Hypervelocity Dust Impacts on the Wind Spacecraft

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THE "ISSUE"

- Lots of dust-
  - Not just in Solar System
  - Also in Milky Way
- What forms galaxies, stars, and planets
- Damages spacecraft

METHOD

- Characterize our surroundings (Local Interstellar Cloud)
- Distinguishing between interstellar dust (ISD) from interplanetary dust (IPD)
- Relationship between dust and solar cycle

WHY SHOULD WE CARE?

- Gain further understanding of our spot in the galaxy
- How the Solar System formed
- Exoplanets and stars
- Knowledge of dust =
  - Prediction of damage to spacecraft

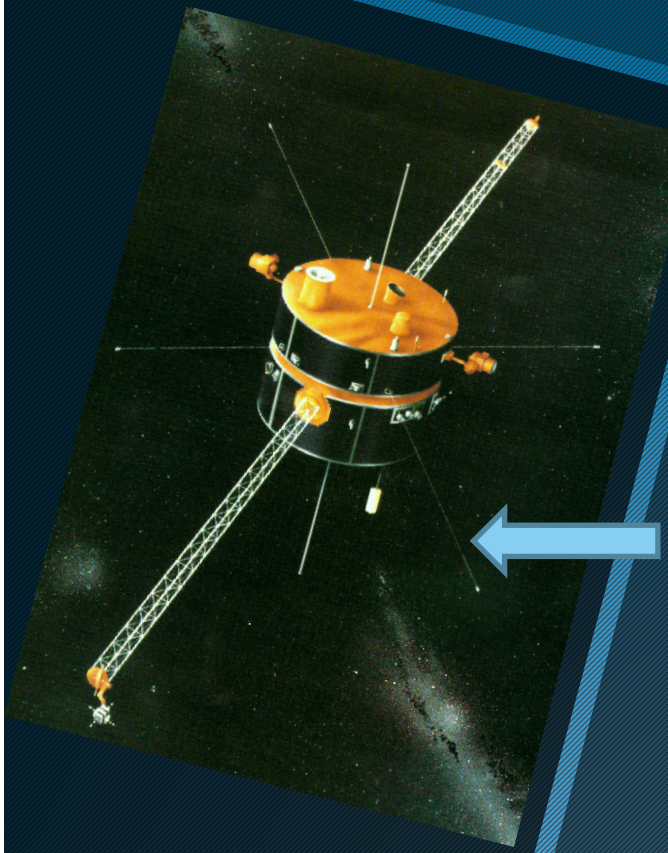
WOUNDED IN THE FIELD

Spacecraft	Dust Source	Consequence
Mariner 4	micrometeoroid shower	attitude compromised thermal shield damage
Giotto	cometary encounter	attitude compromised science instruments damaged
STEREO	interplanetary dust	thermal blanket damage some imaging compromised
Olympus telecomm. sat.	cometary dust (?)	attitude compromised
Image	interplanetary dust(?)	wire boom severed (4x)
Wind	interplanetary dust(?)	wire boom severed (2x)
ISEE3	interplanetary dust(?)	wire boom severed

MY PART

- Get as much data as I can from Wind
- Sift through to find dust impacts
- Determine:
  - Direction
  - Flux
  - Appearance over solar cycle

WHAT IS WIND?



- 1994 – Present
- Sits at L1 – in front of earth equal gravitational pull from Earth-Sun System
- Measures electric field
- Original mission:
  - Study the solar wind before Earth
- BUT after damage due to dust hit…
  - Can better see dust impacts on body
  - Dust on impact → plasma

WHAT IS DUST?

