INTERPRETING DUST IMPACT SIGNALS DETECTED BY THE STEREO SPACECRAFT

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DUST IN SPACE

• There are many types of dust in space: Interstellar, Interplanetary, etc

• Mostly dealing with interplanetary dust

• The spacecraft measure dust signals (Voyager, Cassini, STEREO, etc)
THE STEREO MISSION AND SOLAR WIND CONDITIONS

• Two spacecraft: Ahead (A) and Behind (B)
• Placed at 1 AU (in Earth-like orbit)
• Designed to measure solar wind conditions
• The S/WAVES instrument has three antennas.
• The spacecraft and antennas have a floating potential due to solar wind conditions.
BASICS OF DUST SIGNAL GENERATION

- High-velocity dust that impacts spacecraft partially ionizes and creates a plasma cloud.
- Charge collection and image charging effects are recorded by the antennas.
- It was assumed that the plasma cloud was large and there was a large amount of collection.
- The internal electric field will be small when the plasma cloud is a few centimeters large.
- Electrons and ions will follow single particle trajectories.
OUTLINE OF RESEARCH PROJECT

• There was a model proposed by Zaslavsky [2015] to explain dust signals.

• The charge collection by antennas was assumed to be significant.

• Run SIMION® simulations to test spacecraft/antenna collection.

• Investigate what types of signals occur and how frequently.

• Use findings to investigate the proposed model.
THE TYPICAL DUST SIGNALS

Single Hit

Triple Hit

1. Meyer Vernet, 2009
FLOATING POINT PERTURBATION MODEL

• Want to find a steady state solution to:

\[ \frac{dq}{dt} = I_{sw} + I_{ph} + \ldots \]

• Adding a perturbation to the steady-state solution gives:

\[ \frac{d\delta\phi}{dt} + \frac{1}{\tau} \delta\phi = \frac{I_{dust}}{C} \]

• \( \tau, C, \) and \( I_{dust} \) are different for spacecraft and antenna

• Spacecraft:

\[ I_{dust} = (1 - p_{ant}) \frac{Q}{\sqrt{2\pi\Delta t}} e^{-\frac{t^2}{2\Delta t^2}} \]

• Antenna:

\[ I_{dust} = p_{ant} \frac{Q}{\sqrt{2\pi\Delta t}} e^{-\frac{t^2}{2\Delta t^2}} \]

2. See Zaslavsky, 2015
FPP MODEL CONT.

- If $I_{dust}$ is a simple Gaussian we get the results ($\delta \phi_{meas} = \delta \phi_{ant} - \delta \phi_{sc}$):
REVIEW OF 2008 STEREO A WAVES DATA
SIMION® SIMULATIONS

- Particles were initially in a Maxwell-Boltzmann distribution of energy
- 5ev electrons and 30eV protons (ions)³
- Placed on different spacecraft locations
- Spacecraft was set to 5V and antennas were varied
- Output was TOF for each particle that hit the spacecraft or antenna

³ Collette, et al. 2015
ESTIMATES OF $P_{\text{ANT}}$ ON THE ORDER OF 0.01
FPP MODEL USING $p_{ant}$ FROM SIMULATIONS

- Top: $p_{ant} = \frac{1}{100}$
- Bot: $p_{ant} = \frac{1}{30}$
- These overshoots are not large enough.
CONCLUSIONS

• Many of the assumptions of the model hold such as electron collection times.

• There may not be enough charge collection to support FPP Model.

• The model cannot explain more than one signal at a time. It must be extended or amended.
REFERENCES AND ACKNOWLEDGEMENTS

• Thank you to Zoltan Sternovsky for the project, help and fun time throughout the REU program.
• I acknowledge the support from NASA through the IMPACT node of the Solar System Exploration Research (SSERVI) program. I participated in this project through NSF’s Research Experience for Undergraduates (REU) program.
• Thank you also to David Malaspina, Ted, and others who helped with the project in anyway.
• References:

