The Electric Field of the Sun and Solar Wind
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Q: How can a Solar Photon Flux of \( \Gamma_\varepsilon \gamma \sim 60. \text{ MW/m}^2 \) possibly create a Solar Wind with \( \Gamma_{KE} \sim 60. \text{ W/m}^2 \) ?

A: Electric Fields:

- Gravito-Electric: \( eE_G \sim +1.4 \text{ eV/Mm} \) -- Eddington, Rosseland (1924)
- Photo-Electric: \( eE_\gamma \sim +4.6 \text{ eV/Mm} \) from \( \sigma_{\gamma e} \sim 3 \times 10^{-24} \text{ m}^2 \)
- thereby Levitating protons: \( m_p g \sim -2.8 \text{ eV/Mm} \)

Note: Photon-electron cross-section \( \sigma_{\gamma e} \) is uncertain, add’l theory needed;
Runaway p+ process requires kinetic analysis;
Net charge is exceedingly small; true Poisson solution is difficult.

But: \( \Box \quad \text{MHD} \quad \square \)
Coronal Heating, Solar Wind Energetics are poorly understood

No p+e- Beam, ? What Heating ?

Golub & Pasachoff, Solar Corona
Stellar Hydro Eqns: \[ \begin{align*} 
1 & \quad \nabla^2 \Psi(r) = G m_p n_p(r) \quad \text{Gravity} \\
2 & \quad \nabla \cdot \Gamma_{\varepsilon \gamma}(r) = \frac{d}{dt} \varepsilon(r) \quad \text{Energy Generation} \\
3 & \quad -\frac{d}{dT} (aT^4) T' \gamma = \frac{4}{c} \Gamma_{\varepsilon \gamma} \quad \text{Thermal Diffusion} \\
4a & \quad [n_p T]' + n_p m_p \Psi' + (+e)n_p \Phi' = 0 \quad \text{Proton Force} \\
4b & \quad [n_e T]' - \frac{\Gamma_{\varepsilon \gamma}}{c l_{\gamma}} + n_e m_e \Psi' + (-e)n_e \Phi' = 0 \quad \text{Electron Force} \\
4a + b & \quad [(n_e + n_p) T]' - \frac{\Gamma_{\varepsilon \gamma}}{c l_{\gamma}} + n_p m_p \Psi' = 0 \quad \text{Hydro Force} 
\end{align*} \]
Photon Drive of Solar Wind: γ p+, e-, H*, H(-)

\[ \frac{\Gamma_{\gamma} \sigma_{\gamma e}}{c} + \frac{1}{n_e} [n_e T]' + e \Phi' = 0 \]

Gravi-Electric (hydro)

Photo-Electric

\[ \sigma(H^*) \sim \pi a_0^2 = 0.6 \times 10^{-20} \text{m}^2 \]
\[ \sigma(H^{-}bf) \sim 0.5 \times 10^{-20} \text{m}^2 \]
\[ \sigma(H^{-}ff) \sim 0.5 \times 10^{-20} \text{m}^2 \]
\[ \sigma_{\gamma e} \sim 3.4 \times 10^{-24} = \text{Model} \]
\[ \sigma_T = 0.7 \times 10^{-28} \text{m}^2 \]

\[ 2.8 \text{ eV/Mm} \]

\[ 4.6 \text{ eV/Mm} \text{ from} \]

\[ \Gamma_{\gamma} = 60. \text{MW/m}^2 \rho^{-2} \]

Protons \quad Electrons

\[ \begin{align*}
\Gamma_{\gamma} \sigma_{\gamma e} & + \frac{1}{n_e} [n_e T]' + e \Phi' = 0 \\
\text{Gravi-Electric (hydro)} \\
\text{Photo-Electric} \\
\sigma(H^*) & \sim \pi a_0^2 = 0.6 \times 10^{-20} \text{m}^2 \\
\sigma(H^{-}bf) & \sim 0.5 \times 10^{-20} \text{m}^2 \\
\sigma(H^{-}ff) & \sim 0.5 \times 10^{-20} \text{m}^2 \\
\sigma_{\gamma e} & \sim 3.4 \times 10^{-24} = \text{Model} \\
\sigma_T & = 0.7 \times 10^{-28} \text{m}^2
\end{align*} \]

\[ \frac{d}{dr} \mathcal{E}_p = -m_p \Psi' - e \Phi' - \nu_c (p^+, H^0) \]

