INTERPRETING DUST IMPACT SIGNALS DETECTED BY THE STEREO SPACECRAFT

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Image: jpl.nasa.gov

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)

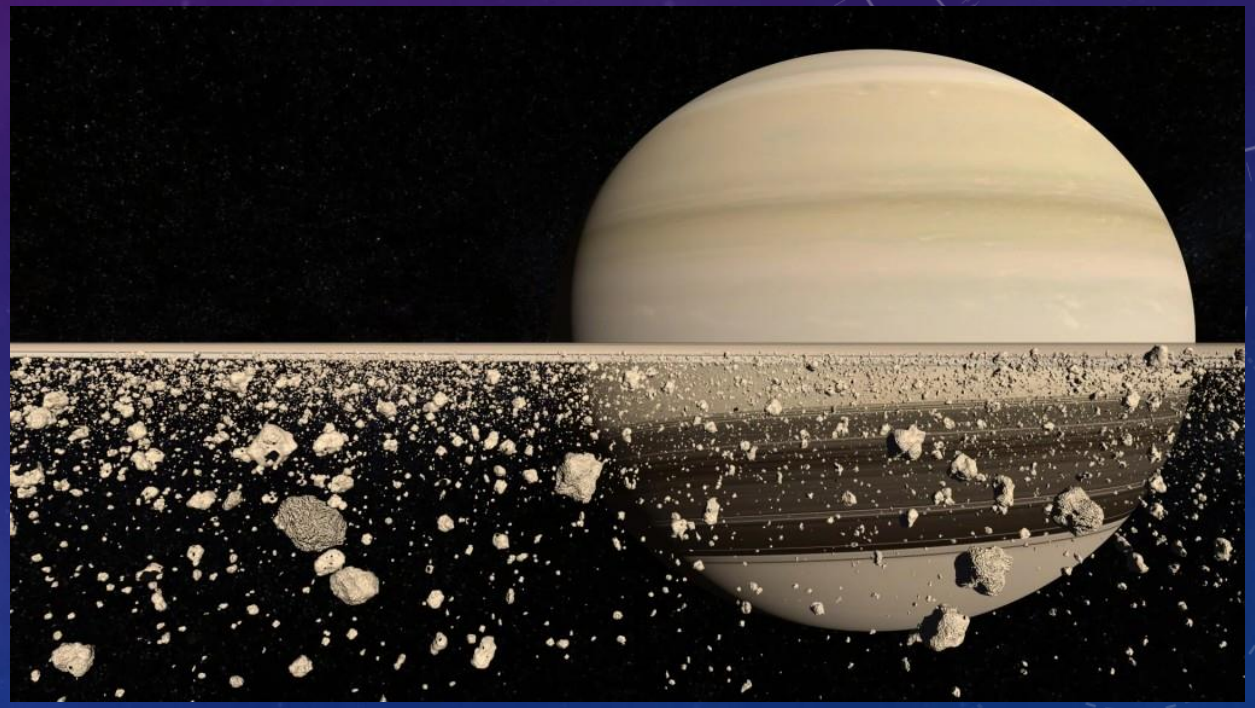


Image: http://iscreamsundae.com/wp-content/uploads/2014/09/rings-of-saturn-image-1024x576.jpg

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.