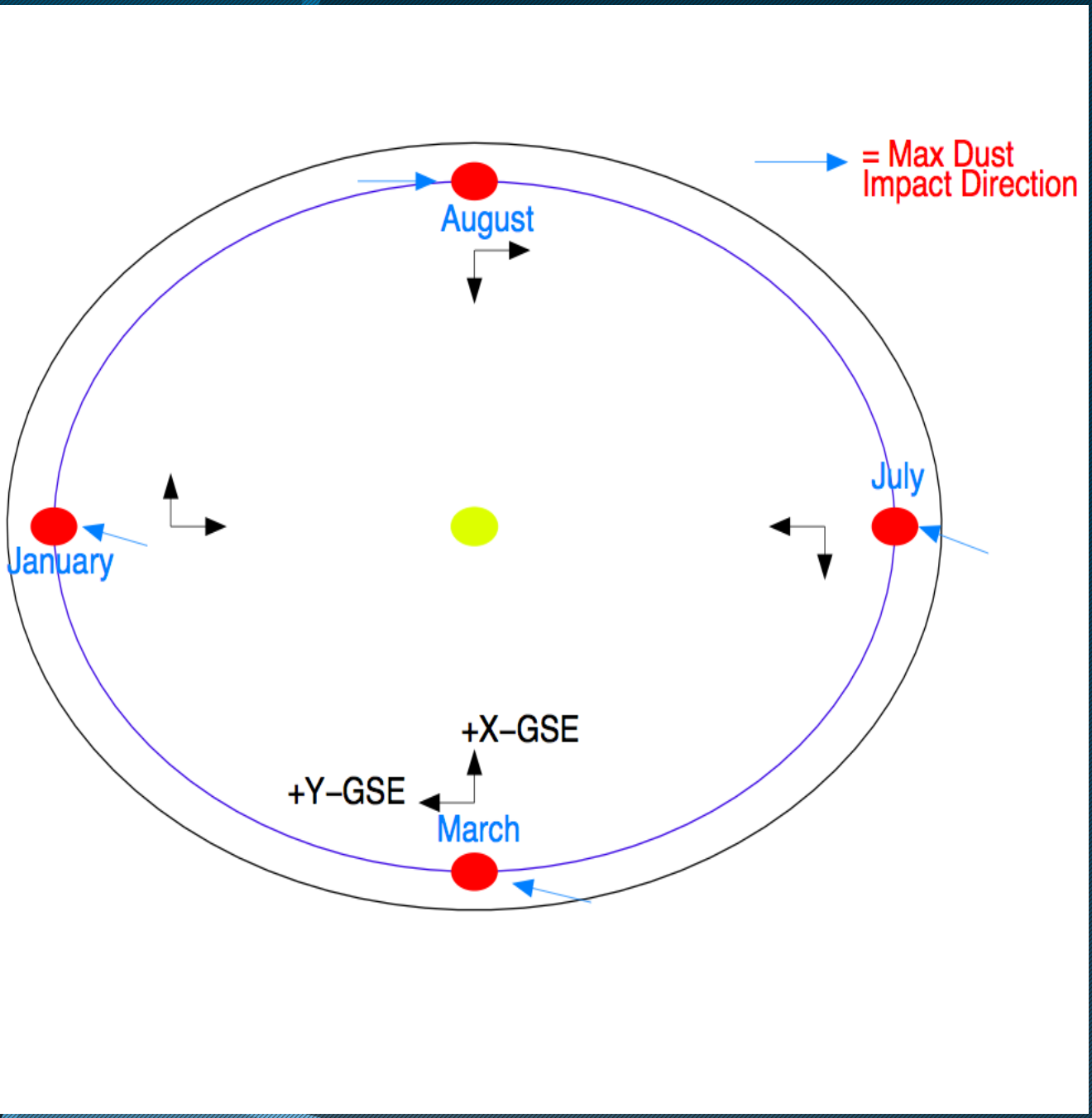
- ISD
  - At 1 AU = ~0.3μm
  - m ~ 2.8 x 10^{-16} kg
- IPD
  - Meteoroids m > 10^{-8} kg
  - β-meteoroids 10^{-18}<m<10^{-15} kg
  - Nanodust m < 10^{-18} kg

OTHER DIFFERENCES

- ISD velocity ~ 26 km/s
  - ~20 yrs. to travel Solar System
- IPD velocity ~ 30 km/s
- Charge release is similar ($q_r = m/v^{3/2}$)
- Limited by spacecraft
  - Saturates at 300 mV/m
- Distinguish between IPD and ISD by direction

