Solar Wind Mass Loading by Ionospheric Outflows

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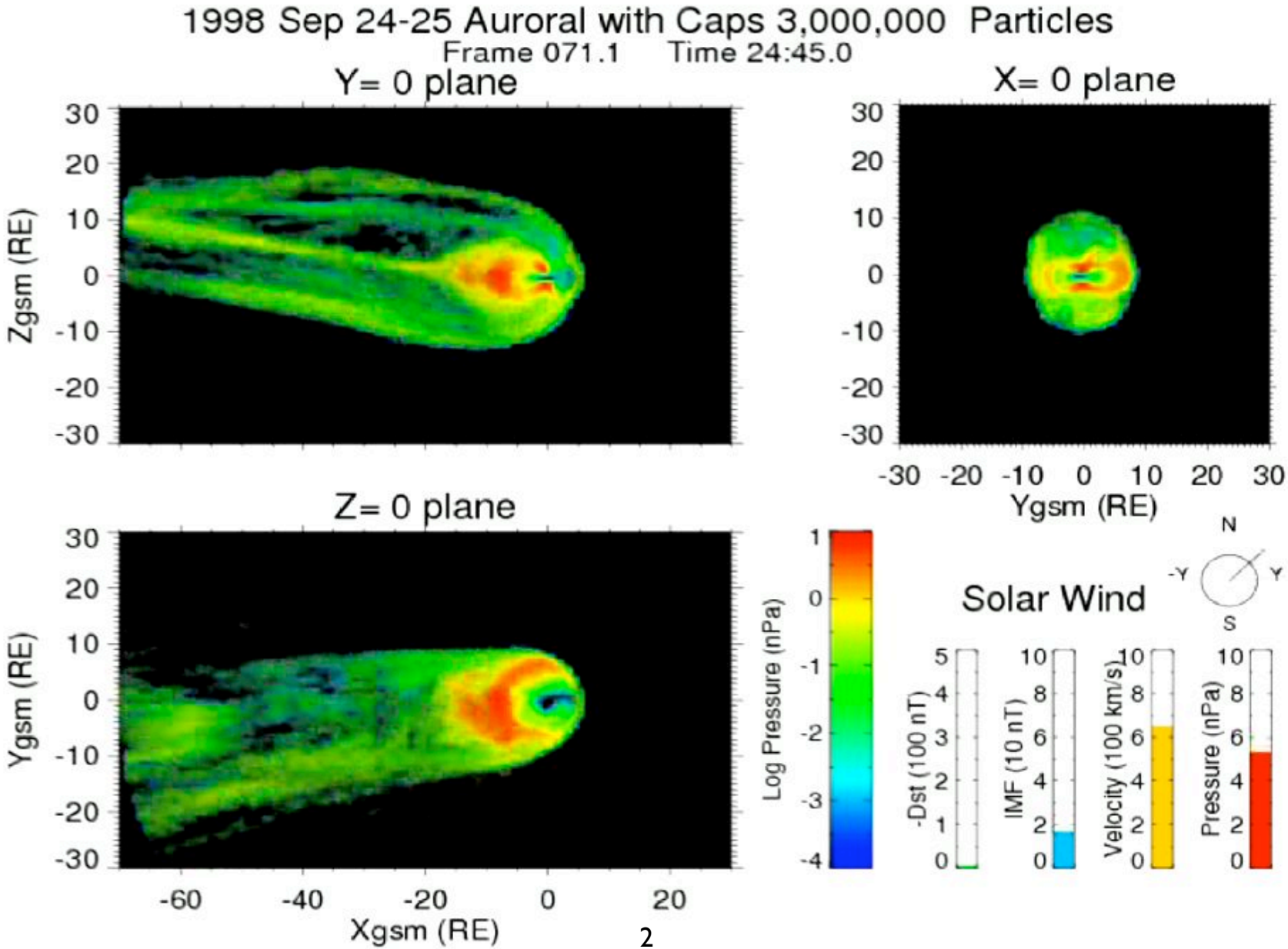
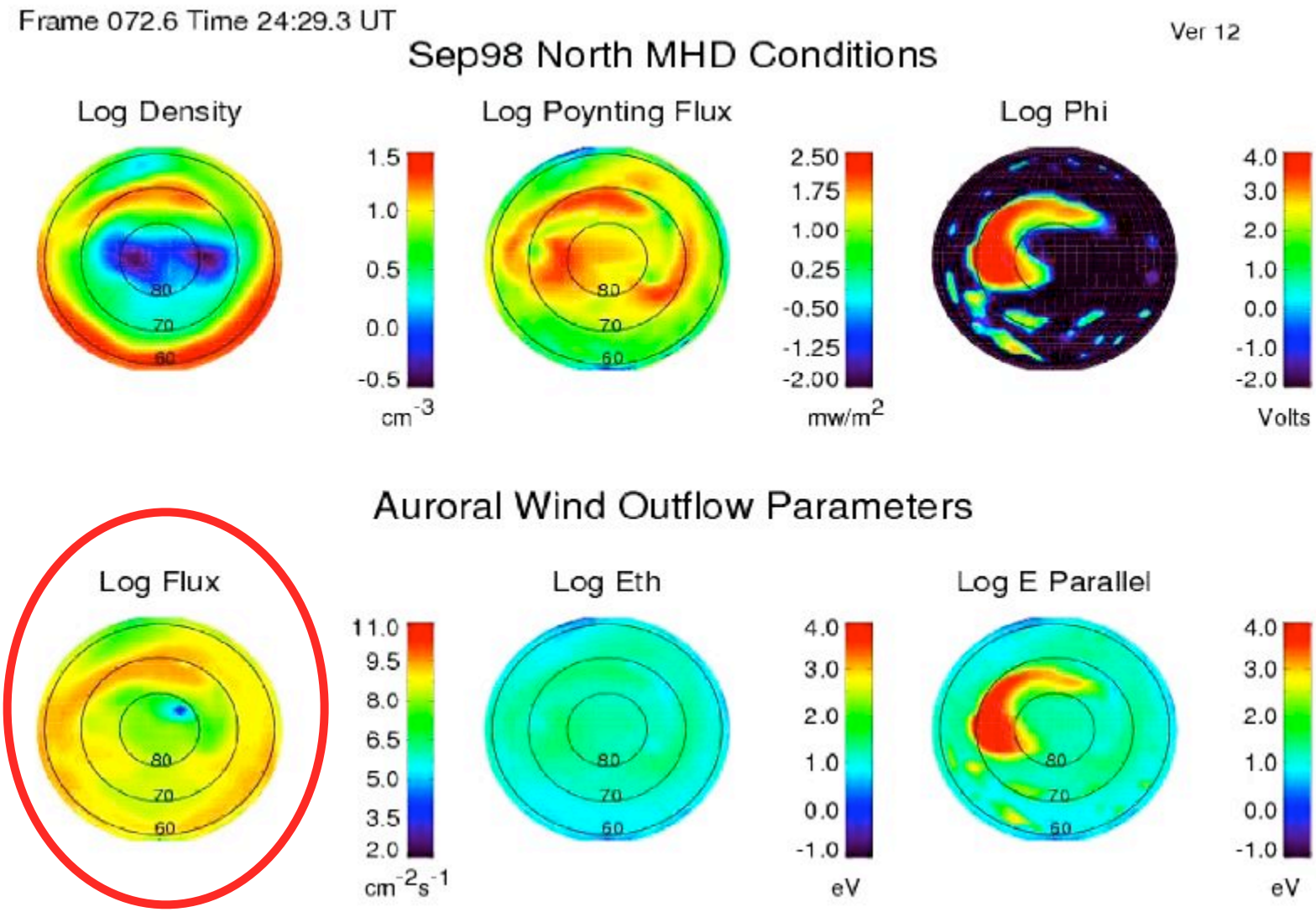
1. Auroral linkage connects solar and ionospheric plasmas
2. Solar wind is mass loaded by ionospheric "pick up"

Auroral Wind Circulation



MHD driven Outflows



Transverse Ion Heating

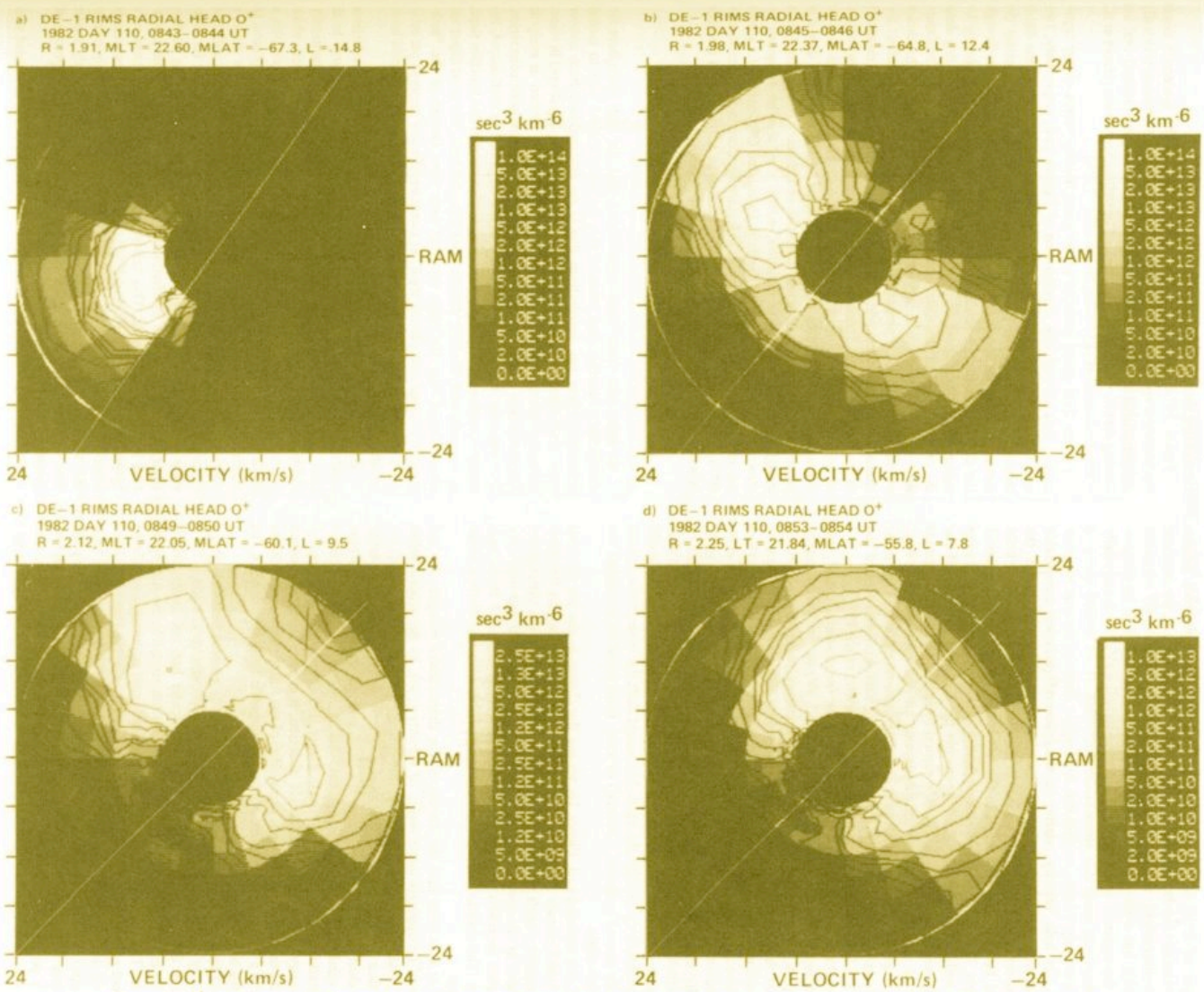
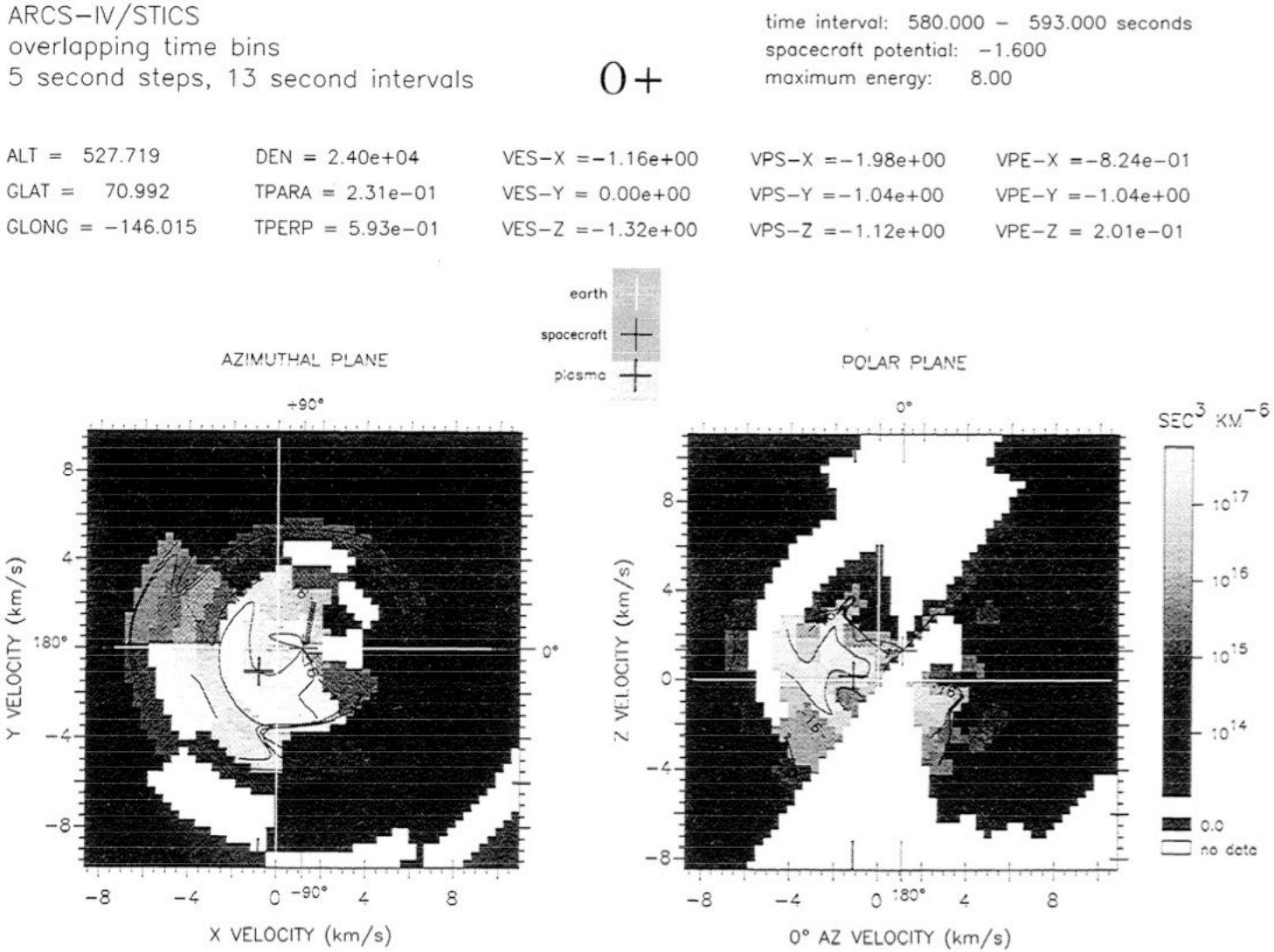


Figure 1. O^+ ion velocity distribution functions at selected points over the polar cap and nightside auroral zone. Panel a shows typical cold O^+ plasma over the polar cap region. Panels b-d show the abrupt appearance and subsequent evolution of a coherent transverse acceleration event.

MOORE ET AL. 51

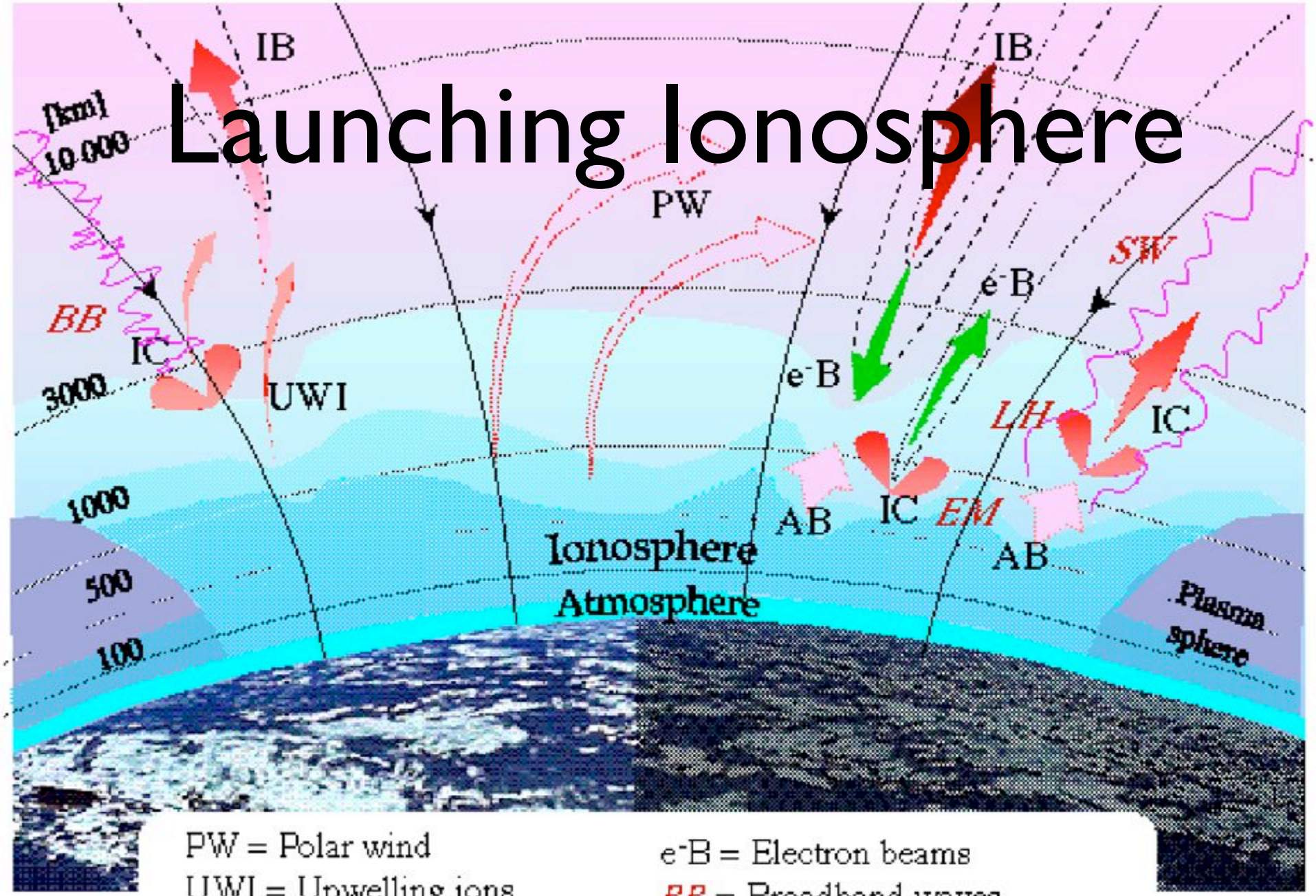
Moore et al. - 1985 - GM#38 - Obs. of coherent ion acceleration