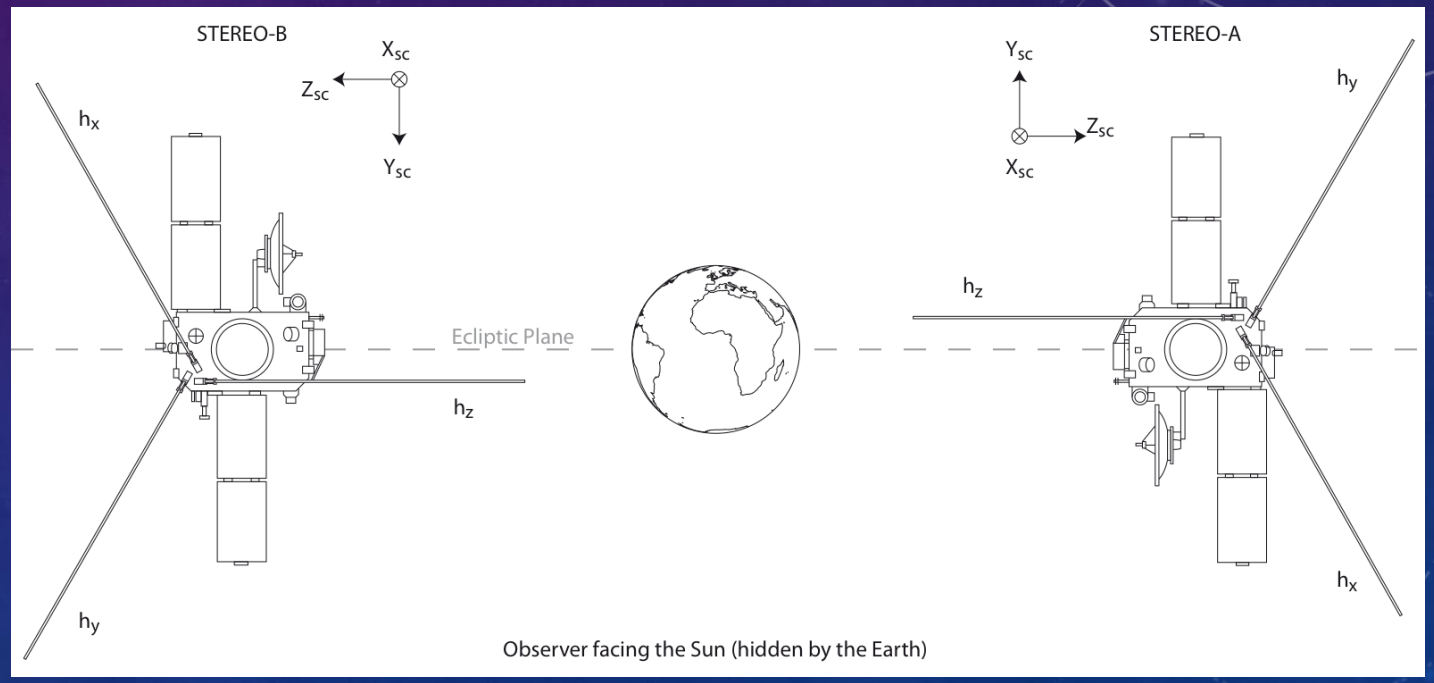
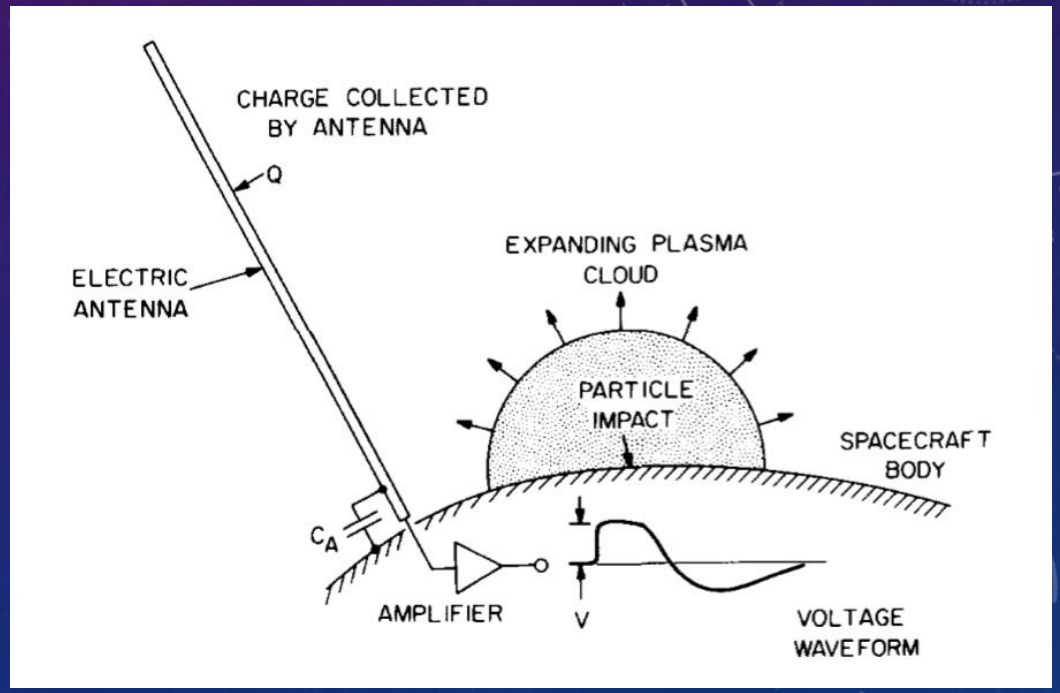


Image: http://typhon.obspm.fr/stereo/Stereo-antennas.png

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.

