

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

A : With Electric Fields

(at surface)
Gravi-Thermo-Electric $eE_G \sim +1.4 \text{ eV/Mm}$ <- - - Eddington, Rosseland (1924)
and Photo-Electric $eE_\gamma \sim +4.6 \text{ eV/Mm}$ from average $\sigma_{\gamma e} \sim 3 \times 10^{-24} \text{ m}^2$
thereby dominating gravity $m_p g \sim -2.8 \text{ eV/Mm}$ modeled here
and “levitating” Protons to **keV** energies.

Note : Photon-electron cross-section $\sigma_{\gamma e}$ varies broadly; photons heat the Wind;
maintaining a “self-consistent drive”; additional theory is needed.
: “Runaway” protons escape H0 background, requiring a kinetic analysis.
: The un-neutralized charge Q is *exceedingly* small ($\sim 10^{-36}$);
: This “global spherical” model identifies the Electric energetics;
but structures on the mega-meter scale are evident the the data.

Here: Diagnosing ACE, Ulysses, and Mariner10 *magnetic fluctuations* characterizes the
electric currents in the (globally neutral) Wind.

We find : 1) pervasive Noise Fluctuations 2) Global North-South Currents
and 3) “Double Filament Currents” creating “Bx(t) - By(t) Dynamical Arcs”

But :  MHD These processes are *precluded* by the assumptions of MHD.

Stellar Hydro Eqns:

mass
 $m_p m_e$

charge
 $e^- p^+$

photons
 γ

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

Gravity

$$2 \quad \nabla \cdot \Gamma_{\varepsilon\gamma}(r) = \frac{d}{dt} \mathcal{E}(r)$$

Energy Generation

$$3 \quad -\frac{d}{dT}(aT^4) T' l_\gamma = \frac{4}{c} \Gamma_{\varepsilon\gamma}$$

Thermal Diffusion

$$4a \quad [n_p T]' + n_p m_p \Psi' + (+e) n_p \Phi' = 0$$

Proton Fluid

$$4b \quad [n_e T]' - \frac{\Gamma_{\varepsilon\gamma}}{c l_{\gamma e}} + n_e m_e \Psi' + (-e) n_e \Phi' = 0$$

Electron Fluid

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

Hydro Forces

$$\underline{4a-4b} \quad \frac{\Gamma_{\varepsilon\gamma}}{c l_{\gamma e} n} + m_p \Psi' + (2e) \Phi' = 0$$

Electric Field

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

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

Gravi-Electric (hydro)

$$\sigma_{\gamma e} = 1 / n l_{\gamma e} \quad \text{Photo-Electric}$$

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

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

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

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

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

Photo-Electric:

When Electric Field on Protons
Exceeds Collisional Drag from H⁰



Runaway p+ :

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

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

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

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

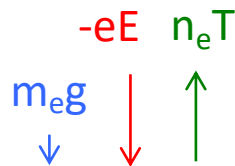
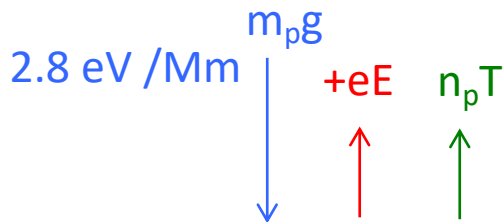
$$\Gamma_p(\rho) \sim 1.6 \times 10^{17} \rho^{-2} \text{ s}^{-1} \text{ m}^{-2}$$

$$\rho \equiv r / R_s$$

Hydro:

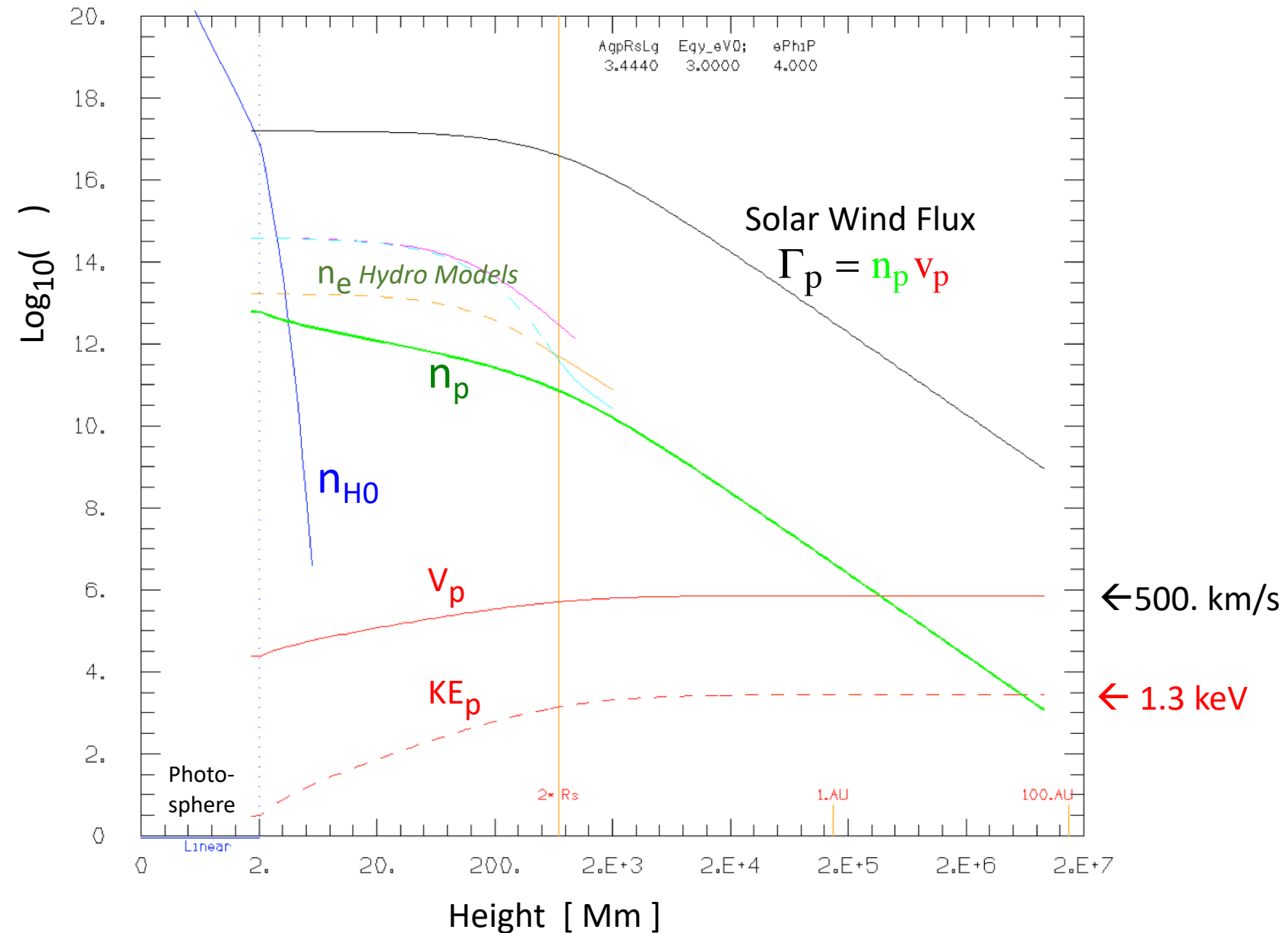
Protons

Electrons

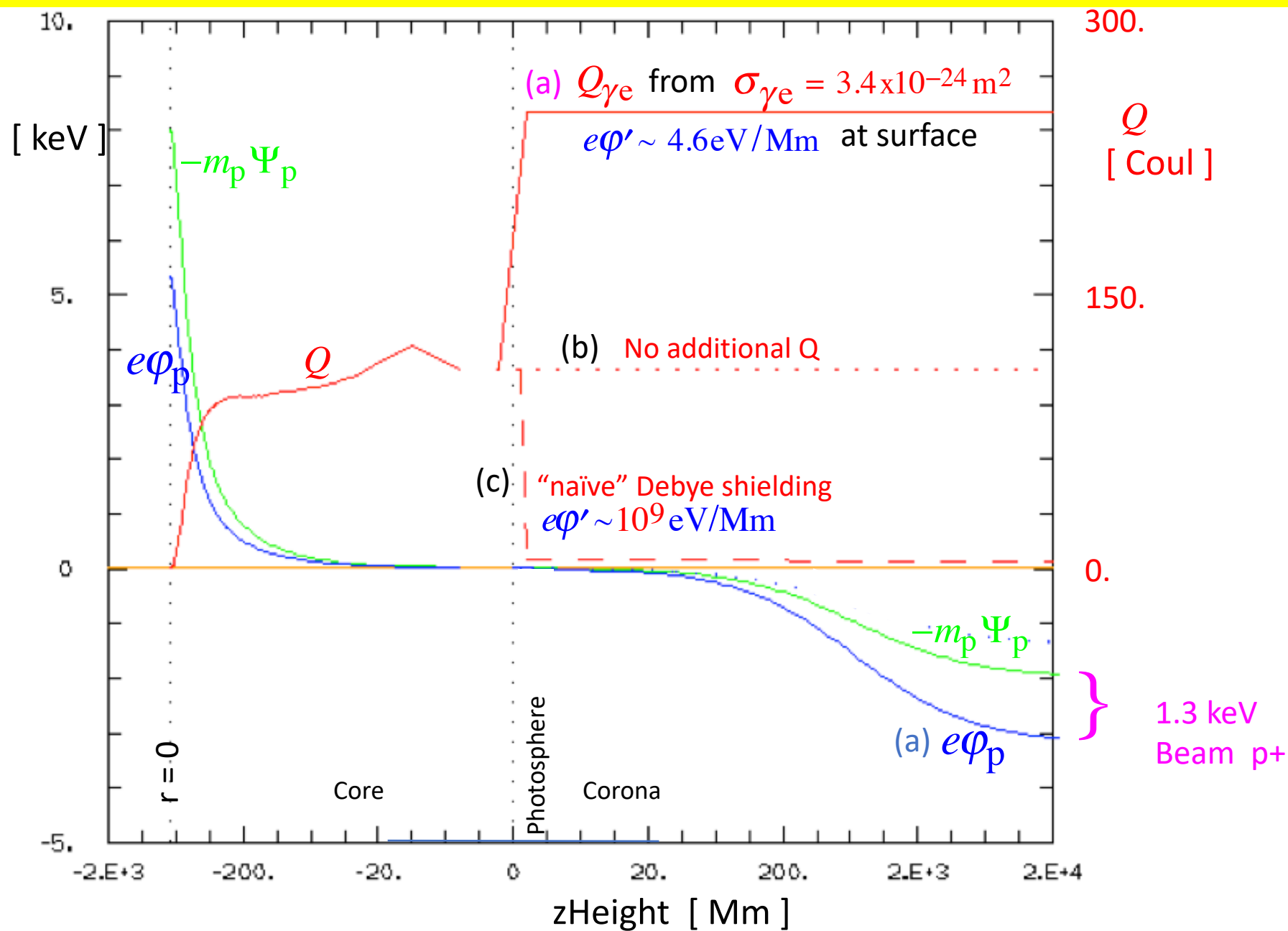


$$\begin{aligned} & \uparrow \mathcal{E}_{\text{PhEI}} \sim 4.6 \text{ eV/Mm} \\ & \text{from} \\ & \Gamma_{\varepsilon\gamma} = 60 \text{ MW/m}^2 \rho^{-2} \end{aligned}$$

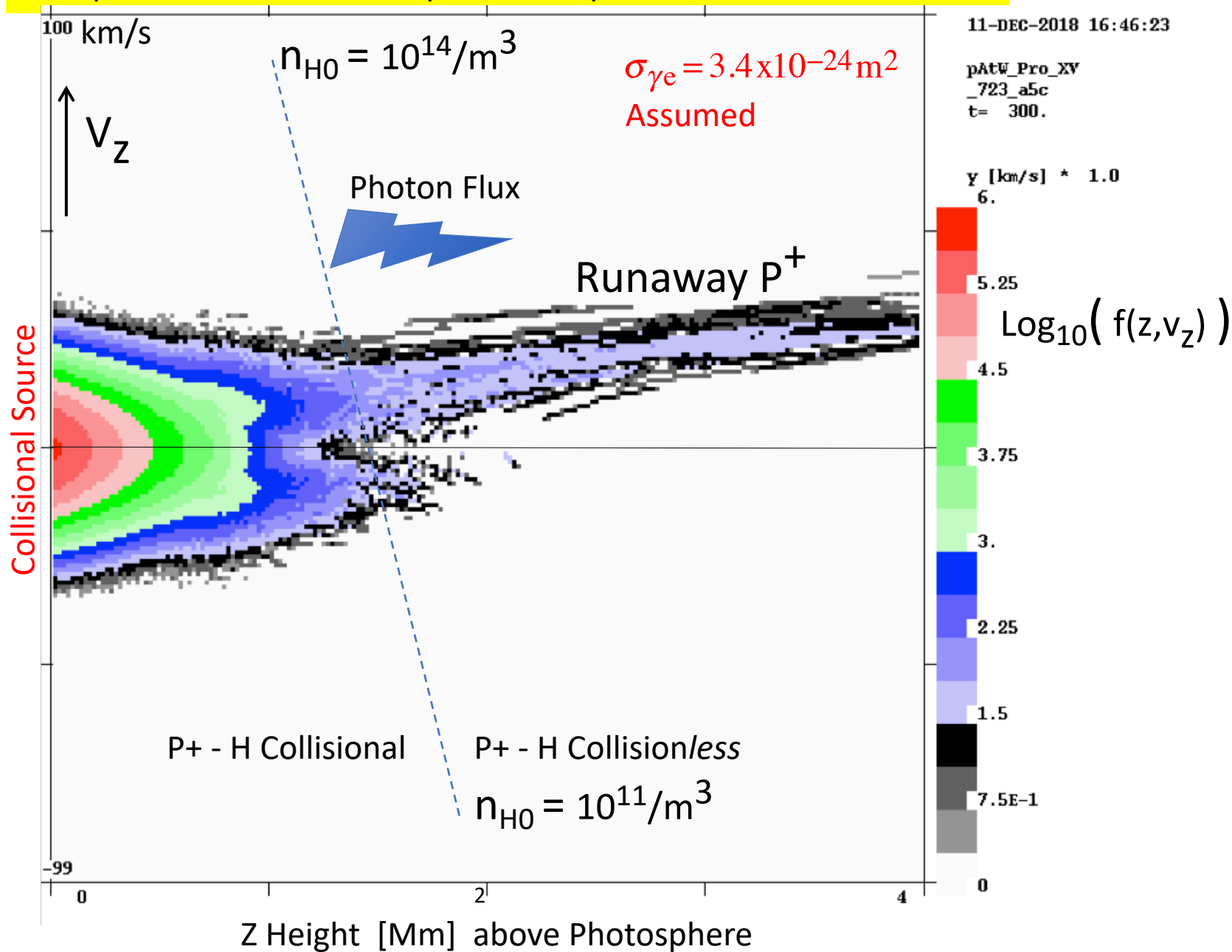
Photon-Driven Solar Wind $p+$ Flux, Density, Velocity, Energy
 assuming average $\sigma_{\gamma e} = 3.4 \times 10^{-24} \text{ m}^2$



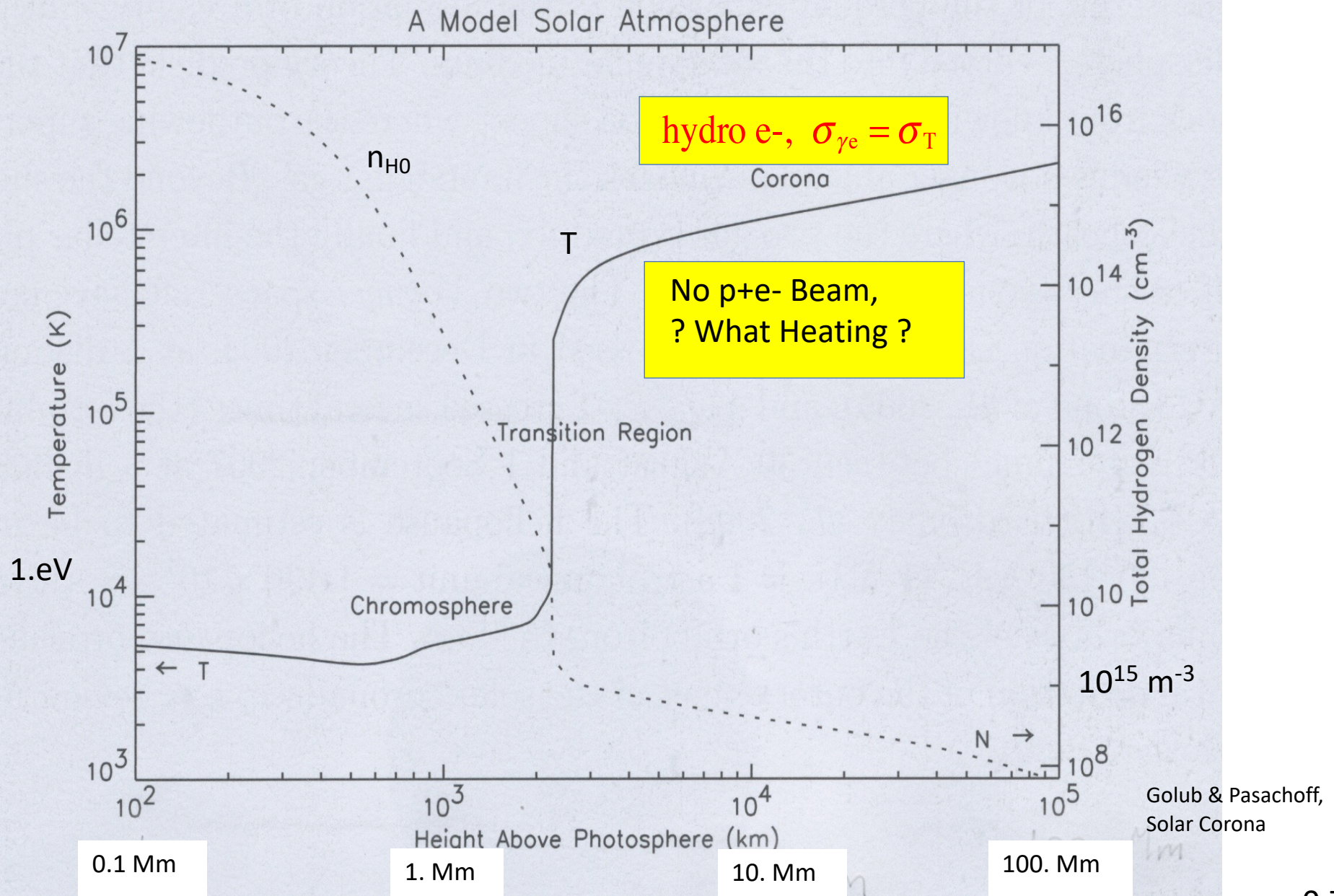
Q, ϕ, Ψ from (a) Photon-driven charge separation, giving 1.3keV Solar Wind;
 (b) No additional charge; (c) “naïve” Debye shielding, giving 10^9 eV/Mm



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



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



Here : Solar Wind creates observed Magnetic Field Spectrum, for $r > 0.3\text{AU}$

