INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

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" SPRING COLLEGE ON GEOMAGNETISM AND AERONOMY "

(2 - 27 March 1987)

" Physics of planetary atmospheres and ionospheres " - II

presented by :

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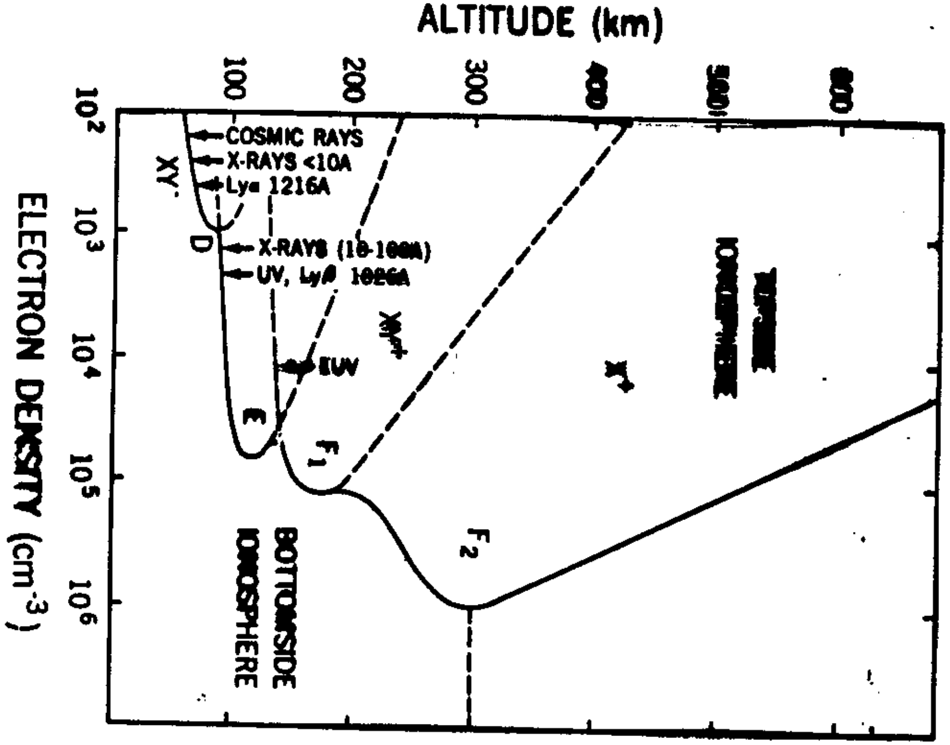


HOMOSPHERE / HETEROSPHERE

$$\bar{m} = \sum n_j m_j / \sum n_j \rightarrow \bar{H}$$

HOMOSPHERE: $d(n_1/n)\,dz = 0$

$$n_1 = n_{10} \exp(-z/\bar{H})$$

HETEROSPHERE: $\frac{dn_1}{dz} = -\frac{n_1}{H_1}$

IONOSPHERE $\quad I = \frac{hc}{\lambda}\Phi$

$XY + h\nu \rightarrow X + Y$

$X + h\nu (\geq IP) \rightarrow X^+ + e^-$

$(T_e > T_i \geq T_n)$ $\quad \tau = \sigma \int n\,dz$

$$q = \sigma_i n(z) \Phi_\infty e^{-\tau(\chi)}$$

$$\left.\begin{aligned} \frac{\partial q}{\partial z} &= 0 \\ \tau_n &= 1 \end{aligned}\right\} \quad z_m = \frac{\sigma_i}{\sigma_a}\underbrace{\frac{\Phi_\infty}{eH}}_{q_m}(\cos\chi)$$

$\tau_0 = 1 \rightarrow \mathcal{N}_0 = n_0 H = 1/\sigma_a$

$\mathcal{N}_0 \geq 10^{20}\,cm^{-2}$: D-layer

$\mathcal{N}_0 = 10^{19}\,cm^{-2}$: E-layer

$\mathcal{N}_0 = 10^{18}\,cm^{-2}$: F_1 Layer

$$\frac{dN}{dt} = q - L(N) - div(N v)$$

$q = L(N)$ Chemical Equil.

<u>Chapman-layer</u> (E, F_1) : $\boxed{q = \alpha N^2}$

– $N_m \propto \cos\chi$ $\quad \frac{1}{N}\frac{dN}{dz} = -\frac{1}{2H_n}$

– $h_m \propto \underline{h_0} + H \ln(\sec\chi)$

<u>Bradbury-layer</u> (F_2)

$q = \beta N \qquad \beta = k\, n(YZ)$

$$N_m = \frac{J\, n(X)}{\underline{k}\, n(YZ)}$$

<u>h_m</u> : where $\tau_c \equiv 1/\beta = \tau_D \equiv H^2/D_a$,

$h_m > h_m(q)$ $\qquad F_2$-layer

$div(N v_D) = 0$ Diffusive Equil.