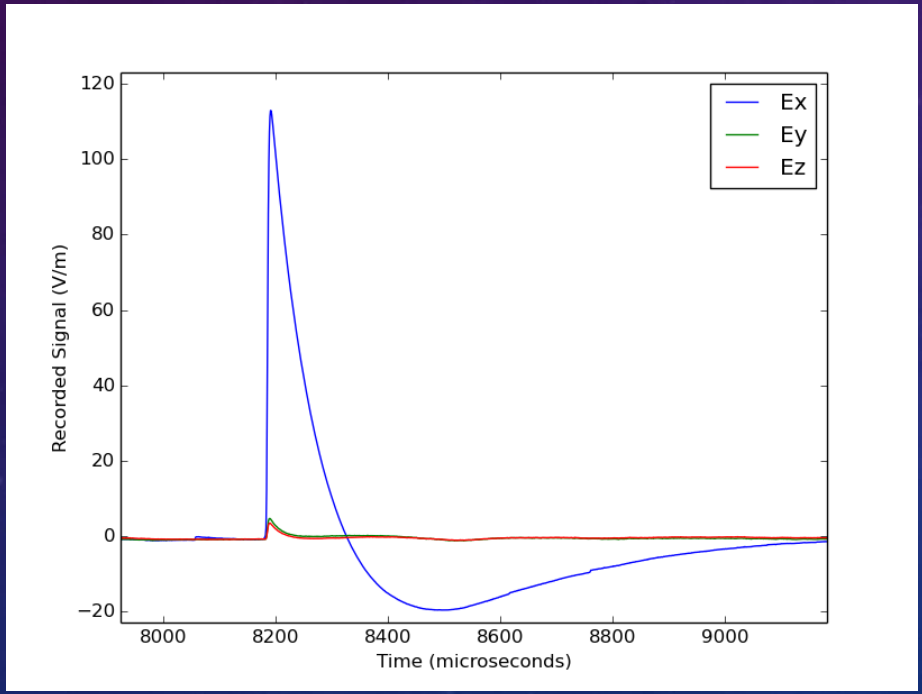


OUTLINE OF RESEARCH PROJECT

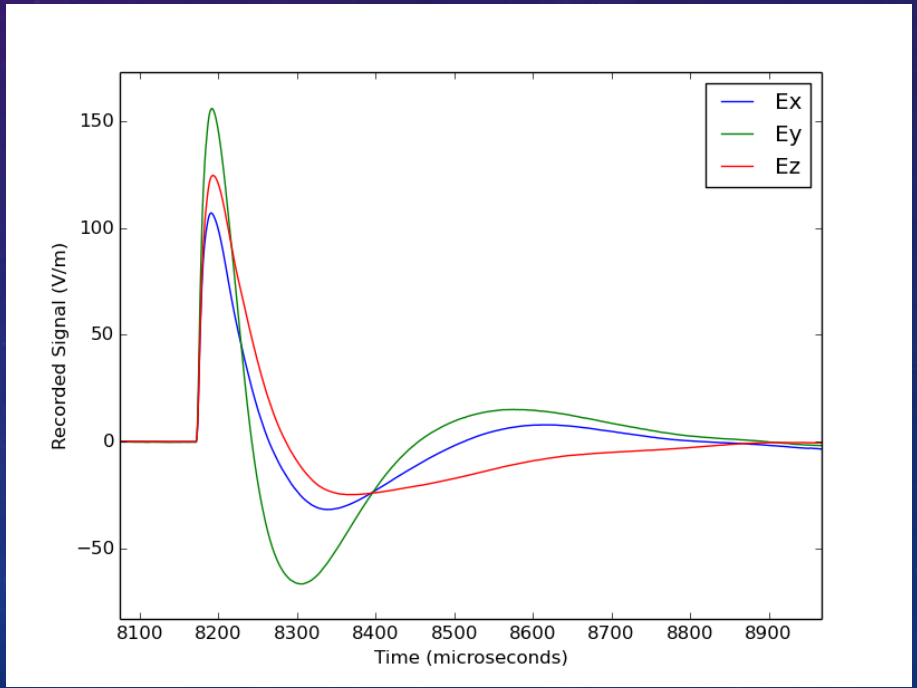
- There was a model proposed by Zaslavsky [2015] to explain dust signals.
- The charge collection by antennas was assumed to be significant.
- Run SIMION® simulations to test spacecraft/antenna collection.
- Investigate what types of signals occur and how frequently.
- Use findings to investigate the proposed model.

THE TYPICAL DUST SIGNALS [1]

Single Hit



Triple Hit



1. Meyer Vernet, 2009

FLOATING POINT PERTURBATION MODEL[2]

- 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:

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

- τ, C, and I_{dust} are different for spacecraft and antenna
- Spacecraft:

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

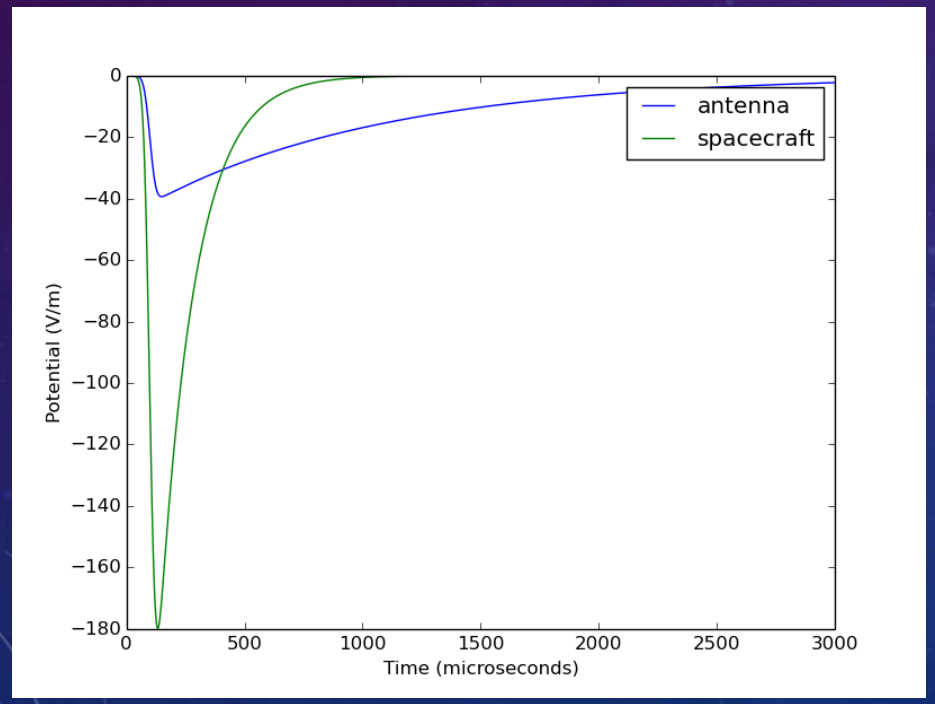
- Antenna:

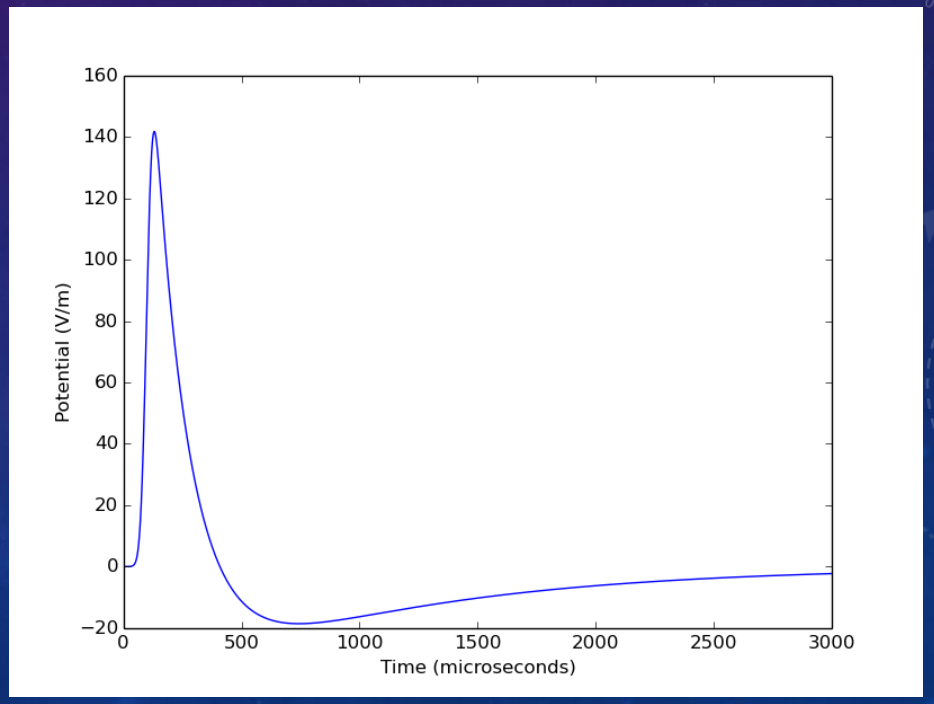
$$I_{dust} = p_{ant}\frac{Q}{\sqrt{2\pi\Delta t}}\ e^{-\frac{t^2}{2\Delta t^2}}$$

2. See Zaslavsky, 2015

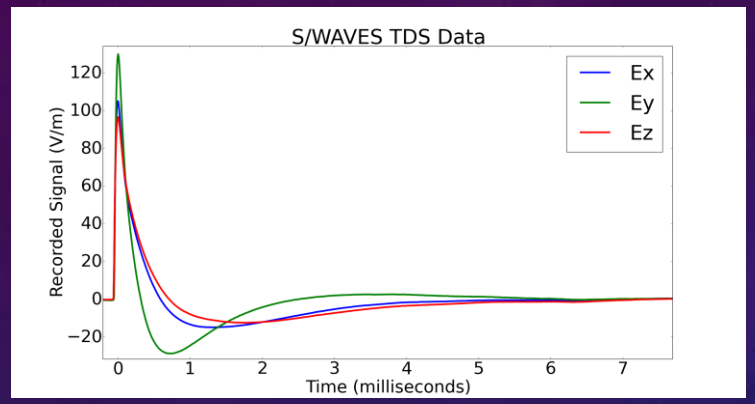
FPP MODEL CONT.

