The Electric Field of the Sun and Solar Wind

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DPP2020 / TO16.7

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Here, electric effects are calculated for the Solar interior, photosphere, and corona, based on standard 1-D radial models by Bahcall (2005) and Fontenla (1993) . The major uncertainty is in the photon-electron scattering cross-section $\sigma_{\gamma e}$ for re-combining (i.e. correlated) plasmas.

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Supported by UCSD and AFOSR

Equlibrium Stellar Fluid Eqns:

mass $m_p\ m_e$ charge $e^-\ p^+$ photons γ

1 $\nabla^2\Psi(r) = G\, m_p\, n_p(r)$ Gravity

2 $\nabla \bullet \Gamma_\varepsilon(r) = \frac{d}{dt}\varepsilon(r)$ Fusion Energy Flux

3 $-(4aT^3)\,T'(r)\,l_\gamma = \frac{4}{c}\Gamma_\varepsilon$ Thermal Energy Diffusion

4a $[n_pT]' + n_pm_p\Psi' + (+e)n_p\Phi' = 0$ Proton Fluid Momentum

Thermo- Photo- Electric

4b $[n_eT]' - \frac{\Gamma_{\varepsilon\gamma}}{c\,l_{\gamma e}} + n_em_e\Psi' + (-e)n_e\Phi' = 0$ Electron Fluid Momentum

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4a+4b $[(2n)T]' - \frac{\Gamma_{\varepsilon\gamma}}{c\,l_{\gamma e}} + n\,m_p\Psi' = 0$ Total Fluid Momentum

4a−4b $\frac{\Gamma_{\varepsilon\gamma}}{c\,l_{\gamma e}n_e} + m_p\Psi' + (2e)\Phi' = 0$ Electric Field

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$-m_pg(r)/2 \approx eE_{\rm Th}(r)$

Thermo-Electric in high-density collisional regime

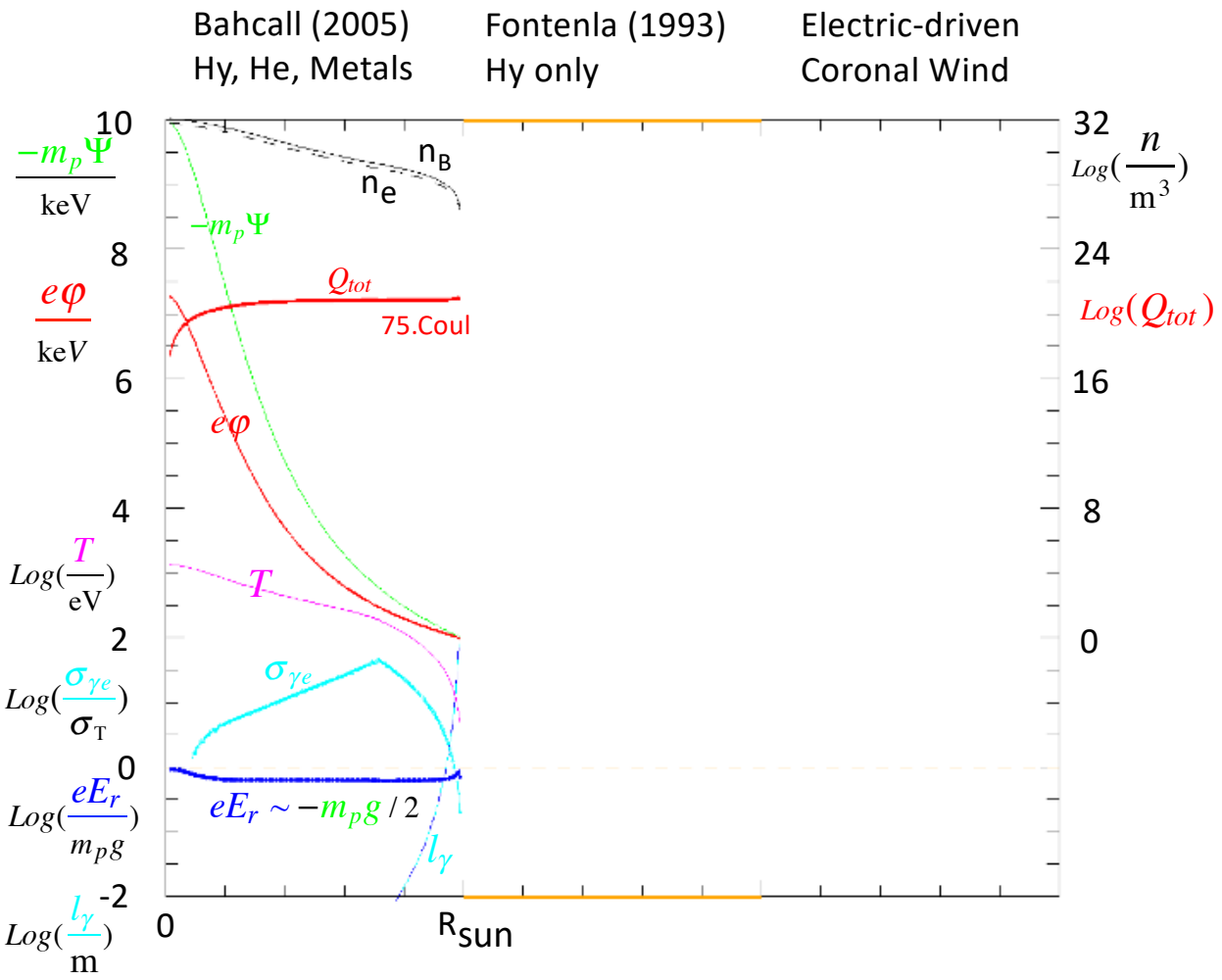
A. Pannekoek
S. Rosseland (1924)
A.E. Eddington

