The Electric Field of the Sun and Solar Wind

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- Q: How can a Solar Photon Flux of $\Gamma_{\epsilon\gamma} \sim 60. MW/m^2$ possibly create a Solar Wind with $\Gamma_{KE} \sim 60.W/m^2$?
- 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 : MH

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Golub & Pasachoff, Solar Corona

Stellar Hydro Eqns:mass
$$m_p m_e$$
charge
 $e^- p^+$ photons
 γ 1 $\nabla^2 \Psi(r) = G m_p n_p(r)$ Gravity2 $\nabla \cdot \Gamma_{\varepsilon \gamma}(r) = \frac{d}{dt} \varepsilon(r)$ Energy Generation3 $-\frac{d}{dT}(aT^4)$ $T' l_{\gamma} = \frac{4}{c} \Gamma_{\varepsilon \gamma}$ Thermal Diffusion4a $[n_pT]'$ $+n_p m_p \Psi' + (+e) n_p \Phi' = 0$ Proton Force4b $[n_eT]' - \frac{\Gamma_{\varepsilon \gamma}}{c l_{\gamma}} + n_e m_e' \Psi' + (-e) n_e \Phi' = 0$ Electron Force $4a+b$ $[(n_e+n_p)T]' - \frac{\Gamma_{\varepsilon \gamma}}{c l_{\gamma}} + n_p m_p \Psi' = 0$ Hydro Force

Photon Drive of Solar Wind : γ p+, e-, H*, H⁽⁻⁾

$$\frac{\Gamma_{e\gamma}}{c}\sigma_{\gamma e} + \frac{1}{n_e}[n_eT]' + e\Phi' = 0$$

Gravi-Electric (hydro)
Photo-Electric
$$\sigma(H^*) \sim \pi a_0^2 = 0.6 \times 10^{-20} \text{ m}^2$$

$$\sigma(H^-bf) \sim 0.5 \times 10^{-20} \text{ m}^2$$

$$\sigma(H^{(-)}ff) \sim 0.5 \times 10^{-20} \text{ m}^2$$

$$\sigma_{\gamma e} \sim 3.4 \times 10^{-24} = Model$$

$$\sigma_T = 0.7 \times 10^{-28} \text{ m}^2$$

When Electric Field on Protons Exceeds Collisional Drag from H⁰

Runaway p+: $\frac{d}{dr} \mathcal{E}_{p} = -m_{p} \Psi' - e \Phi' - V_{c}(p^{+}, H^{0})$ $\mathcal{E}_{p+}(\rho) \sim \mathcal{E}_{0} + (1.3 \text{keV}) [1 - 1/\rho]$ $V_{p}(\rho) \sim (500.\text{km/s}) [1 - 1/\rho]$ $n_{p}(\rho) \sim 3 \times 10^{11} \rho^{-2} \text{ m}^{-3}$ $\Gamma_{p}(\rho) \sim 1.6 \times 10^{17} \rho^{-2} \text{ s}^{-1} \text{m}^{-2}$









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 $\sigma_{\gamma e} = \sigma_{\rm T} = 0.6 \, \mathrm{x} 10^{-28} \, \mathrm{m}^2$

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

Assuming Hydrostatic Equilibrium : $[(n_e+n_p)T]' + \Psi' = 0$ determines the required $T \sim 120.eV$







MHD Assumptions

$$\nabla \cdot E_Q = 4\pi \rho_Q = 0$$

$$\nabla \cdot B_M = 4\pi \rho_M = 0 \text{ (optional)}$$

$$c\nabla \times E_t = -\dot{B} \text{ photons}$$

$$c\nabla \times B = \dot{E}_t + \dot{E}_Q + 4\pi J_Q + 4\pi J_t$$

cancel

$$F = \rho_0 E + (J_0 + J_t) \times B/c$$

$$\nabla \cdot J = 4\pi \rho_Q = 0$$

Dissipation

$$v_{ei} = n \,\overline{v} \, (\frac{e^2}{T})^2 \, \ln \Lambda$$

 $m \Delta \mathbf{v}_{ei} \, \mathbf{V}_{ei} = e E_O \quad (\text{momentum})$ $\sigma = \frac{e^2 n}{m V_{ei}} \approx (10^{14} \text{s}^{-1}) T_{eV}^{3/2}$

Hydro: $v_{ei} \nearrow \Rightarrow T \searrow, \sigma \searrow$ Magnetic: $\sigma \nearrow \Rightarrow T \nearrow, v_{ei} \searrow^*$ Contradictory

No Charges No ElecPotEgy No ThermoElec No GraviElec No Capacitance

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

 $\sigma = \infty$ (Ideal)

?? Moving B-lines live forever

- ?? B-lines "Frozen-Into" Plasma
- ?? Plasma "Stuck on" B-lines
- ?? Particle Streamline \equiv B-line

didactic : Longitudinal, Transverse

r

$$\begin{cases} E \\ B \\ J \end{cases} \equiv \begin{cases} E_Q \\ B_M \\ J_Q \end{cases} + \begin{cases} E_t \\ B_t \\ J_t \end{cases}$$
$$\nabla \times \begin{cases} E_Q \\ B_M \\ J_Q \end{cases} = 0 \quad \nabla \cdot \begin{cases} E_t \\ B_t \\ J_t \end{cases} = 0$$

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





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 $Q(R_s) \sim -75$.Coul. In the (weakly collisional) outer photosphere/chromosphere, electron scattering of the photon flux Γ_E gives $eE = (\Gamma_E/c) \sigma_{\gamma e}$. An (averged) $eE \sim (4.eV/Mm) (r/R_s)^{-2}$ from photon-electron cross-section $\sigma_{\gamma e} \sim 3x10^{-24}m^2 \le 10^{-3} \sigma(H-)$ 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~100eV 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 helplful.

[1] C.F. Driscoll, "The Electric Field of the Sun and Solar Wind", this conference.

[2] O.V. Khabarova, Astronomy Reports, 57, 844 (2013)

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