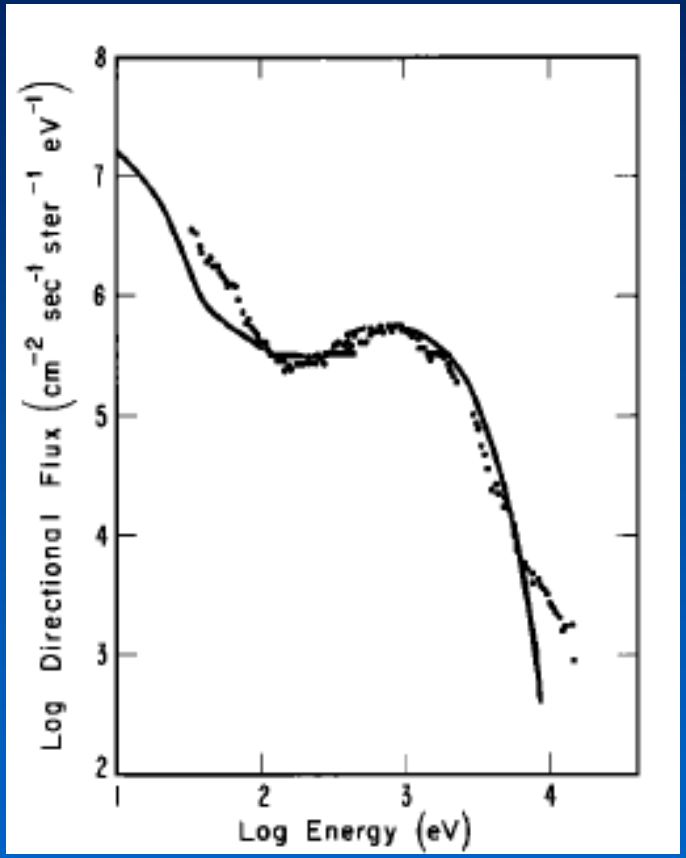
Kletzing et al., [1998]

Establishing $E_{||}$

- To get j|| to the ionosphere, a potential drop was required.
- Magnetic mirror below and electrostatic mirror above explained observations.

$$j_{\parallel,i}(\Delta\Phi) = -en_m\left(\frac{k_B T}{2\pi m_e}\right)^{\frac{1}{2}} R_B \left[1-\left(1-R_B^{-1}\right)\exp\left\{-\frac{e\Delta\Phi}{k_B T_m (R_B-1)}\right\}\right],$$

Knight, [1973]



Evans, [1968]

Upward Cuurent Region

1. Upward current region

J

2. Converging electrostatic shocks.

E E

3. Large-scale density cavity

n_e

4. Down-going, “inverted-V” and field-aligned electrons.

e^-

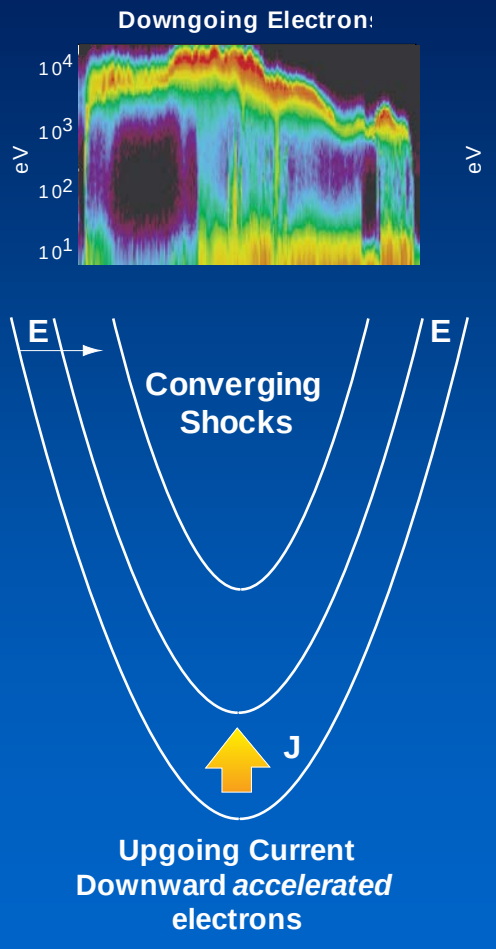
5. Up-going ion beams. Ion conics.

