DPP-2019

# Solar Wind : Filamentation, Currents, Magnetic Fluctuations @ 1AU

$p^+, e^-$ : $v_w \sim 500.\text{km/s}$ $\quad E_{p+} \sim 1.3 keV$

$n_w \sim 10^{24.8}\ [\#/\text{Mm}^3]$ $\quad E_{e-} \sim 10.eV$

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

Measurements :
-- ACE @ .99AU
-- Ulysses @ 1 – 5 AU
-- Mariner @ 0.3 – 1 AU
-- Solar Probe (pending)

Magnetic Signatures :

1) $B_X - B_Y$ Correlation @ Solar $f_{Rot}$ ( $\tau = 27.3$ days)
   -- suggested 45° spiral @ 1AU
   --- Highly variable : 1% - 40% (avg 12%) of $B^2$ Energy
   --- Removing *single* $f_{Rot}$ component eliminates Correlation
   --- From North-South Current, driven by N-S charge imbalance

2) $B_Y(t)$ vs $B_Z(t)$ "Arcs" : Distinctive, ubiquitous dynamical signature
   --- Well-modelled by filamentary radial currents

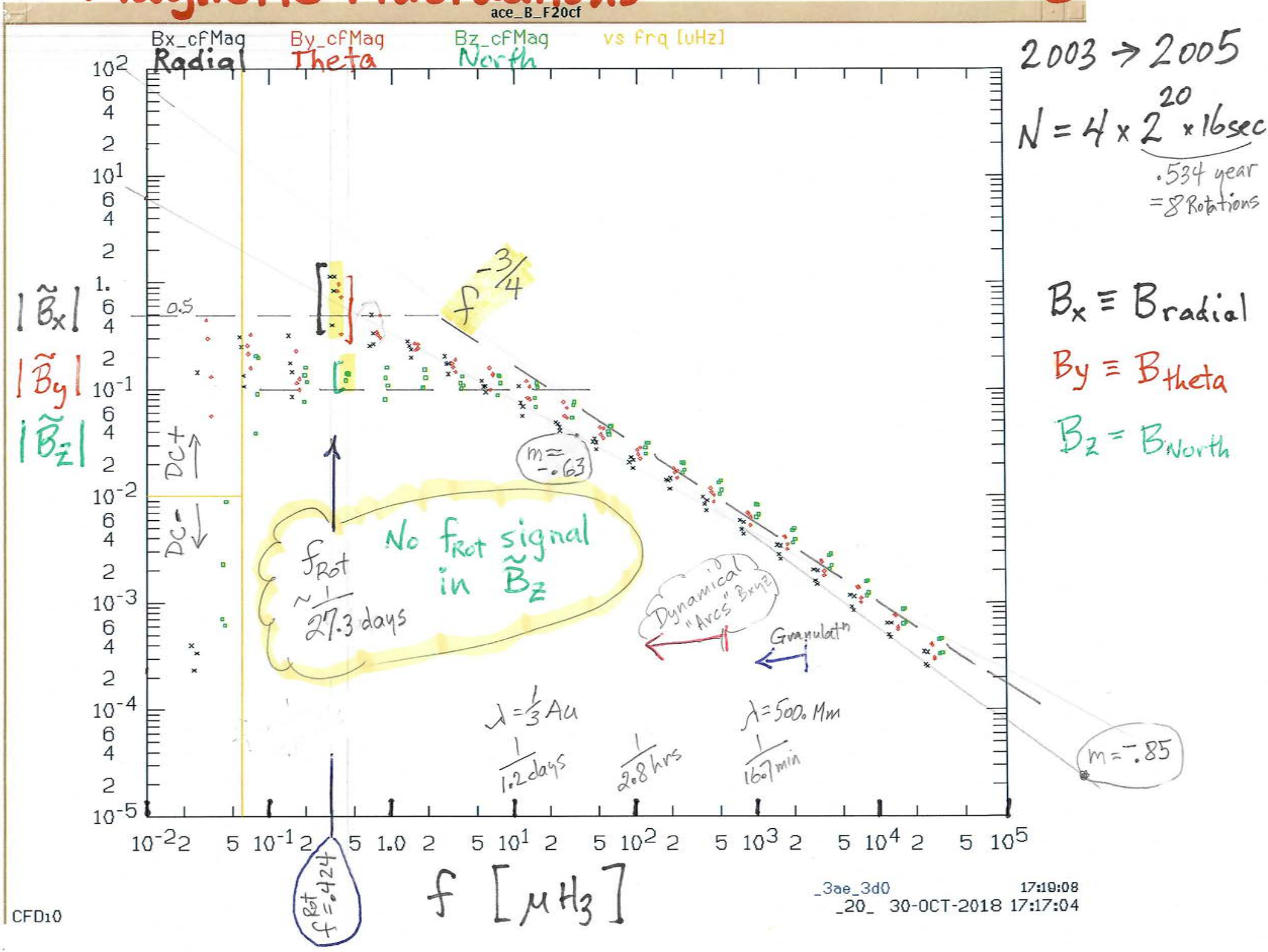
3) Spectral Energy Deposition : $1 - 10^4$ μHz
   --- Granulation of sources on Sun
   --- Dynamical development of filamentary currents

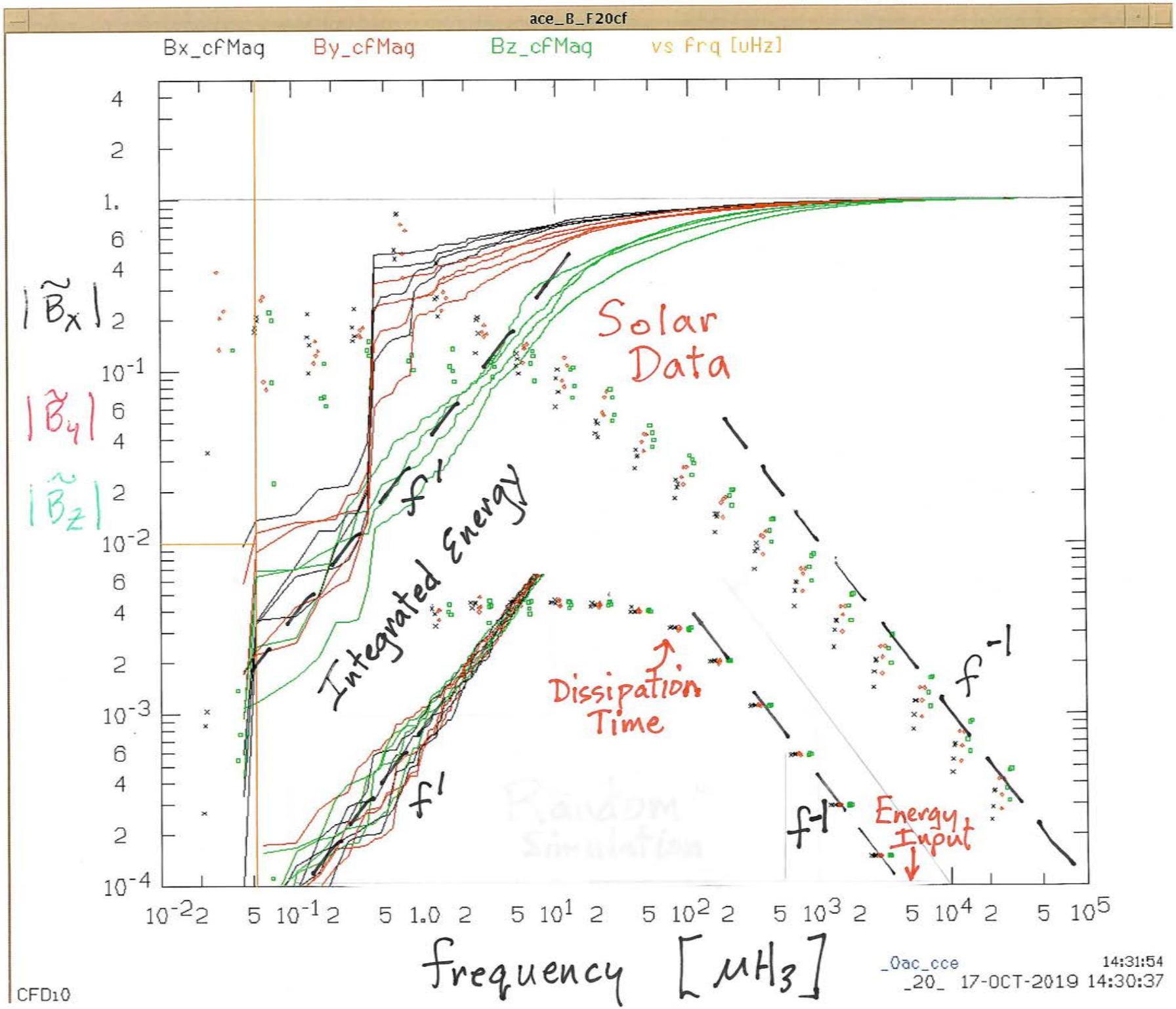
4) Spectrum appears Random above 104 μHz ( $\tau < 100$.sec)