Transverse Ion Heating



Moore et al. - 1996 JGR- Plasma heating and flow in an auroral arc

Launching Ionosphere

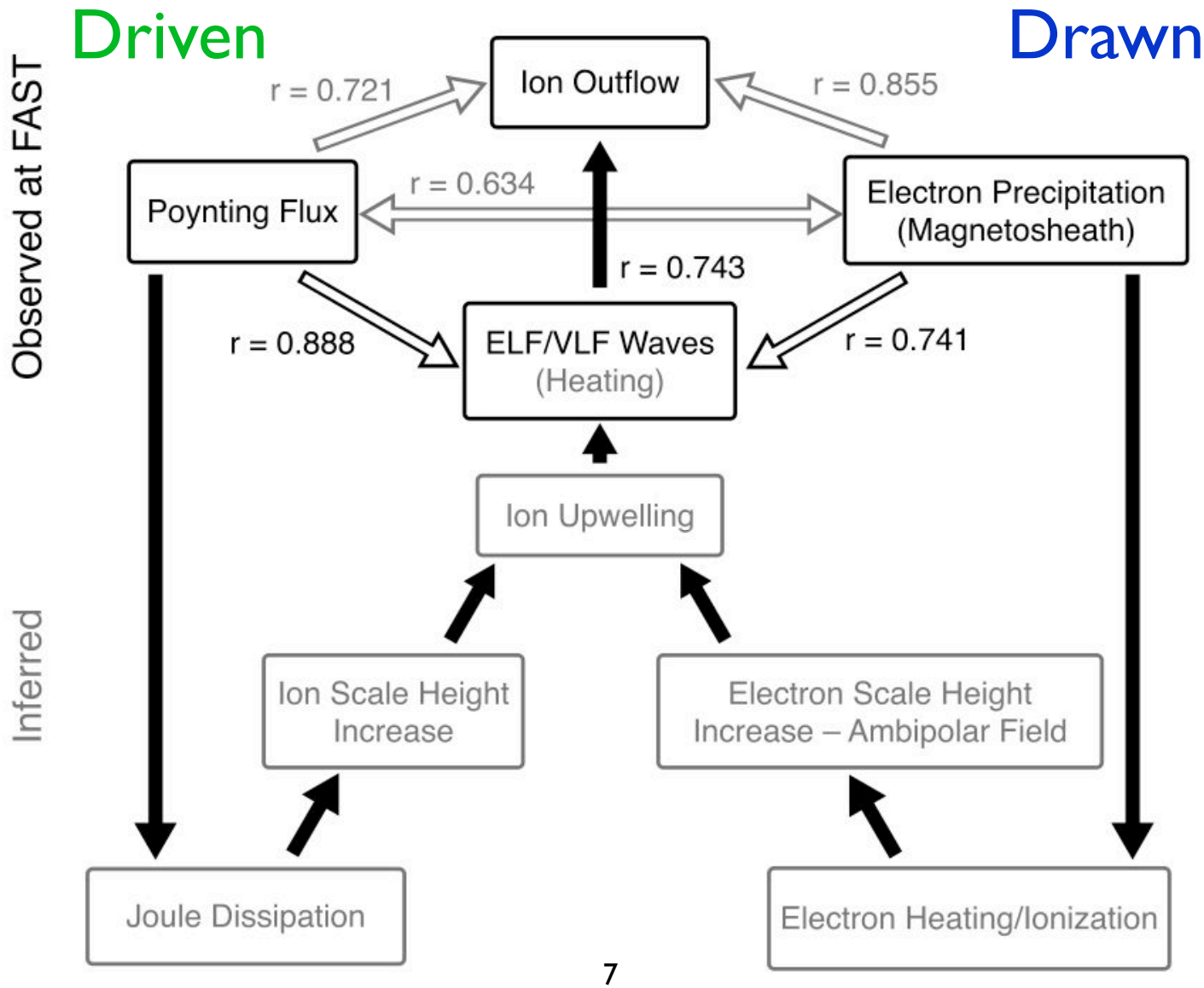


PW = Polar wind
UWI = Upwelling ions
IC = Ion conics
IB = Ion beams
AB = Auroral bulk upflow

e⁻B = Electron beams
BB = Broadband waves
LH = Lower hybrid waves
EM = Ion cyclotron waves
SW = Solitary Kin. Alfvén waves