i^+

6. Large-amplitude ion cyclotron waves and electric field turbulence.

7. Nonlinear time-domain structures associated with ion wave modes.

8. AKR source region.



Downward Cuurent Region

1. Downward current region.

2. Diverging electrostatic shocks.

3. Small-scale density cavities.

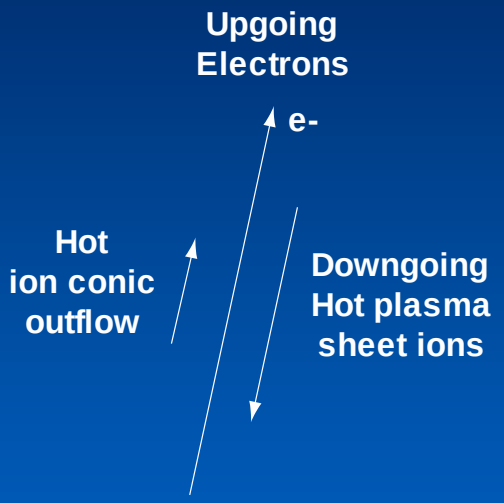
4. Up-going, field-aligned electrons. Counter-streaming electrons.

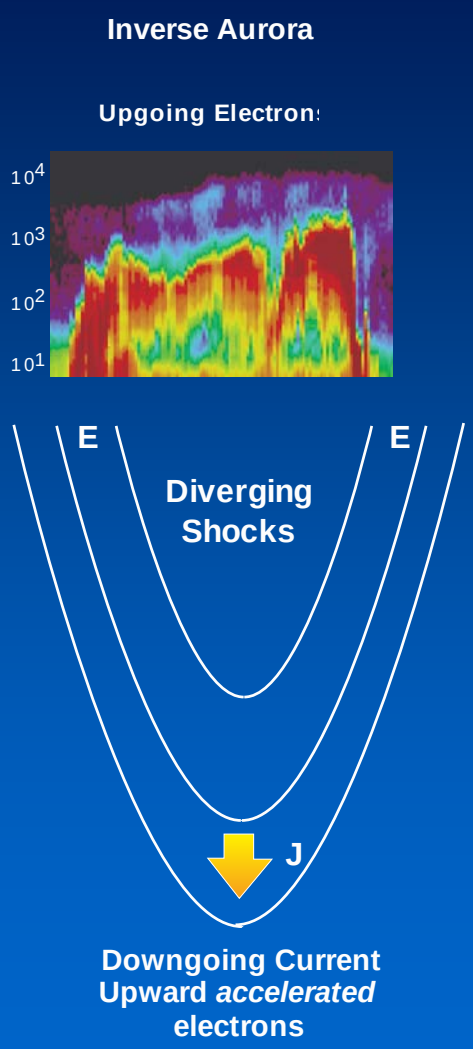
5. Ion heating transverse to **B**. Energetic ion conics.

6. ELF electric field turbulence. Ion cyclotron waves.

7. Fast solitary waves: three-dimensional, rapidly moving electron holes.

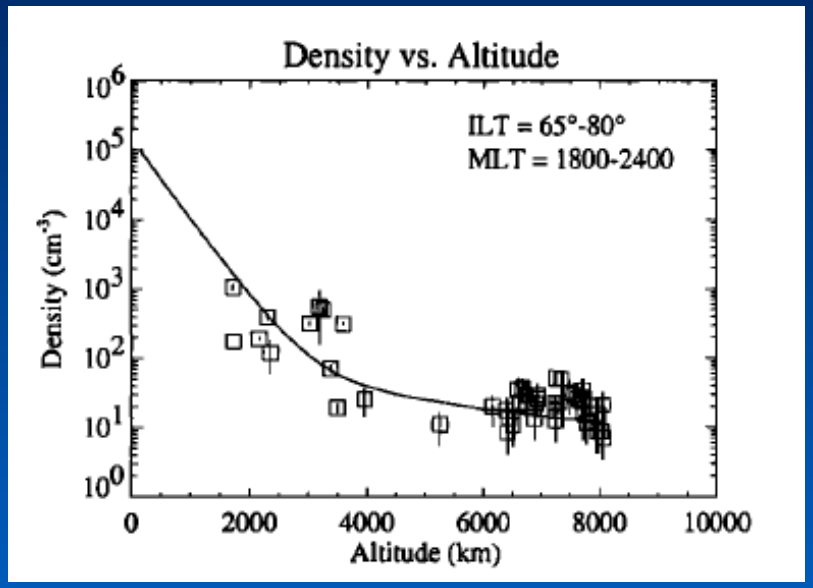
8. VLF saucer source region.