$\sigma_{\gamma e} \equiv \frac{1}{l_{\gamma e}\,n_e}$

$\frac{\Gamma_{\varepsilon\gamma}}{2\,c}\sigma_{\gamma e} = eE_\gamma$

Photo-Electric : Photons de-coupled from T' and ψ'

Electric effects in
2 standard models,
Core & Photosphere



Electric effects in
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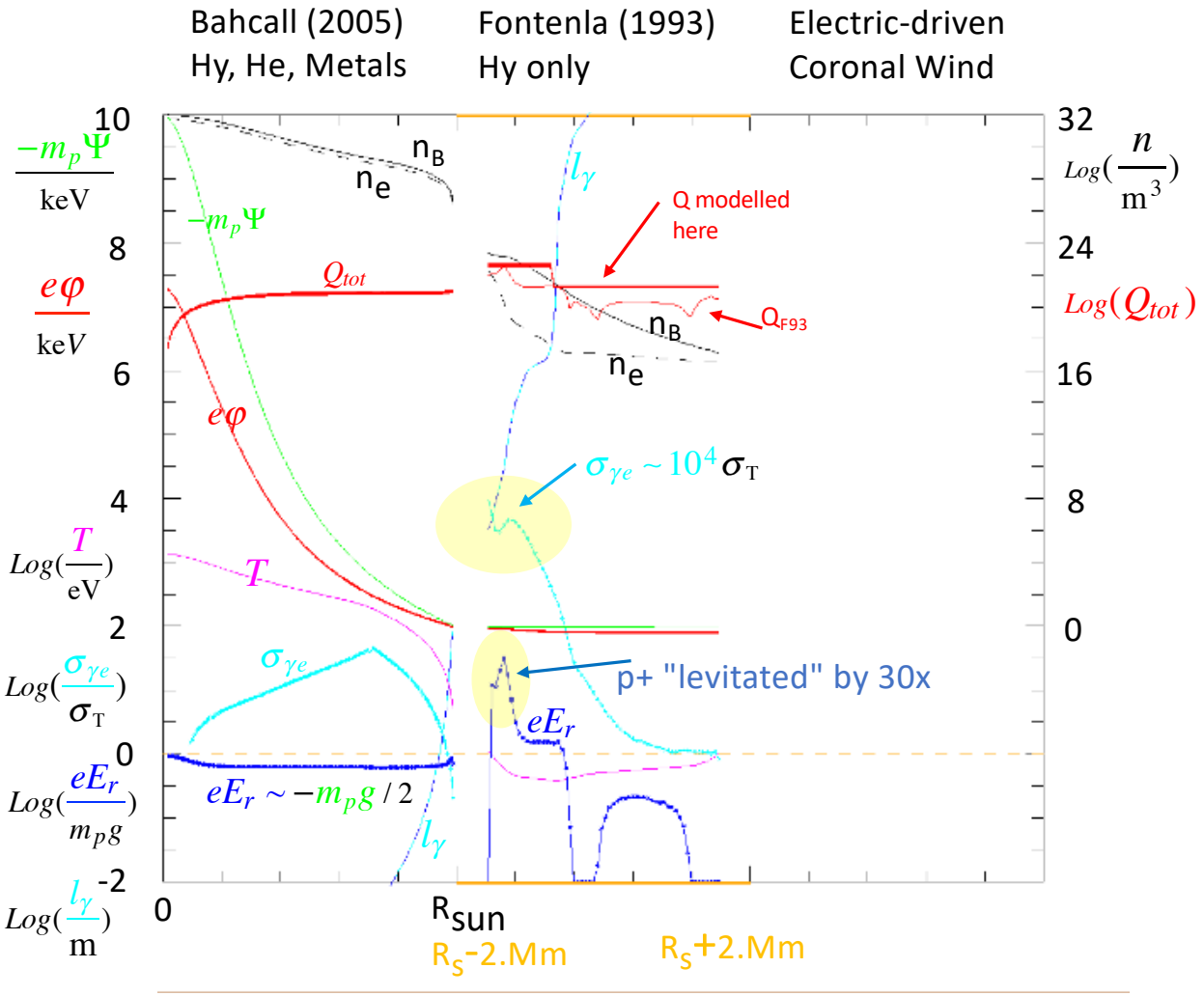
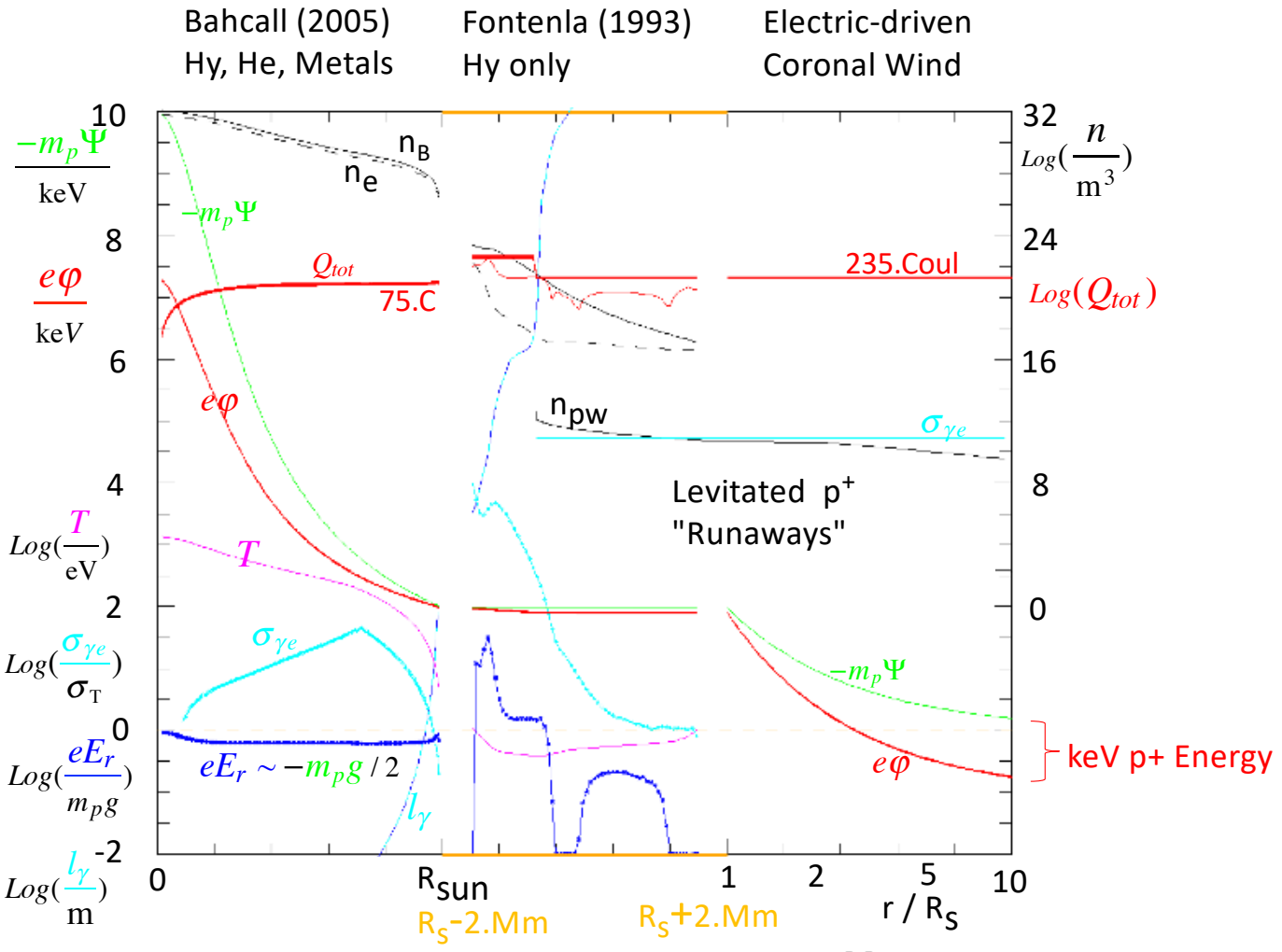