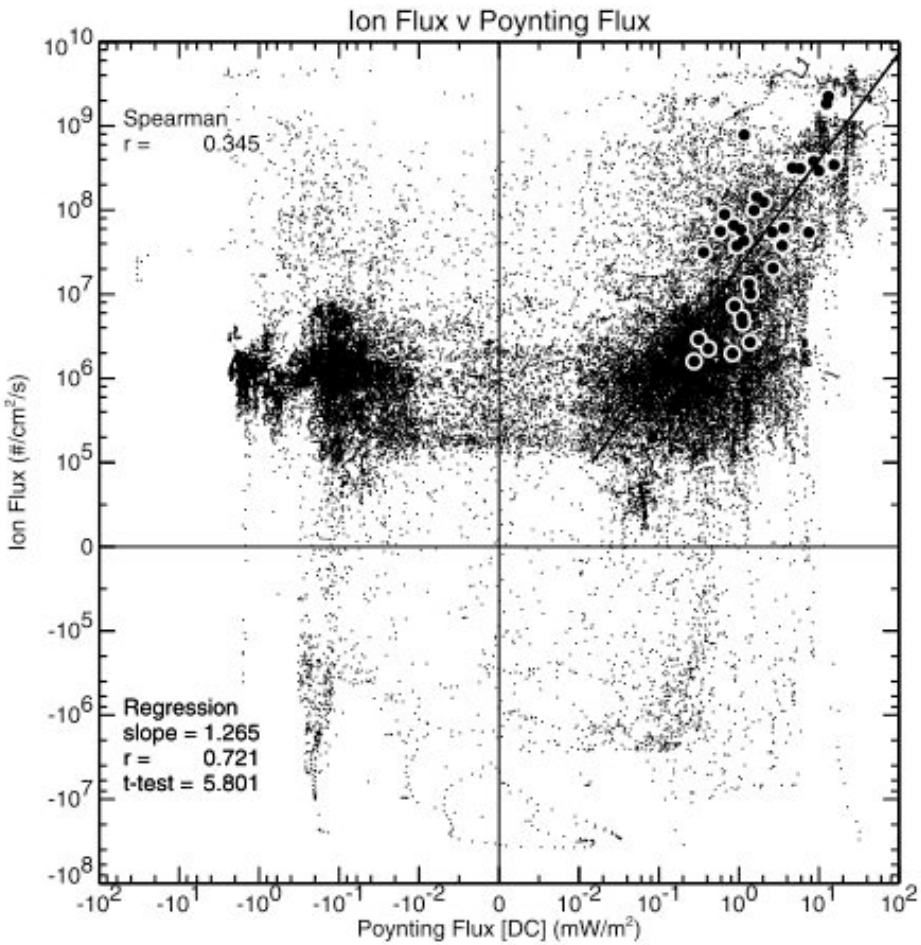
Empirical Outflow Control

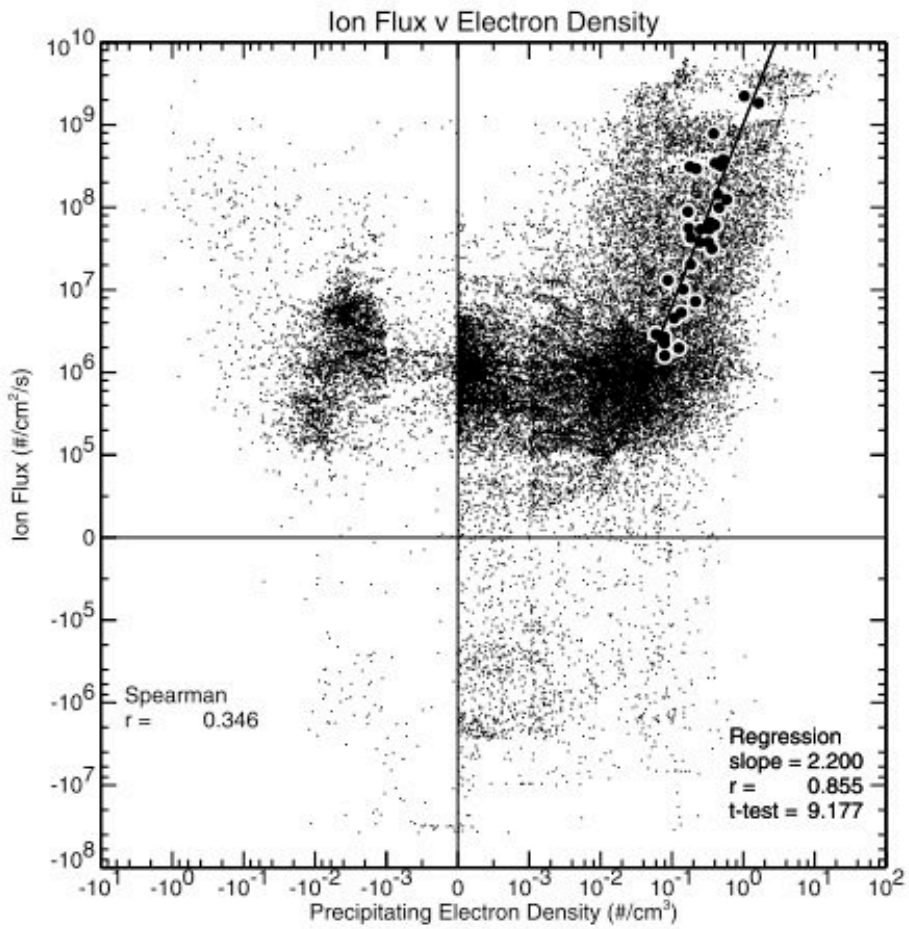
STRANGEWAY ET AL.: ION OUTFLOW CONTROL



Harnessing Solar Wind Energy

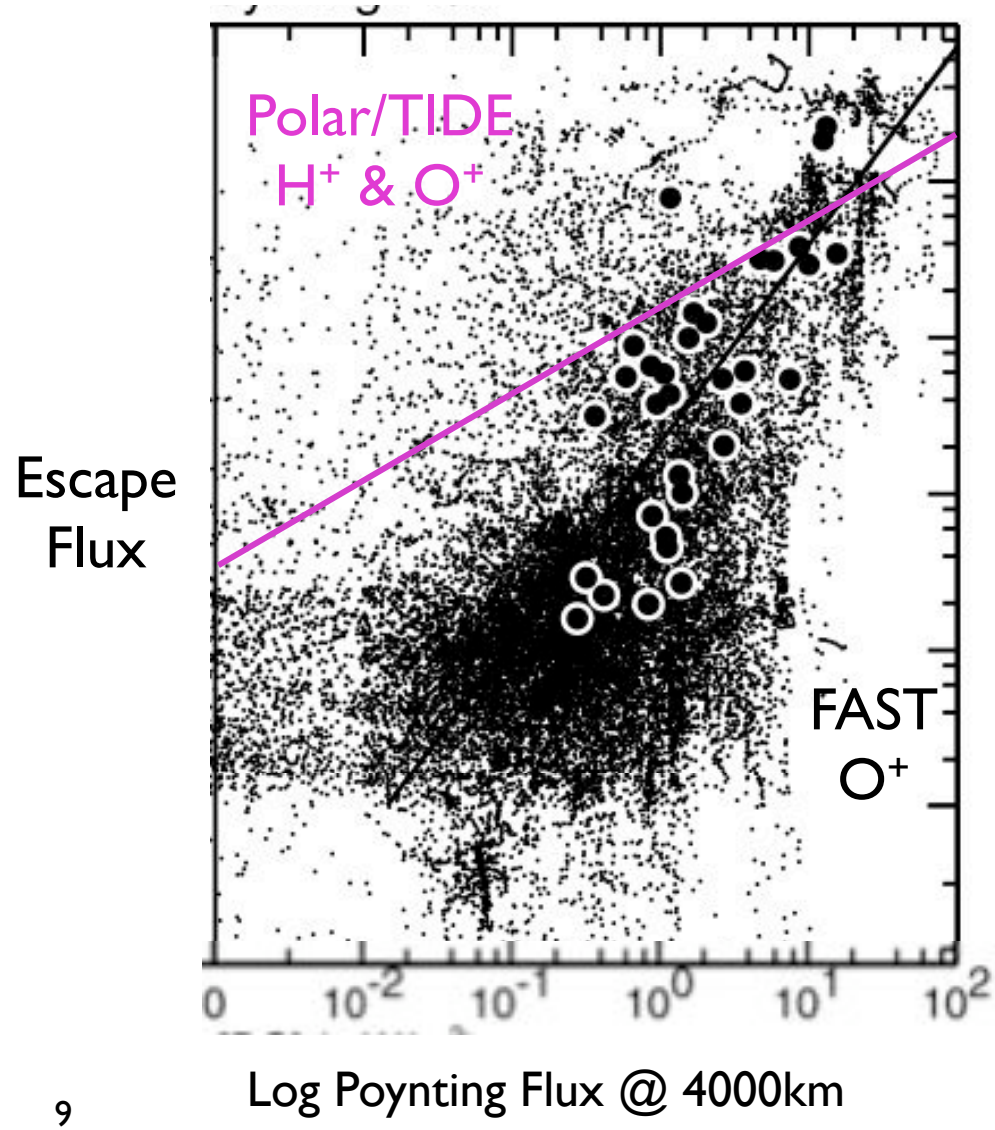
Strangeway et al., 2005 JGR



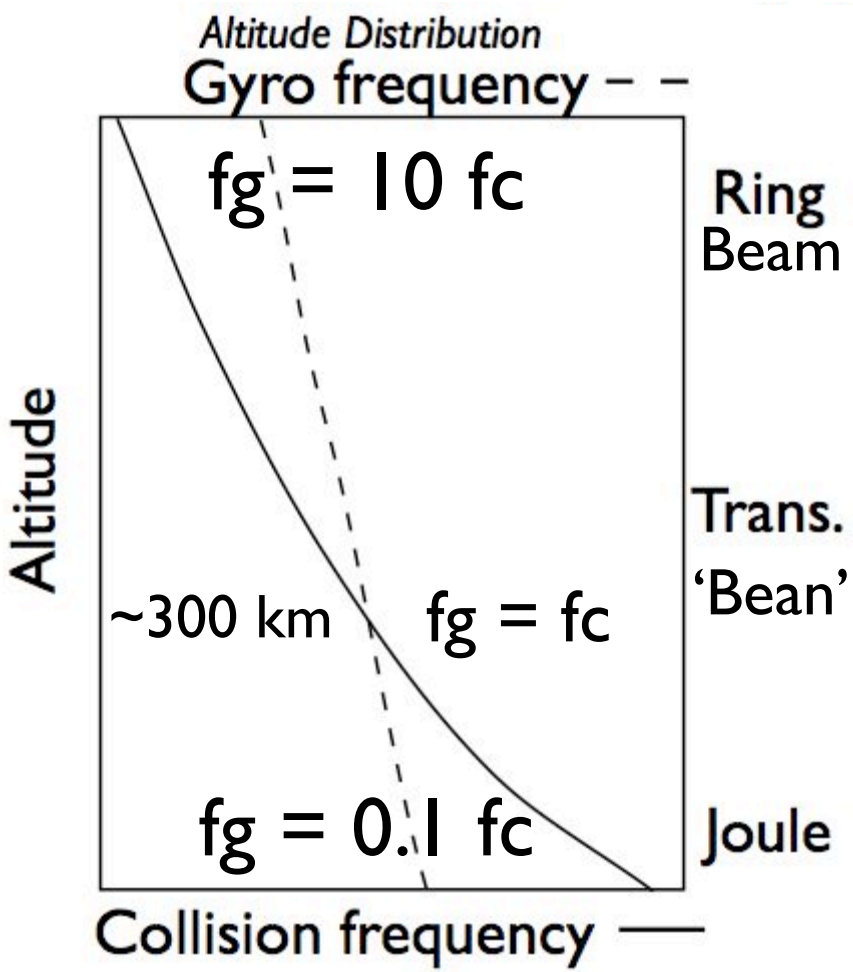


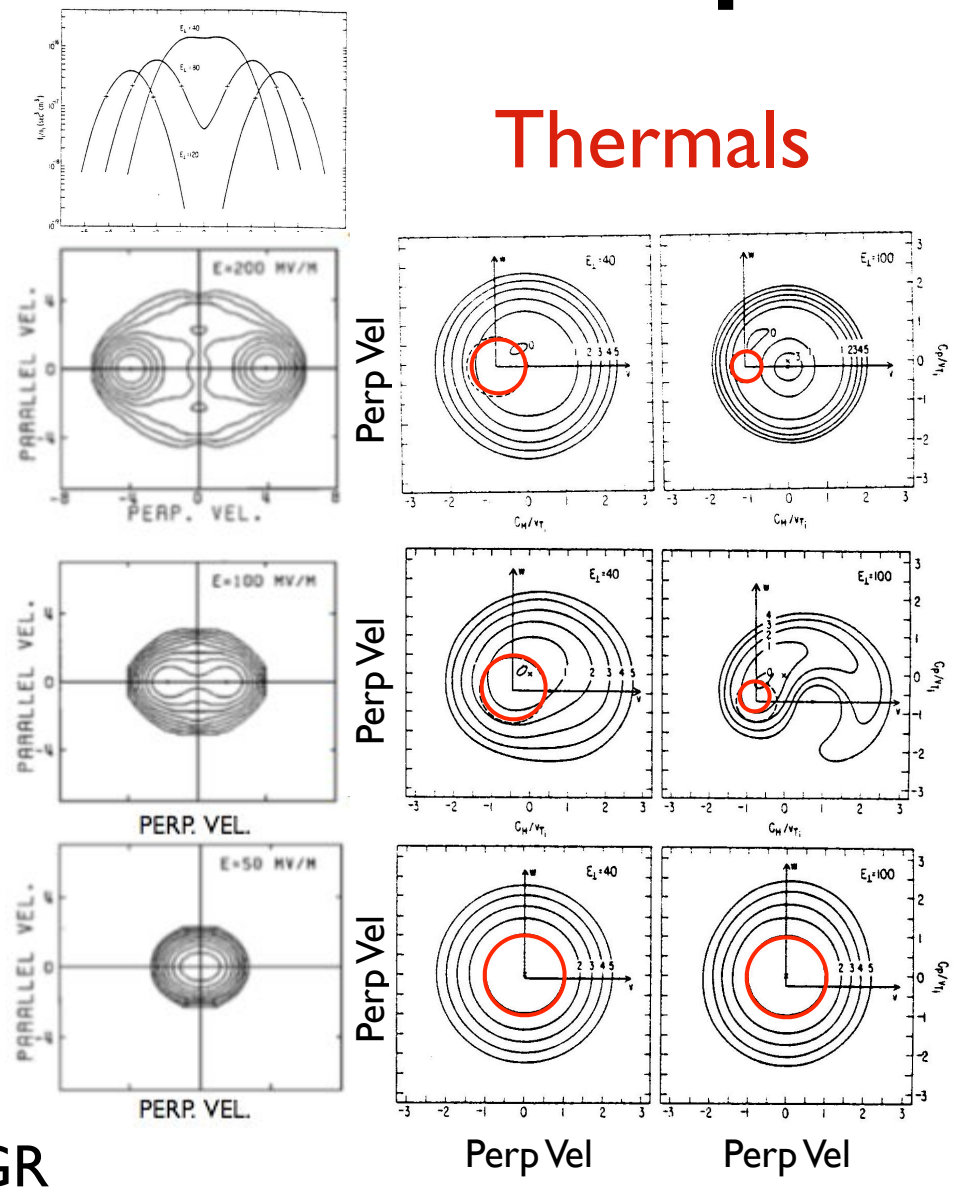
Poynting Flux Effect

- Power law
  ~1.3 Strangeway/FAST
  ~ 0.55 Zheng/Polar
- Low fluxes independent of PF (polar wind H+)
- Steeper dependence inevitable for heavy ions



