INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

H4.SMR/645-13

SCHOOL ON PHYSICAL METHODS FOR THE STUDY OF THE UPPER AND LOWER ATMOSPHERE SYSTEM

26 October - 6 November 1992
Miramare - Trieste, Italy

Magnetosphere

J. Roederer
Geophysical Institute
University of Alaska
Fairbanks, Alaska
USA

MAIN BUILDING Strada Costiera, 11 Tel. 22401 Telefax 224163 Telex 460392 ADRIATICO GUEST HOUSE Via Grignano, 9 Tel. 224241 Telefax 224531 Telex 460449
MICROPROCESSOR LAB. Via Beirut, 31 Tel. 224471 Telefax 224600 Telex 460392 GALILEO GUEST HOUSE Via Beirut, 7 Tel. 22401 Telefax 224559 Telex 460392

MAGNETOSPHERE

SYNOPSIS
- Principal regions
- Principal processes and problems

MODELING
- B-field, mapping
- E-field

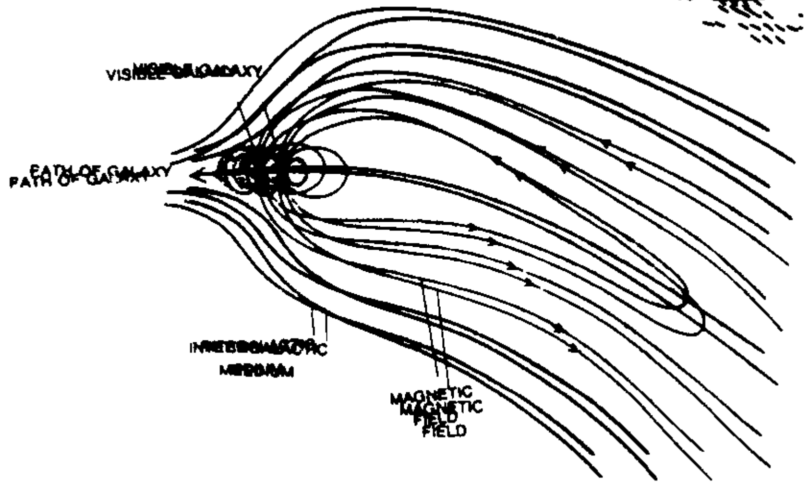
THEORY
- Collisionless plasmas
- Cartoon physics and real physics

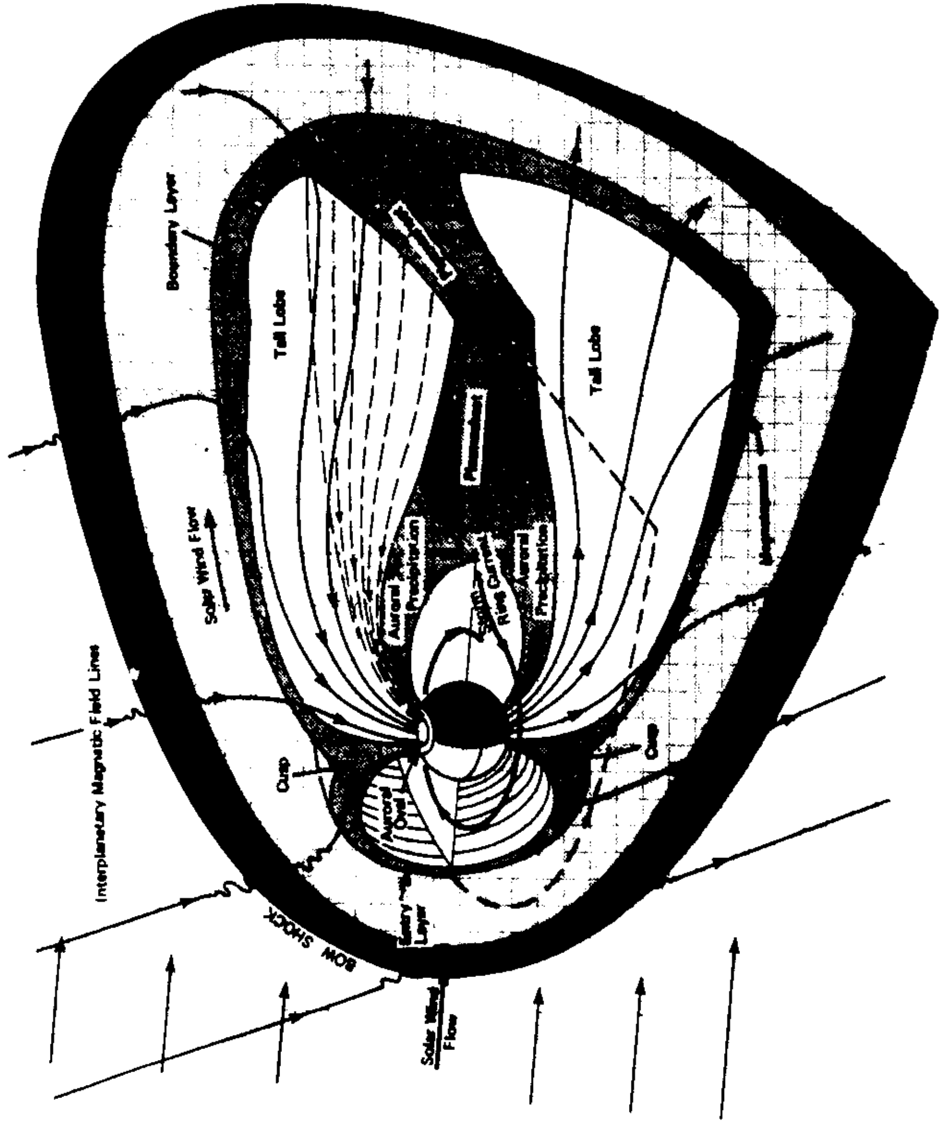
MEASUREMENTS
- From raw data to physical parameters:
- Magnetometers
- Particle detectors
- Data policies