Electric effects in
2 standard models,
Core & Photosphere

& Corona model

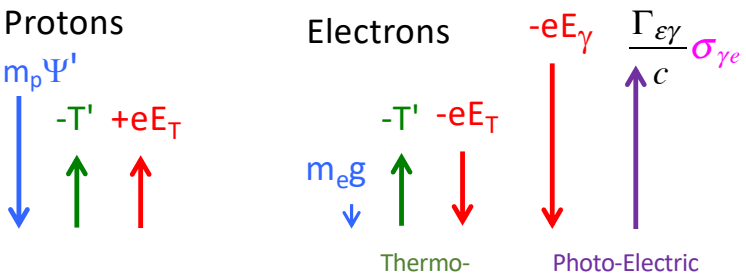


Force Balance with Electric Fields

Hydro:

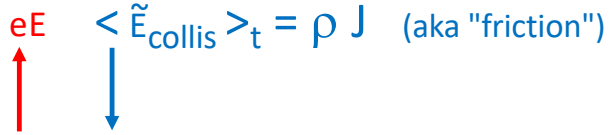
at R_S

2.8 eV /Mm



Ohm's ~~Law~~

Ohm/s Balance



Photon-electron scattering cross-section $\sigma_{\gamma e}$ increases with plasma density & correlation.

e- p+ Strongly Corelated

$$\sigma(\gamma \rightarrow H^*) \sim \pi a_0^2 = 0.6\,\mathrm{x}10^{-20}\,\mathrm{m}^2$$

$$\sigma(\gamma \rightarrow H^- \quad bf) \sim 0.5\,\mathrm{x}10^{-20}\,\mathrm{m}^2$$

$$\sigma(\gamma \rightarrow H + e^- \; ff) \sim 0.5\,\mathrm{x}10^{-20}\,\mathrm{m}^2$$

"inverse Bremstrahling" @ $n=10^{22}$, T=1eV

$$\sigma_{\gamma e} \sim 3.4\,\mathrm{x}10^{-24} = Model$$

isolated electron

$$\sigma_T = 0.7\,\mathrm{x}10^{-28}\,\mathrm{m}^2$$

"1-d PIC Sim" : Collisional e-p+ Source, Photon Force, H^0 Drag, e- p+ Kinetics, Poisson Eqn => e- p+ Beam