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

\[ V_p(\rho) \sim (500 \text{ km/s}) \left[ 1 - \frac{1}{\rho} \right] \]

\[ n_p(\rho) \sim 3 \times 10^{11} \rho^{-2} \text{ m}^{-3} \]

\[ \Gamma_p(\rho) \sim 1.6 \times 10^{17} \rho^{-2} \text{ s}^{-1} \text{m}^{-2} \]

\[ \rho \equiv r / R_s \]
Runaway $p^+$ Beam from Decreasing $H^0$ Collisional Drag
p+ e- Kinetics with Collisional H\(^0\) Background, Poisson E(z)

\[ \eta_{H^0} = \left(10^{17}/m^3\right) 10^{-\frac{z}{3\text{Mm}}} \]

Photon Flux \( \Phi_{\text{EY}} = 10^{26.5} \text{eV/sec/m}^2 \)
Solar Wind $p^+$ Flux, Density, Velocity, Energy
Traditional Hydro Corona Models (no Wind)

Cranmer / Kohl 1999
Strachan / Kohl 1993
Badalyn / Livshitz 1985
Van de Hulst 1950

Models K-Corona polarized Brightness pB coming from Photons scattering off free, isolated electrons.

Assumes $\sigma_{\gamma e} = \sigma_T = 0.6 \times 10^{-28} \, \text{m}^2$

Measured light scattering pB, de-convoluted along the line-of-sight gives $n_e(\rho) = n_p(\rho) = 10^{11.9} \rho^{-2.57} + 10^{14.6} \rho^{-10.5} \, [\text{m}^{-3}]$

Assuming Hydrostatic Equilibrium: $[(n_e+n_p)T]' + \Psi'' = 0$
determines the required $T \sim 120.\text{eV}$
Charge Separation in Core, Photosphere, Corona

\[ Q_{\gamma e} \]
from \( \gamma_{\gamma e} = 3 \times 10^{-24} \text{ m}^2 \)
\[ e\varphi' \approx 4.6 \text{ ev}_\text{Mm} \]
no add’l \( Q \)

"naive" Debye shielding

\[ eE \approx 10^9 \text{ ev}_\text{Mm} \]

Core \hspace{1cm} Photosphere \hspace{1cm} Corona

\[ 1.3 \text{ keV} \]
Beam \( p^+ \)
Magnetic Field Fluctuations @ 1.AU (NASA/ACE)
B-Field Fluctuations are driven by local Solar Wind Flux

NASA/ESA Ulysses $r = 1 \rightarrow 5$ AU

$\theta = -80^\circ \rightarrow +80^\circ$

$\log_{10}(\mid \mathbf{B} \mid) \uparrow$

$\log_{10}\left(\frac{N_p \cdot V_p}{\# / \text{s.m}^2}\right)$

$\mid \mathbf{B} \mid = T_w^{0.75}$
MHD Assumptions

\[ \nabla \cdot E_Q = 4\pi \rho_Q = 0 \]
\[ \nabla \cdot B_M = 4\pi \rho_M = 0 \text{ (optional)} \]
\[ c \nabla \times E_t = -B \]
\[ c \nabla \times B = \dot{E}_t + \dot{E}_Q + 4\pi J_Q + 4\pi J_t \]
\[ F = \rho_Q E + (J_Q + J_t) \times B / c \]
\[ \nabla \cdot J = 4\pi \rho_Q = 0 \]