Densities and Temperatures

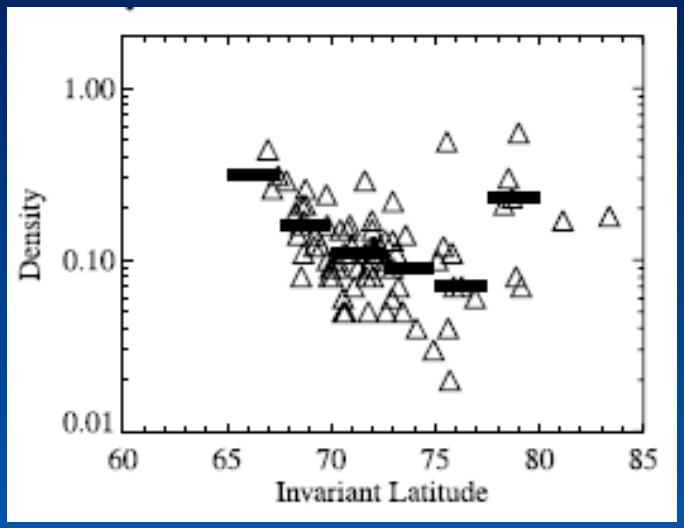
Acceleration Region

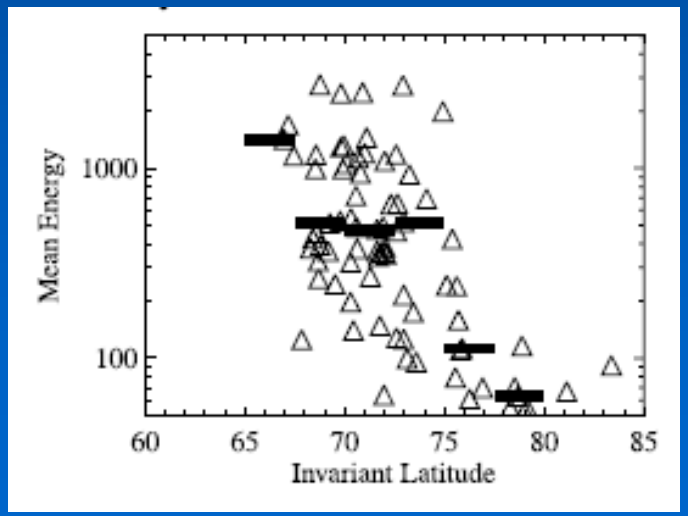


$$n(z) = n_0 e^{-(z-z_0)/h} + n_1 z^{-1.55}$$

Kletzing et al., [1998]