1) $v_D = 0$

$$\frac{1}{N}\frac{dN}{dz} = -\frac{1}{\mathcal{H}} \qquad \mathcal{H} = \frac{k(T_e + T_i)}{m_i g}$$

2) $N v_D = const = F^*$

Polarization field

$$eE = \frac{m_+ g\, T_e}{T_e + T_i}$$

<u>accel</u>: $-(m(X^+) - m_+/2)\,g$

Ionosphäre (2)

Chapman-Schicht (Chem. Glgw.)

$q = \alpha N^2$ Verlust: Rekombination

α_D (Mol) $\simeq 10^{-7}\,cm^3 s^{-1}$

($\alpha_r \sim T^{-1/2}$) α_r (At.) $\simeq 10^{-12}\,cm^3 s^{-1}$

$$N = N_m \exp \tfrac{1}{2}\left[1 - (z/H) - \exp(-z/H)\right]$$

- $h(N_m) \equiv h^* = h(q_m)$
- $H \equiv$ Skalenhöhe des neutral gases

$$H = \frac{k T_n}{mg}$$

$$\boxed{\begin{array}{l} N_m \propto \cos^{1/2}\chi \\ h_m \propto \ln \sec\chi \end{array}}$$

Plasma Diffusion: $\tau_D \le \tau_c \rightarrow h \gg h_m$

$$N = N_0 \exp -(z/\mathcal{H})$$

$$\mathcal{H} = \frac{k(T_e + T_i)}{m_i g}$$

Plasma Skalenhöhe

$T_n \le T_i \le T_e$

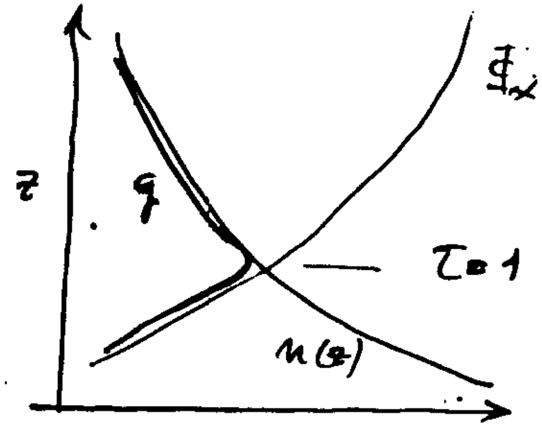
Jupiter
Saturn ?

$T_n \ge T_i \simeq T_e$

Ionosphäre

$$X + h\nu\,(\ge IP) \rightarrow X^+ + e^-$$

$$q = \sigma_i\, n(z)\, \Phi_\infty\, e^{-\tau}$$



$n_0 H = \frac{1}{\sigma_a}$ (N_0)

$N_0 \ge 10^{20}\,cm^{-2}$	D	Schicht
$N_0 \doteq 10^{19}\,cm^{-2}$	E	
$N_0 \doteq 10^{18}\,cm^{-2}$	F_1	

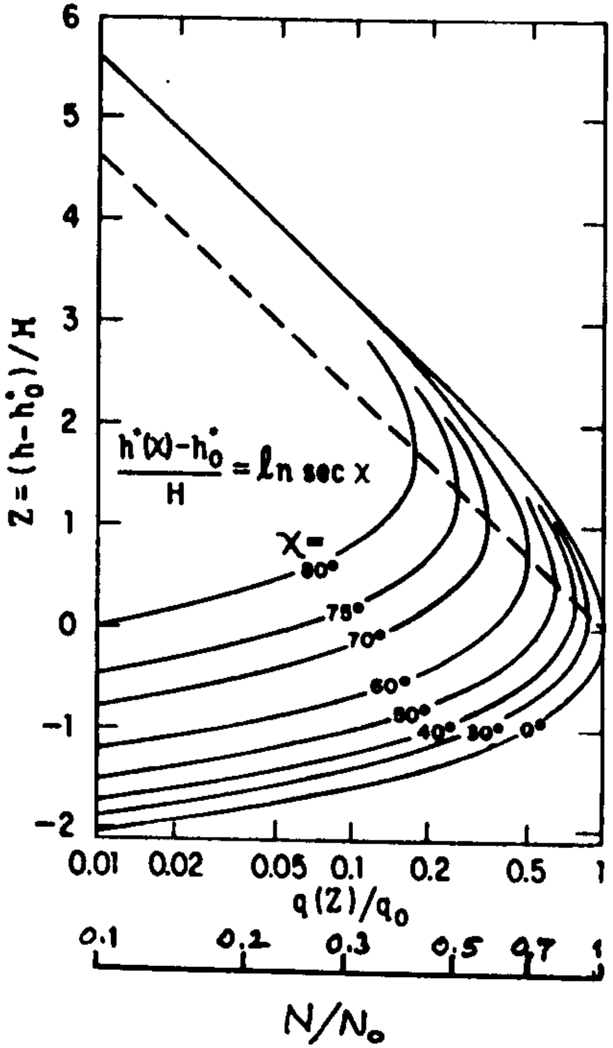
$$q_m = \frac{\sigma_i}{\sigma_a}\frac{\Phi_\infty}{eH}\cos\chi = q_0 \cos\chi$$