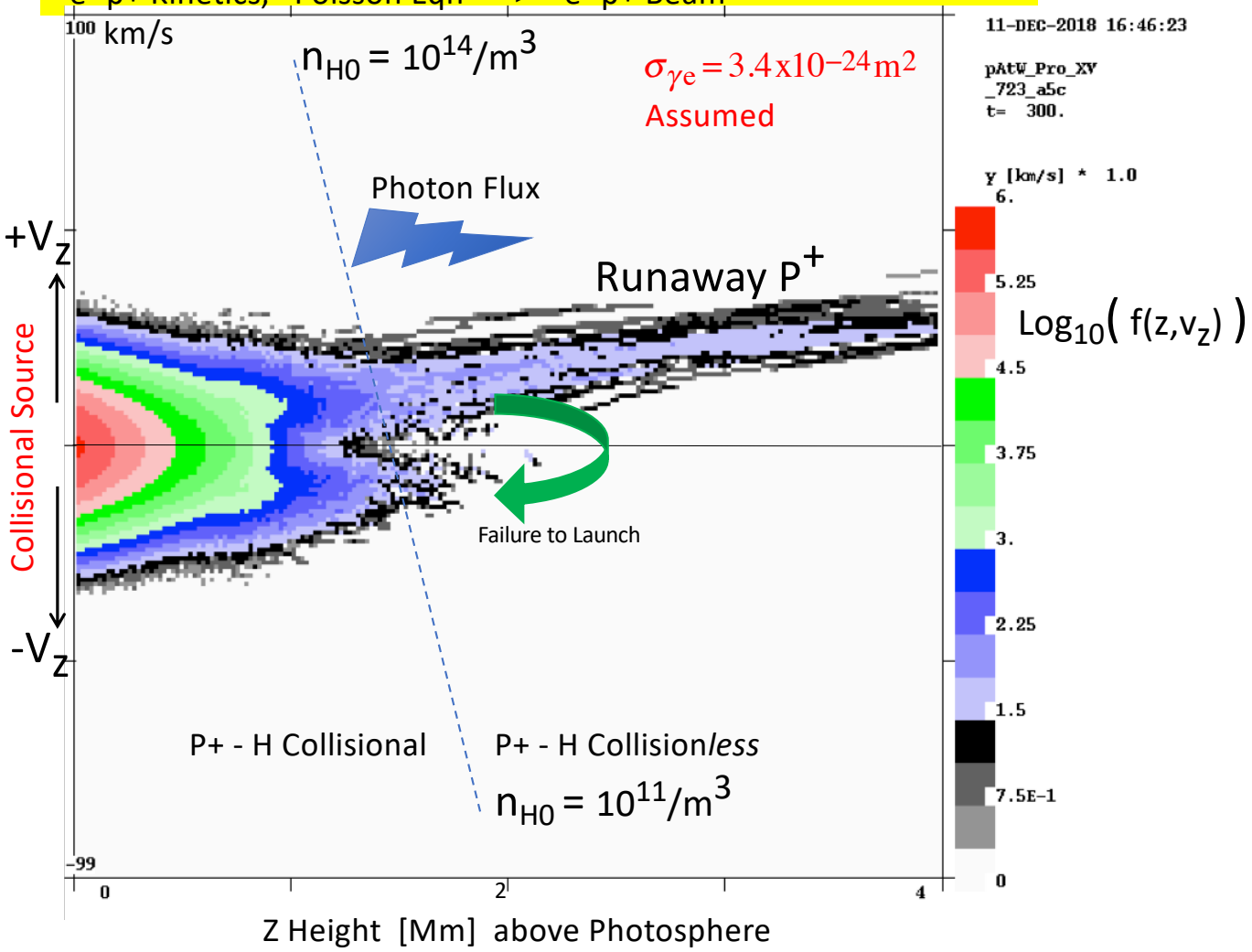