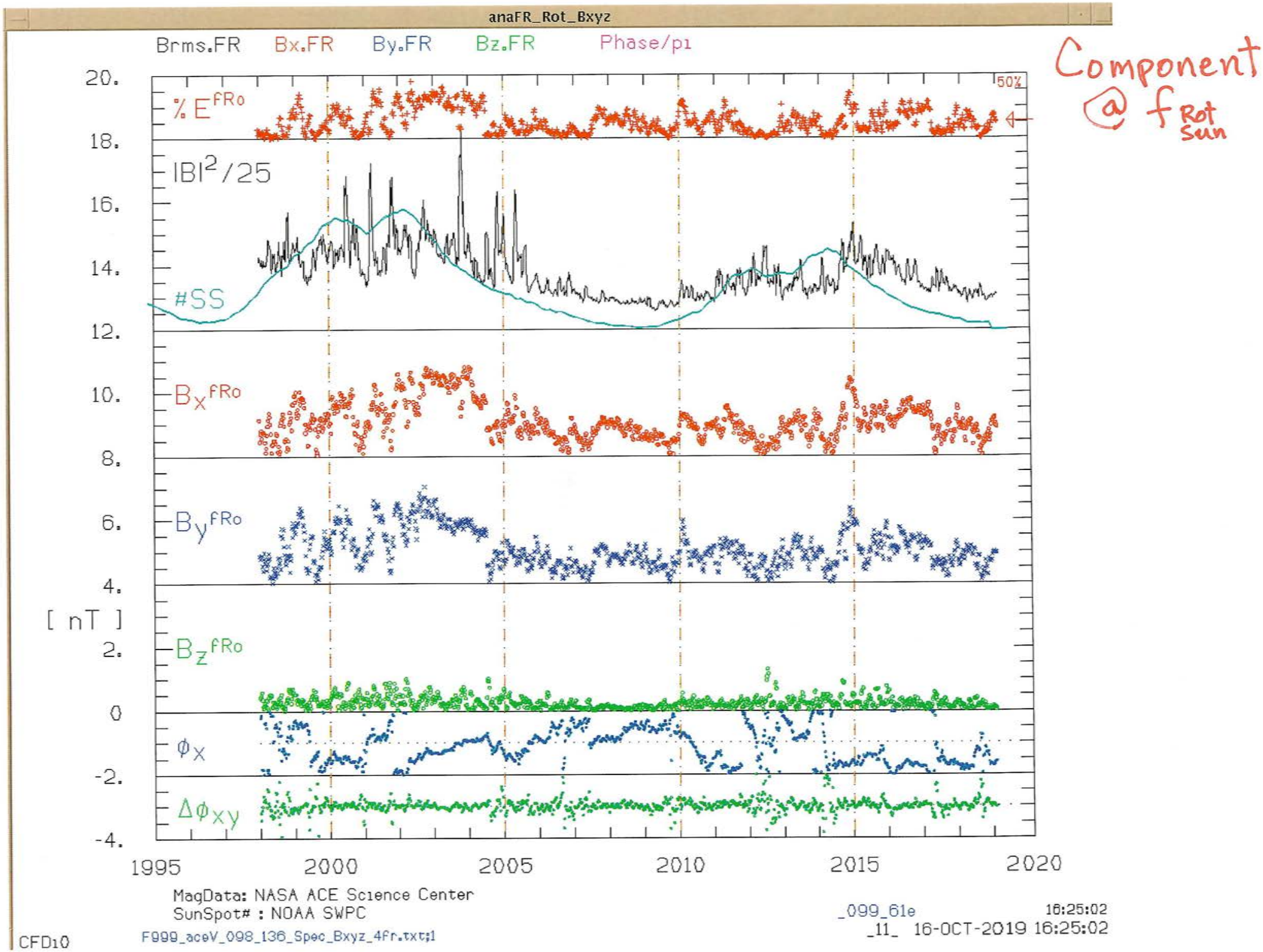
5) $B_{RMS} \propto \Gamma_w^{0.75}$ over 1 – 5 AU .

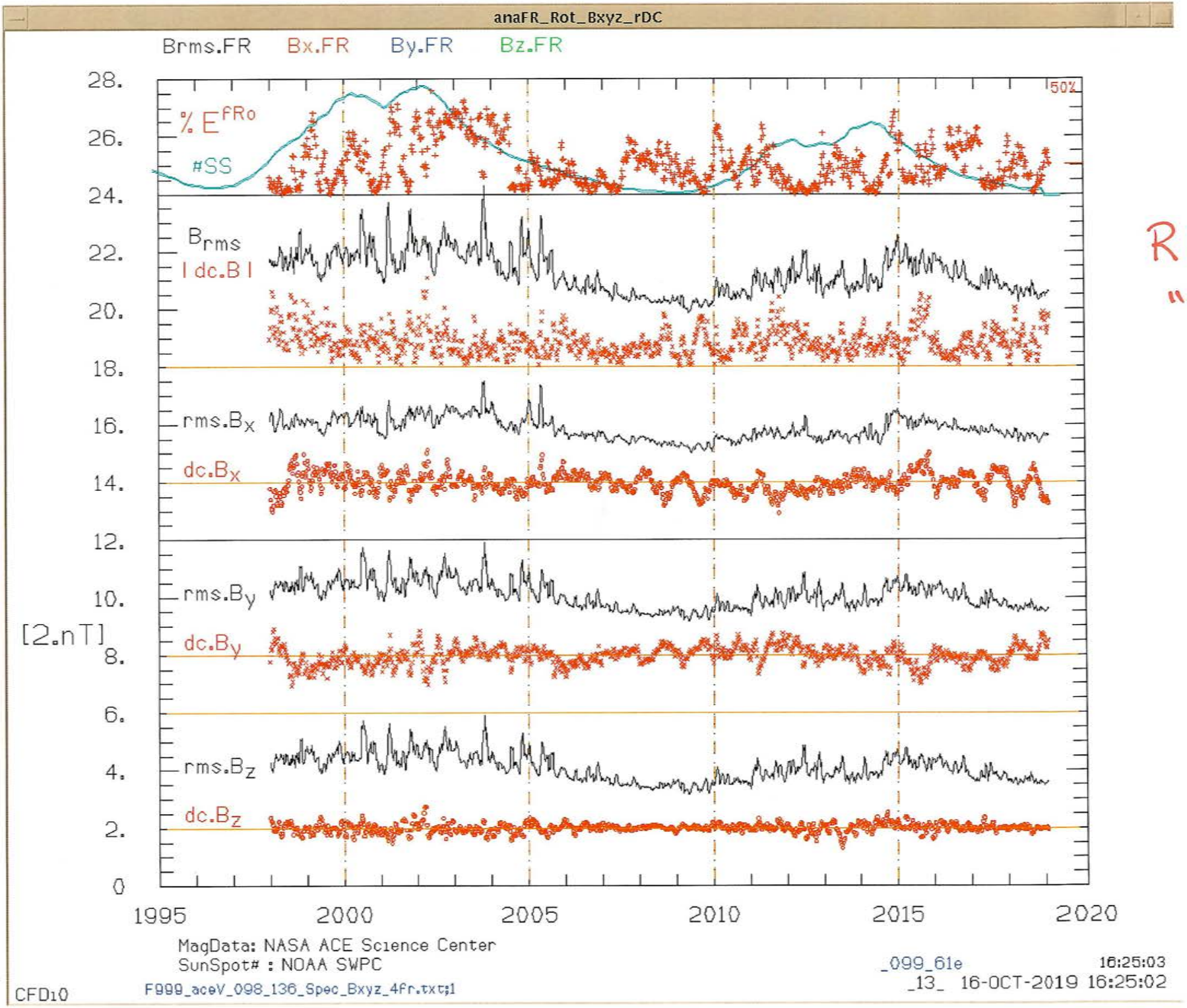
# Magnetic Fluctuations

ACE MAG @ 1. AU




ace_B_F20cf
Bx_cfMag
By_cfMag
Bz_cfMag
vs frq [uHz]
$|\tilde{B}_x|$
$|\tilde{B}_y|$
$|\tilde{B}_z|$
Solar Data
Integrated Energy
Dissipation Time
Energy Input
f-1
f1
frequency [mHz]
_0ac_cce
_20_ 17-OCT-2019 14:31:54
14:30:37
CFD10

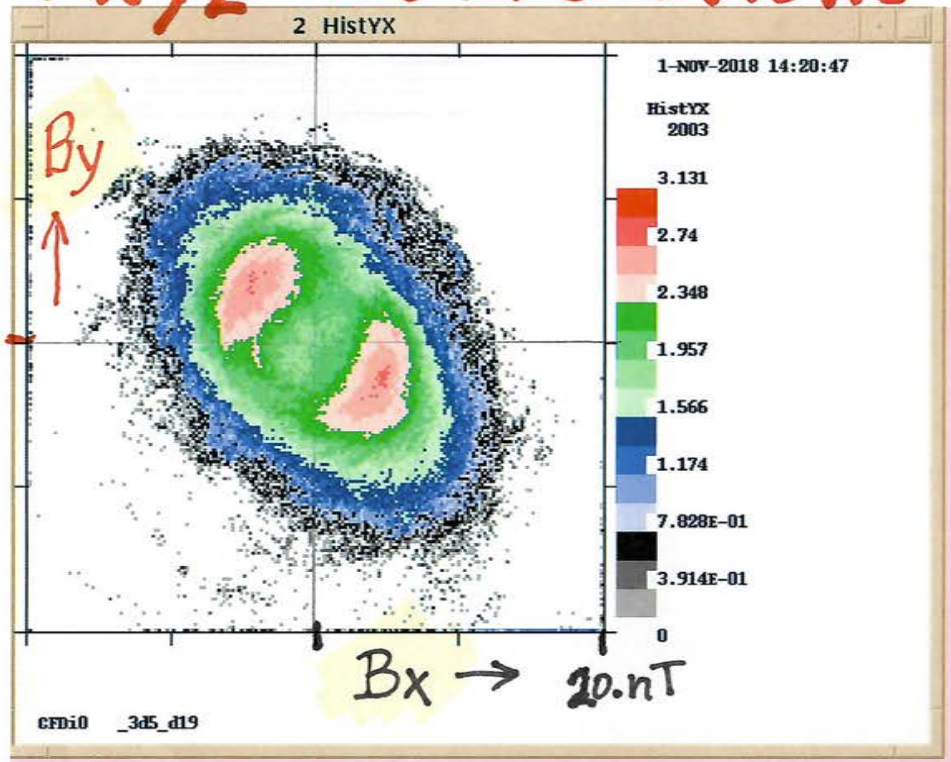

anaFR_Rot_Bxyz
Brms.FR
Bx.FR
By.FR
Bz.FR
Phase/pi
Component @ f Rot Sun
20.
18.
16.
14.
12.
10.
8.
6.
4.
2.
0
-2.
-4.
[ nT ]
% E fRo
50%
IBI2/25
#SS
Bx fRo
By fRo
Bz fRo
φx
Δφxy
1995
2000
2005
2010
2015
2020
MagData: NASA ACE Science Center
SunSpot# : NOAA SWPC
F999_aceV_098_136_Spec_Bxyz_4fr.txt;1
_099_61e
16:25:02
_11_ 16-OCT-2019 16:25:02
CFD10