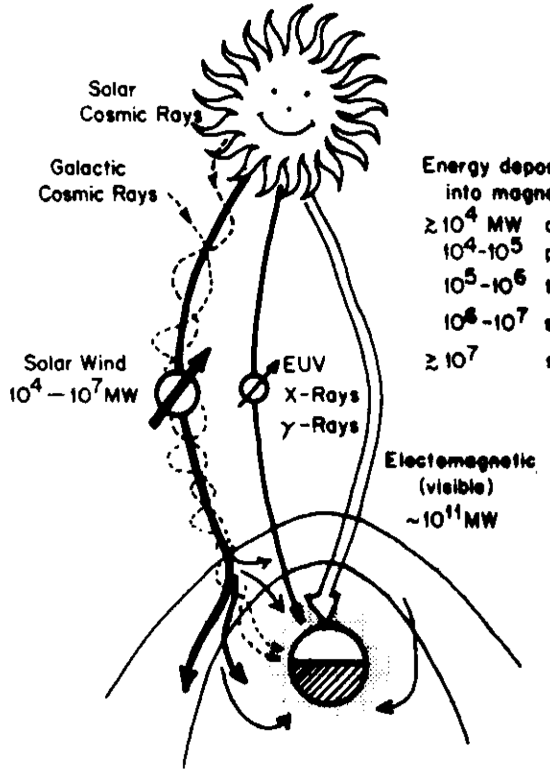
SIMULATION
- The "Affair à trois" in space plasma physics

OPPORTUNITIES
- Energetic electrons
- Convection
- Effects on technological systems
- Effects on biota
- STEP


NGC 1265
NGC 1265
10^7 Ly

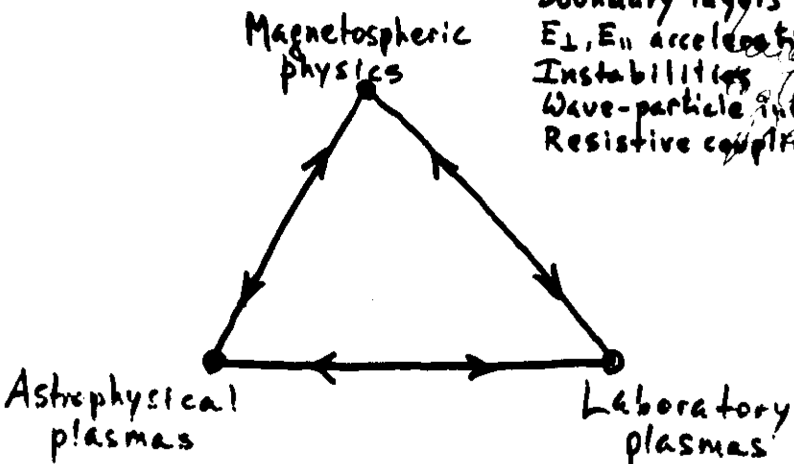

VISIBLE GALAXY
PATH OF GALAXY
INTERGALACTIC MEDIUM
MAGNETIC FIELD


Interplanetary Magnetic Field Lines
BOW SHOCK
Solar Wind Flow
Solar Wind Flow
Boundary Layer
Tail Lobe
Tail Lobe
Cusp
Cusp
Auroral Oval
Ring Current
Auroral Precipitation



Energy deposition rate into magnetosphere:

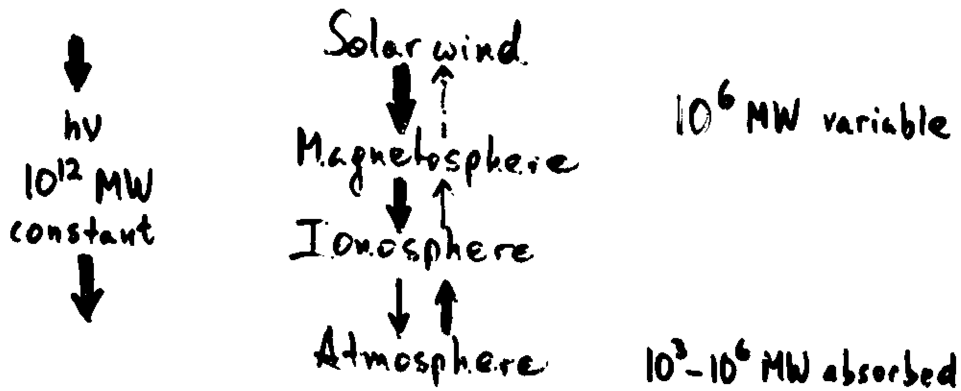
$\gtrsim 10^4$ MW	quiet
10^4-10^5	polar current enhancement
10^5-10^6	typical substorm
10^6-10^7	storm (Dst $\lesssim 100\gamma$)
$\gtrsim 10^7$	storm (Dst > 200γ)