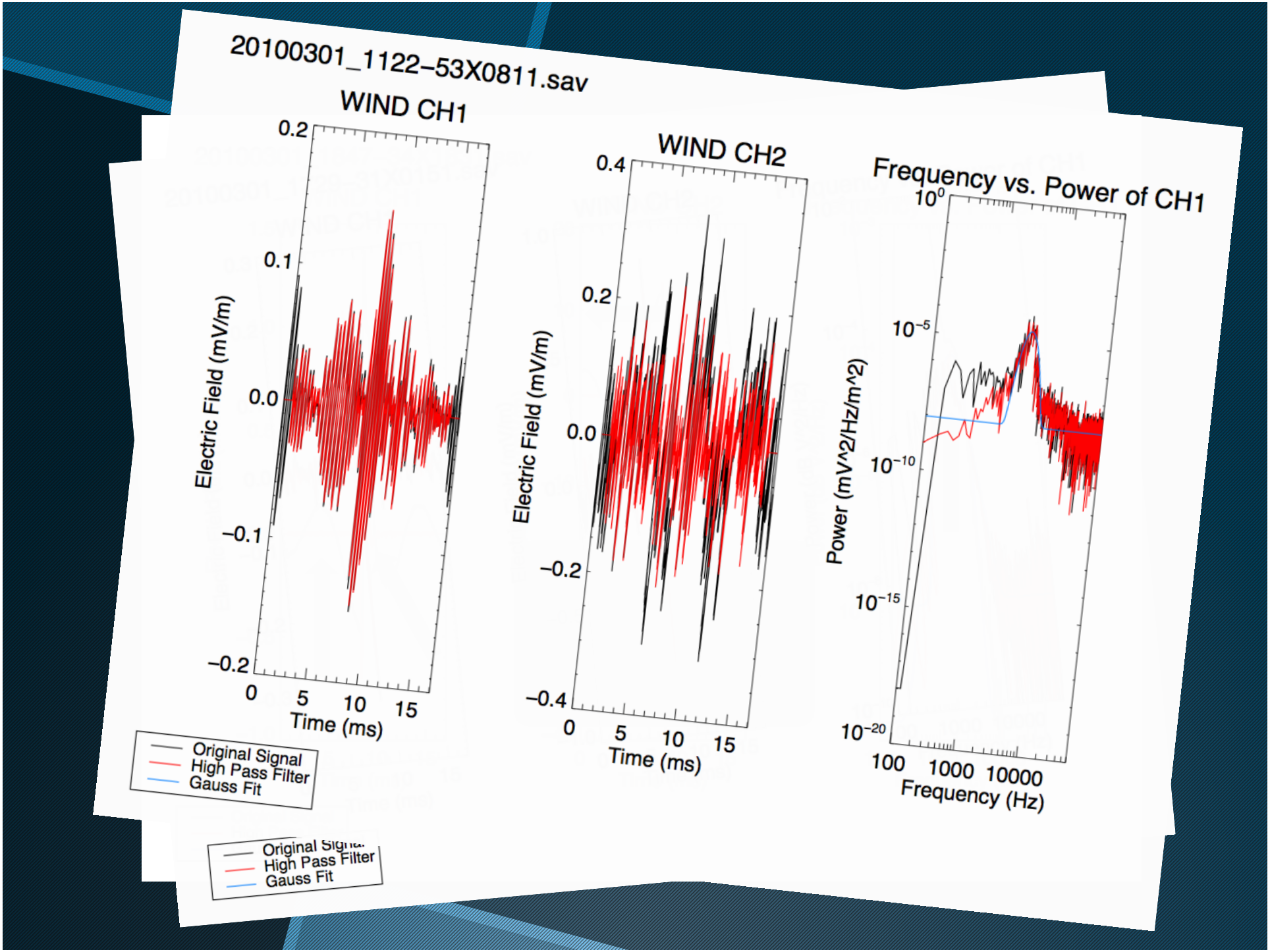
WHAT WE EXPECTED

- Tried to find correlation with interstellar dust (ISD) flux and solar cycle
  - Less ISD at solar maximum with stronger magnetic fields
  - More ISD at solar minimum
  - But with speed of ISD, maybe just trend over longer time period
- Monthly modulation
  - Max # ISD impacts in March