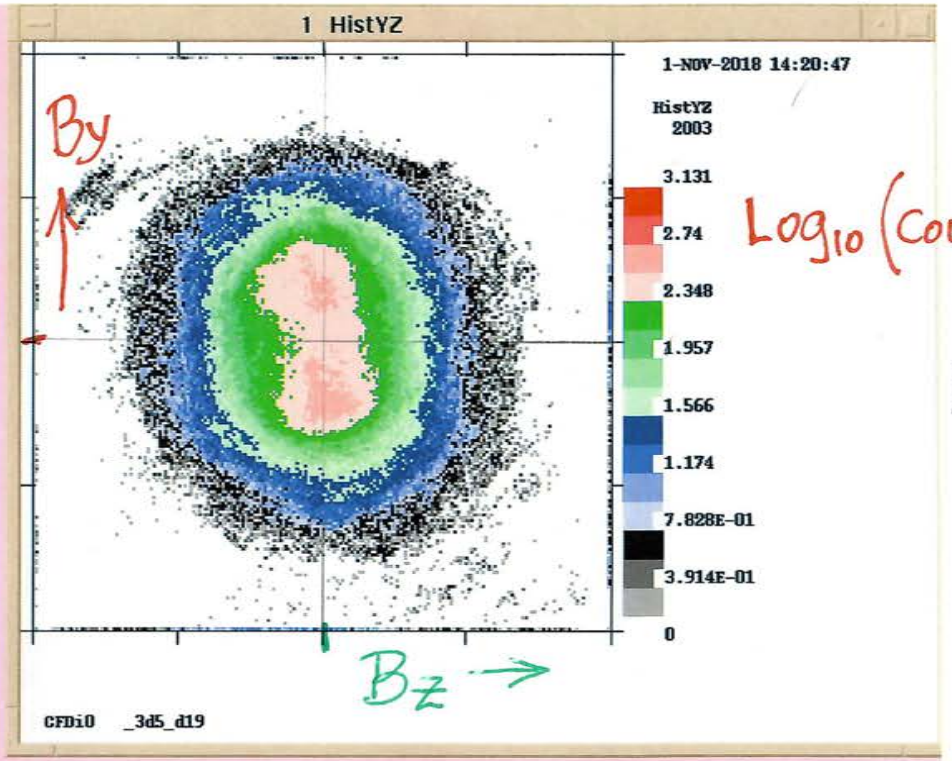

anaFR_Rot_Bxyz_rDC
Brms.FR
Bx.FR
By.FR
Bz.FR
28.
26.
24.
22.
20.
18.
16.
14.
12.
10.
8.
6.
4.
2.
0
[2.nT]
50%
% E^fRo
#SS
Brms
| dc.B |
rms.Bx
dc.Bx
rms.By
dc.By
rms.Bz
dc.Bz
1995
2000
2005
2010
2015
2020
MagData: NASA ACE Science Center
SunSpot# : NOAA SWPC
CFD10
F999_aceV_098_136_Spec_Bxyz_4fr.txt;1
_099_61e
16:25:03
_13_ 16-OCT-2019 16:25:02

RMS, "DC"

# Bxyz Correlations

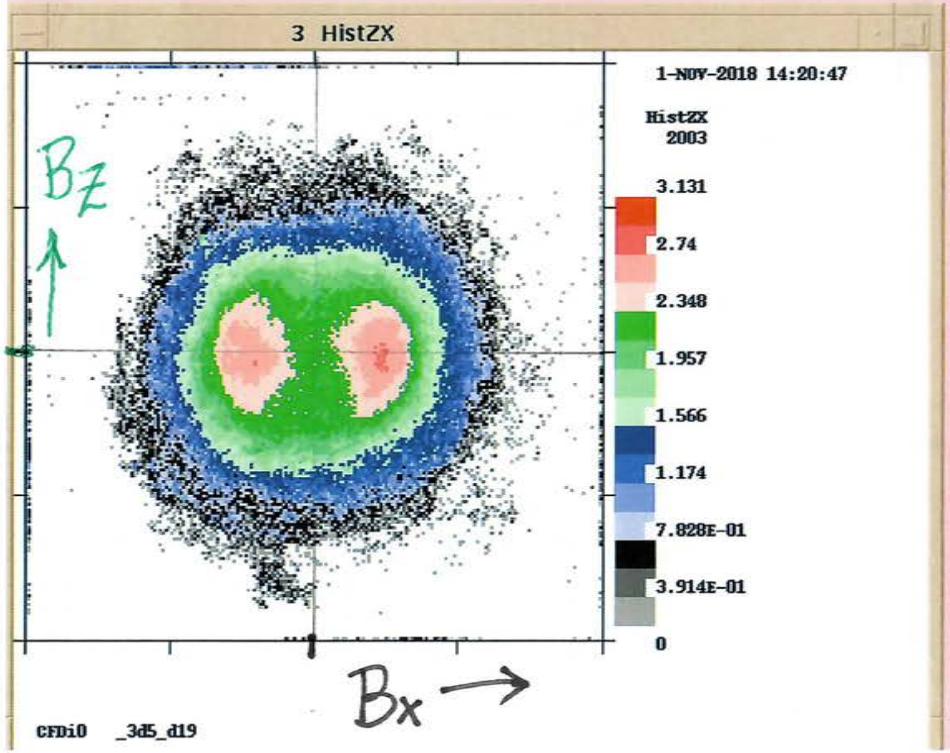
ACE MAG @ 1 AU

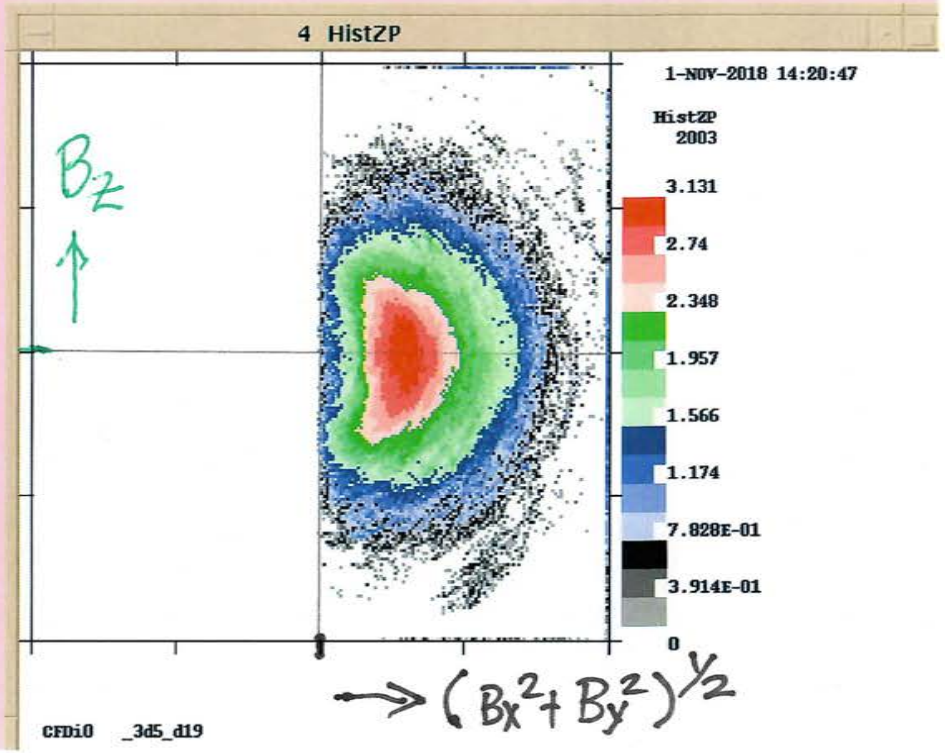


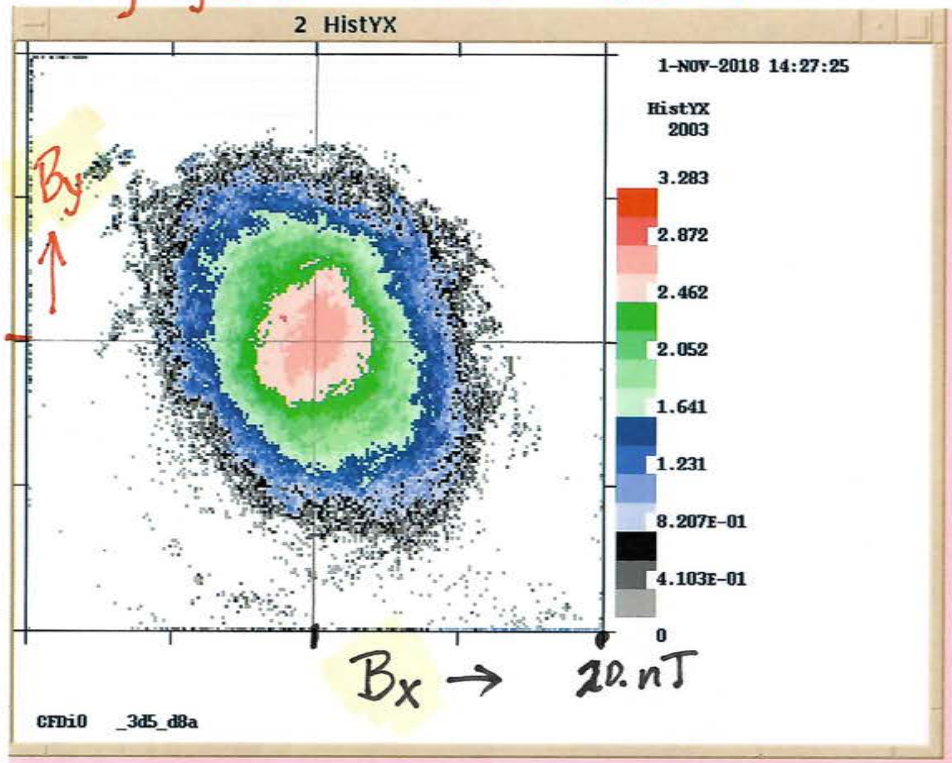

$\text{Log}_{10}$ (counts)