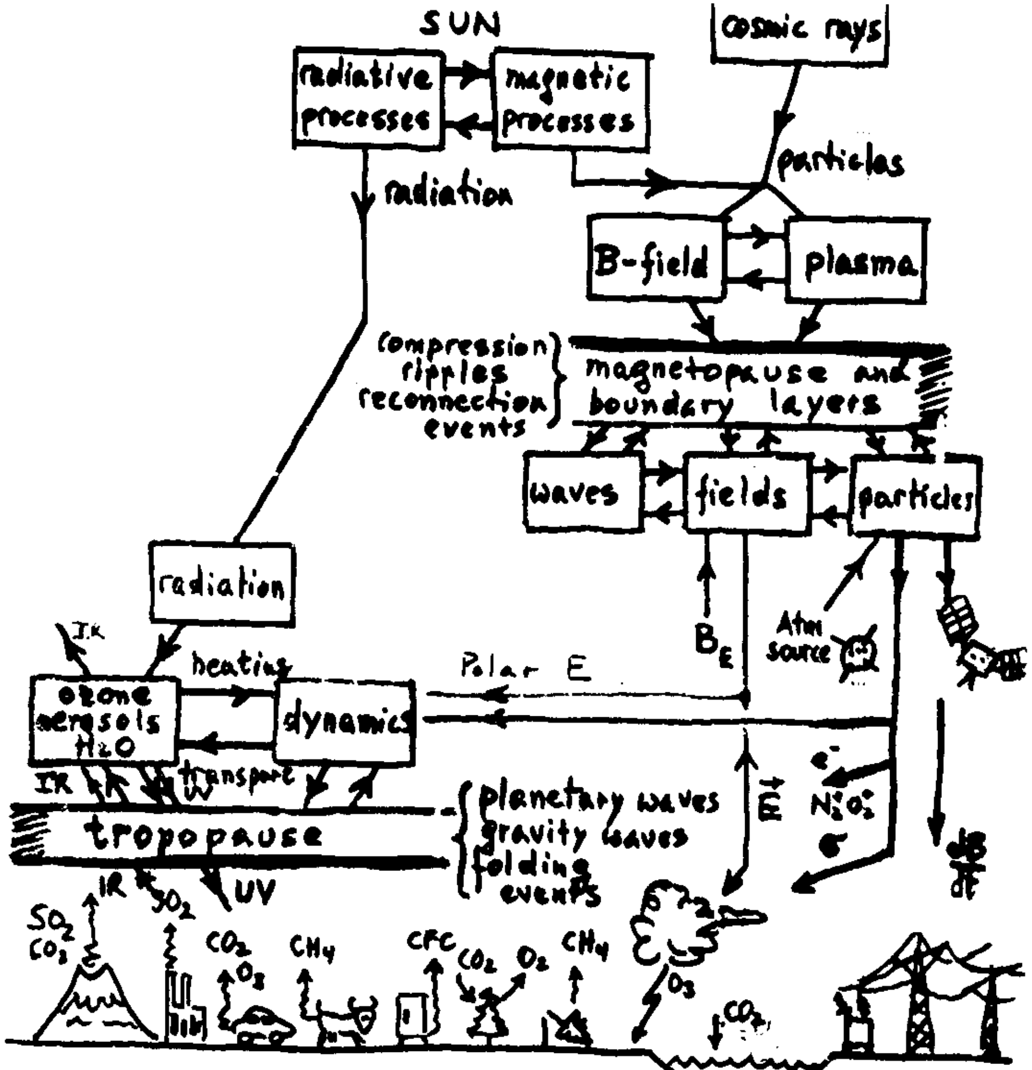


Collisionless plasma + shocks
Boundary layers
$E_\perp, E_\parallel$ acceleration
Instabilities
Wave-particle interactions
Resistive coupling

Stellar dynamos
Stellar atmospheres
Acceleration processes
Planetary formation
Neutron star envelopes
Distribution of galaxies