$h(q_m) \equiv h^*$ wo $\tau = 1$

$$q(z) = q_0 \cos\chi \exp\left[1 - z/H - \sec\chi \exp(-z/H)\right]$$

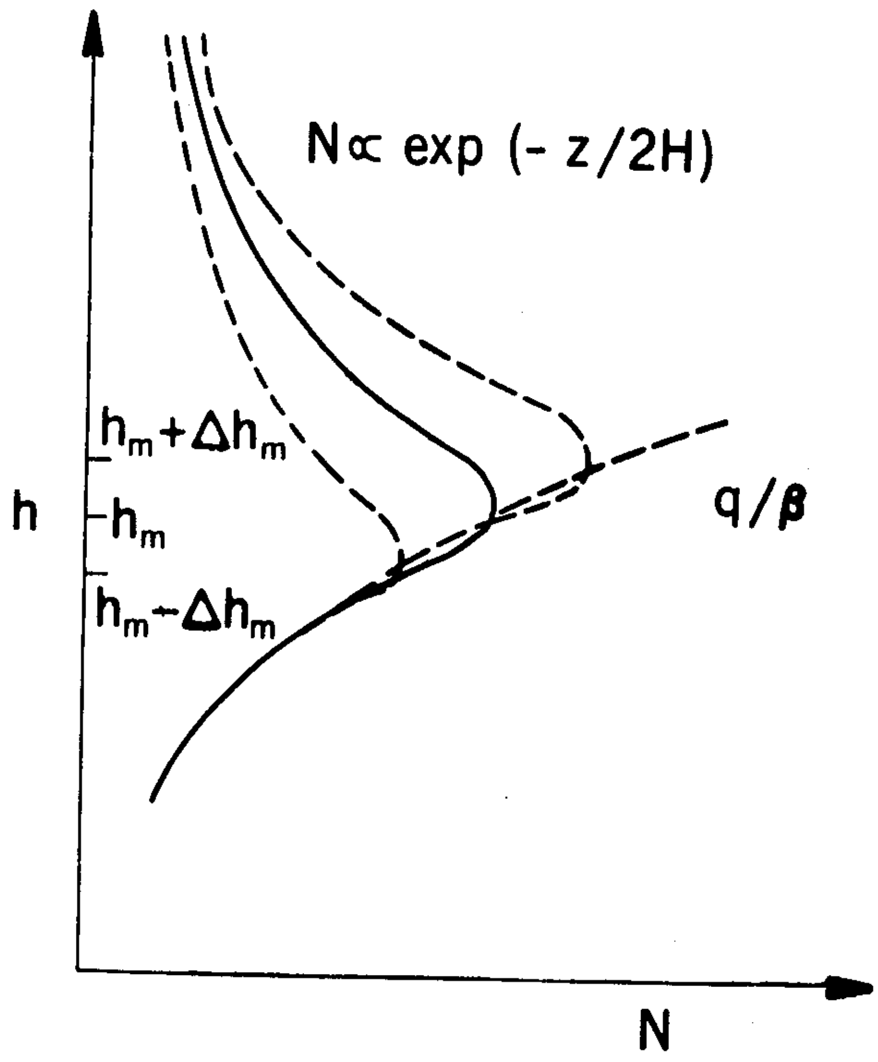
Chapman Produktionsfkt

Chapman-Layer



Chapman-Schicht

F– Layer



Ionospheric Boundaries

Magnetic Planets

$$E_{rot} \simeq E_{conv}$$

Plasmapause $L_{pp}(\epsilon) = 5.7 - 0.47k$

Potential max: g, $\vec{B}$

$$L_c^3 = \left[\frac{2}{3} \frac{GM}{\Omega^2 R^3}\right]$$

Nonmagn. Planets (Venus)