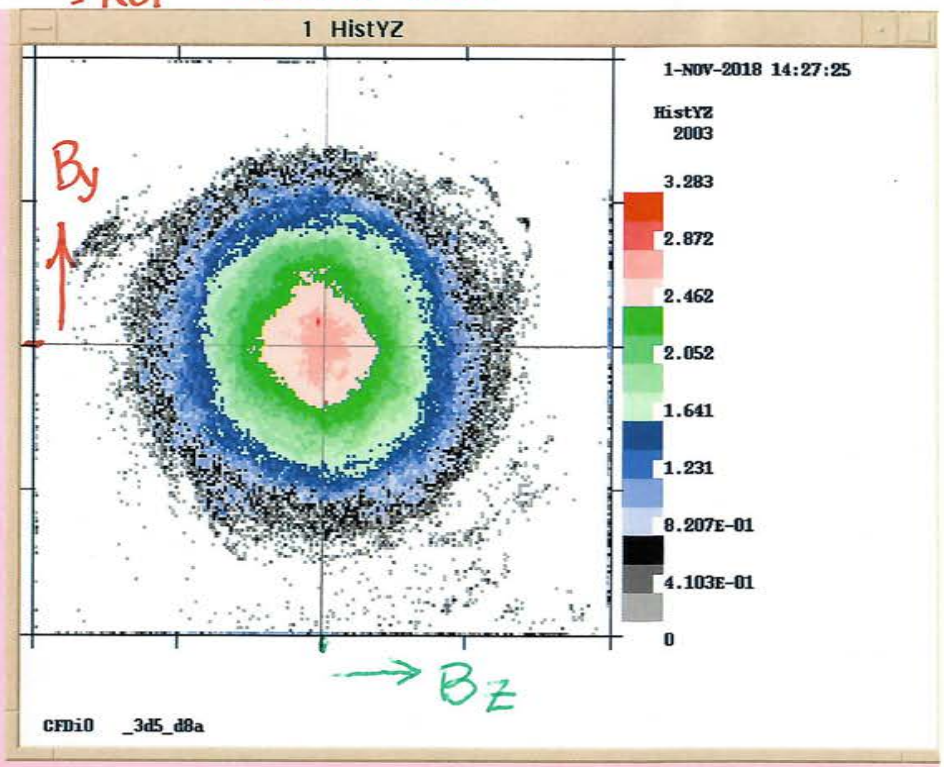
$2^{20}$ Tot

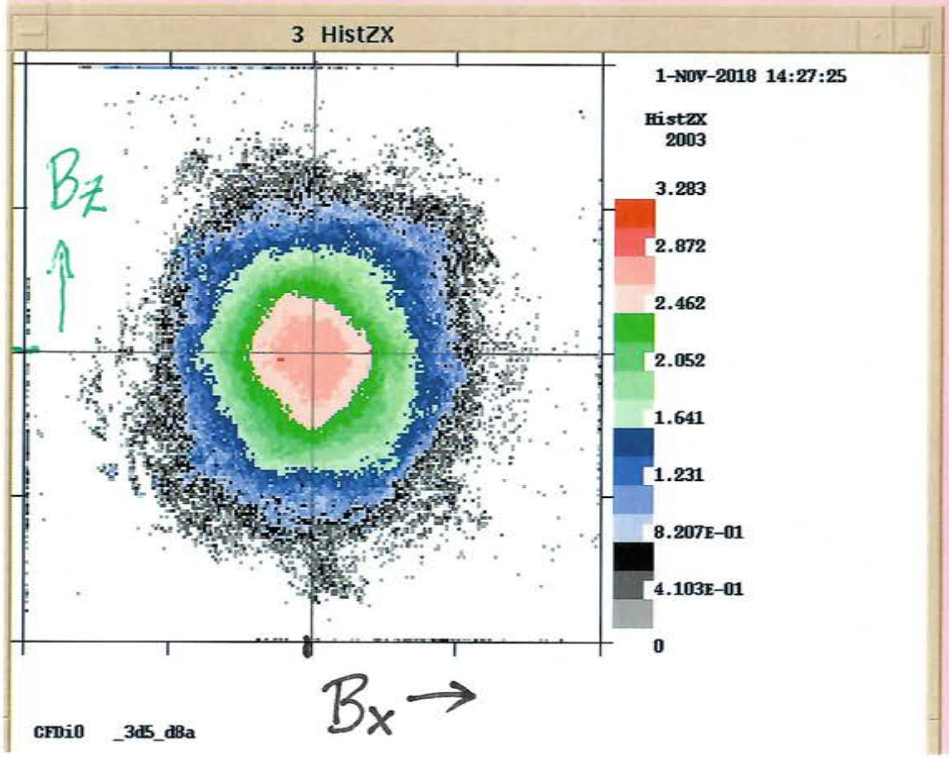


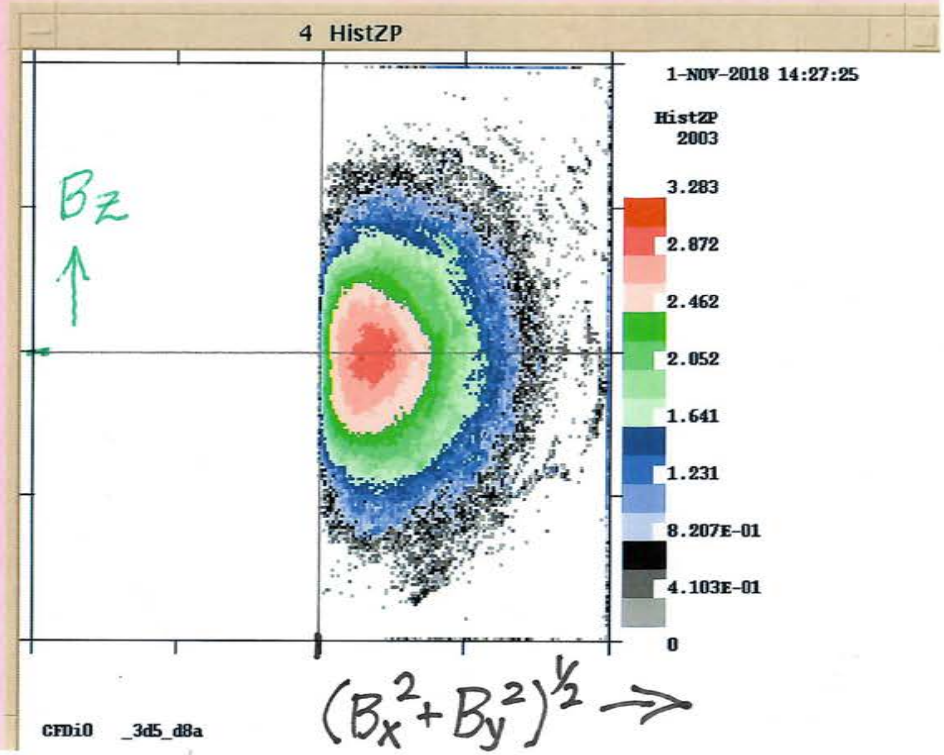



# Negligible Correlations with $f_{Rot}$ Removed

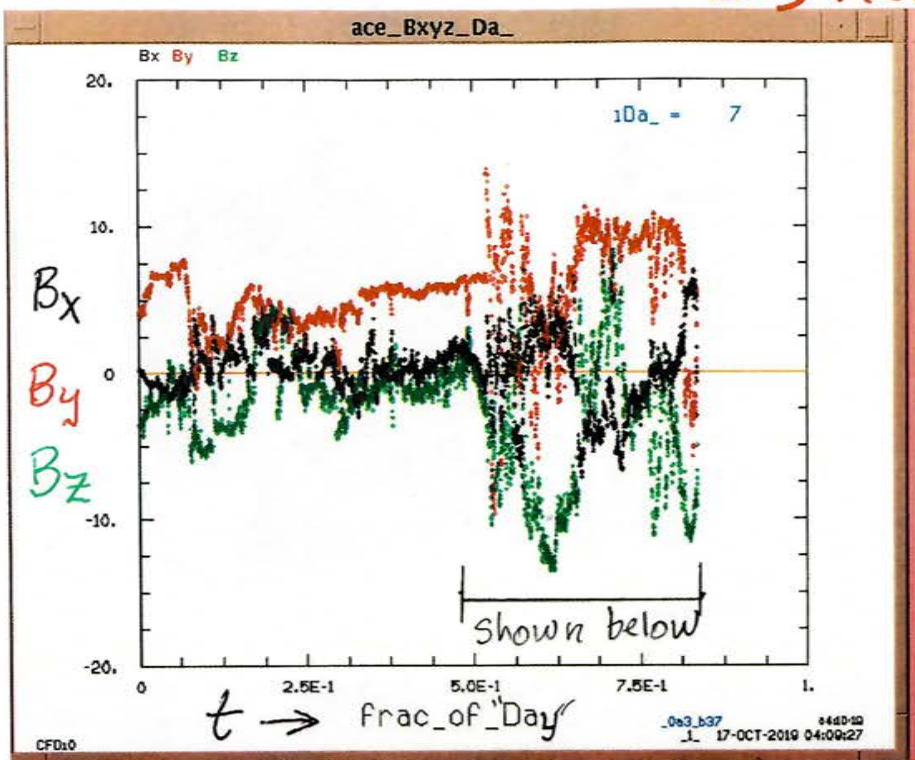


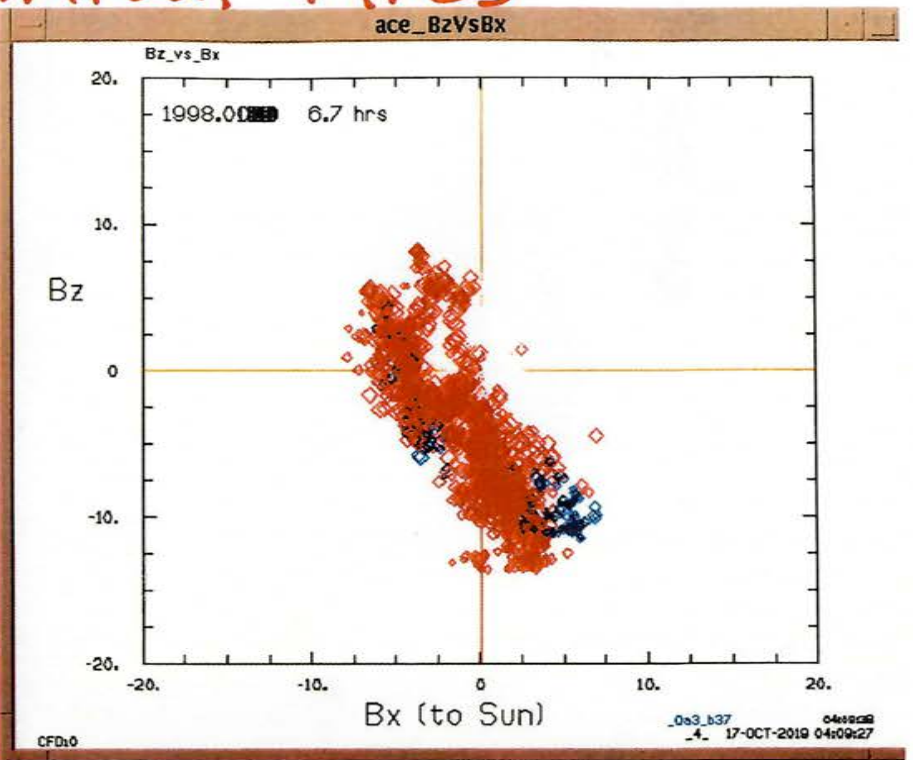