Confinement
Collisions
Scale



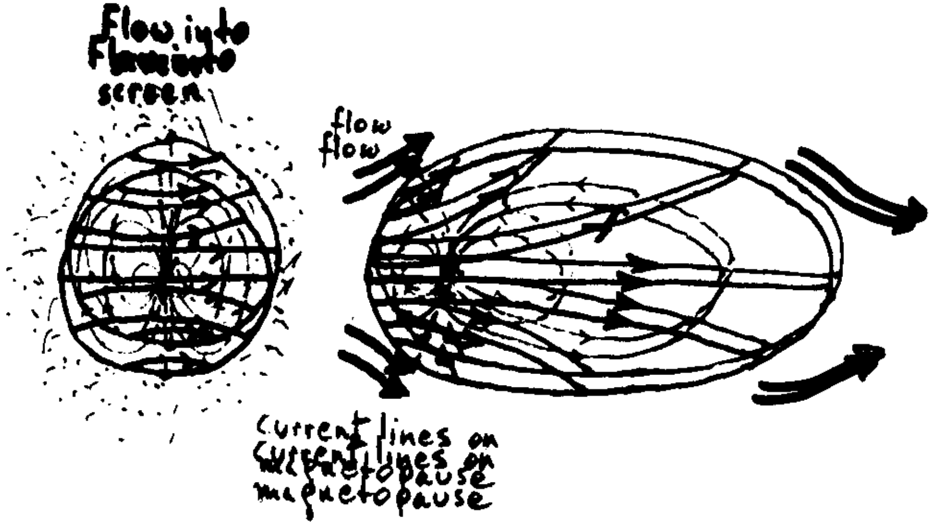


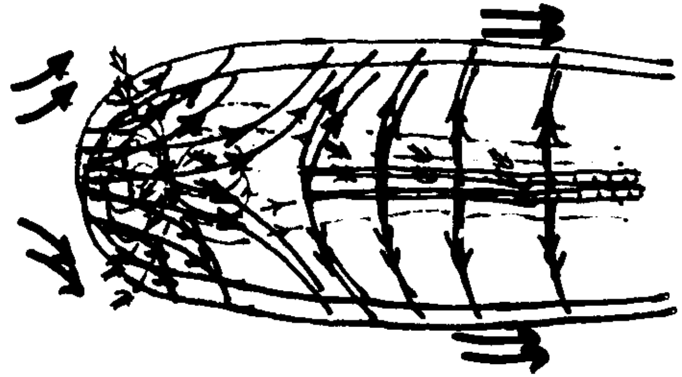
SUN, SOLAR WIND, COSMIC RAYS

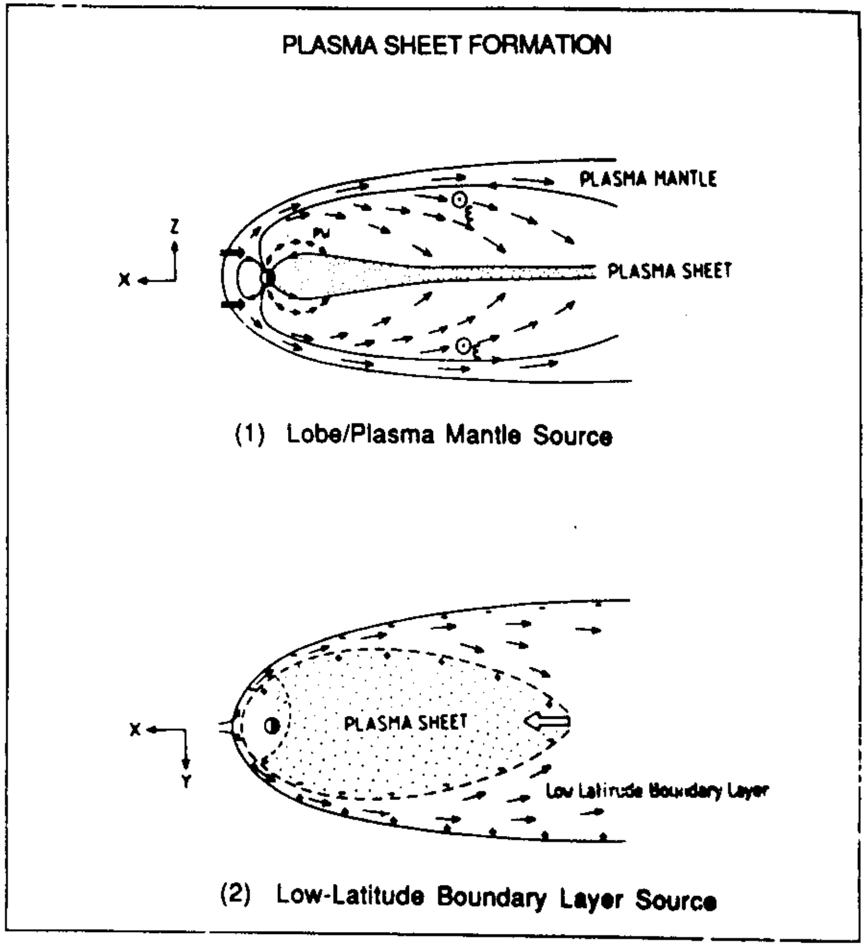
MAGNETOSPHERE, IONOSPHERE, THERMOSPHERE

MIDDLE ATMOSPHERE, STRATOSPHERE

TROPOSPHERE, ANTHROPOSPHERE, BIOSPHERE

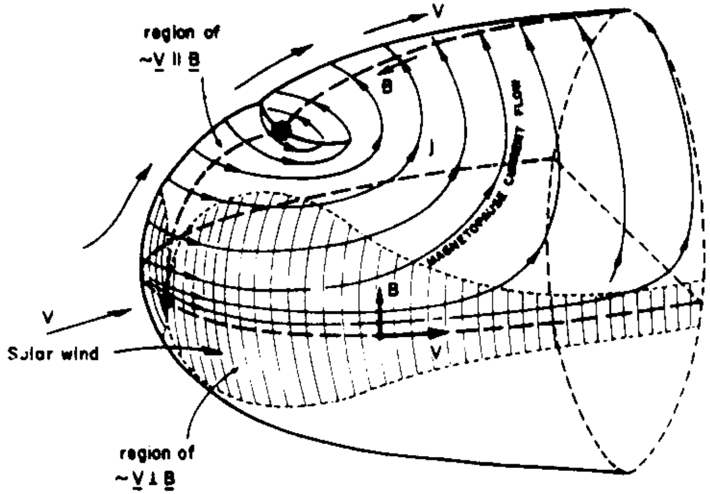


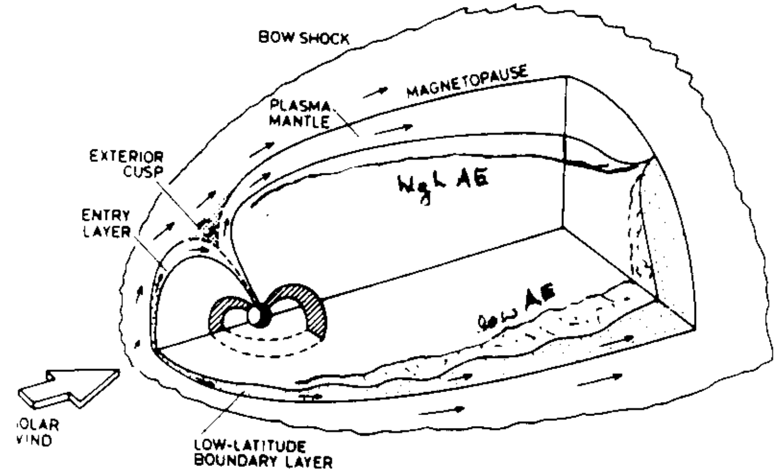