- 1) Random Fluctuations
- 2) f_{Rot} Signature from Global N/S Currents
- 3) Dynamical Bx-By Arcs from "Double Filament" Currents

$$p^+, e^- : v_w \sim 500.\text{km/s}$$

$$E_{p^+} \sim 1.3\text{keV}$$

$$n_w \sim 10^{24.8} \rho^{-2} [\text{##} / \text{Mm}^3]$$

$$E_{e^-} \sim 10.\text{eV}$$

$$\text{Flux } \Gamma_w \sim 10^{24.5} \rho^{-2} [\text{##} / \text{s} \cdot \text{Mm}^2]$$

Measurements :

-- ACE @ .99AU

-- Ulysses @ 1 – 5 AU

-- Mariner @ 0.3 – 1 AU

$$\rightarrow B_{\text{RMS}} \propto \Gamma_w^{0.75} \text{ over } 1 \rightarrow 5\text{AU}$$

$$B_{\text{radial}} == B_x$$

$$B_{\text{theta}} == B_y$$

$$B_{\text{north}} == B_z$$

$$\rho \equiv r / 1\text{AU}$$

$$f_{\text{Rot}} = \frac{1}{27.3 \text{ days}} \\ = 0.424 \mu\text{Hz}$$

1) Pervasive Random Fluctuations

--- Spectrum is random as f^{-1} above $10^4 \mu\text{Hz}$ ($\tau < 100.\text{sec}$)

--- "DC" values ($f < 10.\mu\text{Hz}$, $\tau > 1.\text{day}$) scale as "Mean of random walk",

2) $B_x(t)$ and $B_y(t)$ are *correlated*, by distinct Fourier components at f_{Rot}

--- Highly variable : 1% - 40% (avg 12%) of B^2 Energy

--- Removing *single* f_{Rot} component eliminates Correlation

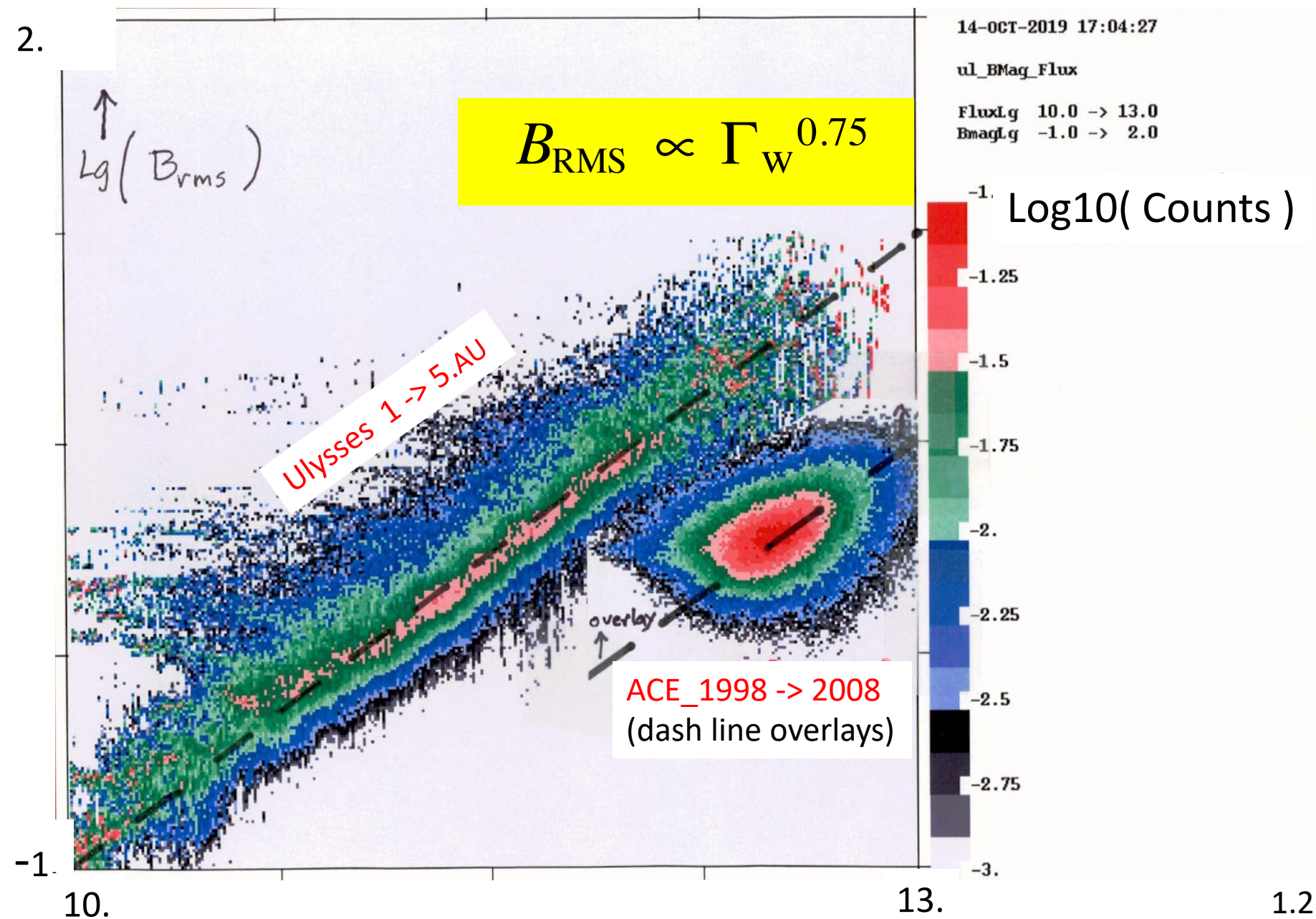
--- ?? From gradient of North-South Current, driven by N-S charge imbalance

3) $B_y(t)$ - $B_z(t)$, $B_z(t)$ - $B_x(t)$, $B_x(t)$ - $B_y(t)$ "Dynamical Arcs" are ubiquitous

--- Well-modelled by "Double Filament" radial Currents

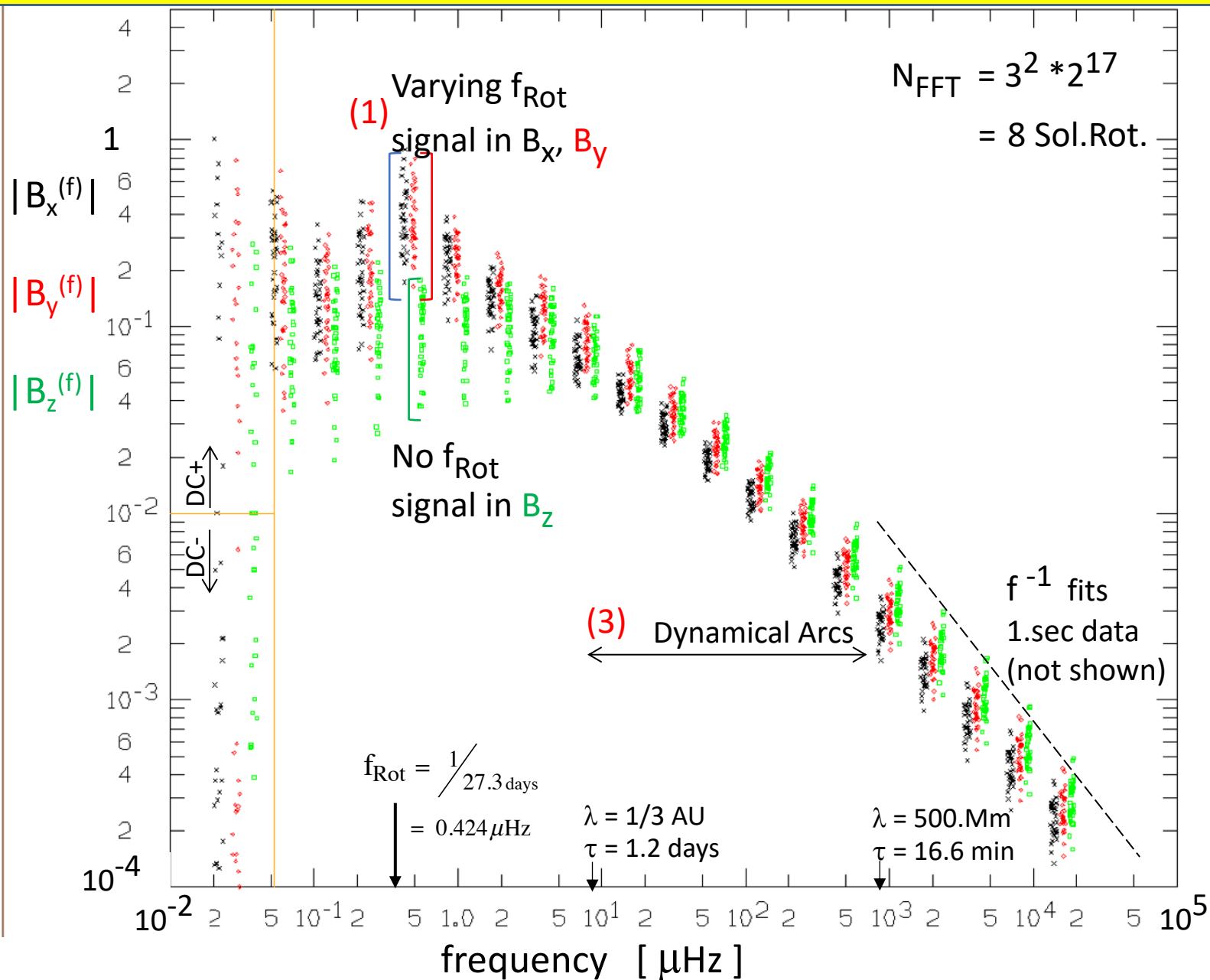
--- Non-random Spectral Energy $10^1 < f < 10^3 \mu\text{Hz}$