  - Least # ISD impacts in August


= Max Dust
Impact Direction
August
July
January
March
+X-GSE
+Y-GSE

DATA

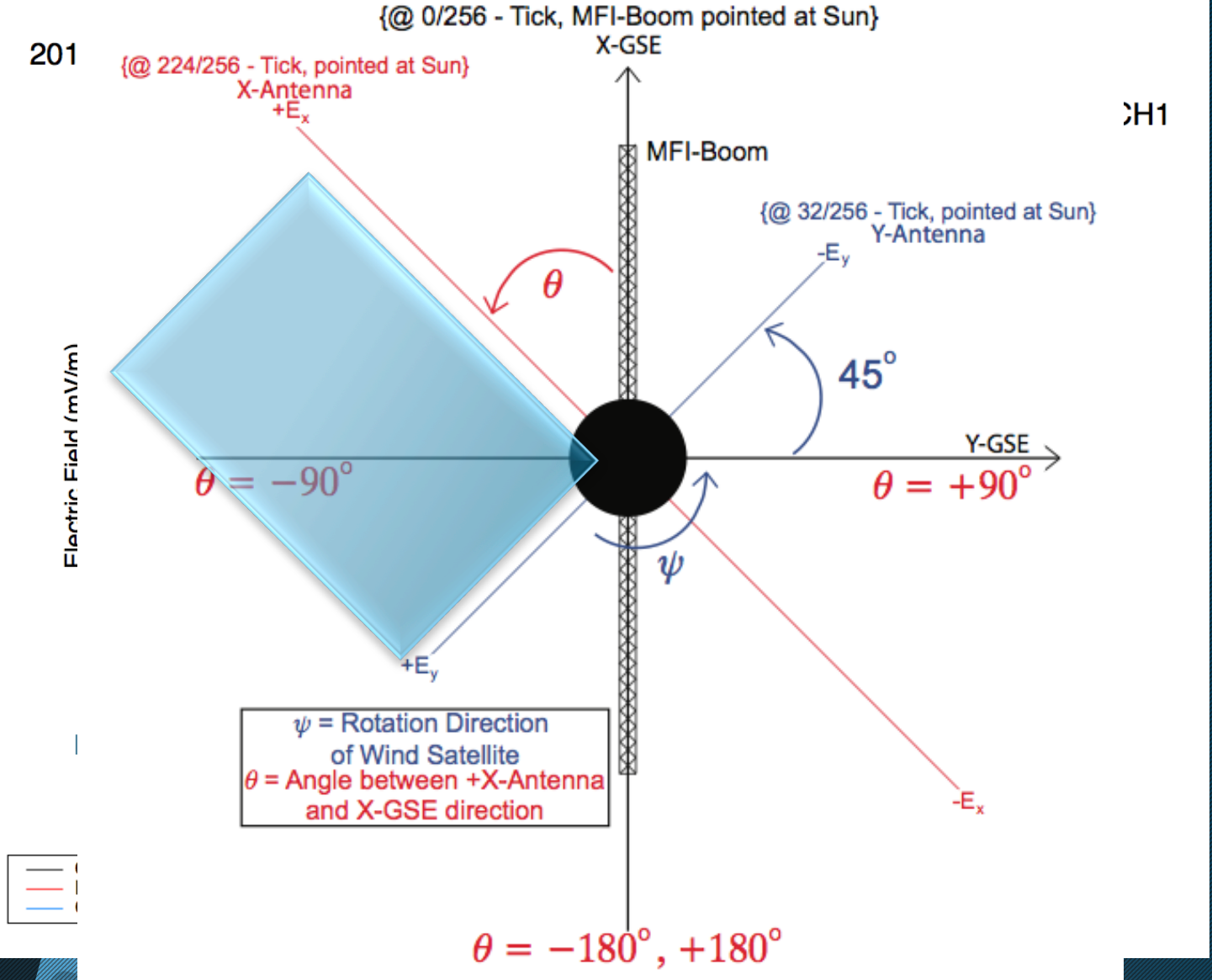
- Comes in → ascii file
  - Electric Field Measurements
  - Taken every 17 ms , 1 month
  - Selected by amplitude – ~100 highest amp/day
- Convert to idlsave file
- FIND DUST!