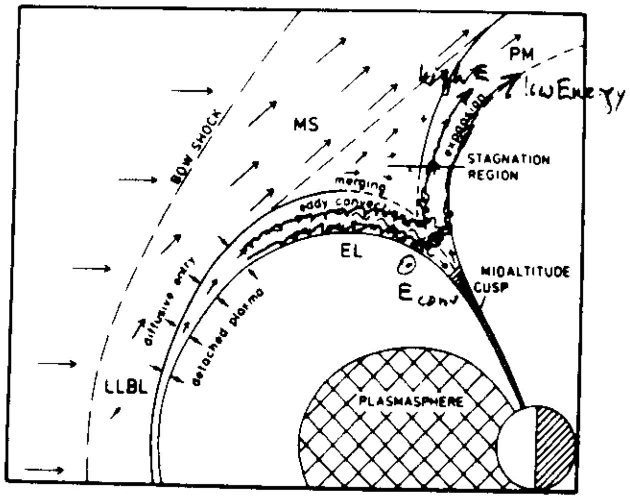


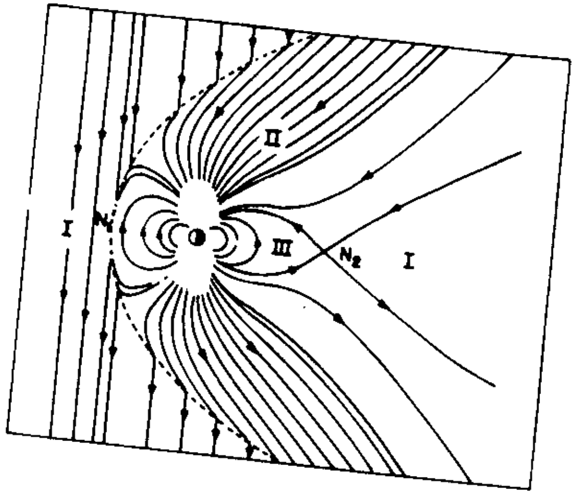
(1) Lobe/Plasma Mantle Source

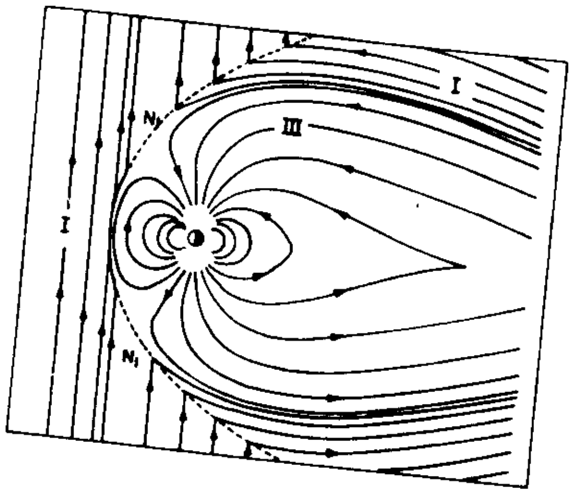
(2) Low-Latitude Boundary Layer Source





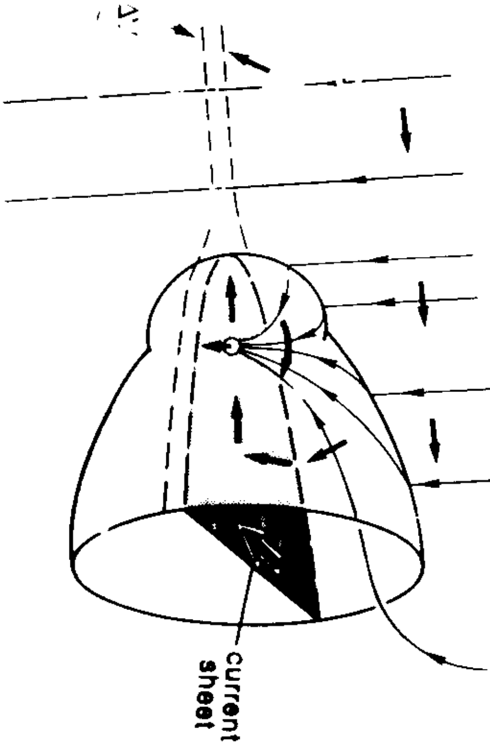


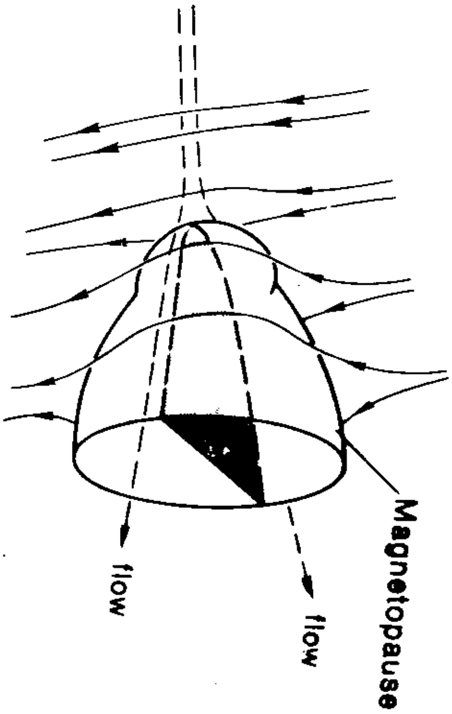


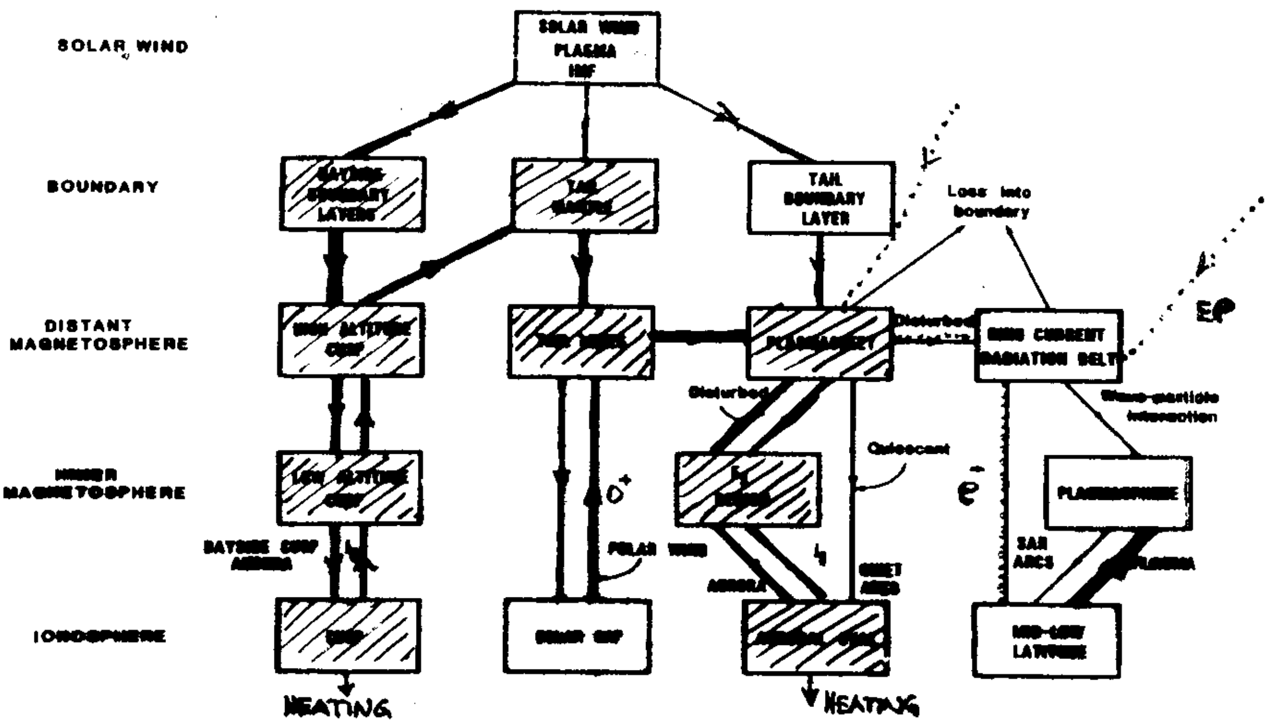


Kennel II B1 -3

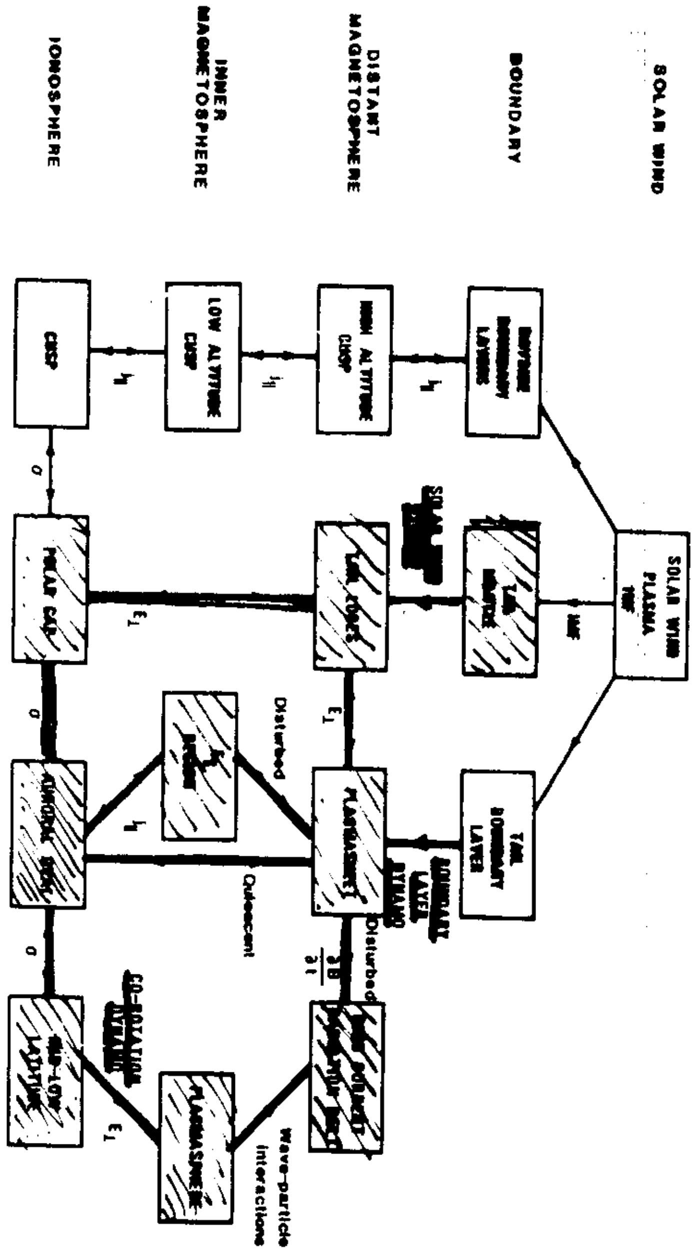