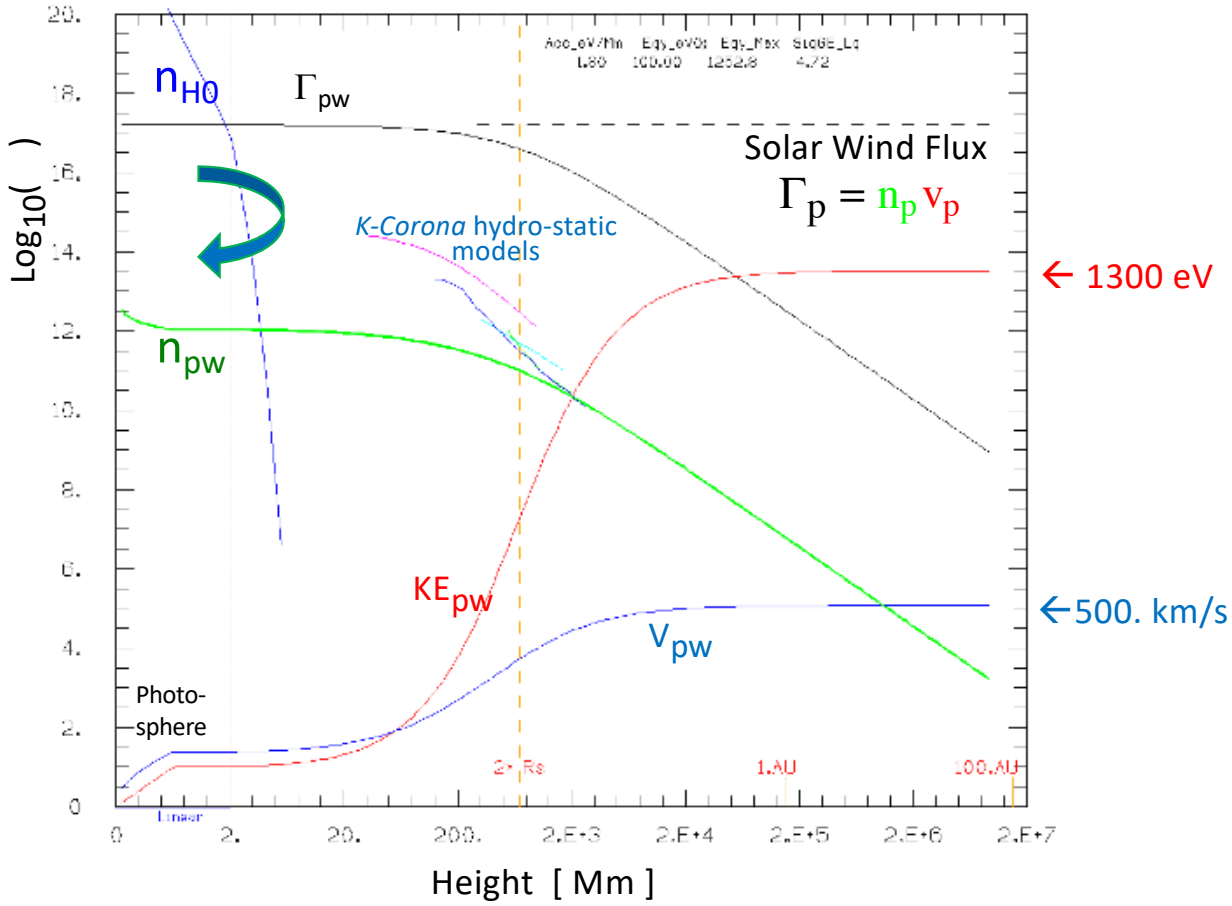