Magnetic Fluctuation Level depends on Solar Wind Flux

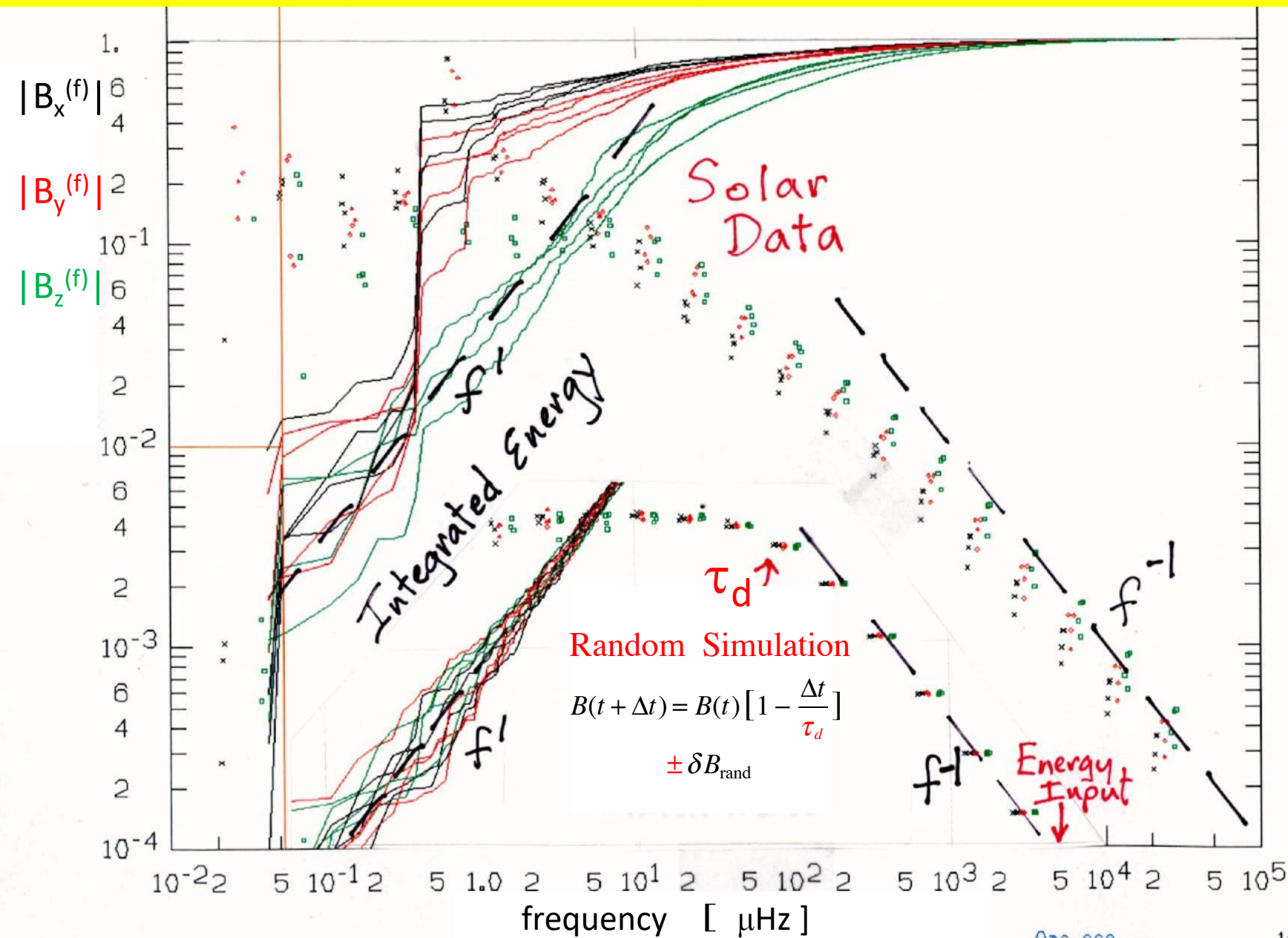


(1) Spectrum of Magnetic Fluctuations : ACE MAG @ 1.AU

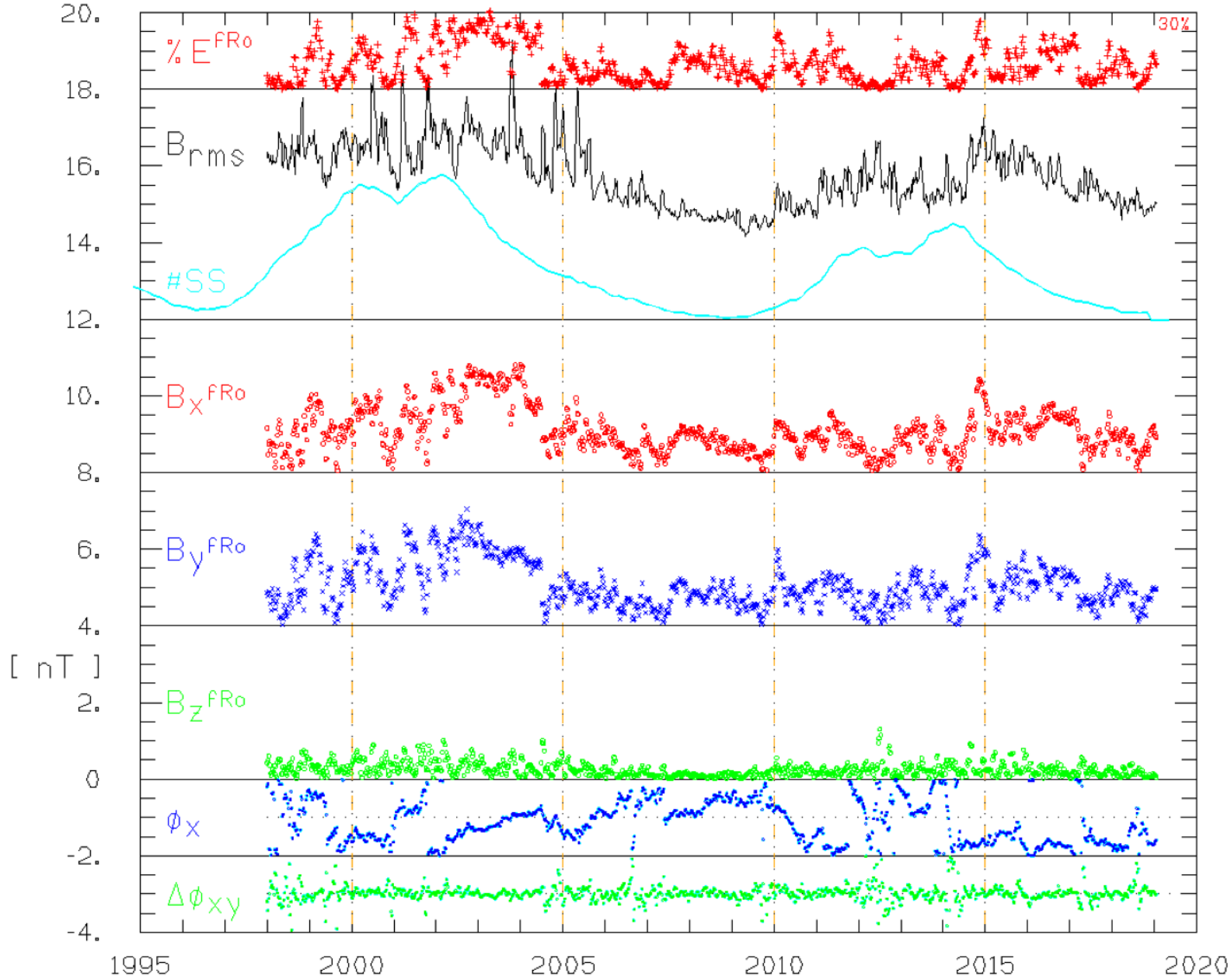
16.sec data, 1998.0 -> 2019.4



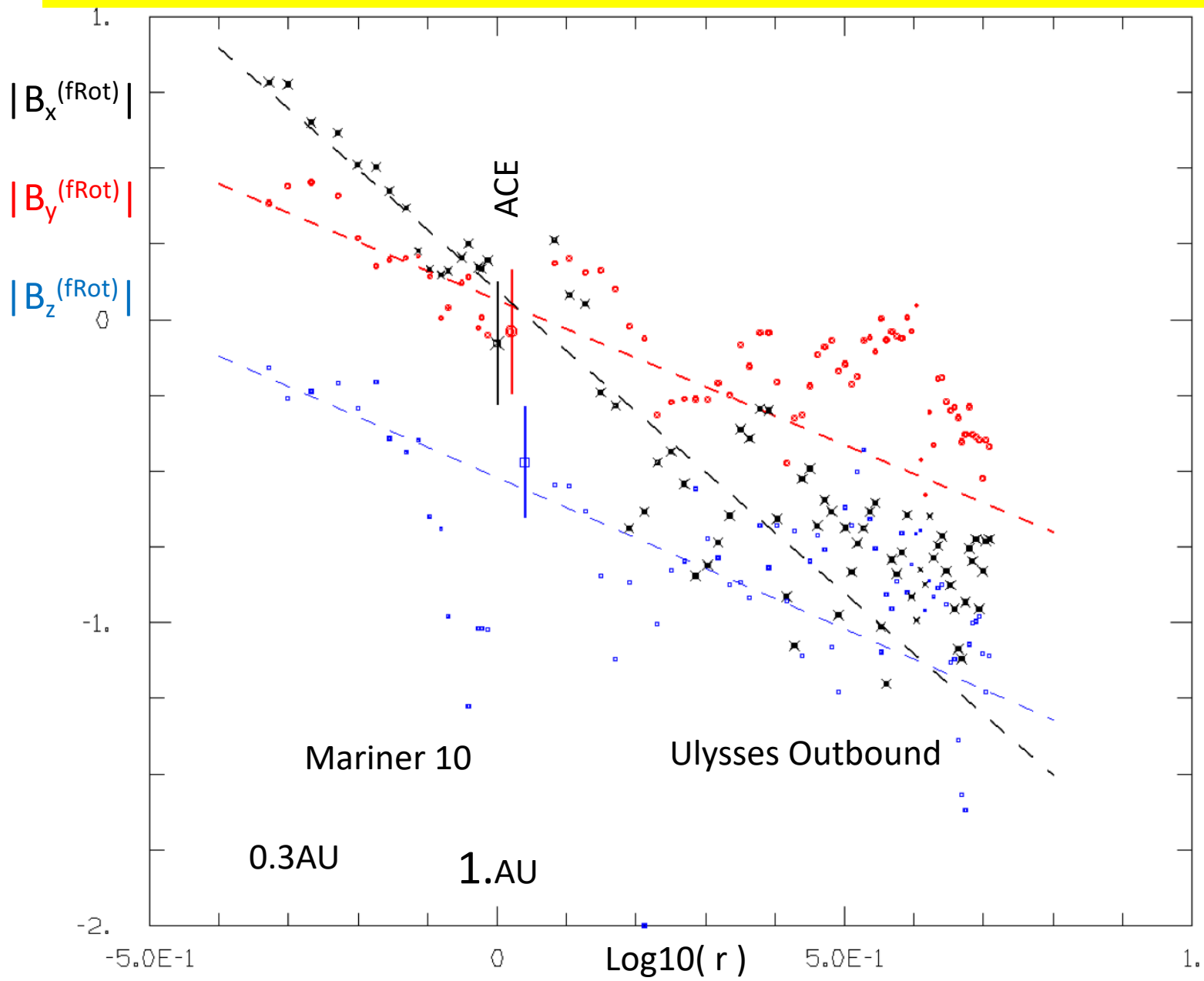
(2) f^{Rot} components are *exceptional* : larger-than-random variations over months
 : provide 180° correlation between B_x and B_y