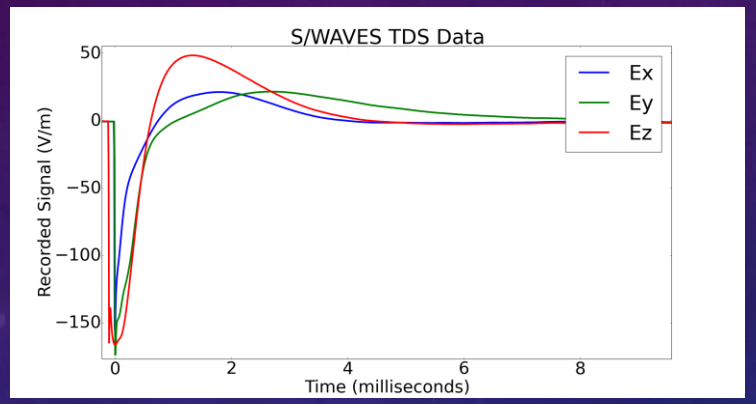
- If I_{dust} is a simple Gaussian we get the results ($\delta\phi_{meas} = \delta\phi_{ant} - \delta\phi_{sc}$):

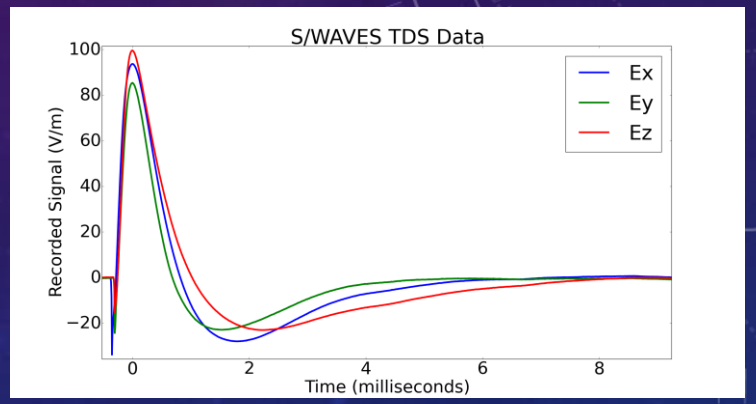


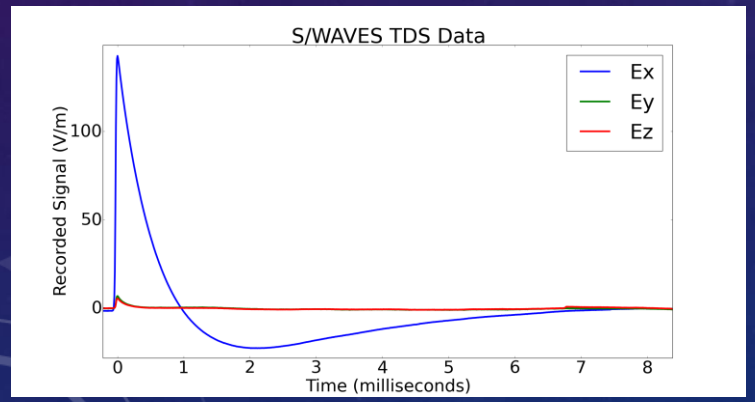


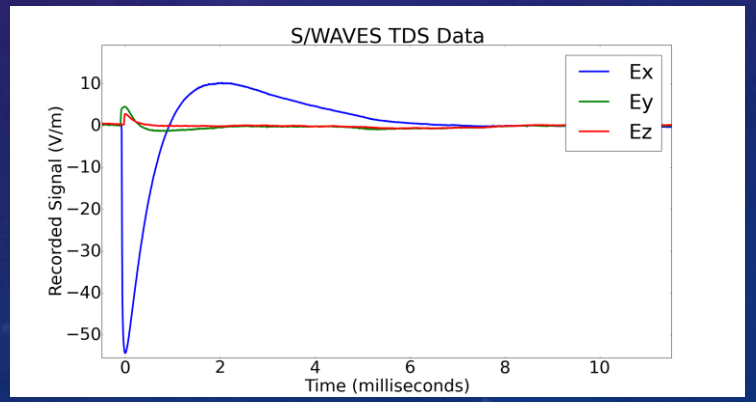
REVIEW OF 2008 STEREO A WAVES DATA