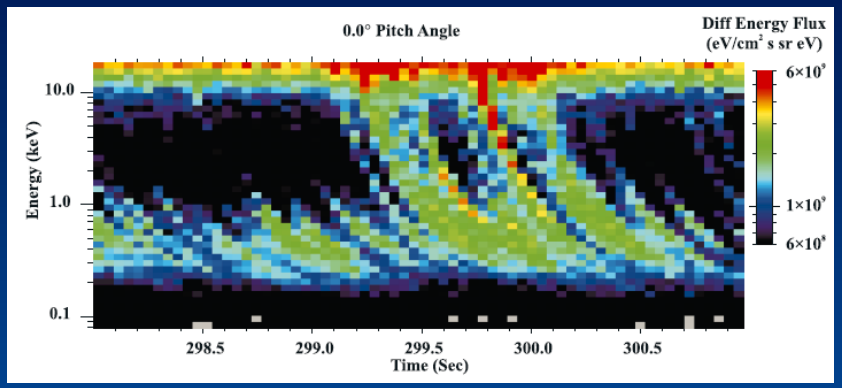
Source Region

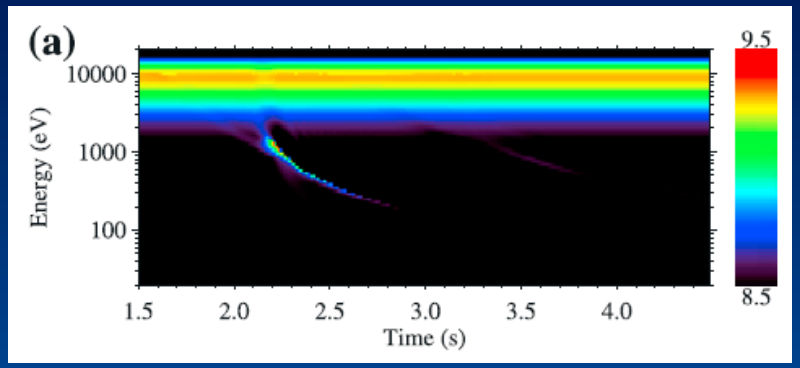




Kletzing et al., [2003]

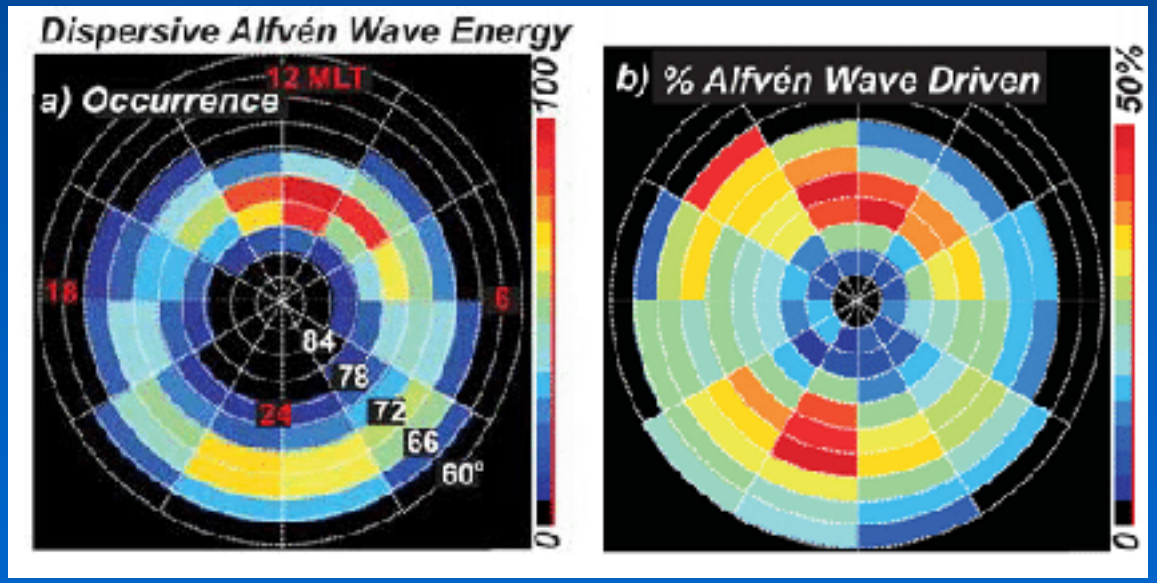
Alfven Waves





Chen et al., [2005]

- Time dispersed electrons indicate Alfven waves.
- FAST survey shows they are ubiquitous.