607



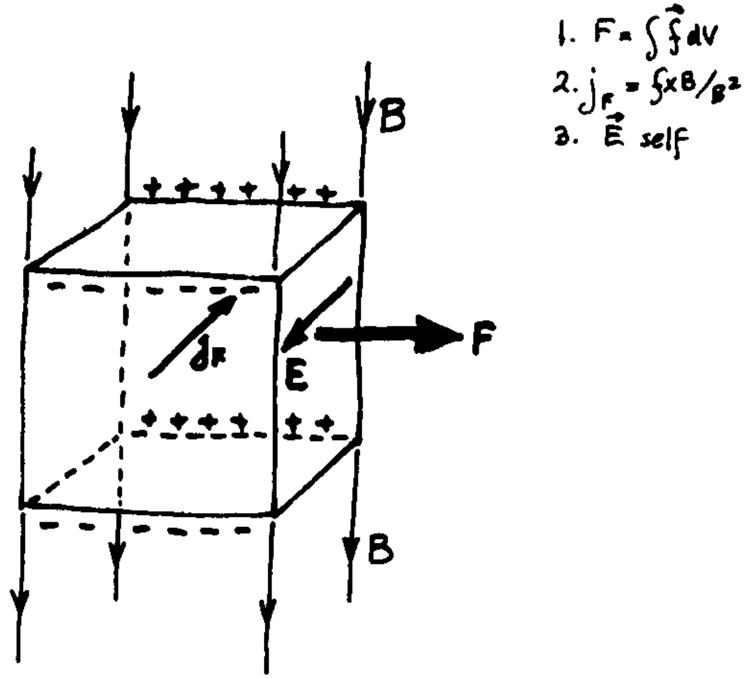


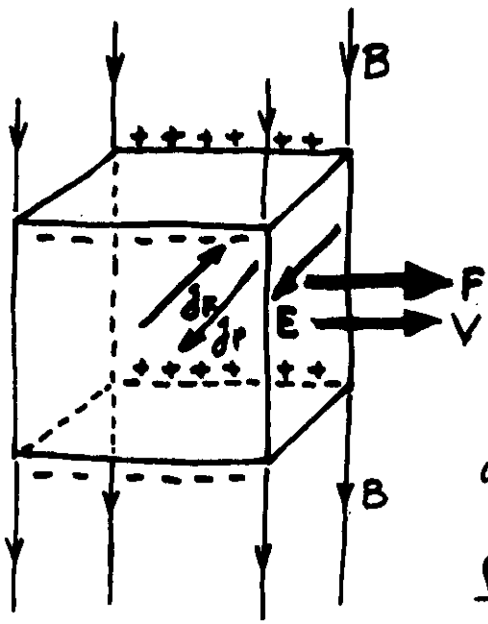


MAGNETOSPHERIC PARTICLE TRANSPORT ROUTES



PRINCIPAL ELECTRICAL COUPLING





1. $F = \int \vec{f}\, dV$
2. $j_F = f \times B / B^2$
3. $\vec{E}$ self $j_F \times B = -f$
4. $V_\perp = \frac{E \times B}{B^2}$
5. $\dot{V} \neq 0$
6. $j_p = -\rho \dot{V} \times B / B^2$