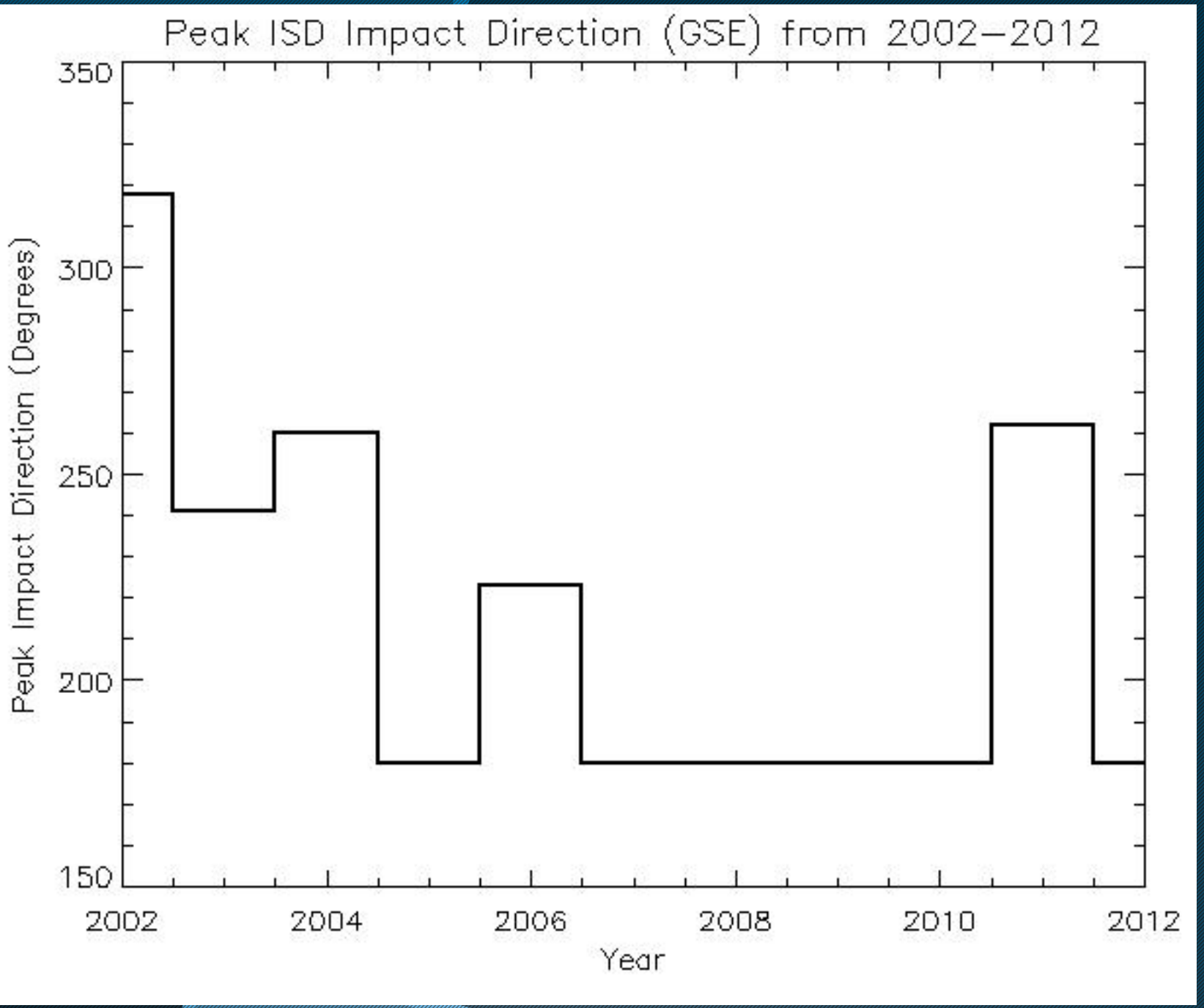

20100301_1122–53X0811.sav
WIND CH1
Electric Field (mV/m)
Time (ms)
Original Signal
High Pass Filter
Gauss Fit
WIND CH2
Electric Field (mV/m)
Time (ms)
Frequency vs. Power of CH1
Power (mV^2/Hz/m^2)
Frequency (Hz)

WHAT DO I WITH ALL THAT?

- Calculate direction and flux
  - Month
  - Year

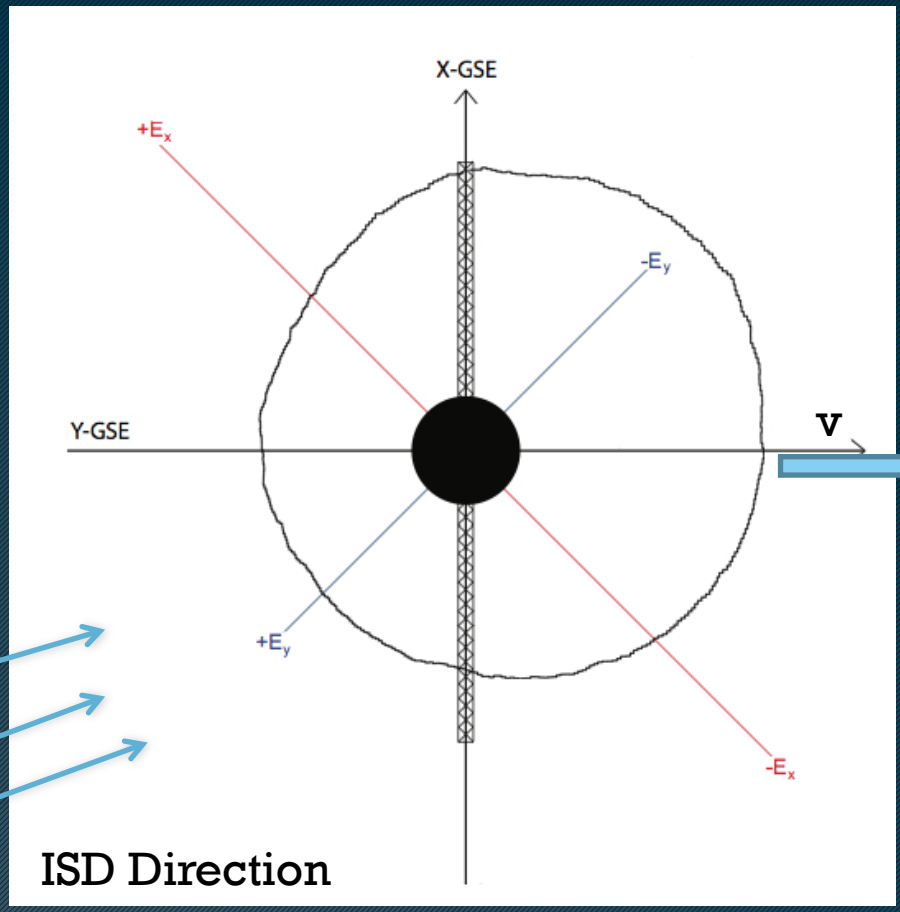
DIRECTION


{@ 0/256 - Tick, MFI-Boom pointed at Sun}
X-GSE
{@ 224/256 - Tick, pointed at Sun}
X-Antenna
+Ex
MFI-Boom
{@ 32/256 - Tick, pointed at Sun}
Y-Antenna
-Ey
θ
45°
Y-GSE
θ = −90°
θ = +90°
ψ
+Ey
-Ex
ψ = Rotation Direction
of Wind Satellite
θ = Angle between +X-Antenna
and X-GSE direction
θ = −180°, +180°


Peak ISD Impact Direction (GSE) from 2002–2012
Peak Impact Direction (Degrees)
350
300
250
200
150
2002
2004
2006
2008
2010
2012
Year