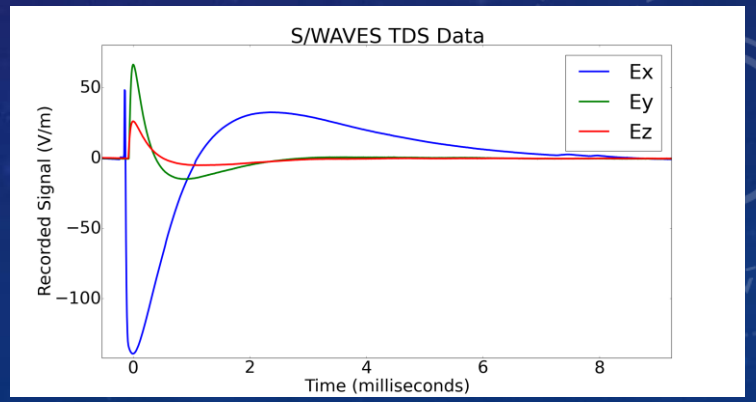






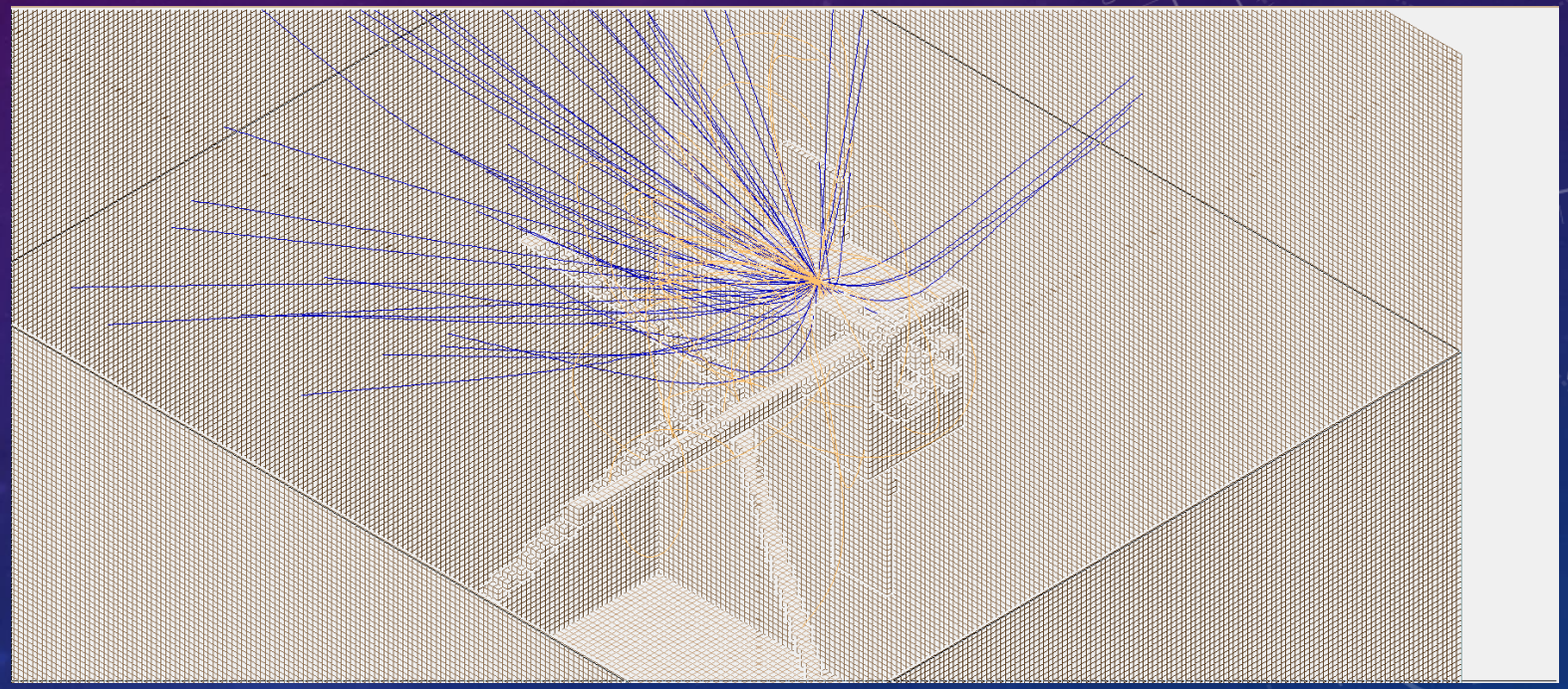






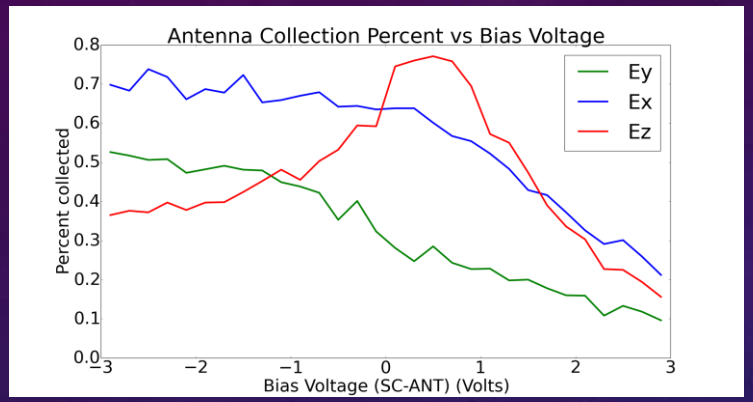
SIMION® SIMULATIONS

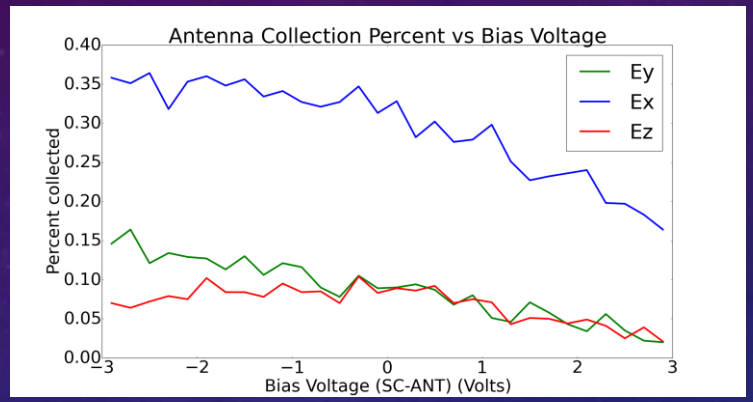
- Particles were initially in a Maxwell-Boltzmann distribution of energy
- 5ev electrons and 30eV protons (ions) [3]
- Placed on different spacecraft locations