Photo-Electric:

When Electric Field on Protons Exceeds Collisional Drag from H^0

Runaway p+ :

Photon-Driven Solar Wind p+ Flux, Density, Velocity, Energy
assuming average $\sigma_{\gamma e} = 3.4 \times 10^{-24}\ \mathrm{m}^2$



← 1300 eV

←500. km/s

$$\frac{d}{dr}\mathcal{E}_p = -m_p\Psi' + eE(r) - \nu_c(p^+, H^0)$$

$$\mathcal{E}_{p+}(\rho) \sim \mathcal{E}_0 + (1.3\mathrm{keV})\left[1 - 1/\rho\right]$$

$$v_p(\rho) \sim (500.\mathrm{km/s})\left[1 - 1/\rho\right]$$

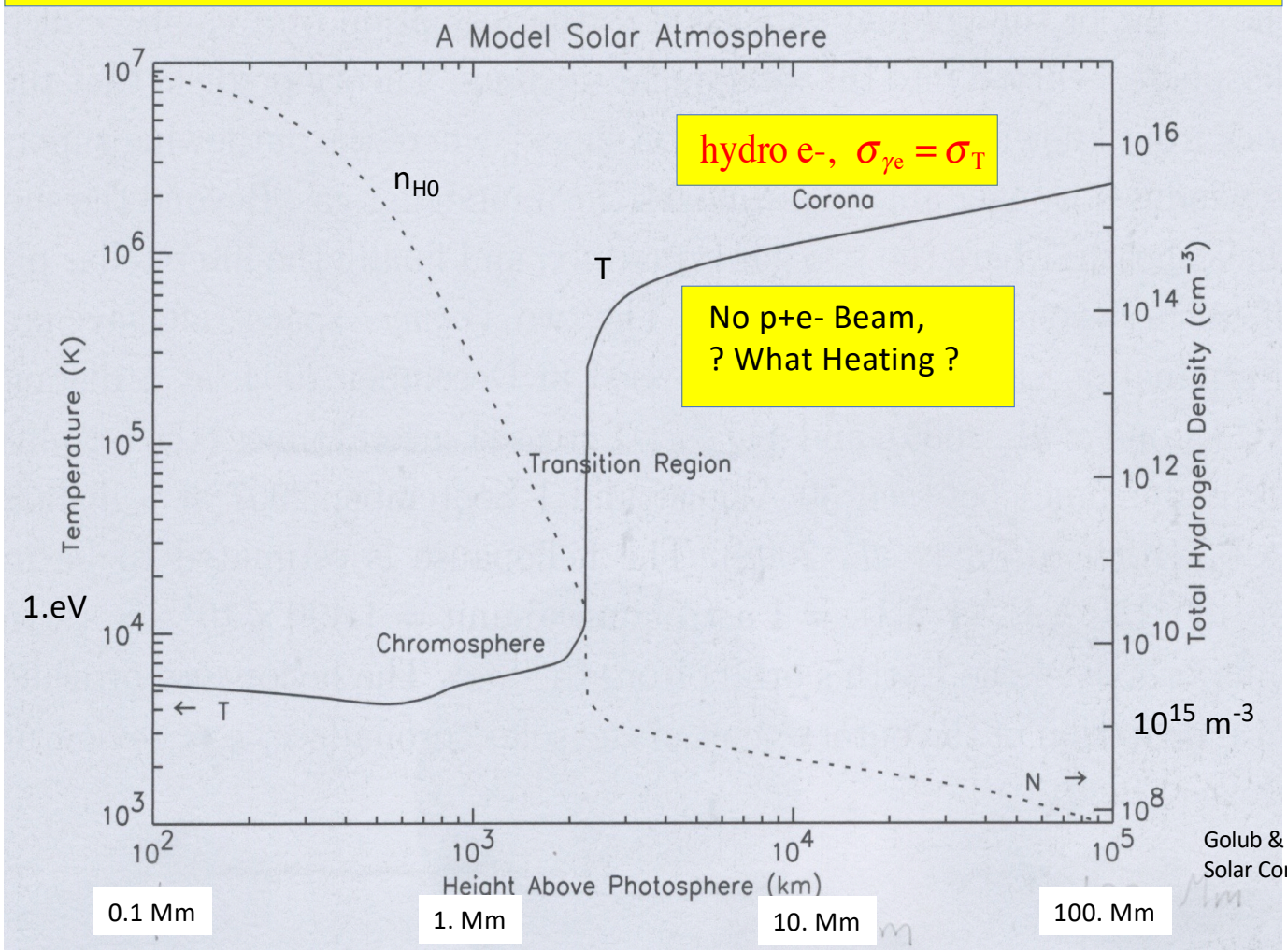
$$n_p(\rho) \sim 3\times10^{11}\ \rho^{-2}\ \mathrm{m}^{-3}$$

$$\Gamma_p(\rho) \sim 1.6\times10^{17}\ \rho^{-2}\ \mathrm{s}^{-1}\mathrm{m}^{-2}$$

$$\rho \equiv r / R_s$$

0.

Traditional MHD Models : Coronal Heating and Solar Wind Energetics remain elusive



Golub & Pasachoff,
Solar Corona

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