Collisional Ion Pickup





St-Maurice 1979 RG; Barakat 1983 JGR
Hubert, 1994 AG; Kinzelin 1993 JASTP

$D^* = V_{ExB} / V_{th} \sim 1$ $D^* \sim 2.5$

Saturation => Thermalization

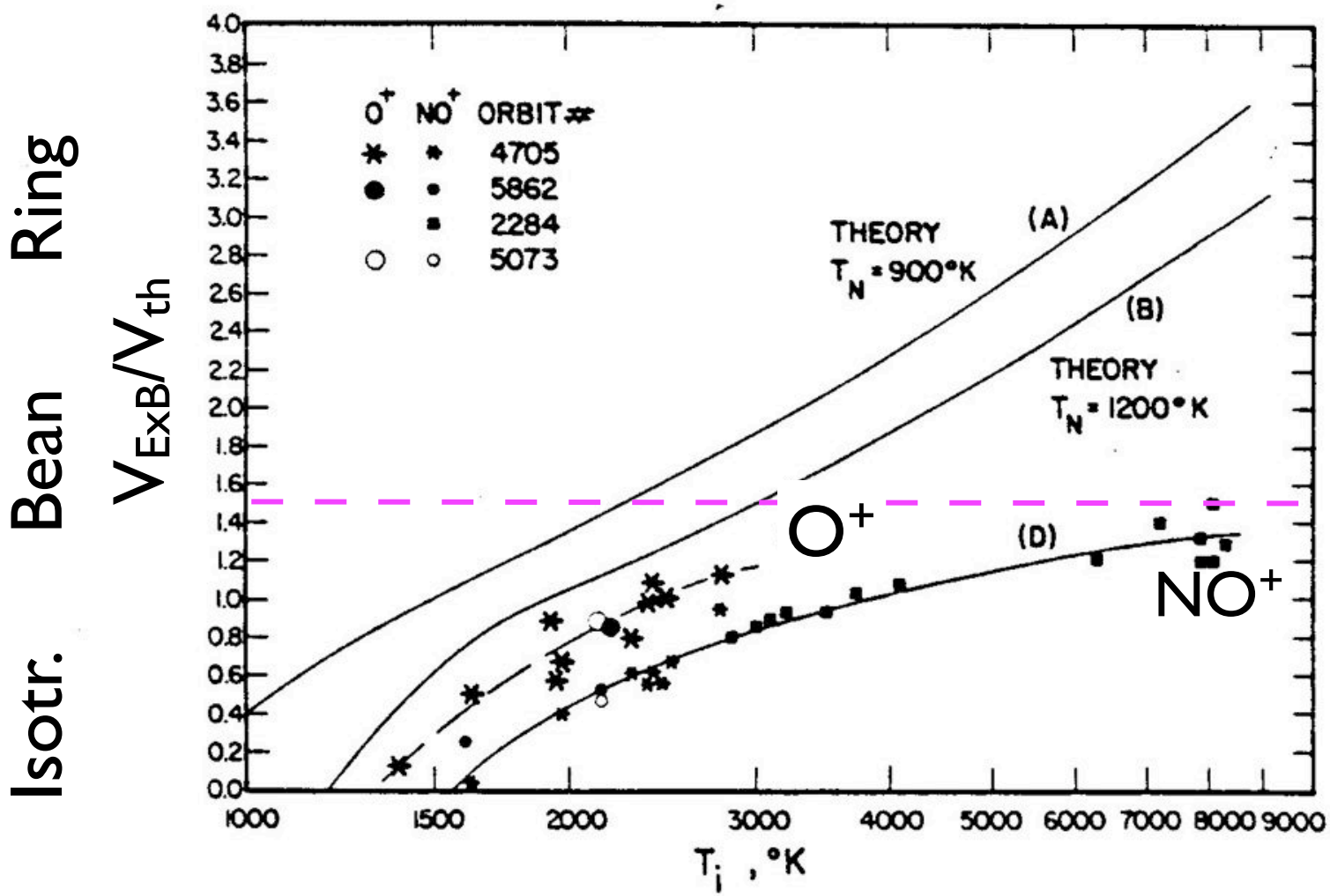


Fig. 24. Shape of the perpendicular ion velocity distribution as determined by the parameter $Ec/BV_{th} = D^*$ as a function of ion temperature. The 'theoretical' curves A and B were evaluated by using the results obtained from the pure relaxation collision model (equation (16)). Curve C represents the average shape of the measured O^+ distribution when O^+ is the major ion. Curve D is the measured shape of the NO^+ distribution. From *St-Maurice et al.* [1976].

OUTBOUND

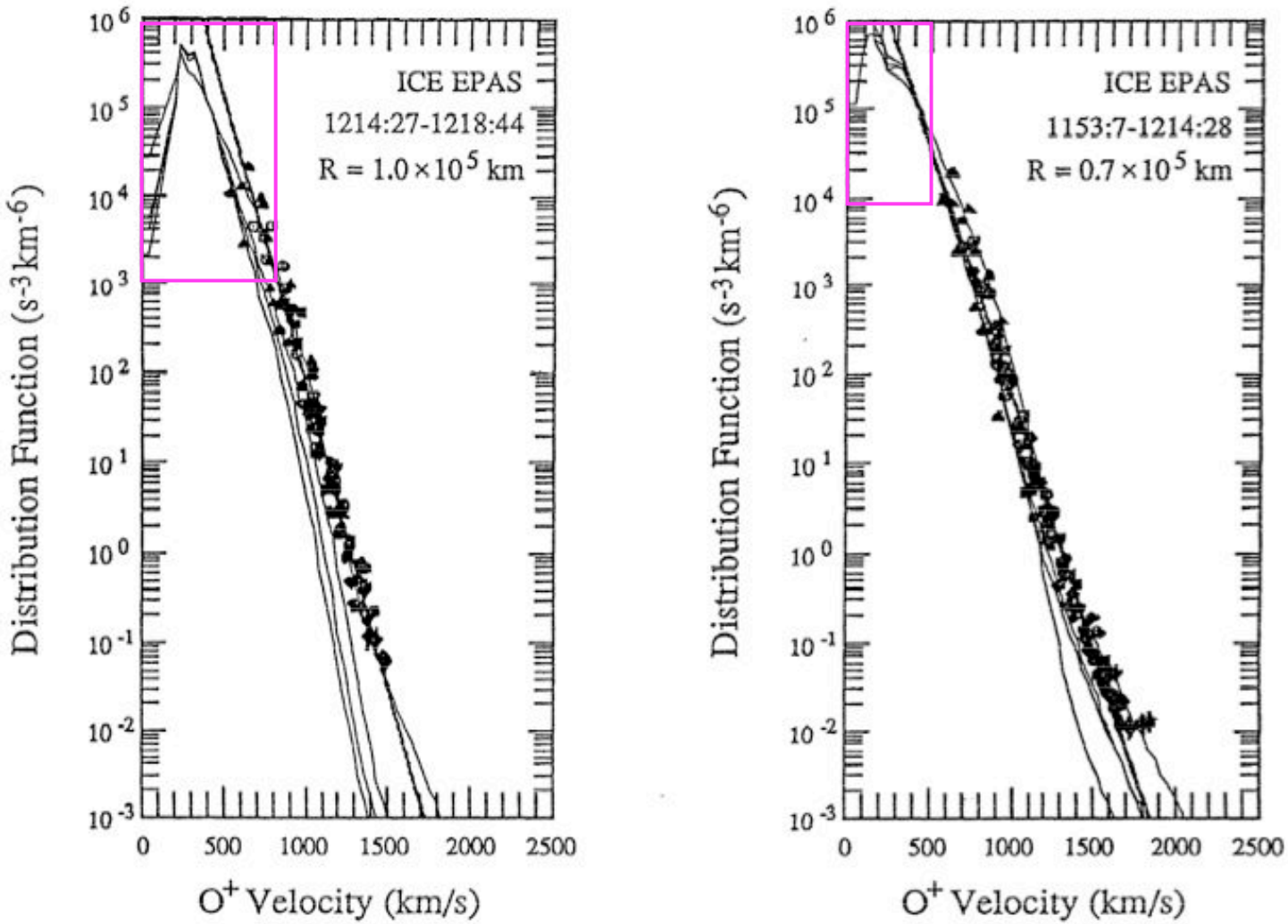


Figure 9. Comparison of quasi-linear model results and measured values from the ICE EPAS experiment [*Richardson et al.*, 1987] for two locations on the outbound trajectory. Four quasi-linear cases are shown. The four cases shown correspond to the following parameters for increasing values of $f(v)$ at large values of v: (1) δB = 1 nT, P_{effect}/P_{total} = 0.3; (2) δB = 2 nT, P_{effect}/P_{total} = 0.1; (3) δB = 4 nT, P_{effect}/P_{total} = 0.03; (4) spatially varying δB, P_{effect}/P_{total} = 0.1.