(2) Fluctuating B_x^{fRo} and B_y^{fRo} are *Correlated*; B_z^{fRo} is noise.
 0% $\rightarrow$ 30% of Magnetic Energy is in $B_{x,y}^{\text{fRo}}$ fluctuations.

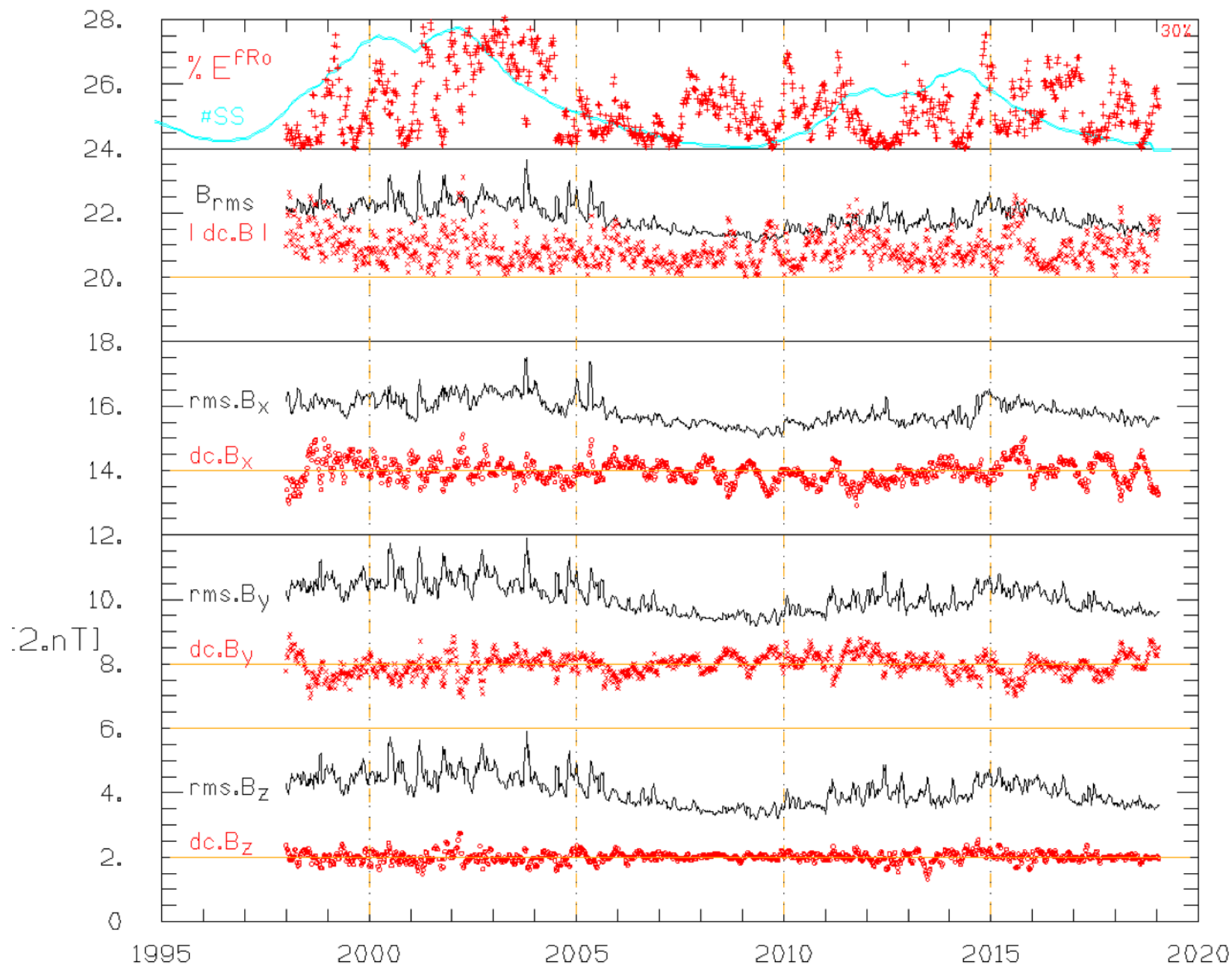


Radial Dependence of fluctuating components B_x^{fRot} B_y^{fRot} B_z^{fRot}



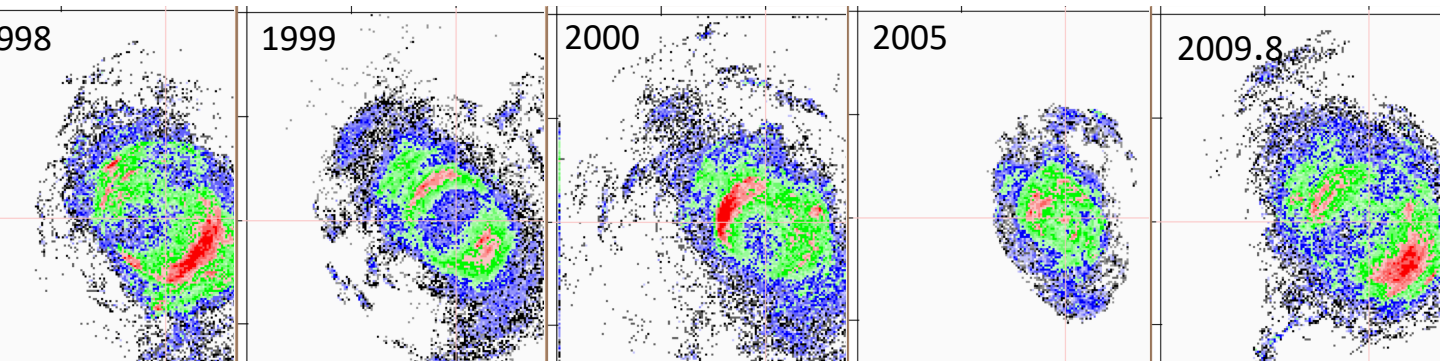
There are no significant "persistent" magnetic fields at 1.AU :

"DC" levels vary $\pm$ as expected from random higher-frequency "drives"

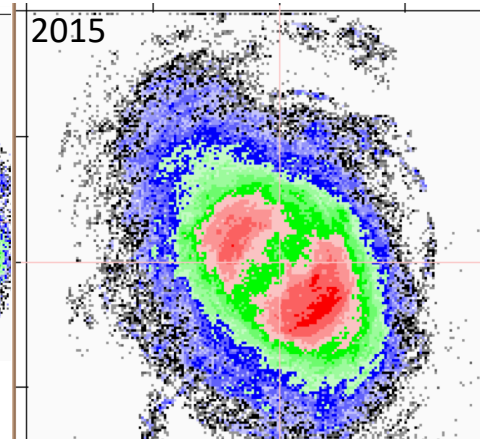


$B_x - B_y$ Correlation is *Removed* when the Fourier Components at f_{Rot} are *Removed*