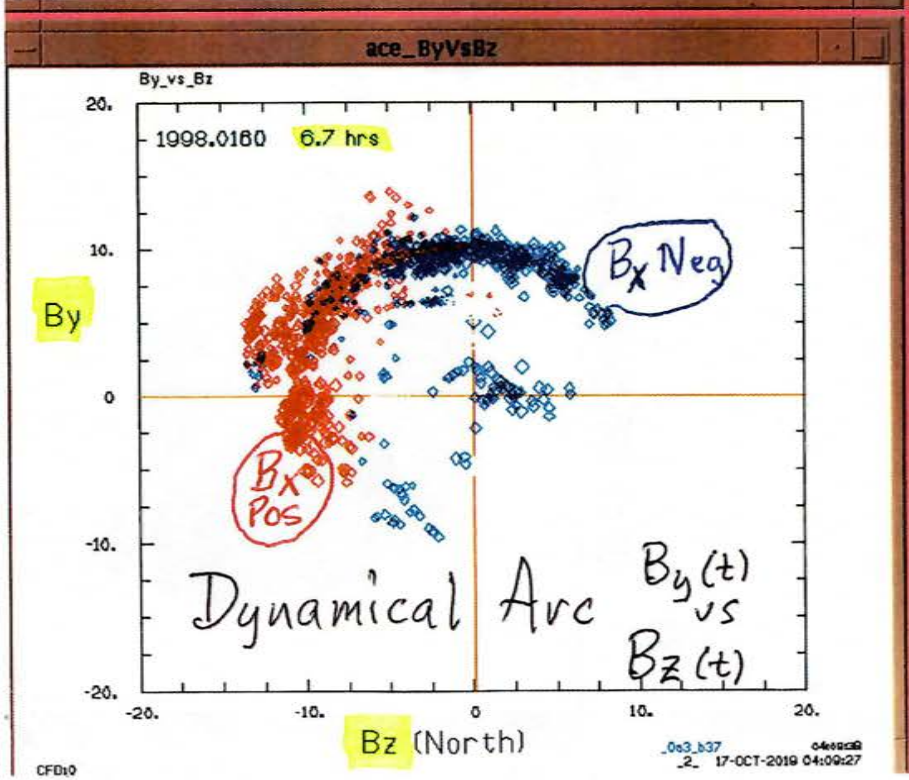



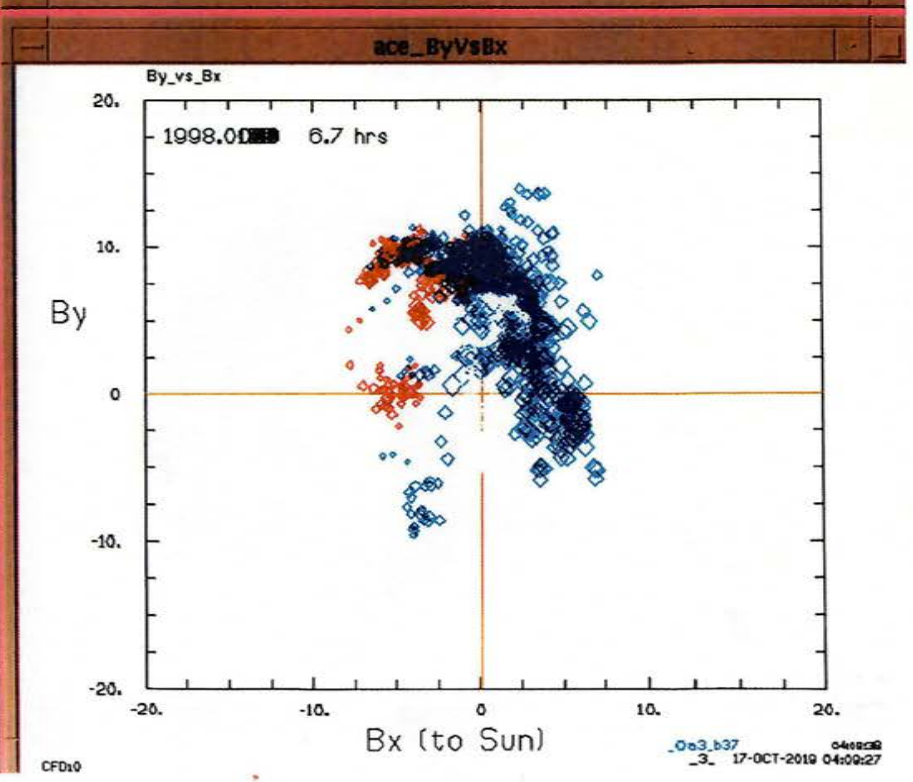



# Dynamical Arcs.

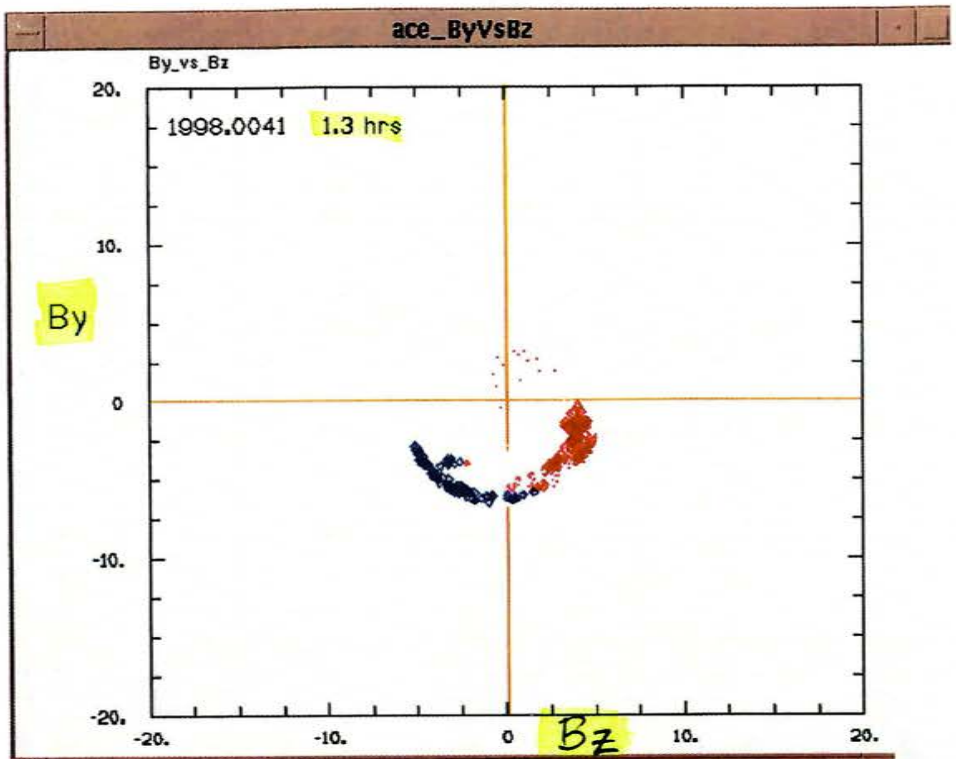


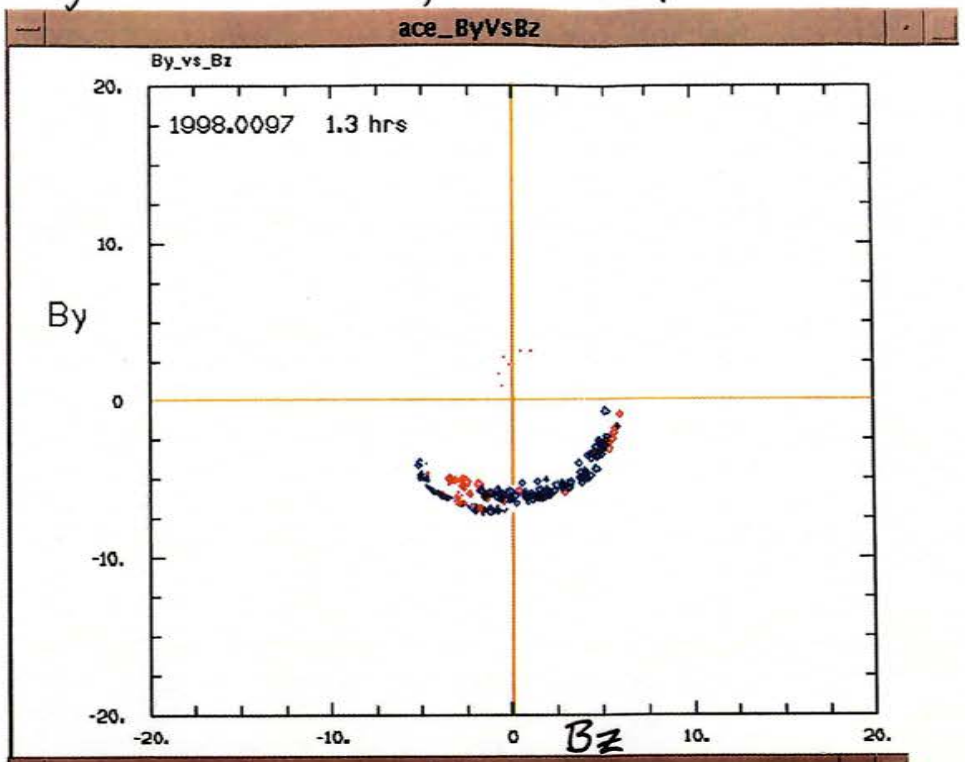



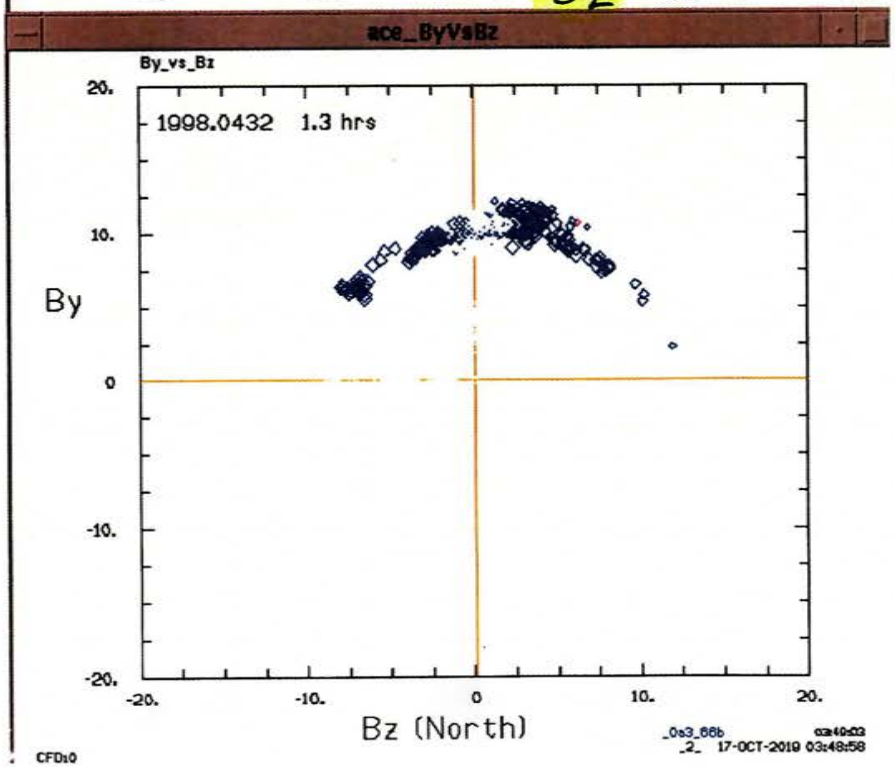



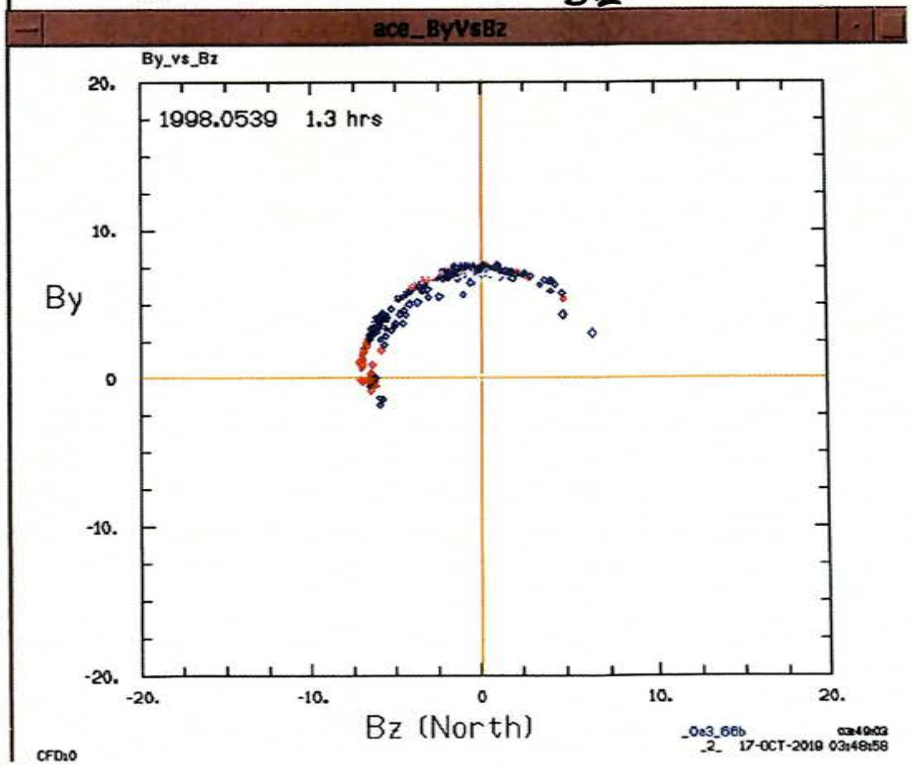