Hot Tail vs Velocity

906 PUHL, CRAVENS, & LINDGREN 1993 Ap J Vol. 418

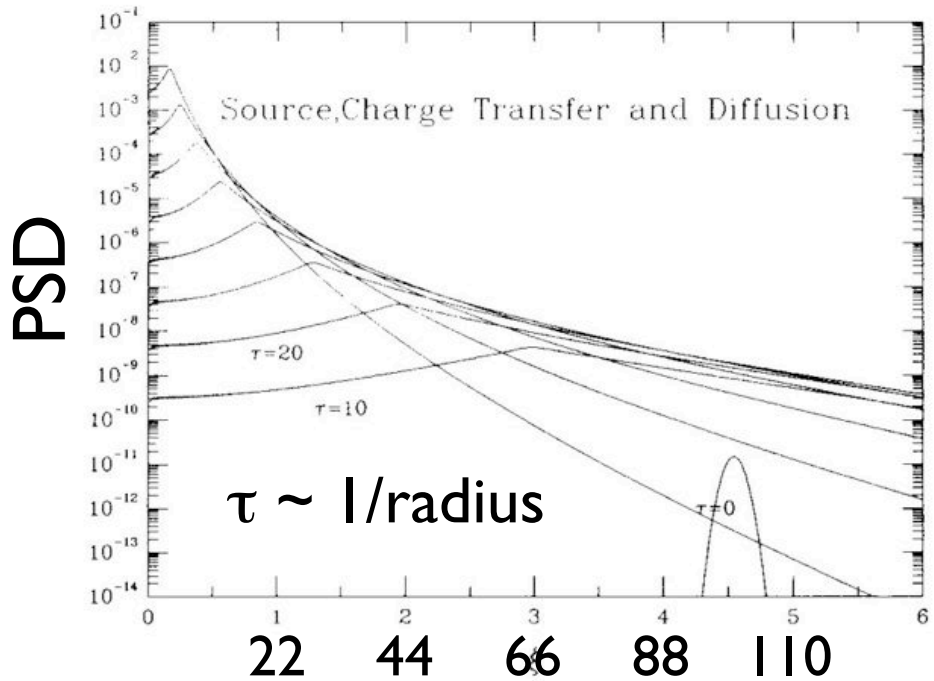


FIG. 6a

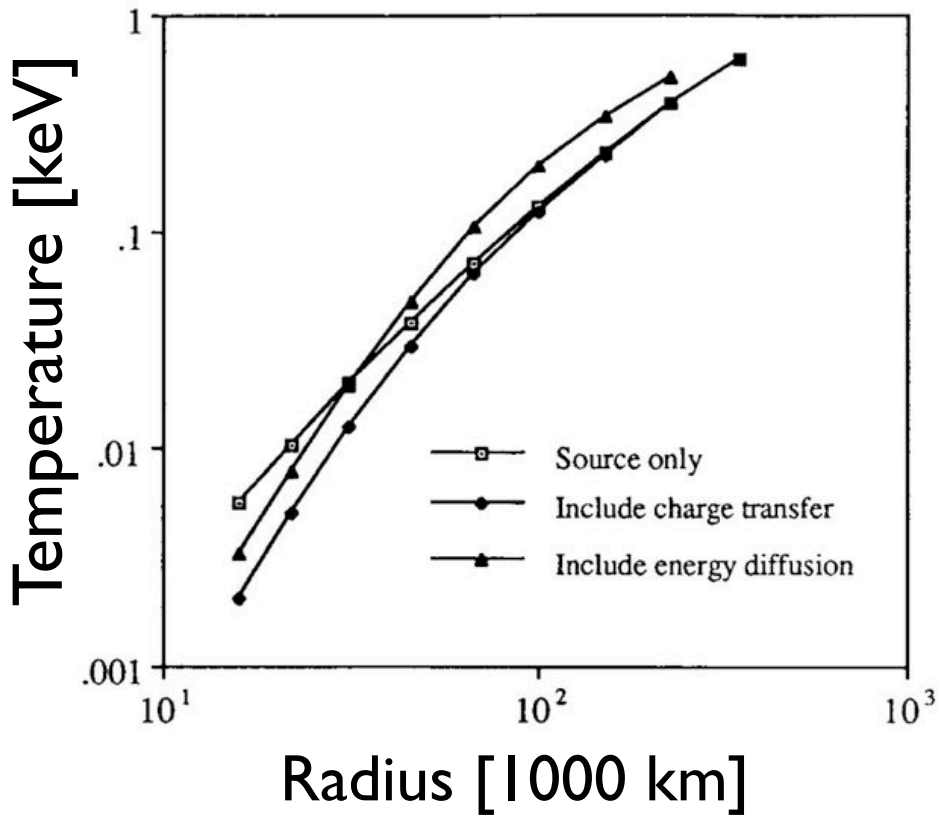
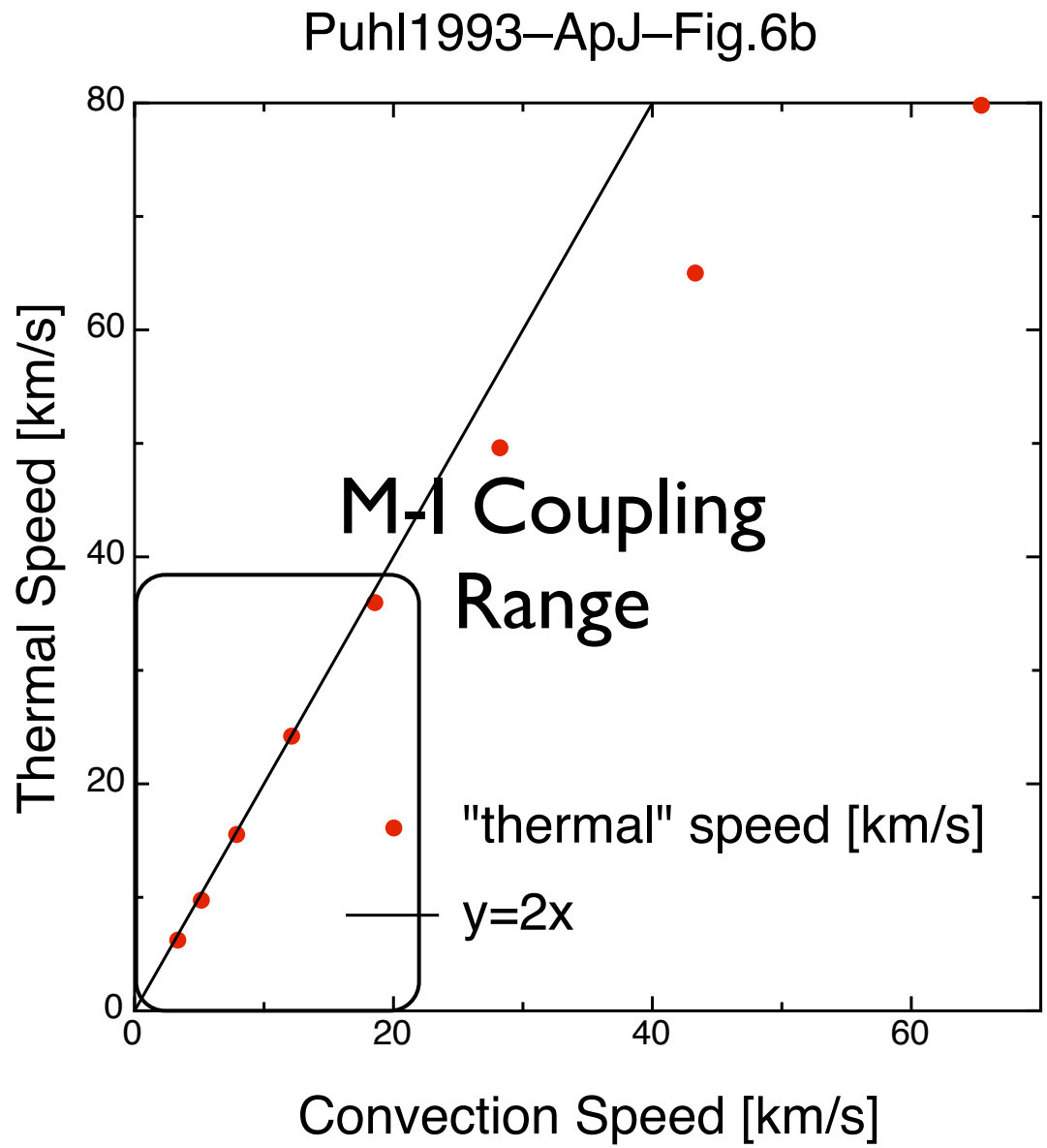


Figure 6

Hot tail vs local flow

- Puhl et al. ,1993 ApJ Fig.6b
- Vth from temperature moment; exponential tail from energy diffusion eqn
- Vconv specified as fct. of radius in comet coma
- Curve starts linear with slope 2 and flattens to ~3.9*Vconv$^{0.73}$
- Use 2*Vconv here