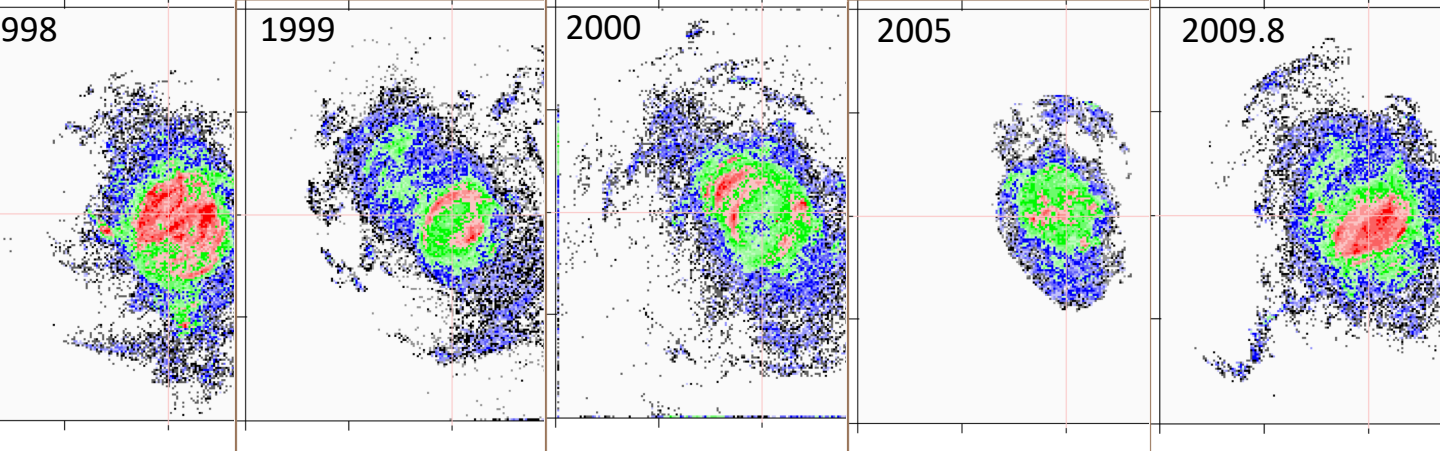
ACE Data, T = 1 Rotation



ACE Data, T = 8 Rotation

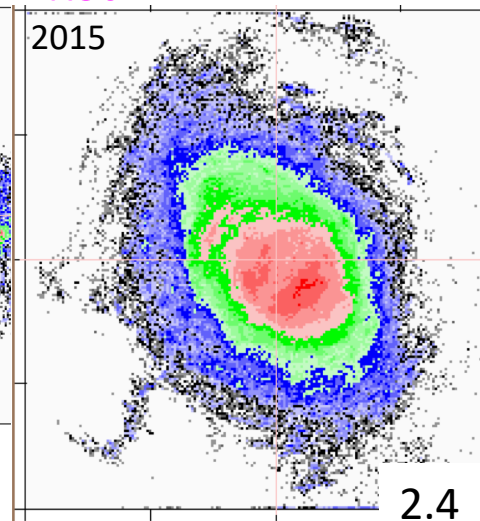


ACE Data, T = 1 Rotation, f_{Rot} components *Removed*

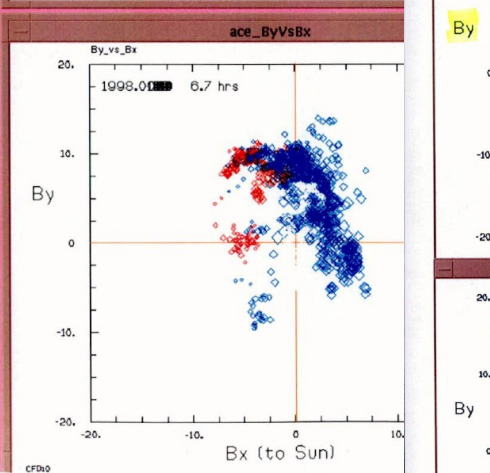
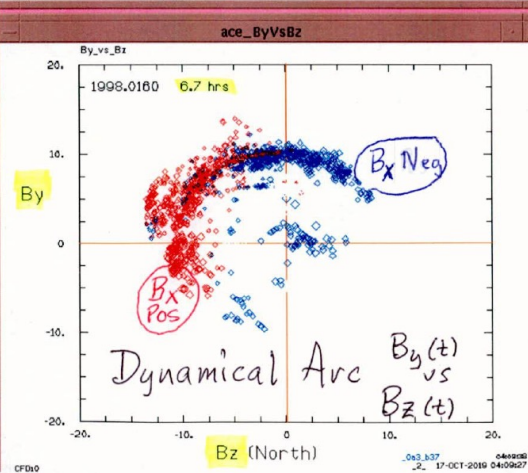
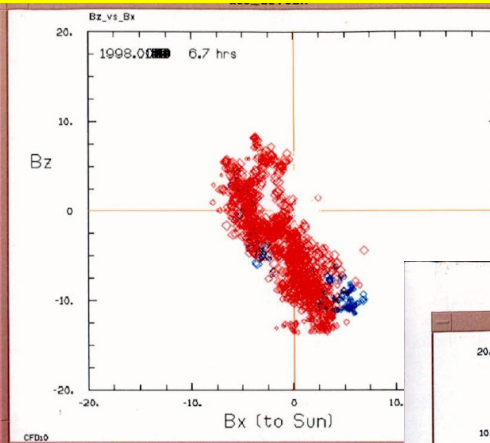
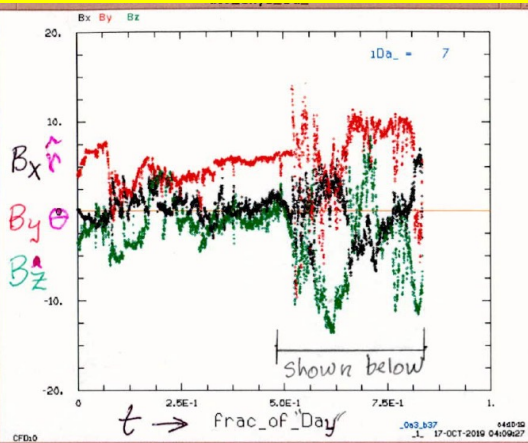


ACE Data, T = 8 Rotation

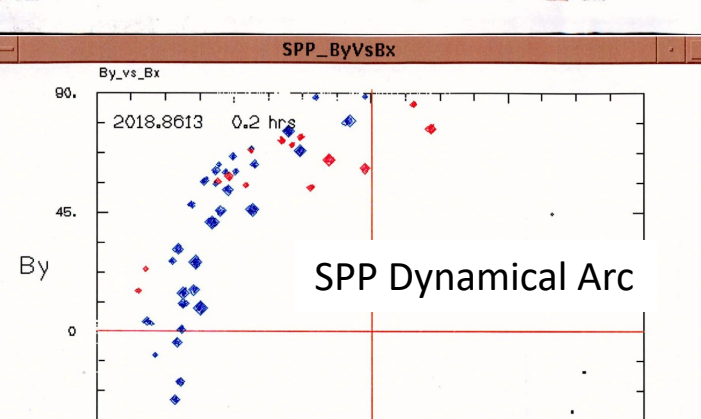
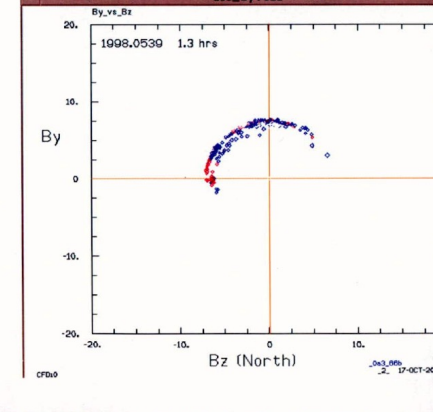
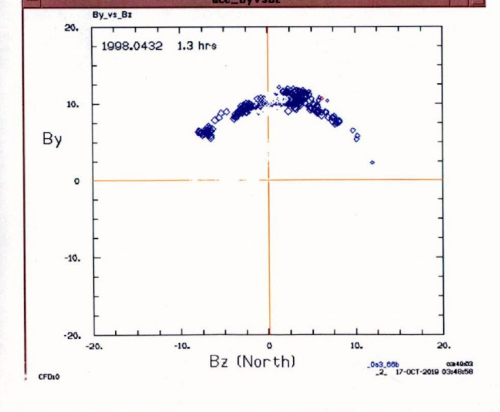
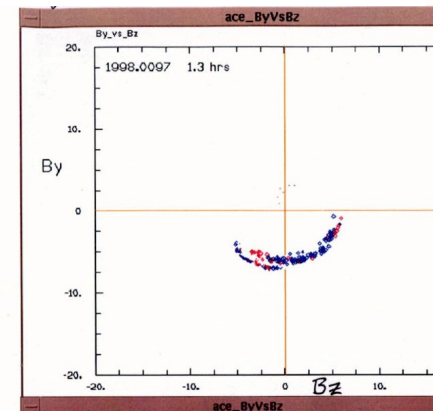
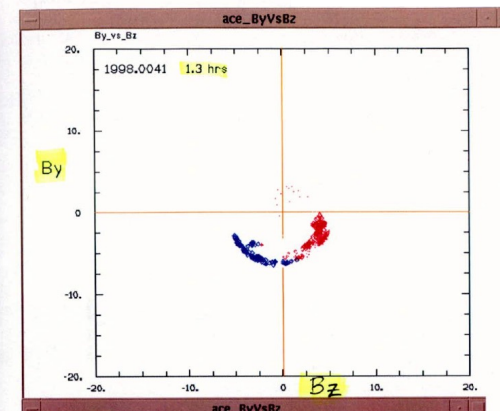
f_{Rot} components *Removed*



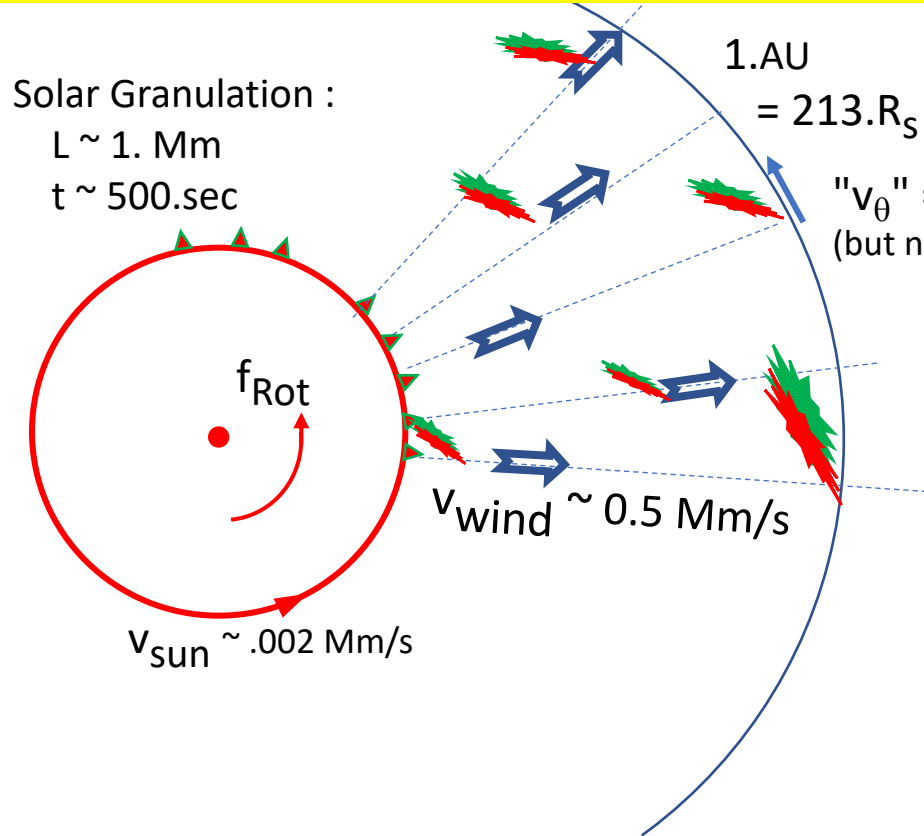
(3) "Dynamical Arcs", apparently from Double Current Filaments