Dissipation

\[ \nu_{ei} = n \bar{\nu} \left( \frac{e^2}{T} \right)^2 \ln \Lambda \]
\[ m \Delta \nu_{ei} \nu_{ei} = e E_Q \text{ (momentum)} \]
\[ \sigma = \frac{e^2 n}{m \nu_{ei}} = (10^{14} \text{ s}^{-1}) T_e^{3/2} \]

Hydro: \[ \nu_{ei} \uparrow \Rightarrow T \downarrow, \sigma \downarrow \]
Magnetic: \[ \sigma \uparrow \Rightarrow T \nearrow, \nu_{ei} \searrow \]

Contradictory

No Charges
No ElecPotEgy
No ThermoElec
No GraviElec
No Capacitance

No Causality
(Simultaneous)
No E // B
Yes: Inductance

\[ \sigma = \infty \text{ (Ideal)} \]

?? Moving B-lines live forever
?? B-lines "Frozen-Into" Plasma
?? Plasma "Stuck on" B-lines
?? Particle Streamline \[ \equiv \text{ B-line} \]
Fluctuating B-fields measured by Spacecraft are generated by Filamentary Currents in the outward-flowing Solar Wind; NOT BY the Chimera of a Rotating Dipolized Monopole Magnetic Spiral.
Solar Models, Core & Photosphere: p+ Levitation in Photosphere/Corona

Bahcall 2005

Fontenla 1993
The Electric Field of the Sun and Solar Wind

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Body:
A simple model of solar electric fields explains the solar wind energetics and chromospheric heating, invoking only gravitational settling and photon scattering. In the (collisional) solar interior, gravity necessarily generates a radial electric field $eE \sim -\frac{1}{2} m_p g$; protons are 50% levitated, with $eE(R_s) \sim 1.4$eV/Mm from displaced charge $Q(R_s) \sim -75$ C. In the (weakly collisional) outer photosphere/chromosphere, electron scattering of the photon flux $\Gamma_g$ gives $eE = (\Gamma_g/c) \sigma_{ye}$. An (averaged) $eE \sim (4$eV/Mm) $(r/R_s)^{-2}$ from photon-electron cross-section $\sigma_{ye} \sim 3 \times 10^{-24}$m² ≤ $10^{-3} \sigma$(H-) can generate the observed solar wind: protons are accelerated out of the 2.keV gravity well and up to 1.3keV kinetic energy within several $R_s$, with total particle energy flux $\sim 10^{-6} \Gamma_E$. This coherent proton/electron "flow-sheath" is the K-Corona, obviating the $T \sim 100$eV hydrostatic model (Van deHulst, 1950). Filamentation $(\sim 1$Mm)² of the flow arises from the convection/recombination ("roiling") dynamics of surface granulations, with local electric fields generating strong currents and local magnetic fields. Statistical charge fluctuations, current filamentation, and neutral gas drag on the distant proton/electron flows produce the pervasive fluctuating magnetic fields observed by spacecraft.

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Special Instructions:
Beam-Generated Waves and Fluctuations in the Heliosphere

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Body:
Waves and fluctuations in heliospheric plasmas are primarily generated by the coherent outward-flowing photon and particle beams, which are poorly described by MHD equations with "frozen-in" magnetic fields. In the solar chromosphere and corona, low inter-particle collision rates preclude hydro models. Rather, plasma sheath kinetics is required to describe the development of the (60.W/m²) solar wind beams by the (60.MW/m²) outward photon flow[1], with resultant coronal "heating". In contrast, the many contradictions of the "frozen-in" moving magnetic spiral model are readily apparent [2], and the model provides no valid equilibrium basis for waves and fluctuations. Within planetary magnetospheres, modern models properly describe magnetic distortions and waves driven by the solar wind. Elsewhere, the rapidly fluctuating magnetic fields observed by spacecraft are apparently caused by local fluctuating currents from statistical charge fluctuations, current filamentation, and neutral gas interactions with the solar wind. Here, the images of a spiral IMF "rooted" in the solar surface are less than helpful.


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