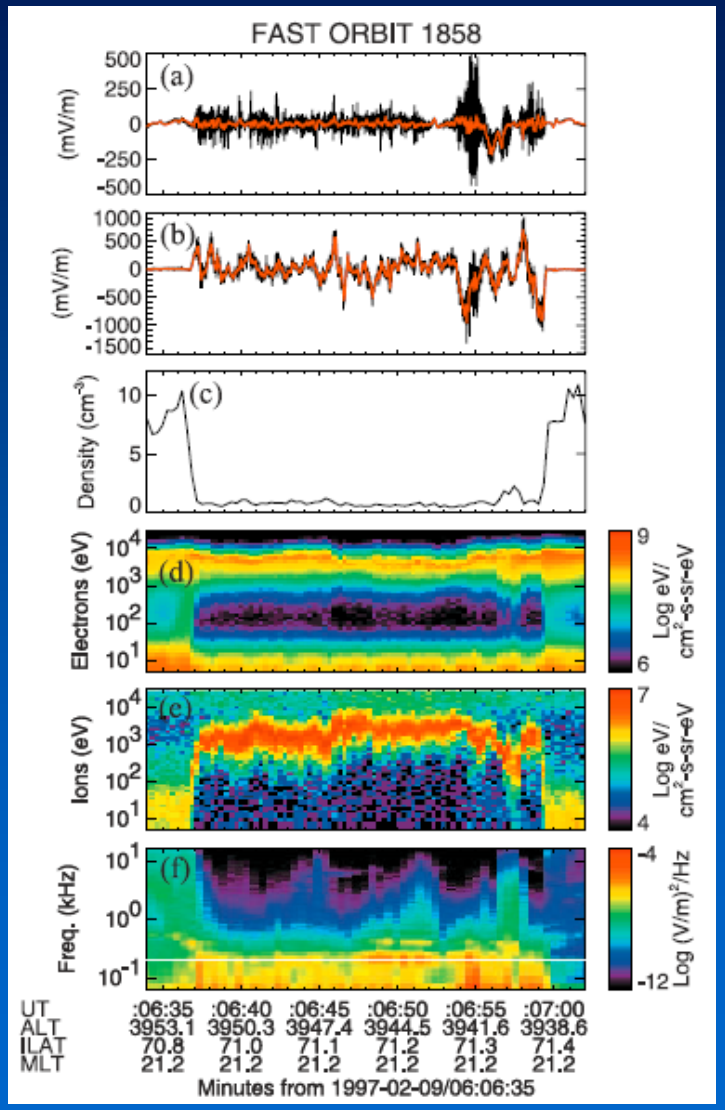
Chaston et al., [2007]

What We Don't Know

- What is the distribution of the potential drop along the magnetic field?
- How/Do inertial scale Alfven waves evolve to establish a quasi-static potential drop?
- How do we construct a self-consistent model of the plasma along a field line.
- What are the details of current closure through the ionosphere.

Potential Along Field Line

- How to determine this?
- Particle distributions: Chiu and Schultz, [1978], Ergun, [2004]
- Direct measurements?



$E_{||}$

$E_{\perp}$

ni (>5keV)