ACE 4 Examples



Model : Double Current Filaments => $B_y(t)$ vs $B_z(t)$ "Dynamical Arcs"



"Neutral" Flow" of $\begin{Bmatrix} p+ \\ e- \end{Bmatrix}$

$$n_w \sim 10^{6.8} [\text{##}/\text{m}^3]$$

$$\Gamma_w \sim 10^{12.5} [\text{##}/\text{s.m}^2]$$

$$\sim 10^{24.5} [\text{##}/\text{s.}(\text{Mm})^2]$$

Suppose $\delta n = \alpha n_w$
 $= (n_+ - n_-)$

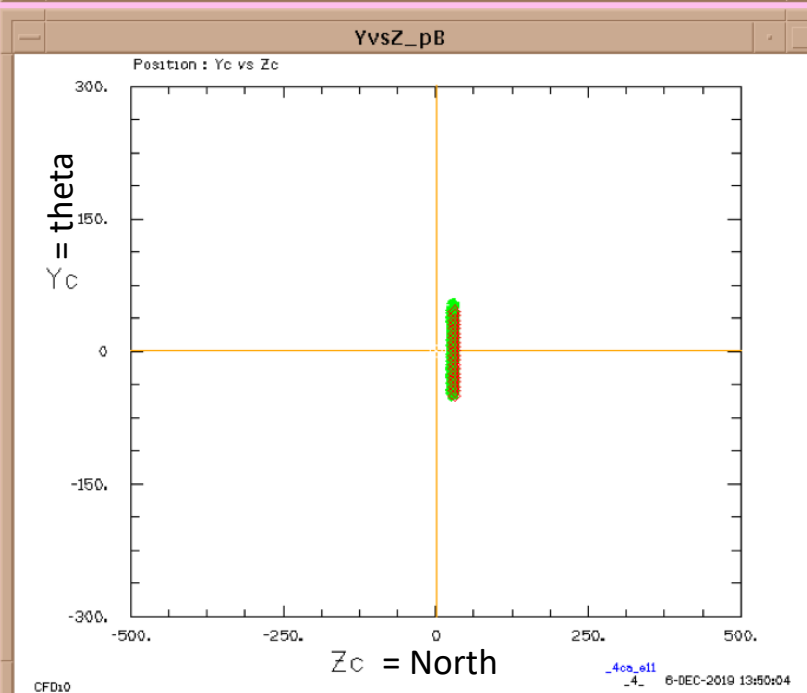
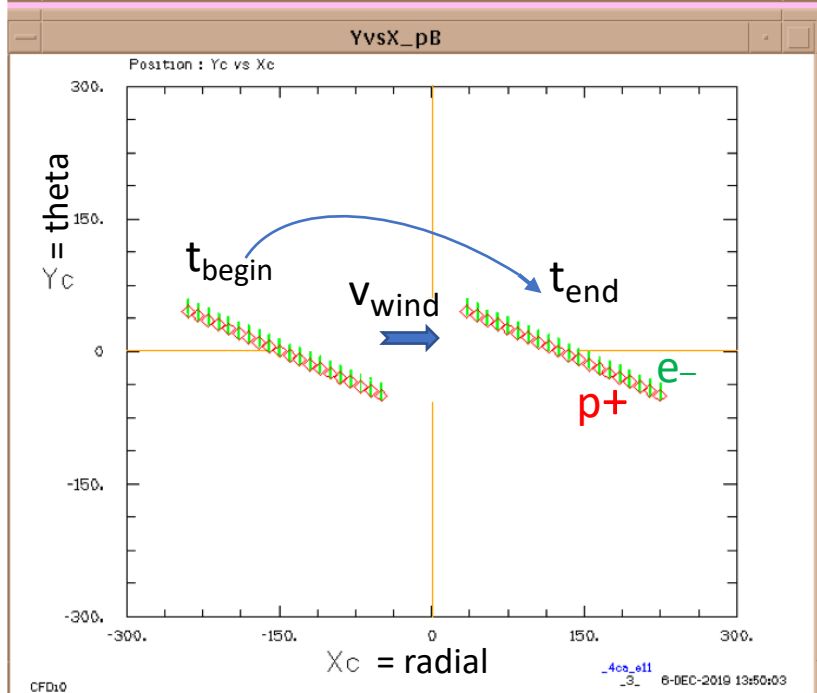
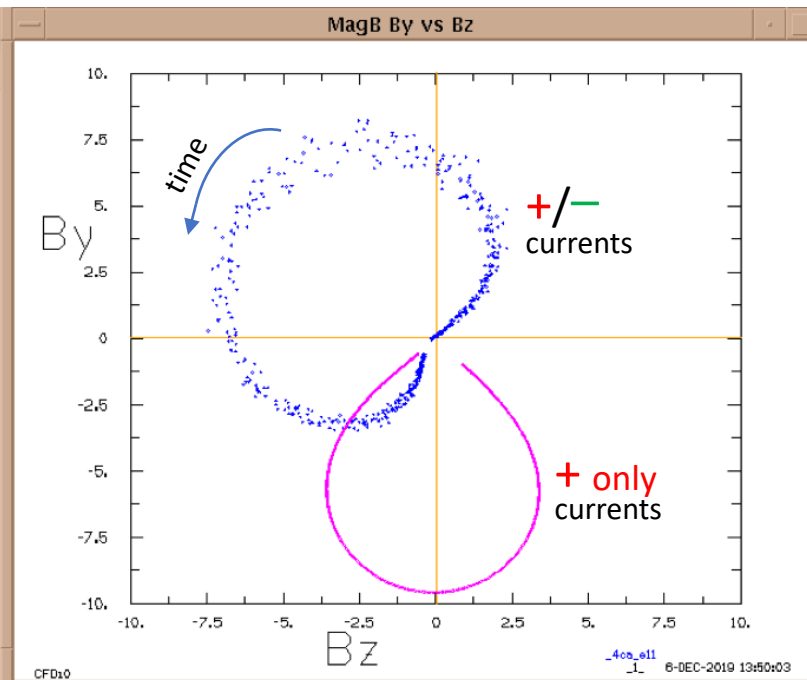
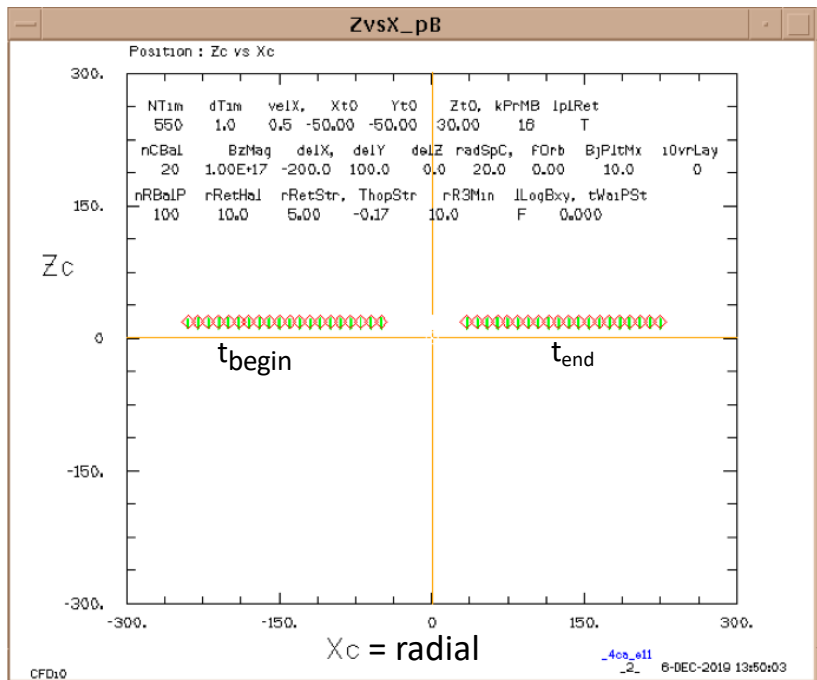
from
 Shot Noise,
 Filamentation,
 Dynamics,
 Current Pinch

Then

$$B \approx \frac{2}{cr} (\alpha e n_w v_w) (\pi r_0^2)$$

$B \sim 5. \text{ nT}$ implies :