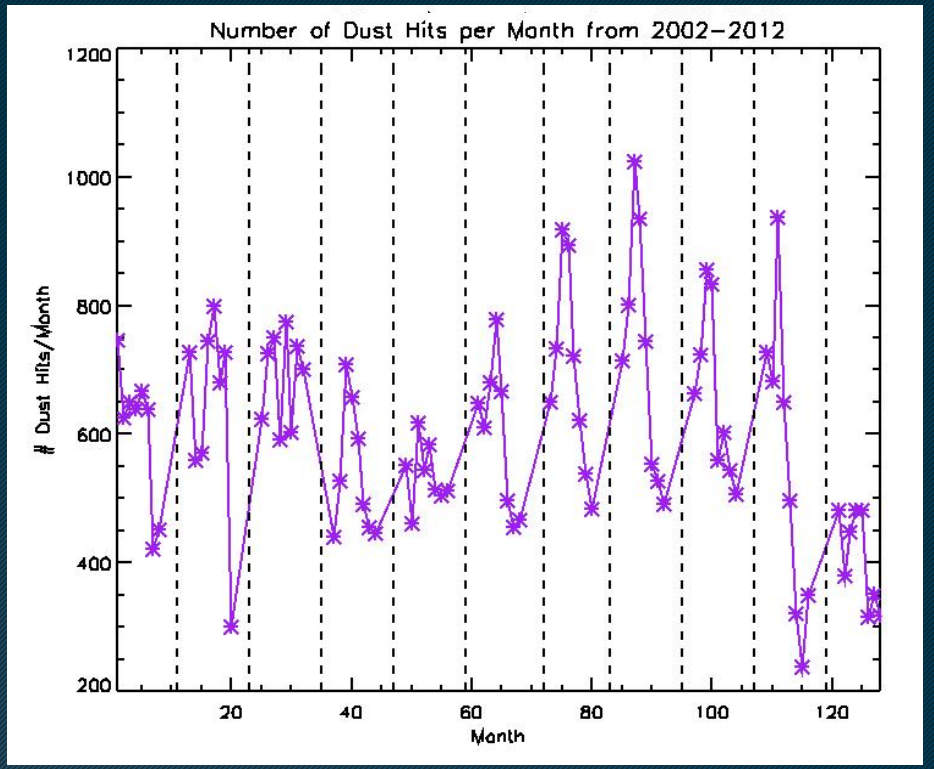
MONTHLY

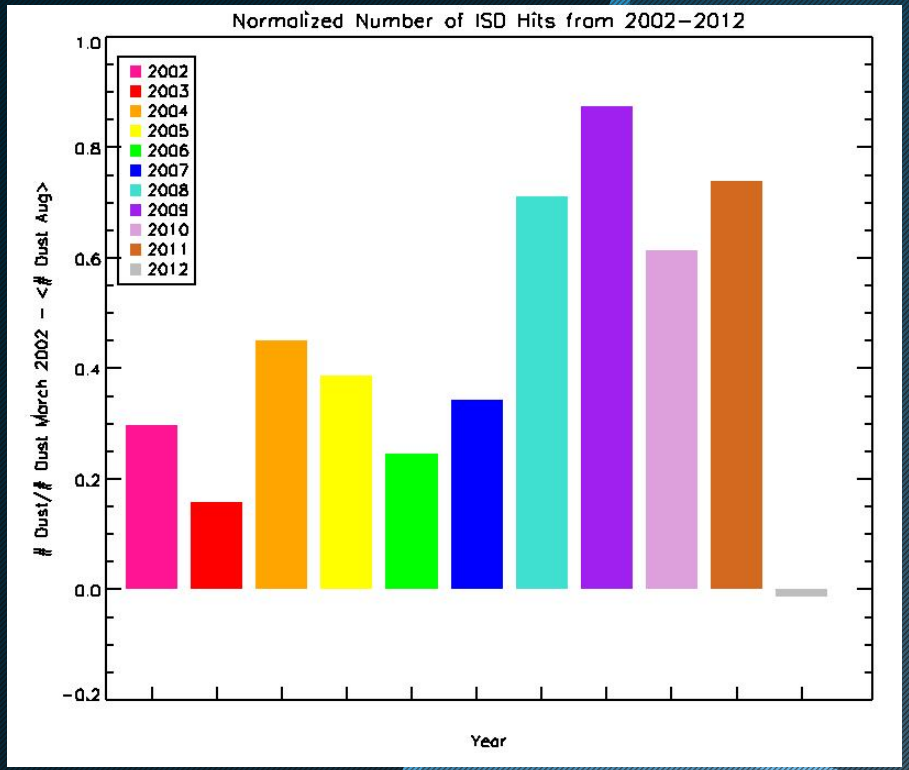
SUN



EARTH

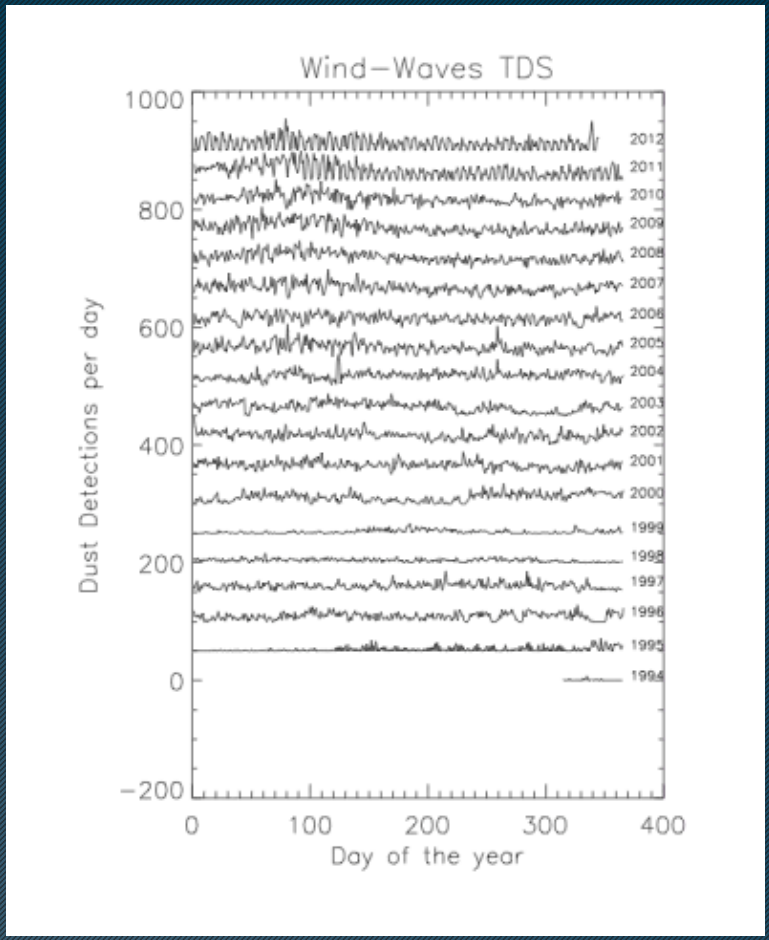
YEARLY


Number of Dust Hits per Month from 2002–2012
Dust Hits/Month
Month
1200
1000
800
600
400
200
20
40
60
80
100
120


Normalized Number of ISD Hits from 2002–2012