- Spacecraft was set to 5V and antennas were varied
- Output was TOF for each particle that hit the spacecraft or antenna

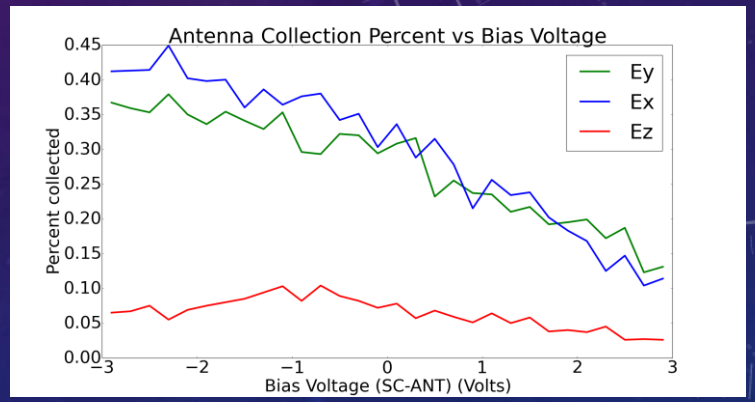


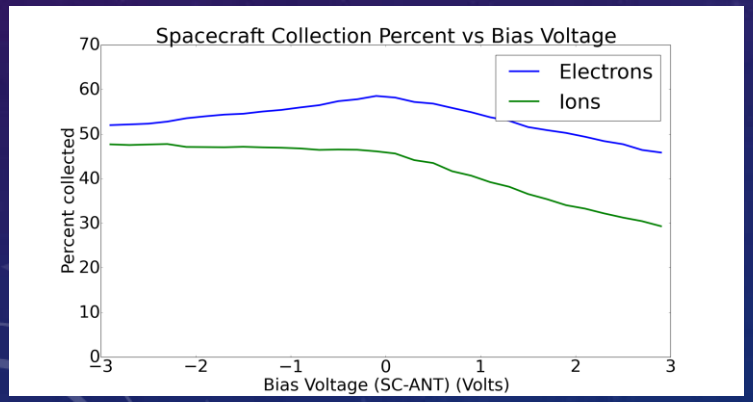
3. Collette, *et al.* 2015

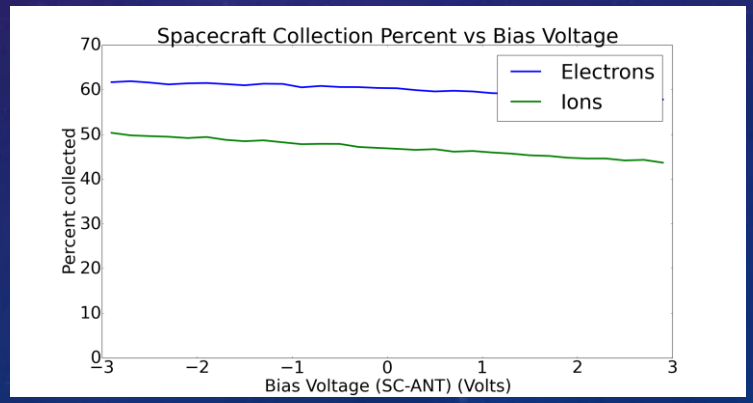
ESTIMATES OF P_{ANT} ON THE ORDER OF 0.01