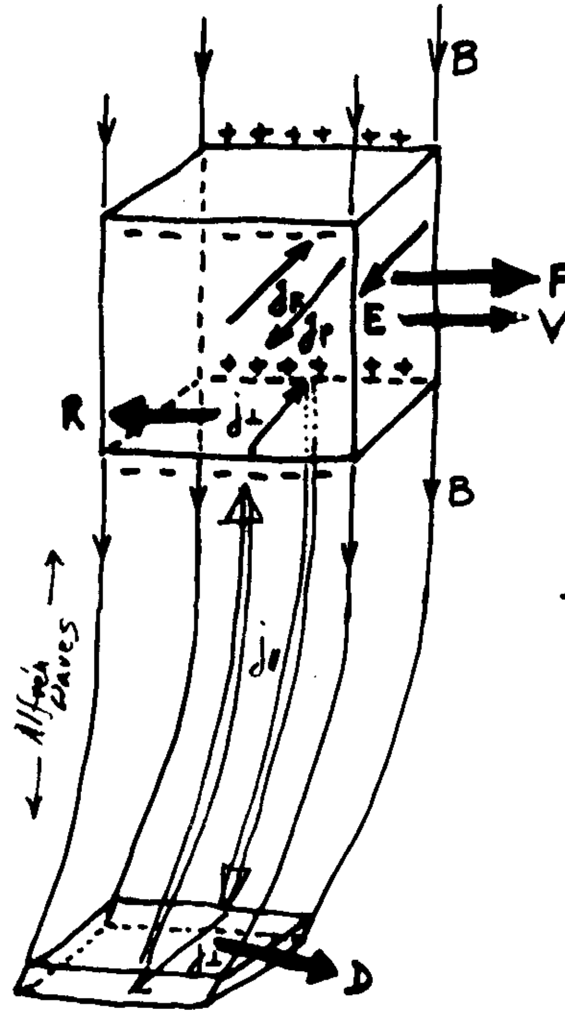
$j_F + j_p = (f - \rho \dot{V}) \times B / B^2$

7. $j_p + j_F \to 0$

and $\rho \dot{V}_\perp = f_\perp$

with other currents j (e.g. grad B curv)

$\rho \dot{V}_\perp = f_\perp + j \times B$



1. $F = \int \vec{f}\, dV$
2. $j_F = f \times B / B^2$
3. $\vec{E}$ self $j_F \times B = -f$
4. $V_\perp = \frac{E \times B}{B^2}$
5. $\dot{V} \neq 0$
6. $j_p = -\rho \dot{V} \times B / B^2$

$j_F + j_p = (f - \rho \dot{V}) \times B / B^2$

7. $j_p + j_F \to 0$

and $\rho \dot{V}_\perp = f_\perp$

with other currents j (e.g. grad B curv)

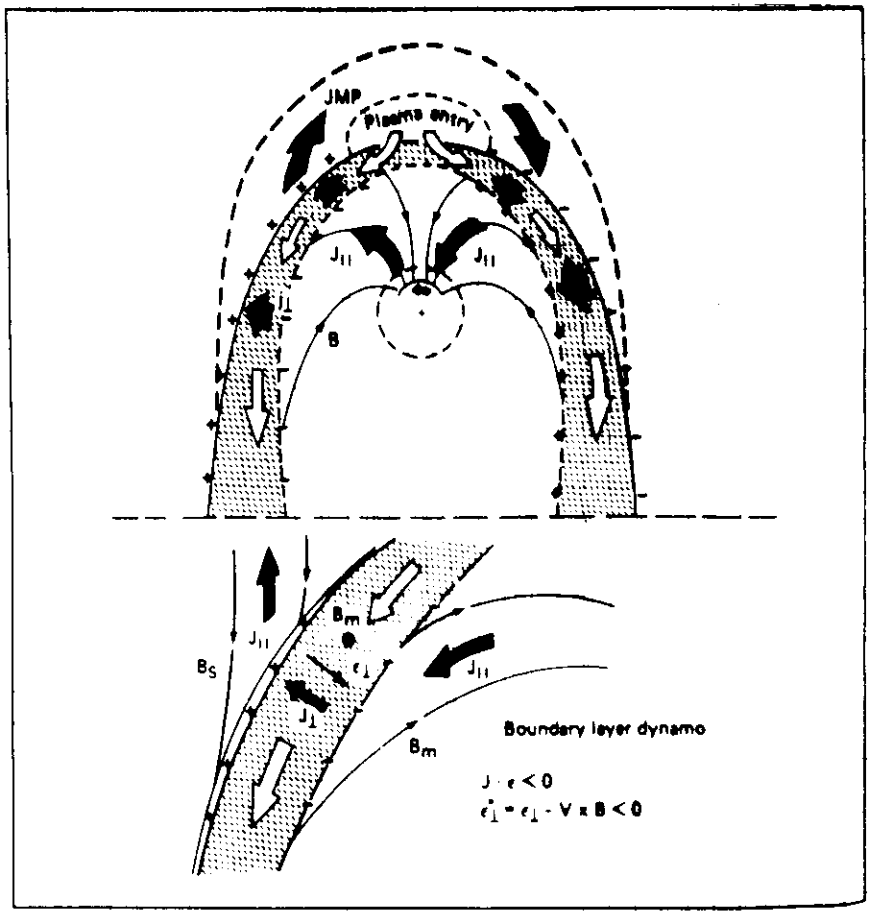
$\rho \dot{V}_\perp = f_\perp + j \times B$