α	r_0	$\tau = v_w r_0$
10^{-3}	10^1 Mm	20.sec
10^{-5}	10^3 Mm	0.5 hour

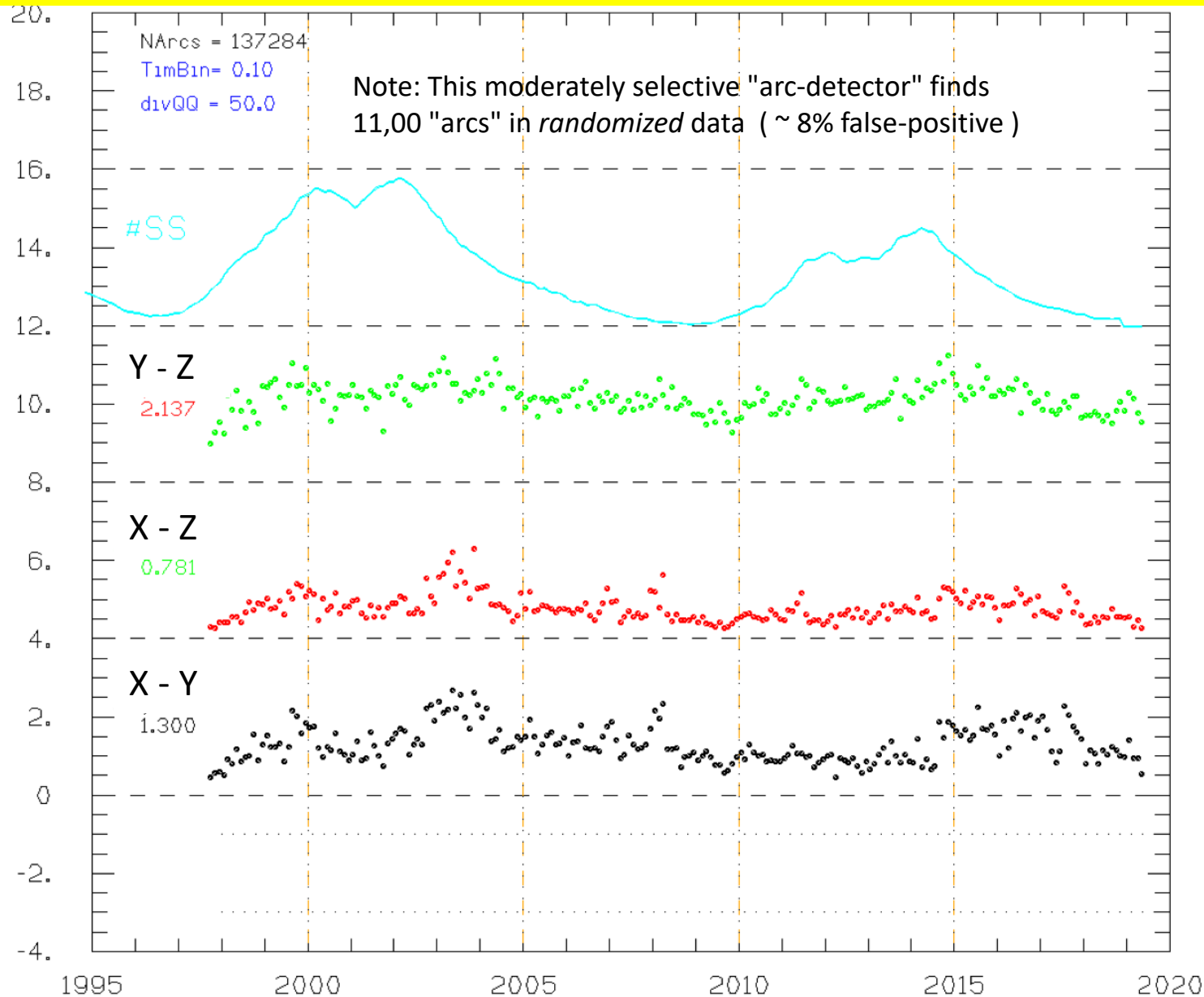


ACE MAG : 137,000 "Dynamical Arcs" in 21 years.

T ~ 0.5 hr

All orientations : By-Bz , Bx-Bz , Bx-By .

Rate ~ 18/day



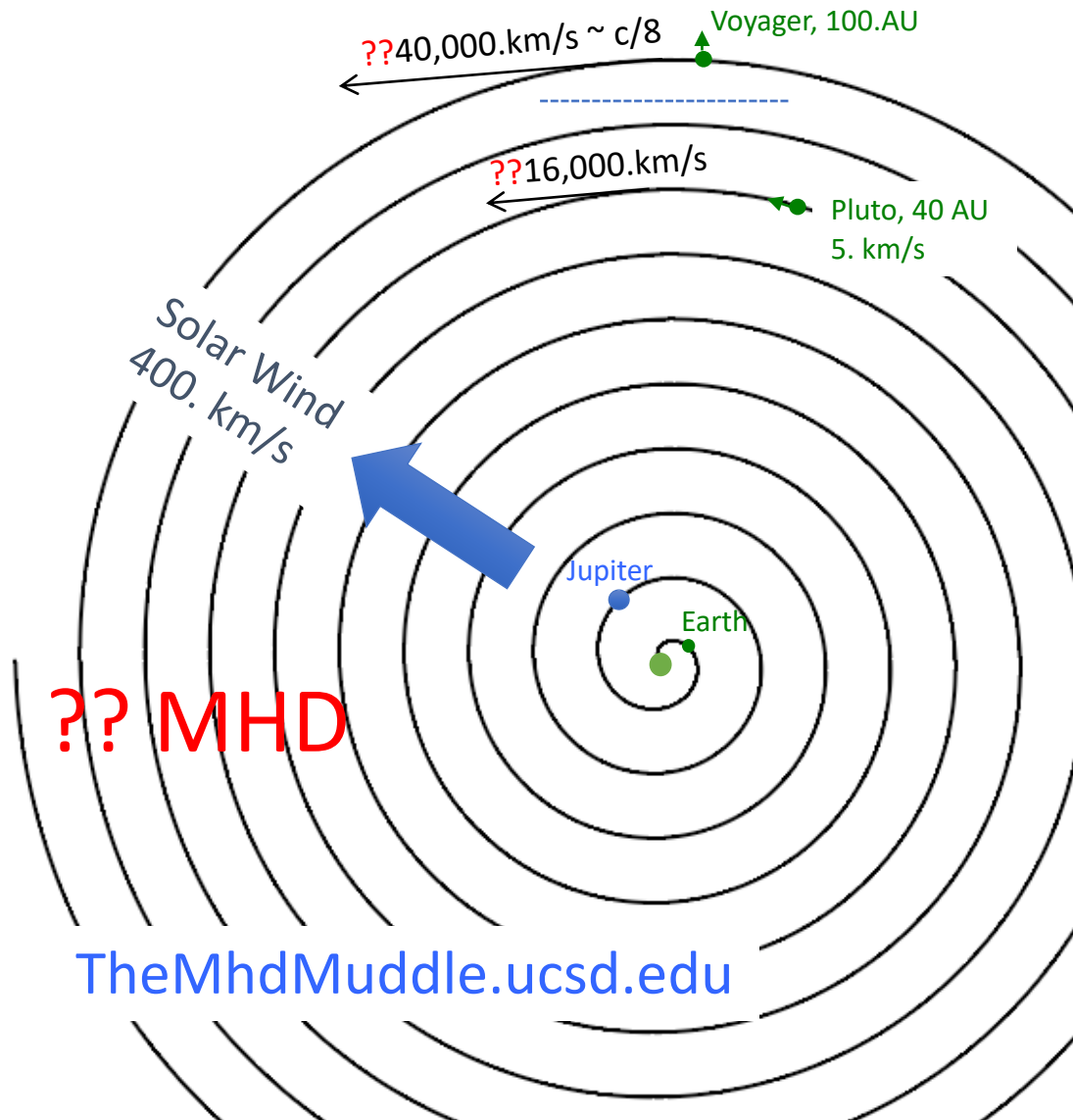
MagData: NASA ACE Science Center
SunSpot# : NOAA SWPC

_4e8_3c3

23:13:08

21 7 FEB 2010 22:12:07

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



Chimera Apulia (Louvre)

MHD Assumptions :

$$\nabla \cdot E_L = 4\pi \cancel{\rho_Q} = 0$$

$$\nabla \cdot B_L = 0$$

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

$$c \nabla \times B_T = \cancel{\dot{E}_T} + \dot{E}_L + 4\pi J_L + 4\pi J_T$$

cancel

$$F = \cancel{\rho_Q} E + (\cancel{J_L} + J_T) \times B_T / c$$

$$\nabla \cdot J = -4\pi \cancel{\rho_Q} = 0$$

Dissipation of Particle Current

$$v_{ei} = n \bar{v} \left(\frac{e^2}{T} \right)^2 \ln \Lambda$$

$$m \Delta v_{ei} v_{ei} = e E_Q \text{ (momentum)}$$

$$\sigma = \frac{e^2 n}{m v_{ei}} \approx (10^{14} \text{ s}^{-1}) T_{\text{eV}}^{3/2}$$

Hydro : $v_{ei} \nearrow \Rightarrow T \searrow, \sigma \searrow$

Magnetic: $\sigma \nearrow \Rightarrow T \nearrow, v_{ei} \searrow$

* Contradictory

$\rho_Q = 0$: No Charges

$E_L = 0$: No Elec.Pot.Egy

No Thermo.Elec

No Gravi.Elec

No Capacitance

No Photons

No Causality

(Simultaneous)

No E // B

$J_L = 0$: No Convective Current

$J_T = \sigma_T E_T$ Induction of J_T only

$\sigma_T = \infty$ (Ideal)

?? Spin Currents do not dissipate

?? Moving B-lines live forever

?? B-lines "Frozen-Into" Plasma

?? Plasma "Stuck on" B-lines

?? Particle Streamline $\equiv$ B-line

: Longitudinal, Transverse
or : Irrotational, Solenoidal

$$\begin{Bmatrix} E \\ B \\ J \end{Bmatrix} \equiv \begin{Bmatrix} E_L \\ B_L \\ J_L \end{Bmatrix} + \begin{Bmatrix} E_T \\ B_T \\ J_T \end{Bmatrix}$$

$$\nabla \times \begin{Bmatrix} E_L \\ B_L \\ J_L \end{Bmatrix} = 0 \quad \nabla \cdot \begin{Bmatrix} E_T \\ B_T \\ J_T \end{Bmatrix} = 0$$

J_T is "curling"
or "spin" current