Escape from Gravity

Puhl et al. 1993

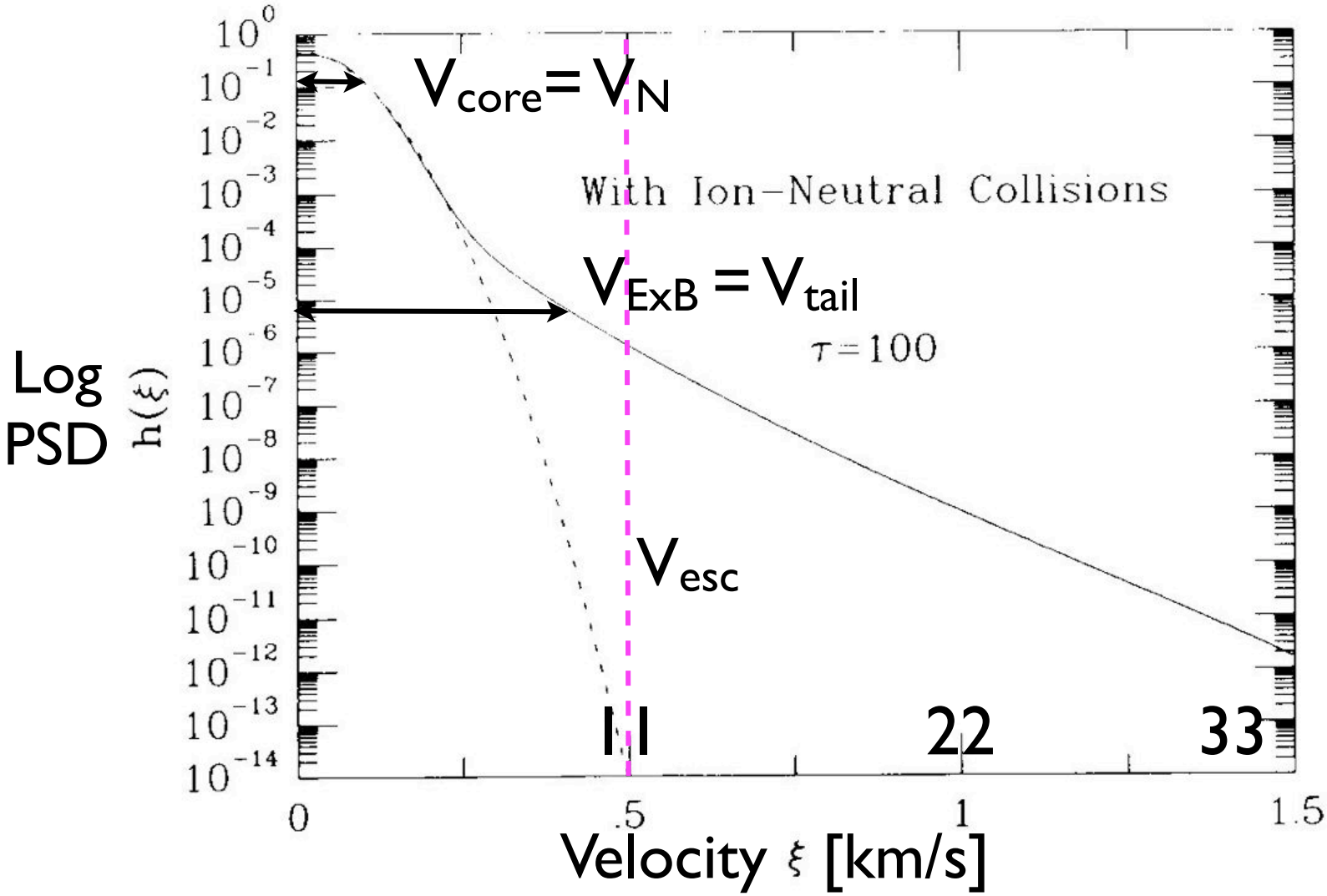
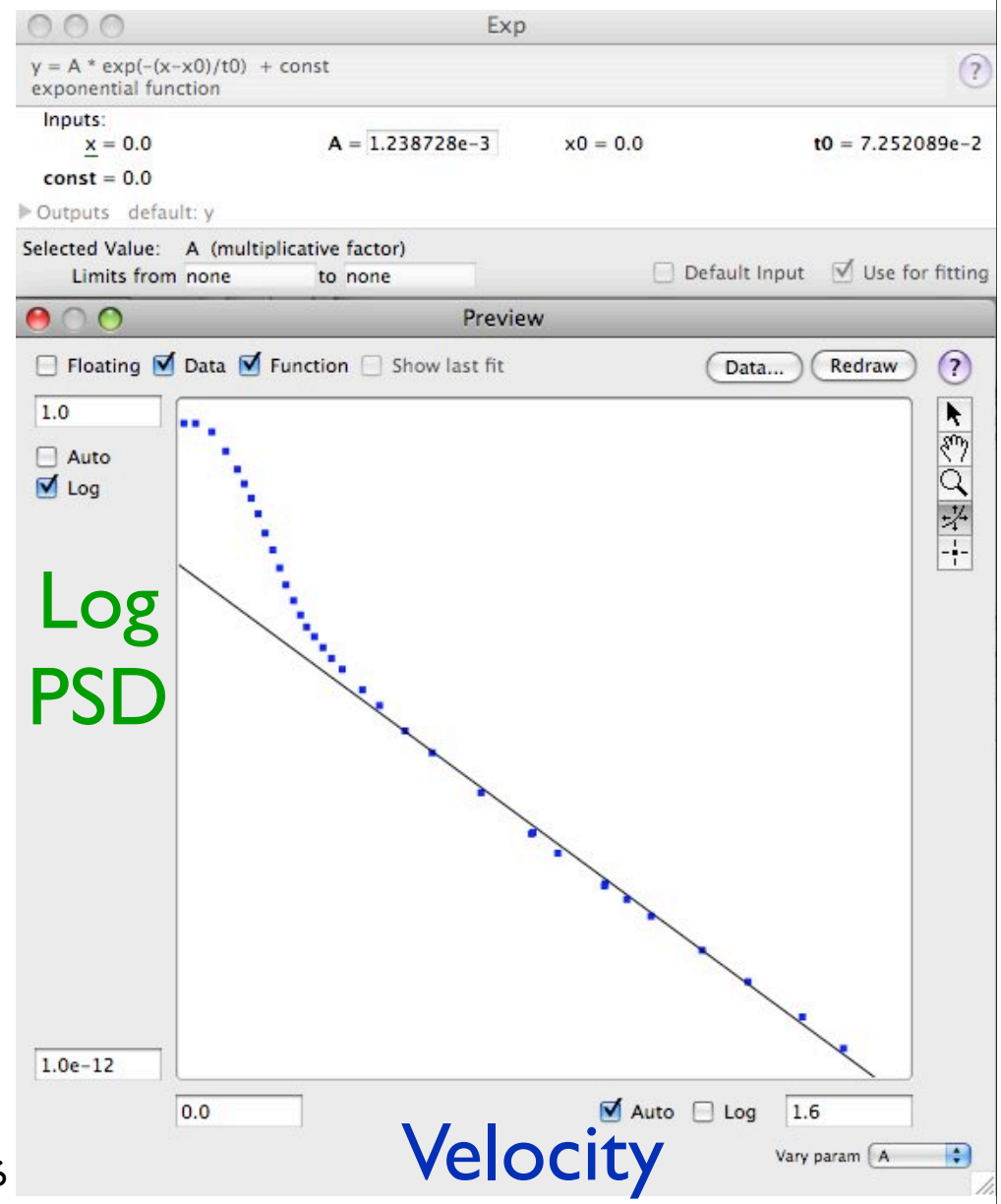


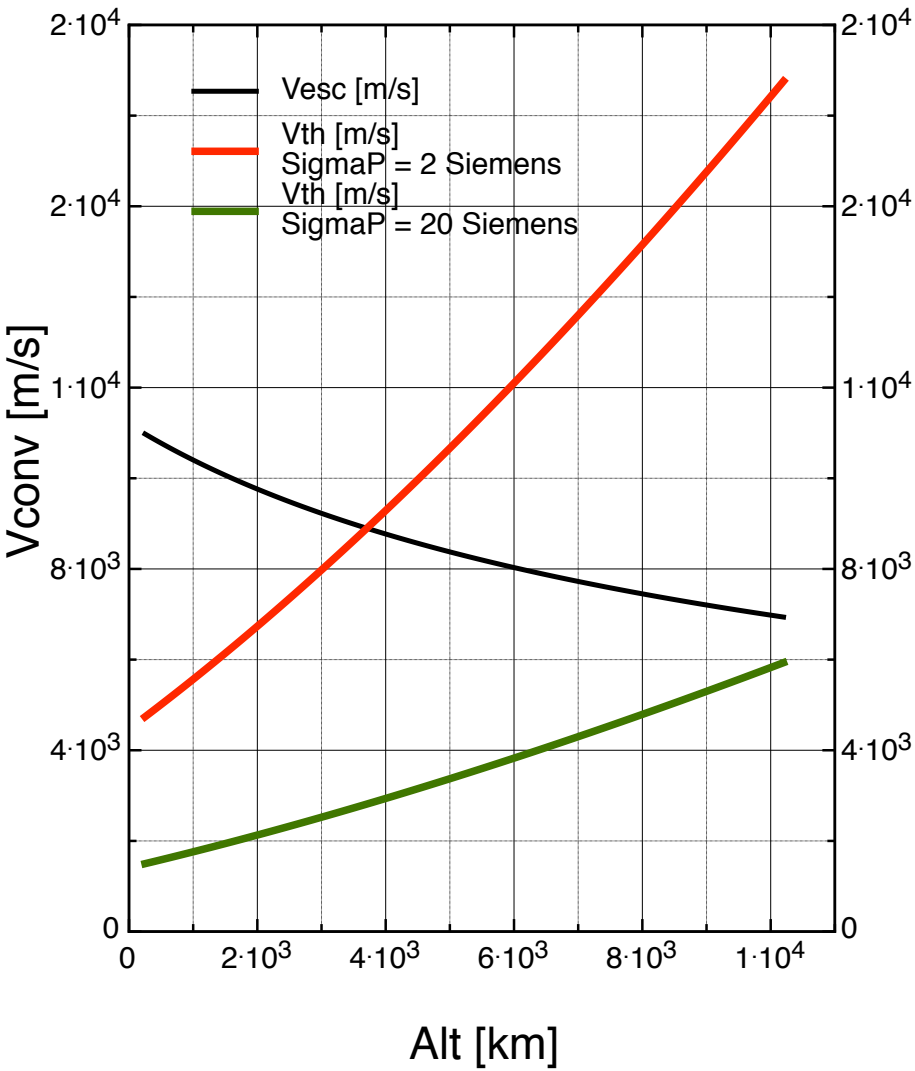
FIG. 14.—An extended version of Fig. 13*b*. The normalized velocity range has been extended to 1.5 (33 km s^{-1}) in order to view the high-energy tail.