# Dynamical Arcs, 4 Examples

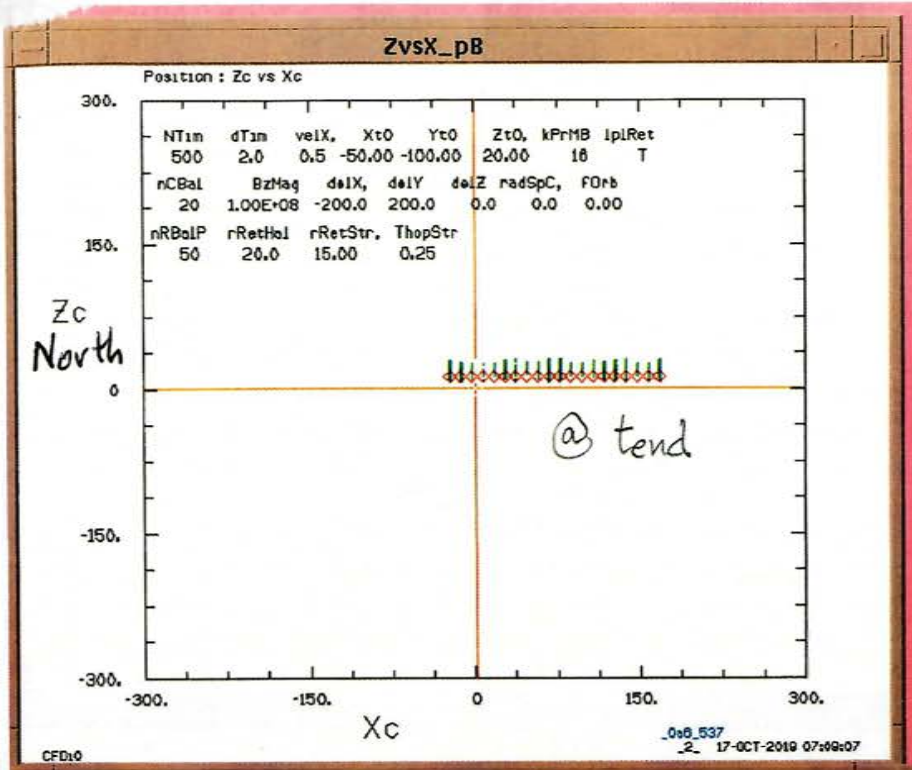


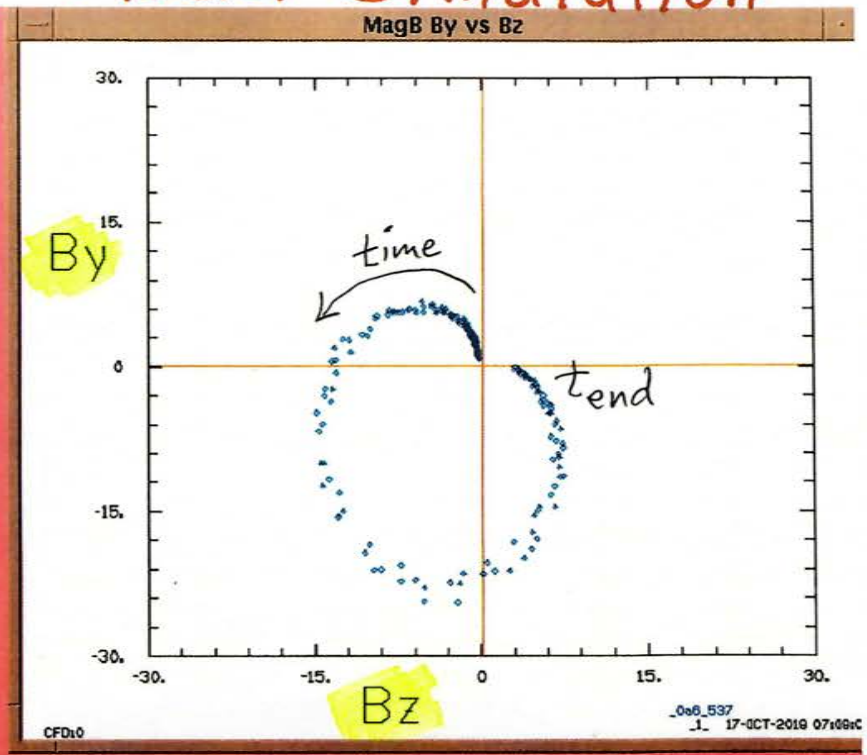



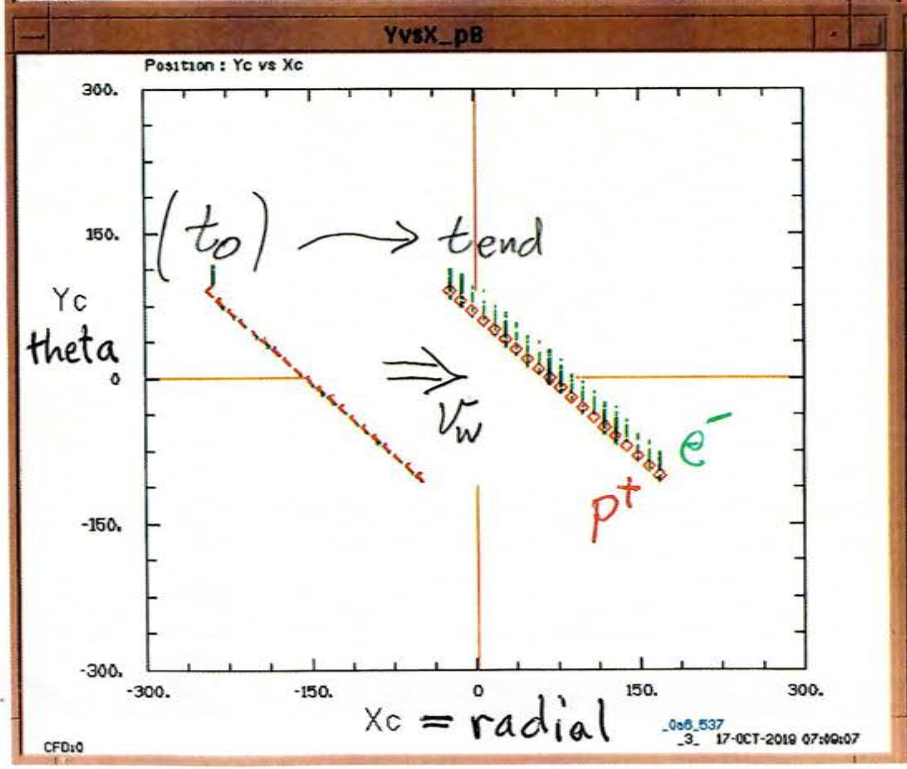



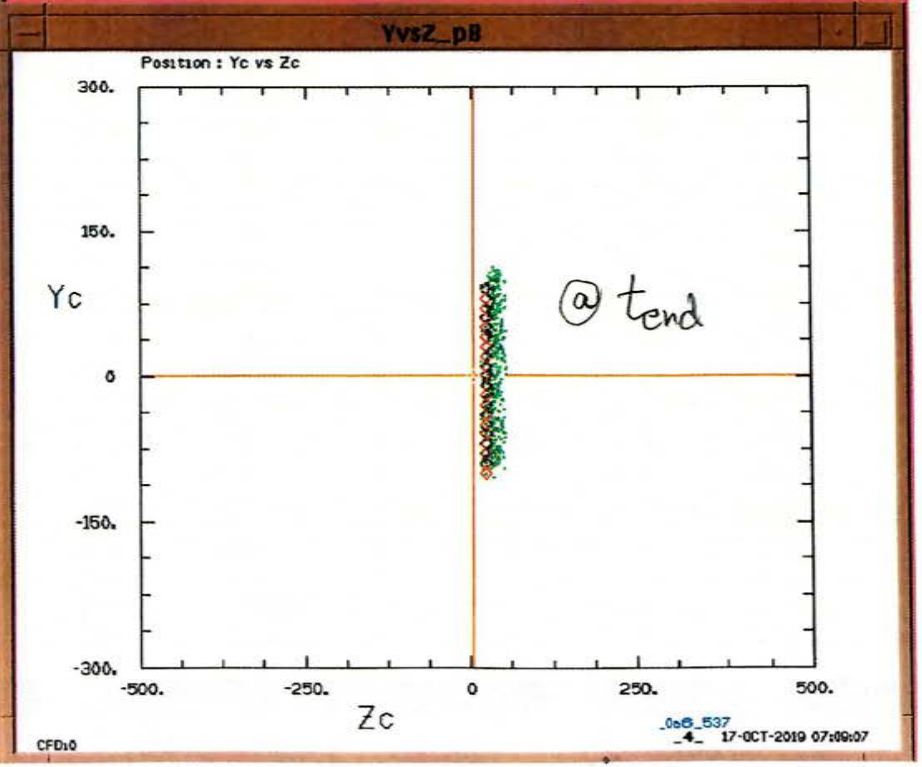



# Model Simulation



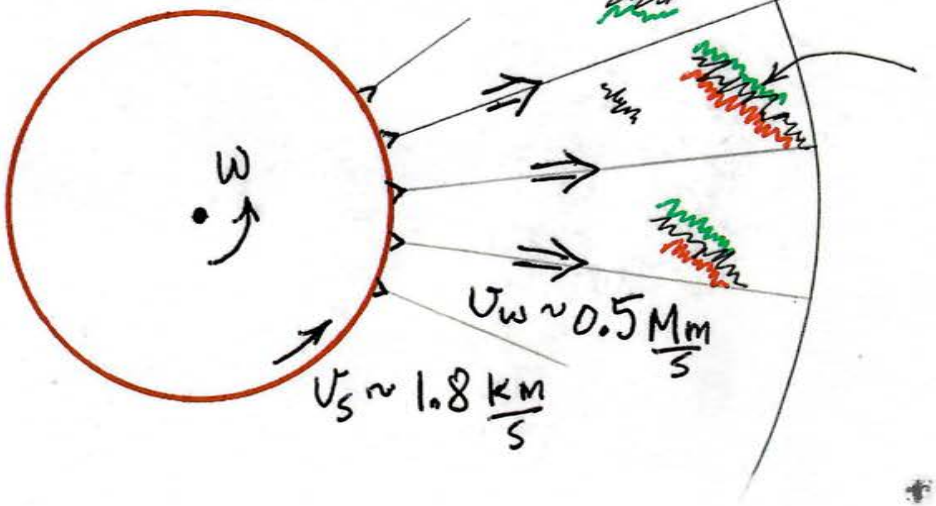



# Model:

## Current Filaments ⇒ $B_y^{(t)}$ vs $B_z^{(t)}$ "Dynamical Arcs"

Solar Granulation
$L \sim 1.\,Mm$
$\tau \sim 500.\,sec$




"Neutral" Flow of {Pos / Neg}

$n_w \sim 10^{6.8} \frac{\#\#}{m^3}$

$T_w \sim 10^{12.5} \frac{\#\#}{s \cdot m^2}$

$\sim 10^{24.5} \frac{\#\#}{s \cdot Mm^2}$

Suppose from Shot Noise Filamentation Dynamics, "Pinch"