Dust/# Dust March 2002 – <# Dust Aug>
Year
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
1.0
0.8
0.6
0.4
0.2
0.0
-0.2

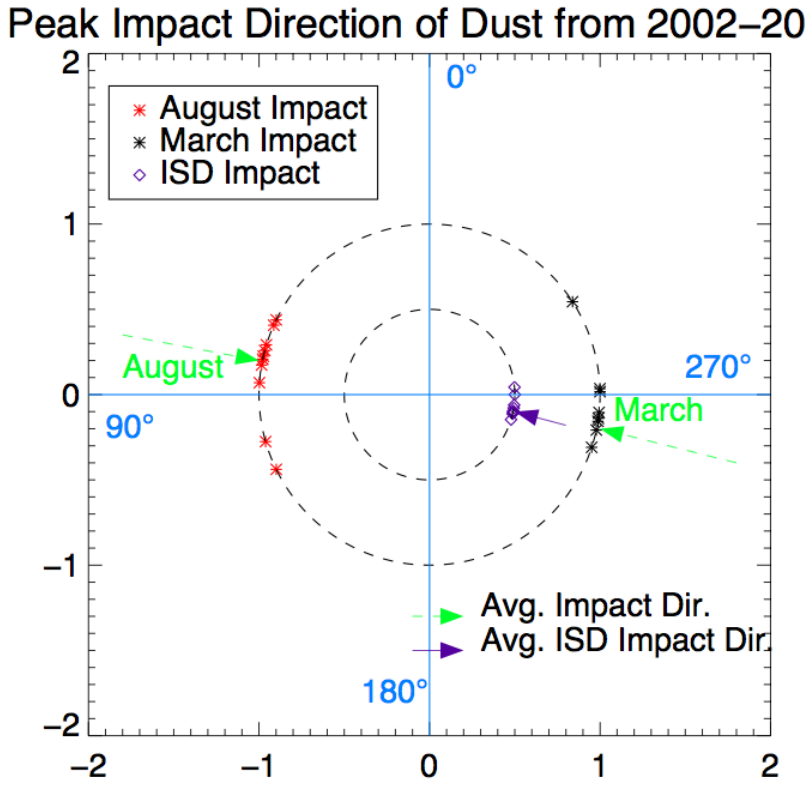
MATCHING WITH ULYSSES

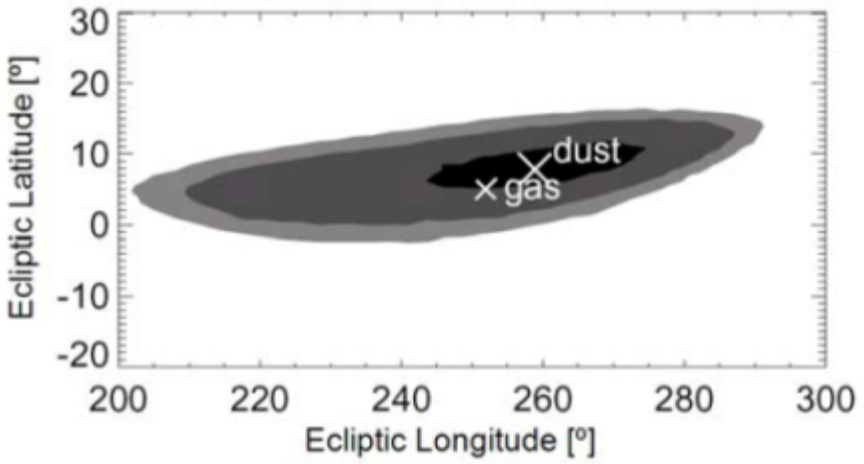
- Not much dust seen until ~2000
- Still see low point in '99



Kellogg, Paul. University of Minnesota. July 12, 2013.