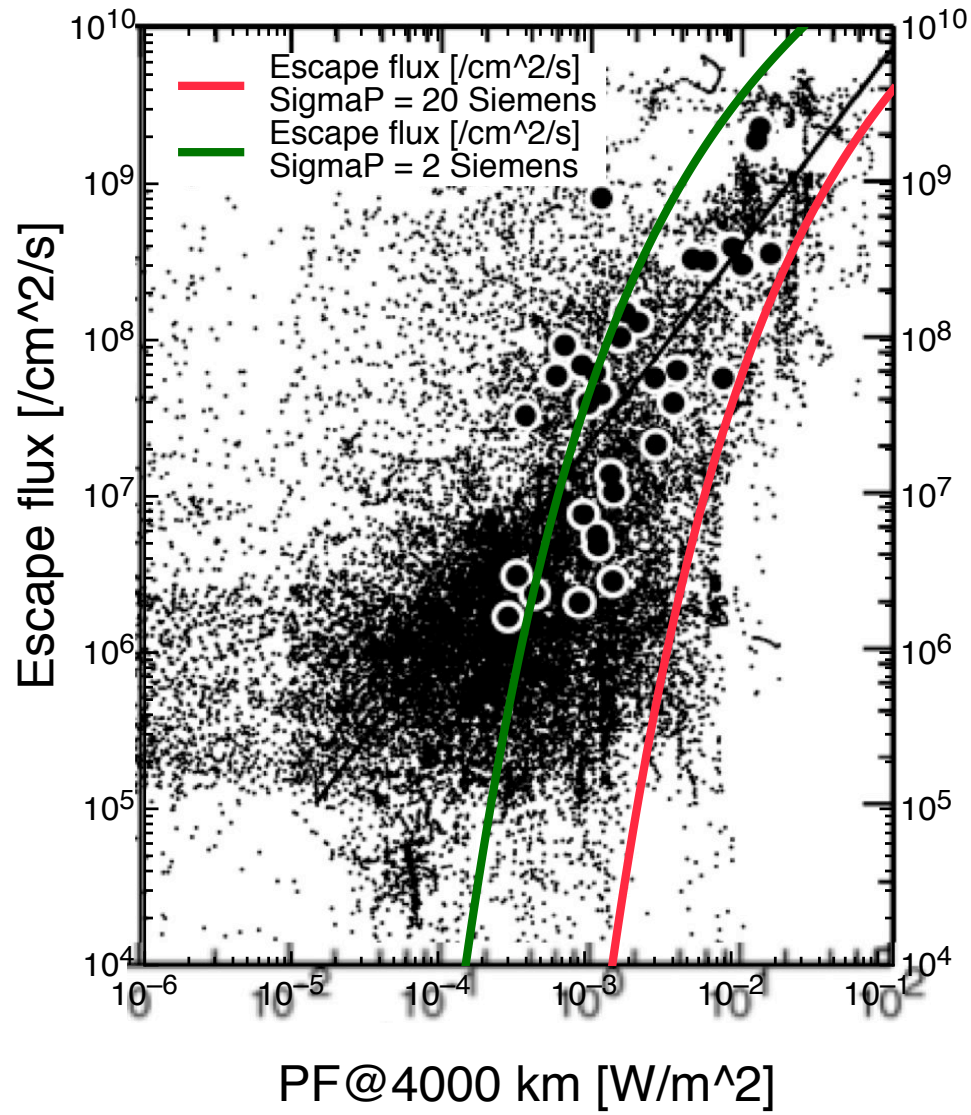
Estimating Escape Flux

- Cold core has negligible escape
- Exponential tail $\exp(-V/V_{tail})$
- V_{tail} e-folding velocity tracks local $2*V_{ExB}$
- Invoke "thermalization" of convective ring beam motion
- Vary Poynting flux, hence V_{ExB}, hence Vtail
- Compute escape flux (above Vesc)
- Escape flux estimate (1D) ~ $F_{limit}*(V_{ExB}/Vesc)*\exp(-V_{esc}/V_{ExB})$

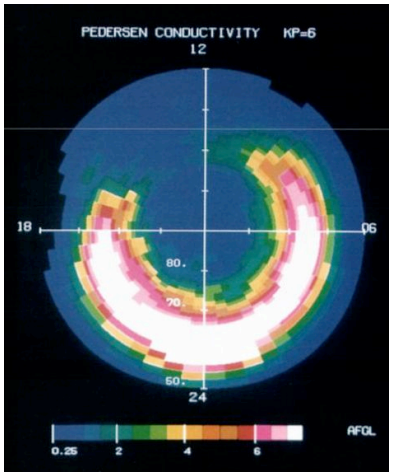


O^+ Escape Flux vs. PF

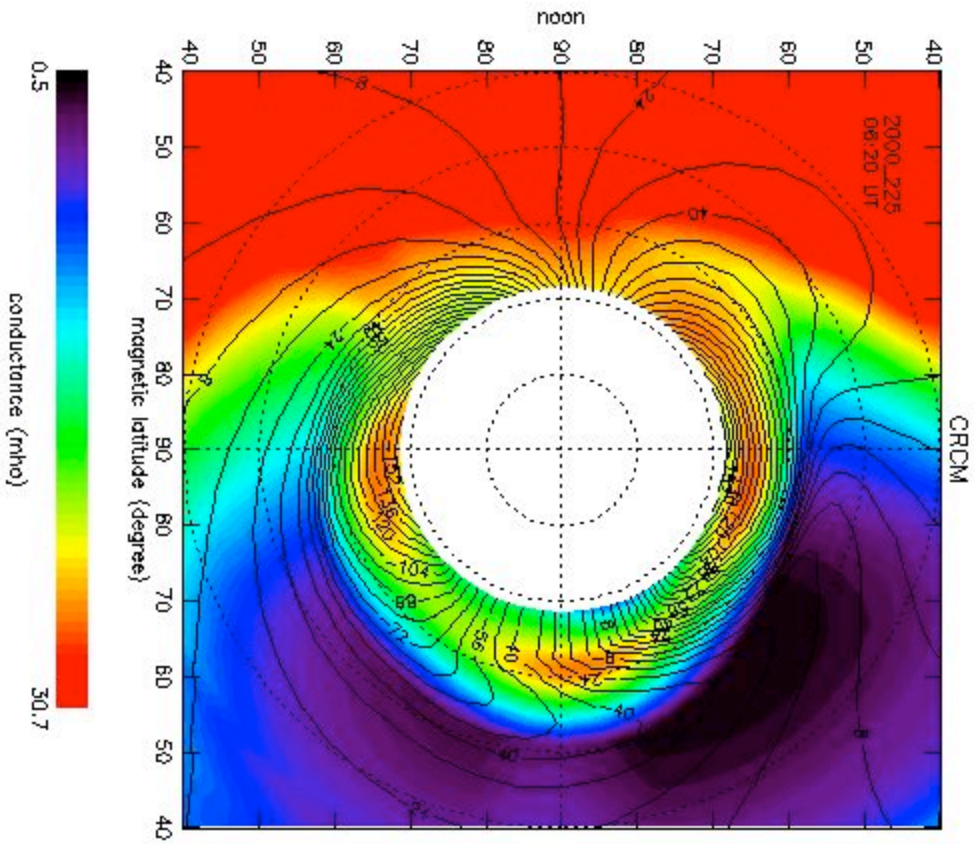




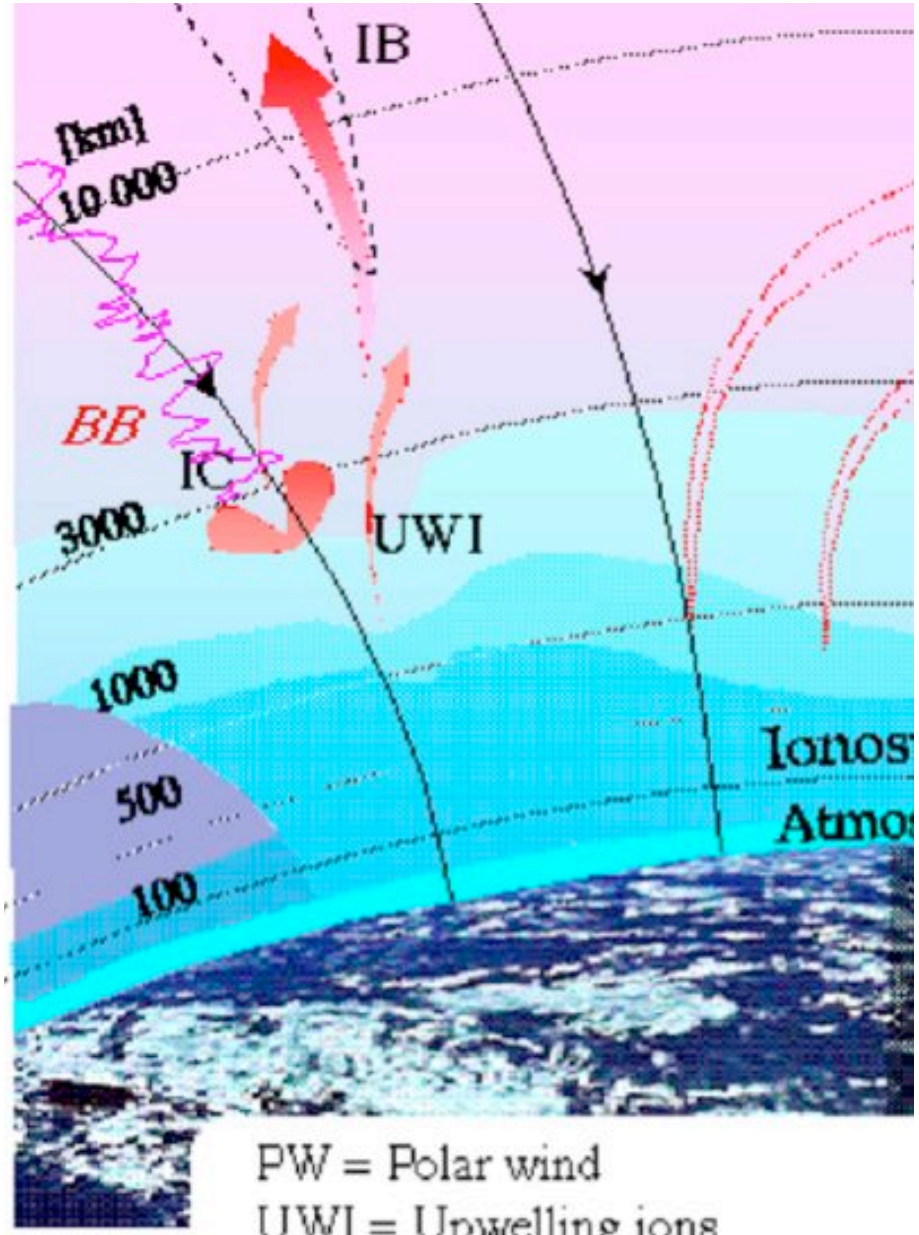
What's $\sum p$?



- Hedin 1991 MSIS, Bilitza 1993, Riley 1994 IRI, Hardy 1987 for aurora
- For given PF, higher $\sum p$ => lower V_{ExB}
- ~ 20 S for dayside auroral zone,
- >2 S in the nightside auroral zone



Conclusions



PW = Polar wind
UWI = Upwelling ions
IC = Ion conics

- Reconnexion creates two-way linkages
- Ring-beam thermalization likely key process in outflow of heavy ion plasma
- Need to study the plasma physics: How does it work in the strong field case where $V << V_A$?