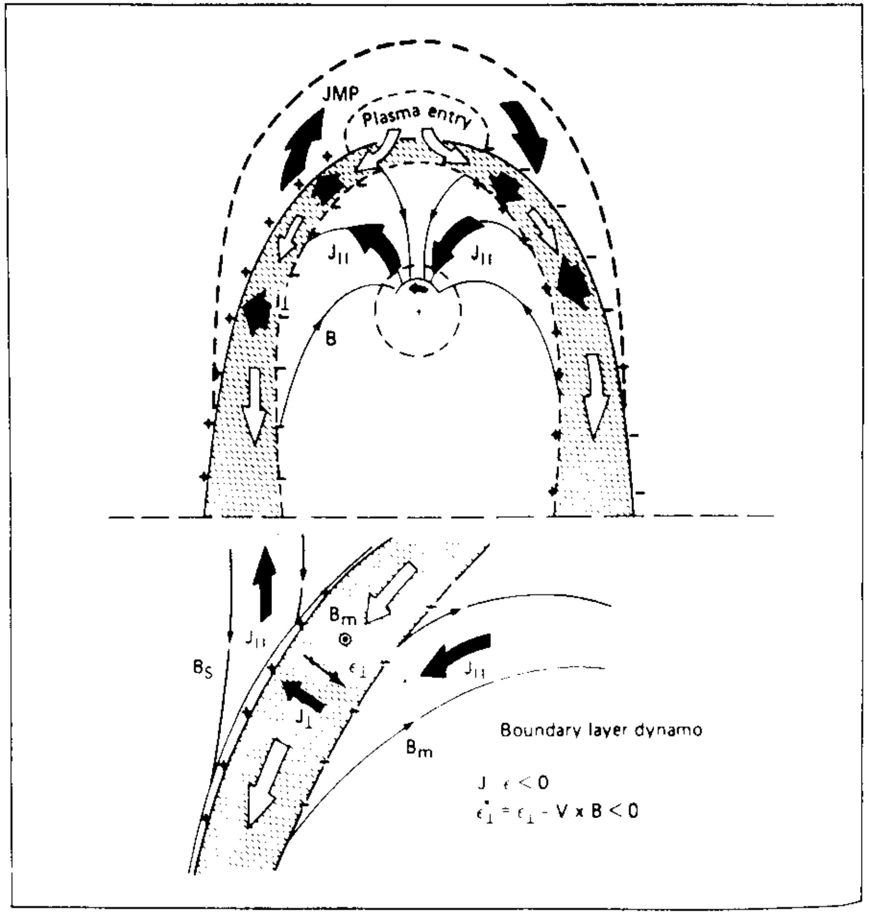
8. $j_\parallel$, $j_\perp$
9. $R = j_\perp \times B_{pl}$

$D = j_{Iono} \times B_{Iono}$

$R \sim V$ (viscous)

10. Curving B
11. Curvature-drift current → R
12. Communications via Alfvén w.
13. "Peeling off" and discontinuities


JMP
Plasma entry
$J_{||}$
$J_{||}$
$J_\perp$
B
B_m
$J_{||}$
B_S
$\epsilon_\perp$
$J_{||}$
$J_\perp$
Boundary layer dynamo
B_m
$J \cdot \epsilon < 0$
$\epsilon_\perp^* = \epsilon_\perp - V \times B < 0$


JMP
Plasma entry
$J_{||}$
$J_{||}$
$J_\perp$
B
B_m
$J_{||}$
B_S
$\epsilon_\perp$
$J_{||}$
$J_\perp$
Boundary layer dynamo
B_m
$J \cdot \epsilon < 0$
$\epsilon_\perp^* = \epsilon_\perp - V \times B < 0$

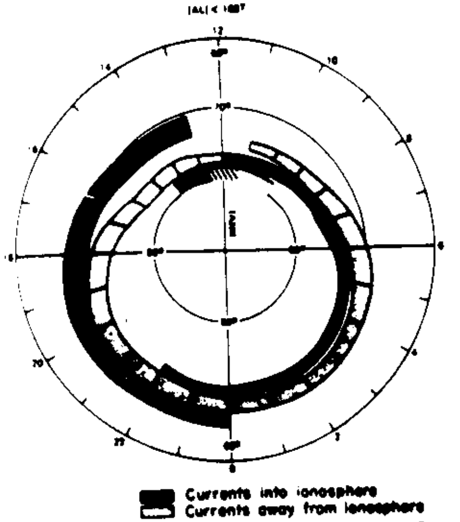


Fig. 6.24. A more complete pattern of field-aligned currents when the IMF has a southward component and $B_z = 0.1$. An additional field-aligned current system resides near local noon. These 'cusp' currents have a dominant polarity determined by the y component of the IMF. [After Iijima and Potemra (1976). Reproduced with permission of the American Geophysical Union.]

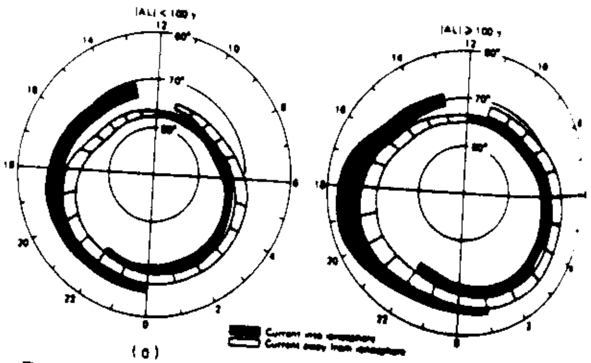


Fig. 6.23. Two overlapping rings of field-aligned currents always exist at high latitudes. They occur at higher latitudes and have smaller latitudinal extent during quiet times. The inner ring is termed region 1 current and the outer ring region 2. [After Iijima and Potemra (1978). Reproduced with permission of the American Geophysical Union.]

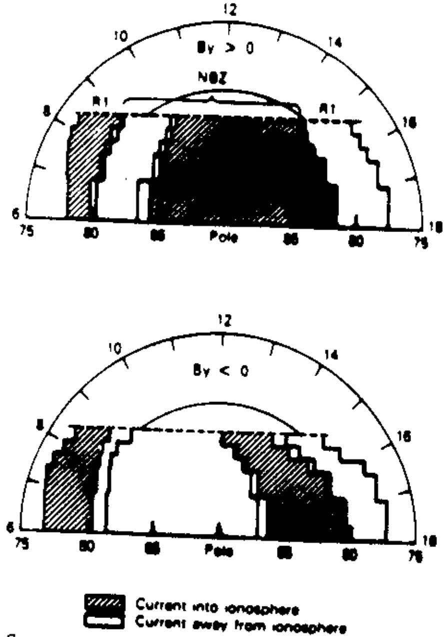


Fig. 6.25. Cusp currents in the southern hemisphere shown for the case when the IMF has a northward component. The cusp currents expand to fill the polar cusp and have been called NBZ currents. Their dominant polarity is determined by the y component of the IMF. [After Iijima *et al.* (1984). Reproduced with permission of the American Geophysical Union.]