electrons

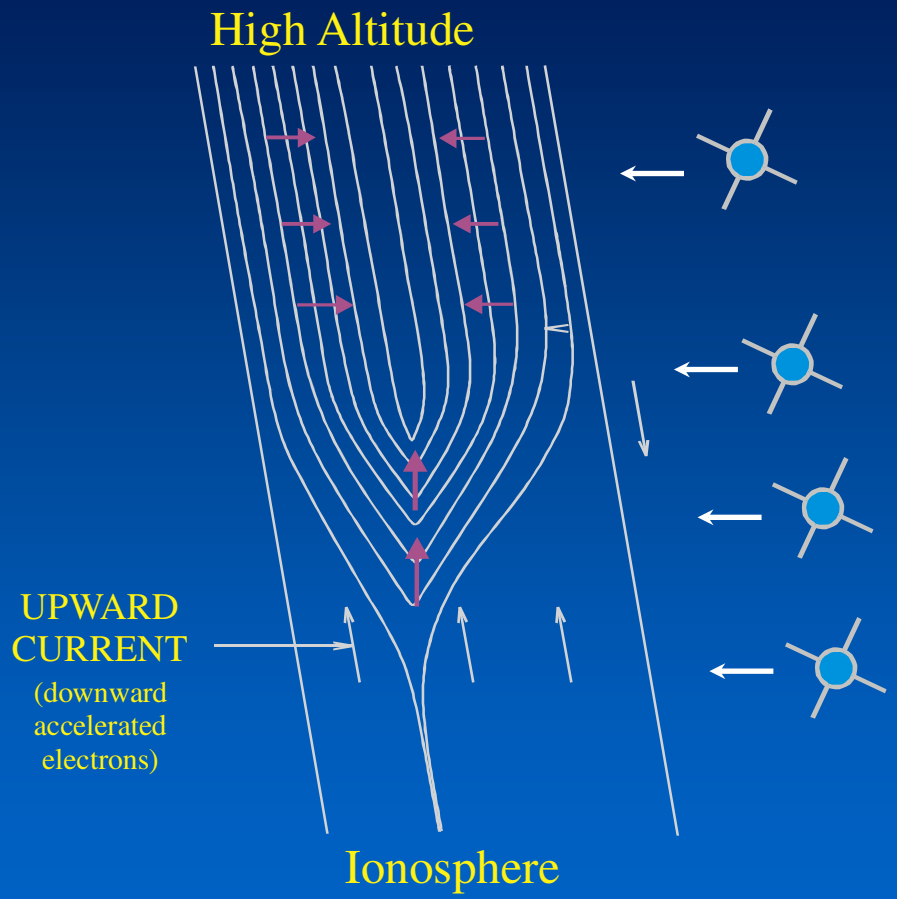
ions

waves

Ergun, [2004]

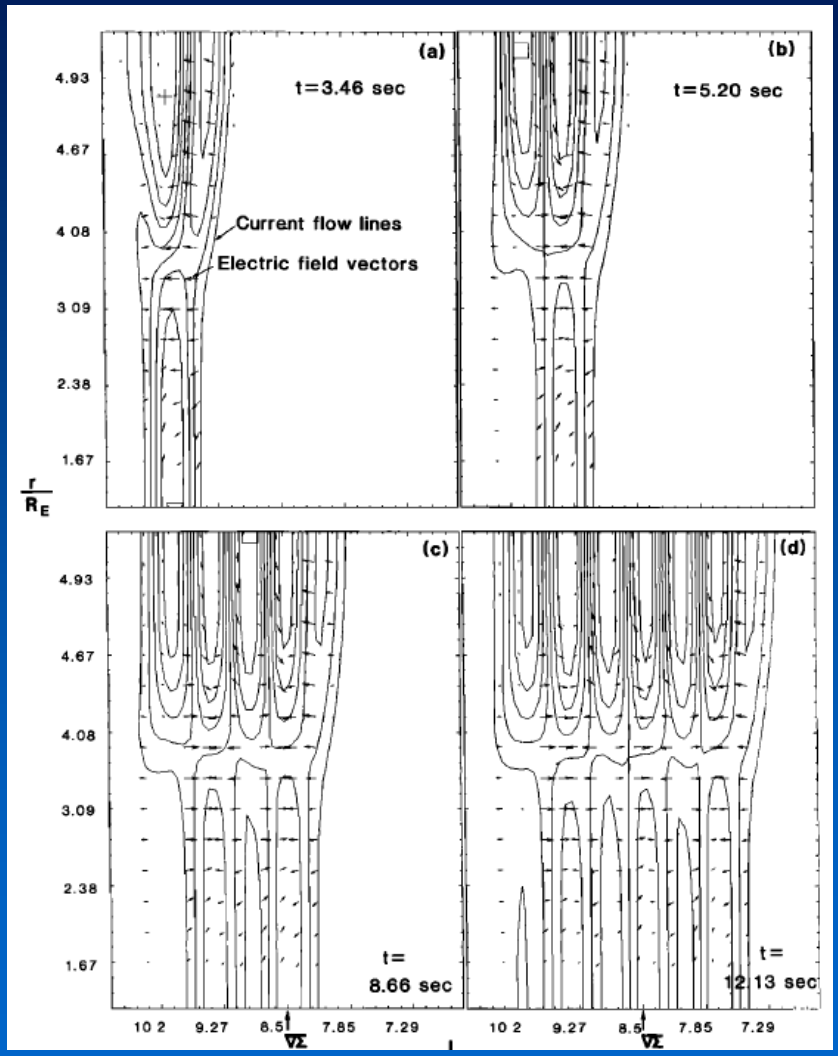
Measuring Potential Drop

- How to determine this?
- Particle distributions: Chiu and Schultz, [1978], Ergun, [2004]
- Direct measurements?



Alfven Waves & Stable Arcs

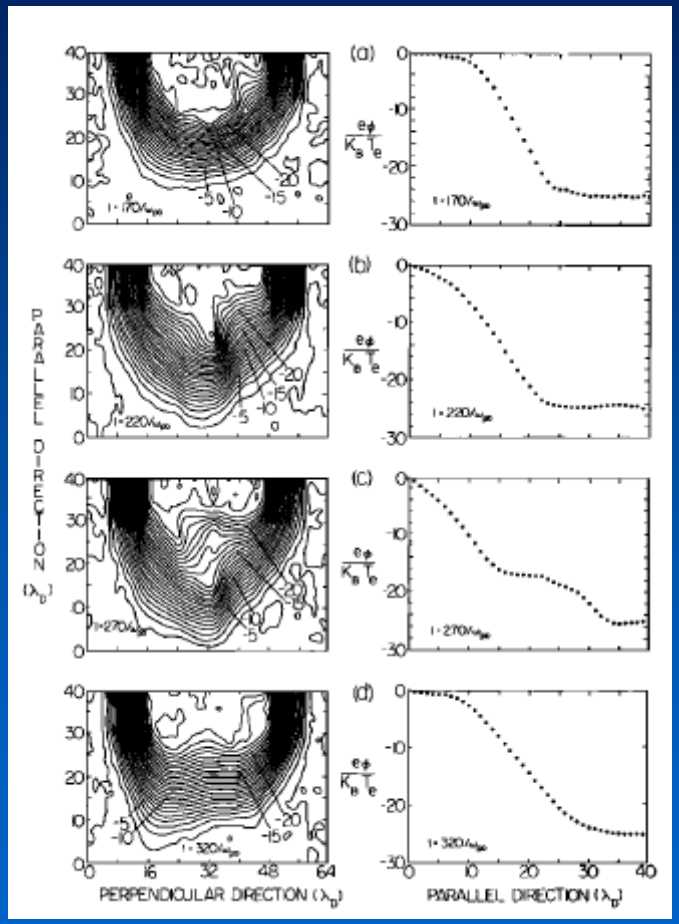
- What is the connection?
- Do Alfven waves evolve to ‘stable’ arcs?
- If so, how does this happen?



Lysak, [1985]

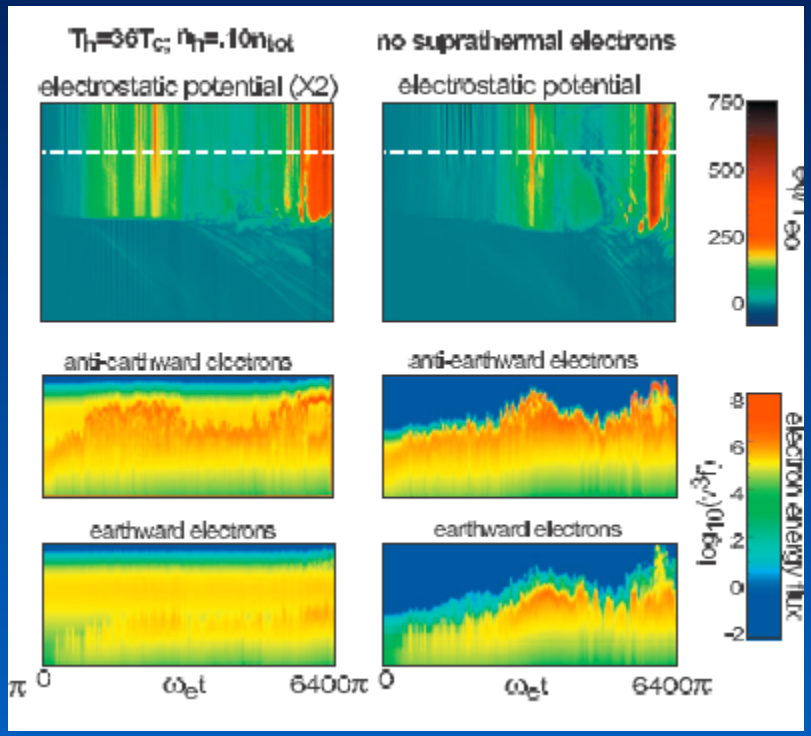
Acceleration Region Model

Then



Borovsky and Joyce, [1983]