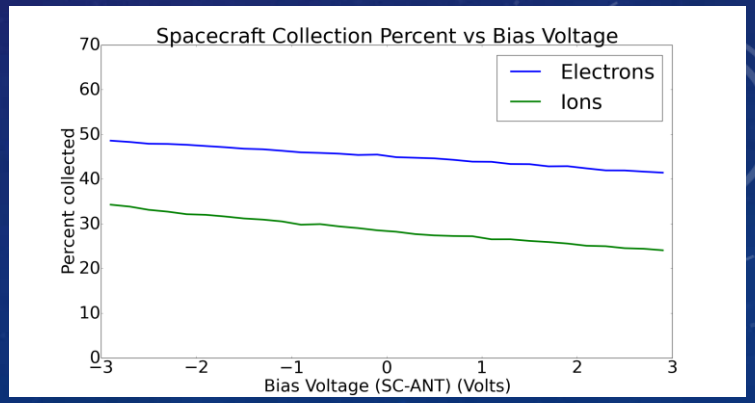






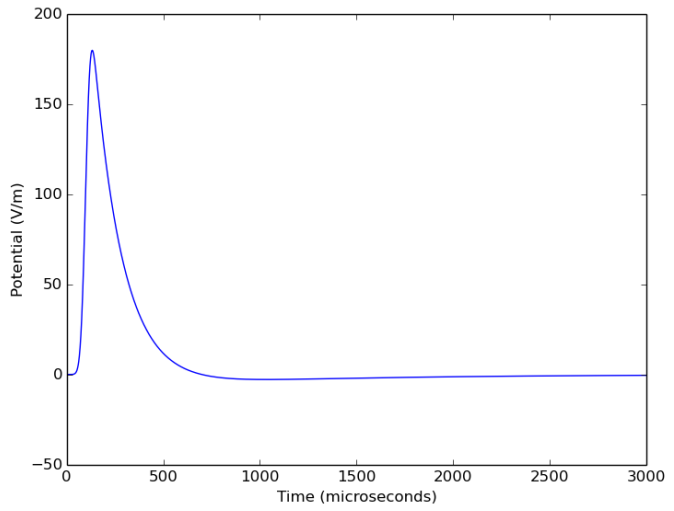


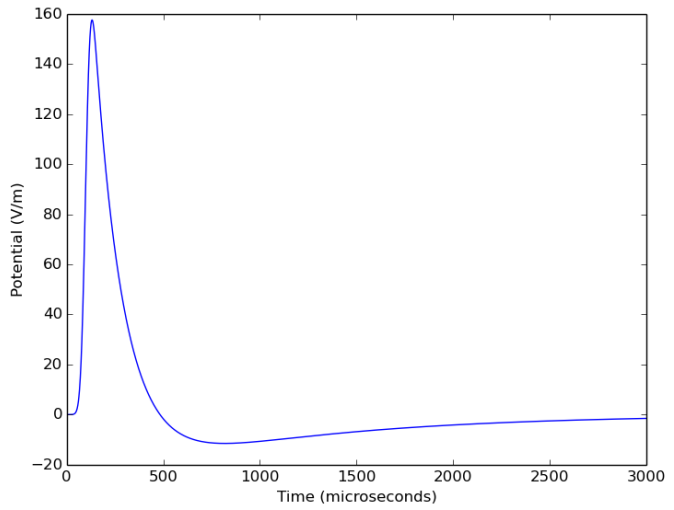




FPP MODEL USING p_{ant} FROM SIMULATIONS

- Top: $\mathrm{p_{ant}} = \frac{1}{100}$
- Bot: $\mathrm{p_{ant}} = \frac{1}{30}$
- 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

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- Thank you also to David Malaspina, Ted, and others who helped with the project in anyway.

- References:

Meyer-Vernet, N., et al. (2009), Dust detection by the wave instrument on STEREO: Nanoparticles picked up by the solar wind?, Sol. Phys., 256, 463–474, doi:10.1007/s11207-009-9349-2.

Zaslavsky, A. (2015), Floating potential perturbations due to micrometeoroid impacts: Theory and application to S/WAVES data, J. Geophys. Res. Space Physics, 120, 855–867, doi:10.1002/2014JA020635.

Collette, A., G. Meyer, D. Malaspina, and Z. Sternovsky (2015), Laboratory investigation of antenna signals from dust impacts on spacecraft, J. Geophys. Res. Space Physics, 120, doi:10.1002/2015JA021198.

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