Ionopause:

$$p_{sw} \equiv (\rho v^2)_{sw} = p_{in} \equiv N k (T_e + T_i)$$

Ionosphere (Venus + Mars)

• Chapman Layer

$CO_2 + h\nu \rightarrow CO_2^+ + e$

$CO_2^+ + O \rightarrow \boxed{O_2^+} + CO$

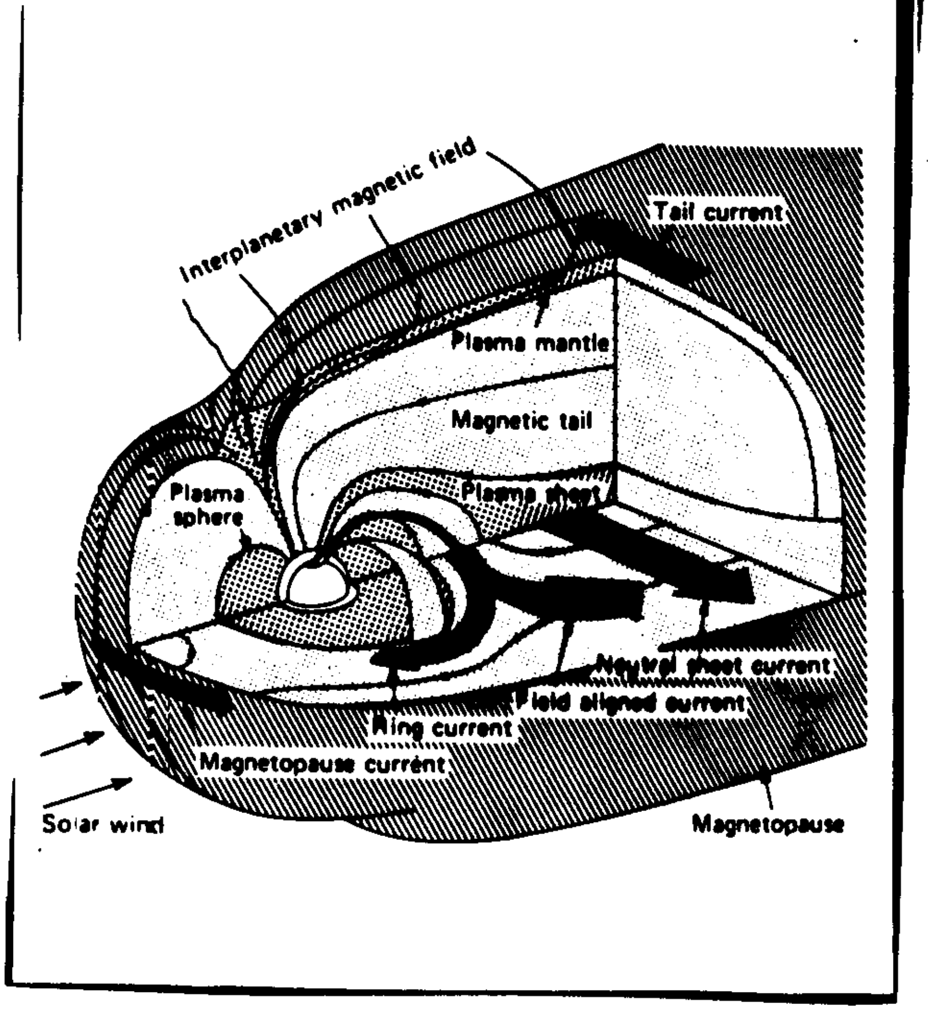
• $h_m \sim 130 - 150$ km $\sim \ln \sec \chi$

• $N_m \sim 5 \times 10^5\ cm^{-3}$ $\sim \cos^{1/2} \chi$

Venus : Ionopause ($p_{sw} \approx p_{ion}$)
Solar wind interaction

Mars : "Protected" by weak magnetosphere ($B_0 \approx 20$ nT)

$p_{sw} \approx \frac{B_0^2}{8\pi} > p_{ion}$ ($B_0 \approx 50$ nT)



Atmospheric Escape

1) $v > v_{esc}$
2) 'no' collisions (EXOSPHERE)

Exobase : mfp ≈ H

Venus, Mars	160-180 km
Earth	500-600 km
Mercury, Moon	surface

Atmospheric Mass Loss over 4.5 Byr.

VENUS	~1%	(H)
EARTH	~3%	(H)
MARS	~3.5	(H, N, O)

of present atmospheric mass

$$\frac{\Delta M_a}{M_a}$$

Thermal escape ~ T_∞

Non-thermal escape : Chemical react.