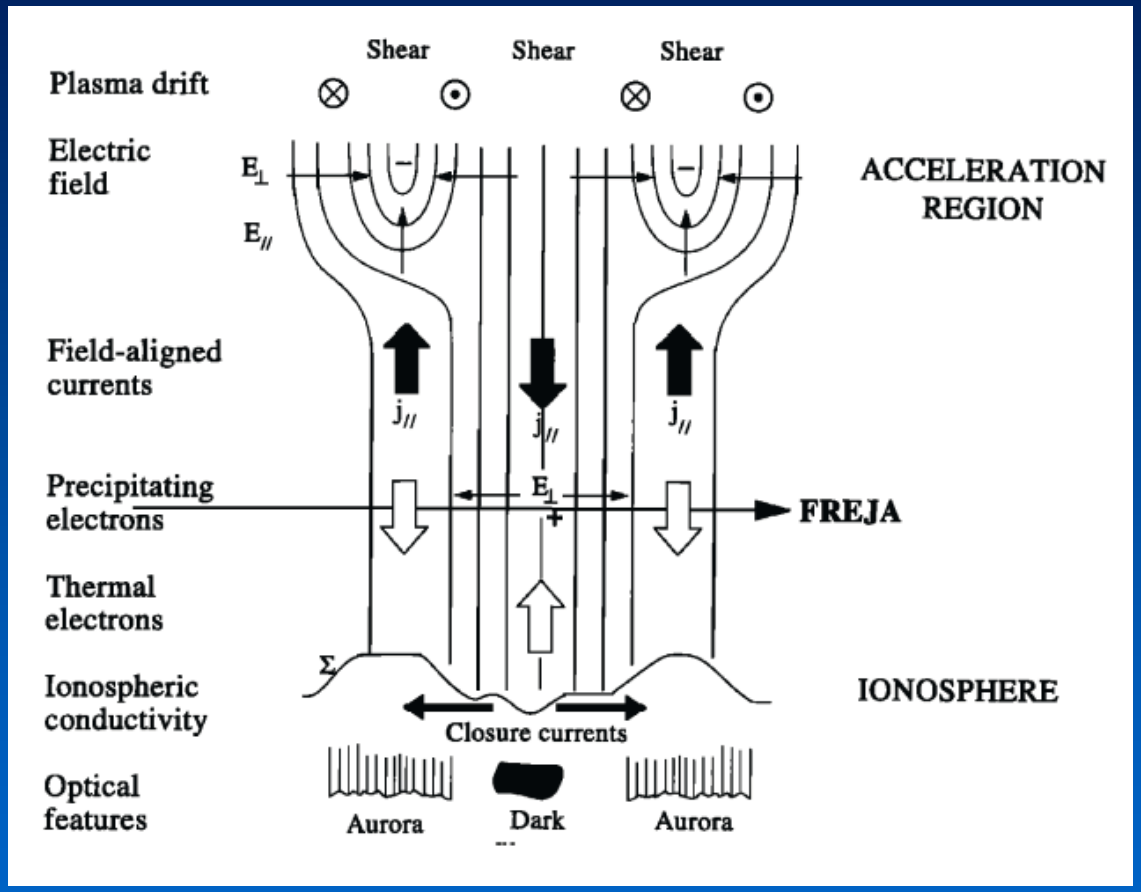
Now



Newman et al., [2008]

- Only small region of field line modelled.
- Not self-consistent.
- Current or voltage driven?

Current Closure



- Can ionization, electric fields and currents be self-consistently modeled?
- Downward region should be much lower density, but rarely observed.

Marklund et al., [1997]

Problems to Work On

- What is the distribution of the potential drop along the magnetic field? – *Need multipoint measurements*
- How/Do inertial scale Alfven waves evolve to establish a quasi-static potential drop? - *More realistic models needed*
- How do we construct a self-consistent model of the plasma along a field line. – *Large simulations?*
- What are the details of current closure through the ionosphere. – *More measurements and models*.

That’s all folks!