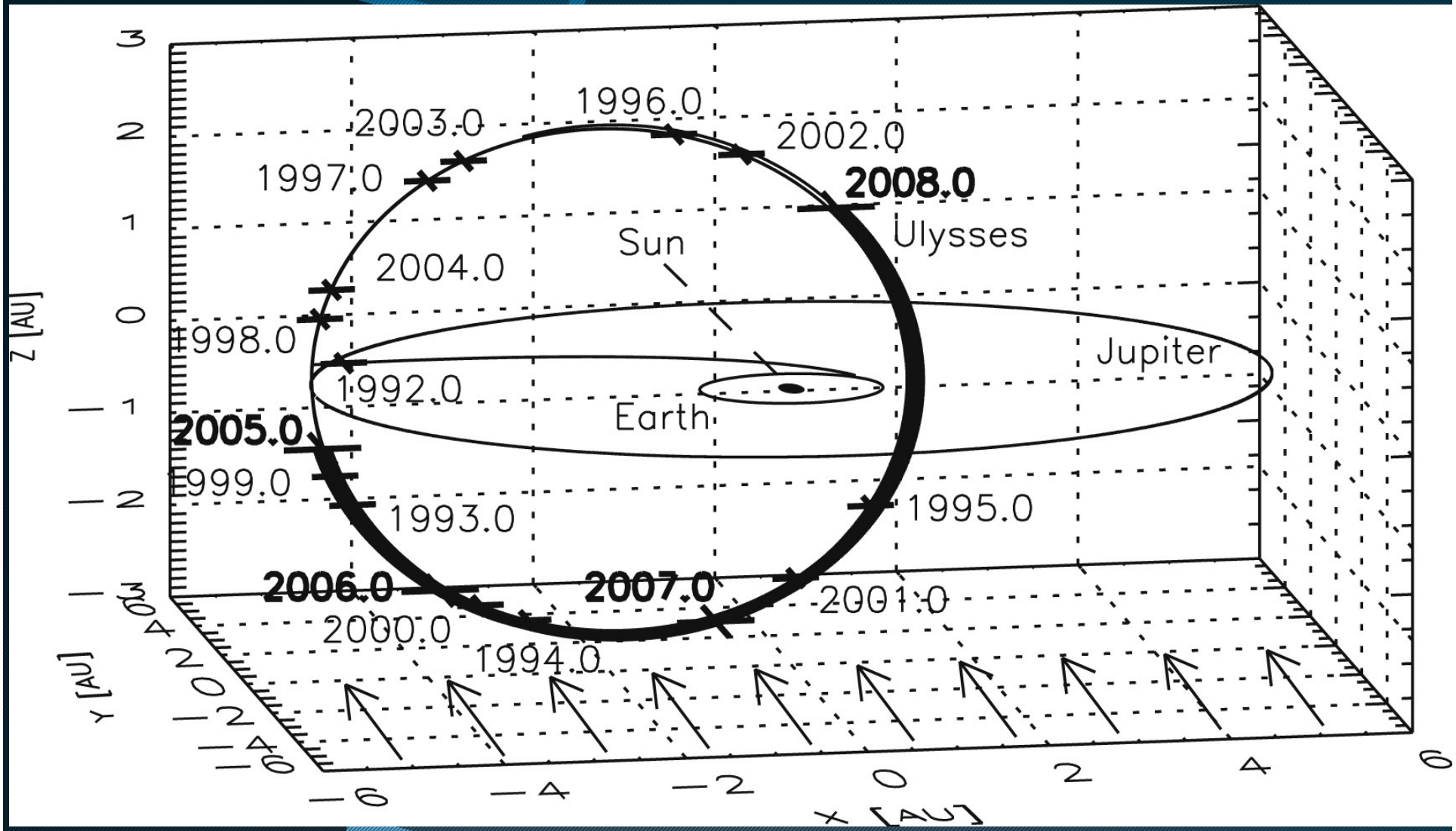
“ Same direction of origin seen





Horányi, Mihaly. “iDUST: Dust Tomography of the Heliosphere.” PowerPoint Presentation. Lunar Science Forum. 2011.

ULYSSES TRAJECTORY



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RESULTS

- Dust modulation seen per month
- Able to separate IPD/ISD component
- No obvious solar cycle correspondence
- Consistencies between Ulysses and Wind dust measurements