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

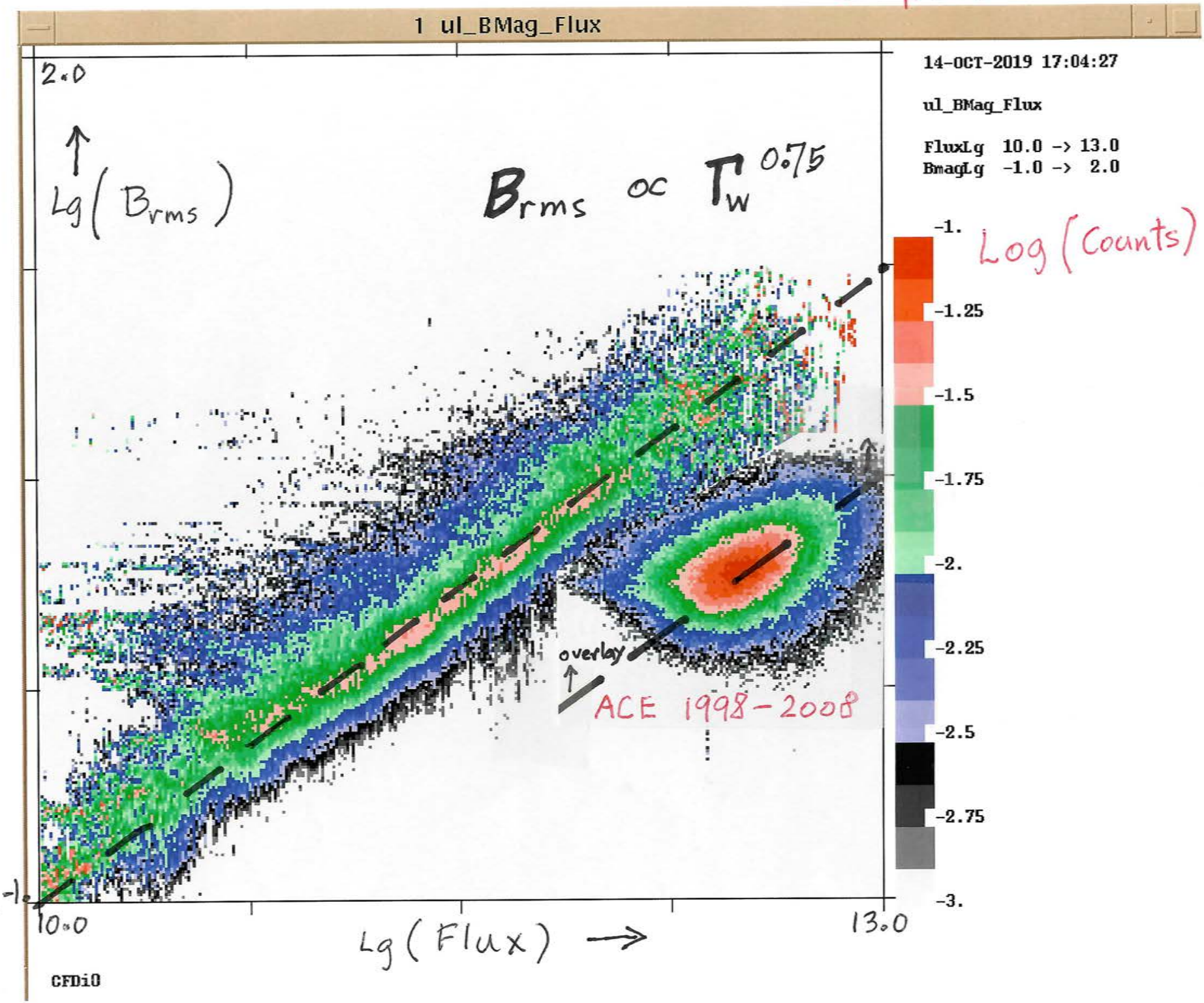
Then

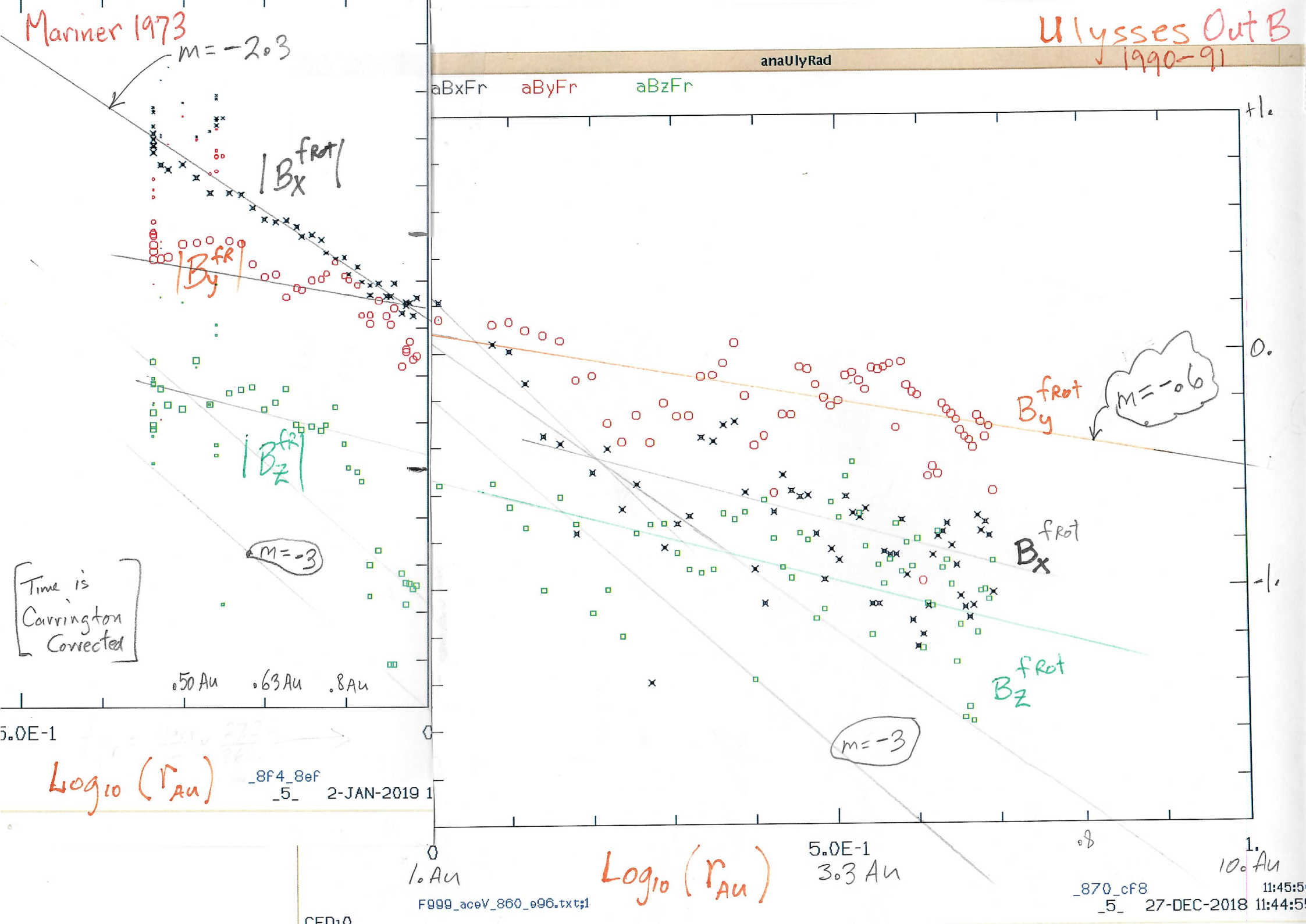
$B \sim \frac{2}{cr} (e \alpha n_w v_w)(\pi r^2)$

$B \sim 5.\,nT$ Suggests:

| $\alpha$ | $r_{Mm}$ | $\tau \equiv v_w r$ |
|---|---|---|
| $10^{-3}$ | 10. Mm | 20. sec |
| $10^{-5}$ | $10^3$ Mm | $\frac{1}{2}$ hour |

Ulysses 1→5. AU




Mariner 1973
m = -2.03
$|B_x^{frot}|$
$|B_y^{fr}|$
$|B_z^{fr}|$
m = -3
Time is Carrington Corrected
.50 Au
.63 Au
.8 Au
5.0E-1
$Log_{10}(r_{Au})$
_8f4_8ef
_5_ 2-JAN-2019 1
Ulysses Out B
1990-91
anaUlyRad
aBxFr aByFr aBzFr
+1.
0.
-1.
$B_y^{frot}$
m = -.6
$B_x^{frot}$
$B_z^{frot}$
m = -3
0
1. Au
5.0E-1
3.3 Au
1.
10. Au
$Log_{10}(r_{Au})$
F999_aceV_860_e96.txt;1
_870_cf8
_5_ 27-DEC-2018 11:44:55

Stellar Hydro Eqns: mass $m_p$ $m_e$ charge $e^-$ $p^+$ photons $\gamma$

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

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

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

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

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

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

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

# MHD Assumptions :

didactic : Longitudinal, Transverse

$$\begin{Bmatrix} E \\ B \\ J \end{Bmatrix} \equiv \begin{Bmatrix} E_Q \\ B_M \\ J_Q \end{Bmatrix} + \begin{Bmatrix} E_t \\ B_t \\ J_t \end{Bmatrix}$$

$$\nabla \times \begin{Bmatrix} E_Q \\ B_M \\ J_Q \end{Bmatrix} = 0 \qquad \nabla \cdot \begin{Bmatrix} E_t \\ B_t \\ J_t \end{Bmatrix} = 0$$

No Charges
No ElecPotEgy
No ThermoElec
No GraviElec
No Capacitance

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

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

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

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

cancel

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

$$F = \rho_Q E + (J_Q + J_t) \times B / c$$

$$\nabla \cdot J = 4\pi \dot{\rho}_Q = 0$$

## Dissipation

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

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

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

$\sigma = \infty$ (Ideal)

?? Moving B-lines live forever
?? B-lines "Frozen-Into" Plasma
?? Plasma "Stuck on" B-lines
?? Particle Streamline ≡ B-line

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

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

* Contradictory

# MHD Assumptions :

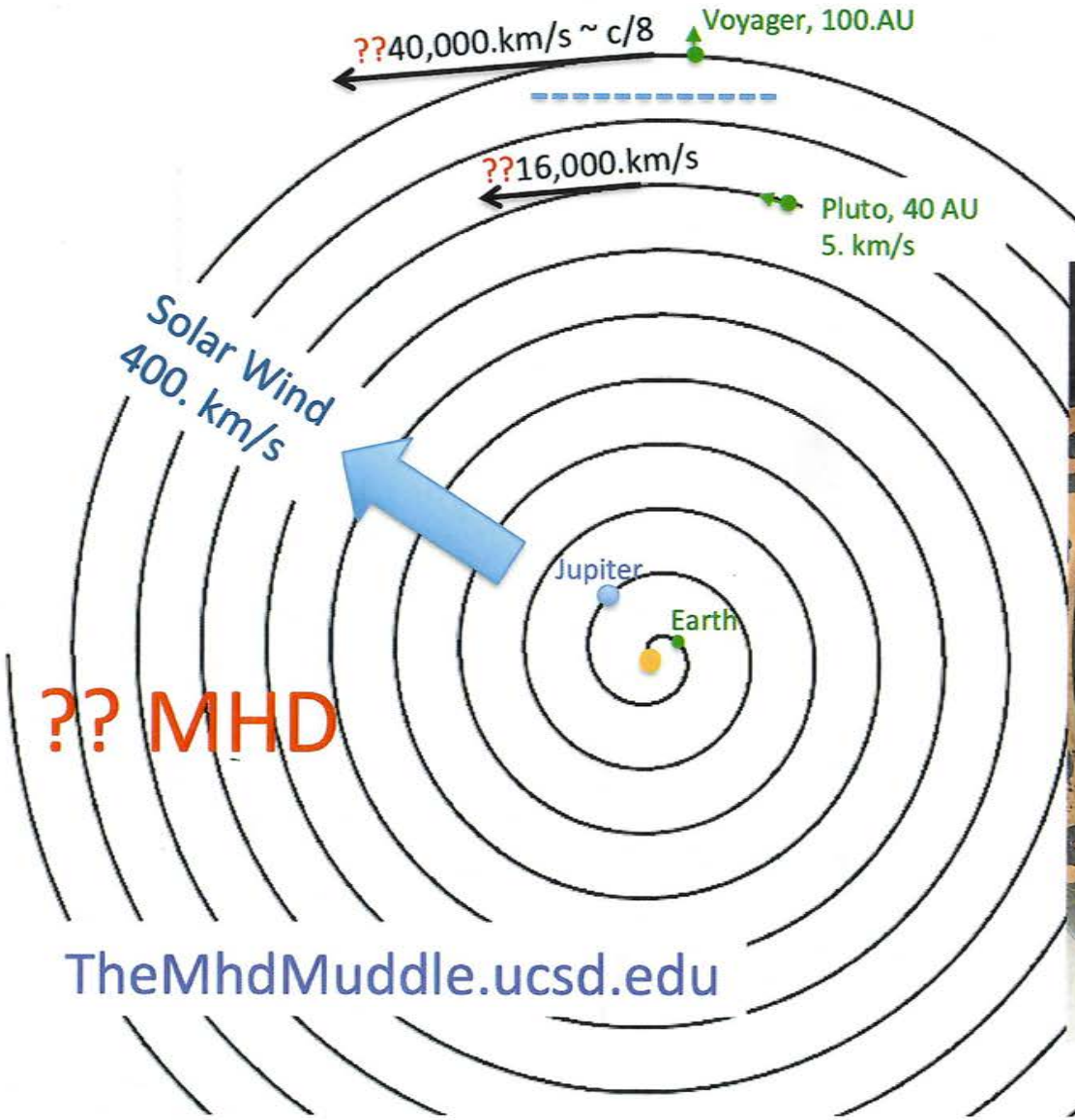
One-fluid MHD describes a mathematical Fluid with Mass, but no Charge $\rho_Q$ ,
which can nevertheless contains a disembodied (transverse) Current $J_t$ ,
which creates the (transverse) Magnetic Field $B_t$ ,
which then pushes on the Current and Mass .
Connection to the physics of Maxwell-Lorentz is tenuous at best.

Eliminating Charge eliminates the longitudinal Electric Field $E_Q$ and Potential $\varphi$,
as well as the Current $J_Q$ from the motion of charges.
This eliminates all Electrostatic Potential Energy, as well as all Thermo-Electric and Gravi-Electric effects,
and the eliminates the dynamics of Capacitance from charge position.
The much-discussed "No E parallel to B" follows from this mutilation of Maxwell-Lorentz.

The subtle "time-scale" assumption that $\dot{E}_t$ is negligible eliminates Photons, Time-retardation, and
Causality, enabling "tractable," instantaneous solutions everywhere, given "knowledge" of $J_t$ everywhere.
Nature's ubiquitous entropic Dissipation was "Ideally" eliminated in the transition from particles to fluid,
and assuming $J_t$ to be dissipation-less enables B-field "lines" to "live forever", while "frozen-into" the
fluid which is "stuck-on" the lines themselves.

For validity, MHD should require strong local particle collisionality to justify the fluid approximation,
and weak current resistivity to justify the "ideal" assumptions.
However, plasma-particle resistivity $\rho_{\mathrm{d}}$ and collisionality $\nu_{\mathrm{c}}$ vary *oppositely* with plasma temperature;
and $\rho_{\mathrm{d}}$ depends *only* on temperature T and the fundamental (particle) constant $r_{\mathrm{e}}$ .
These contradictory physical requirements make "the MHD regime" somewhat ill-defined.

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)