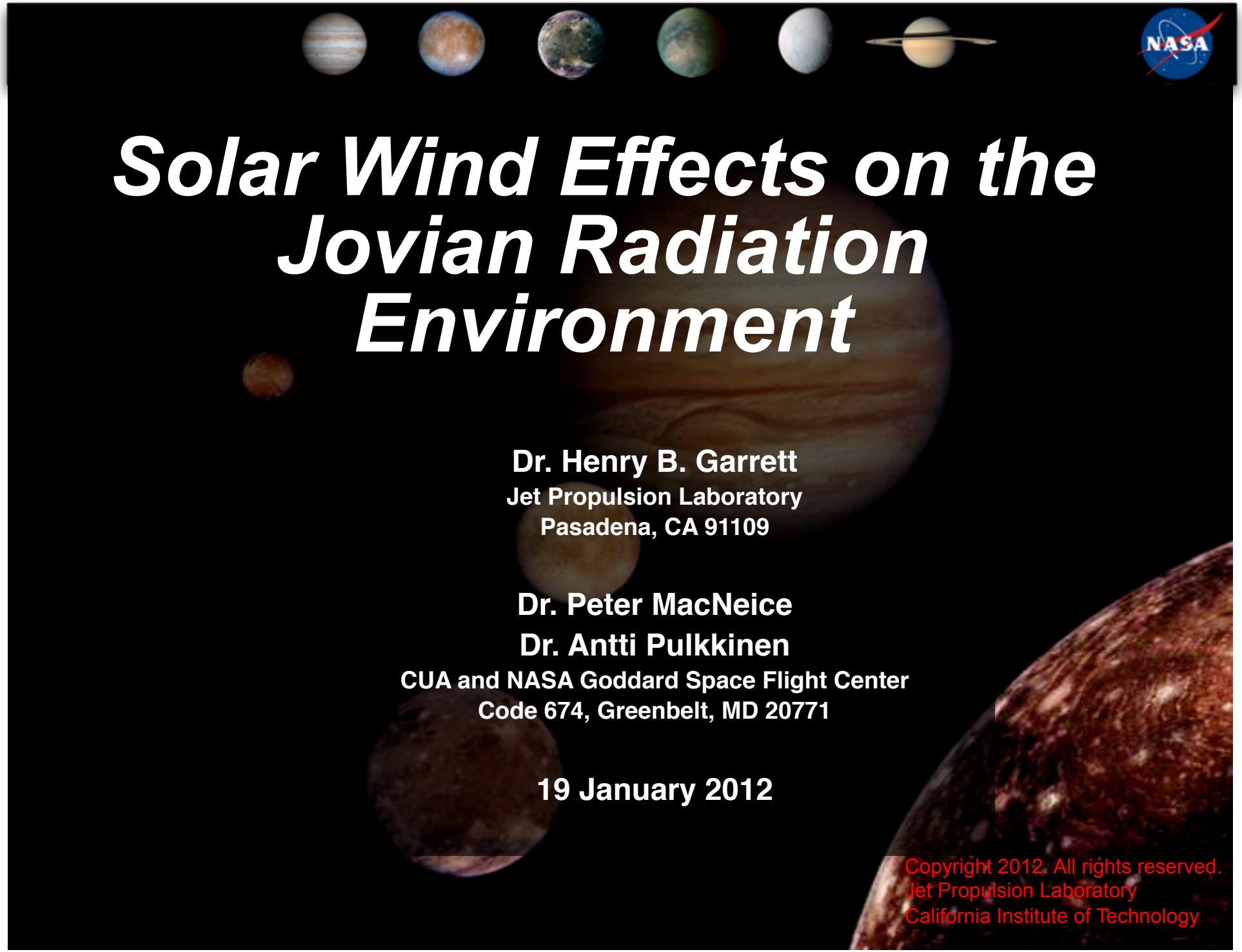

Solar Wind Effects on the Jovian Radiation Environment

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Dr. Antti Pulkkinen
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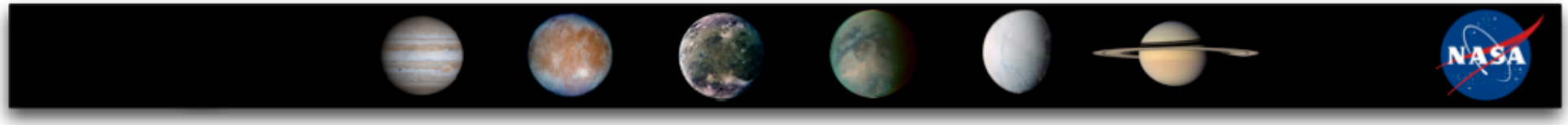
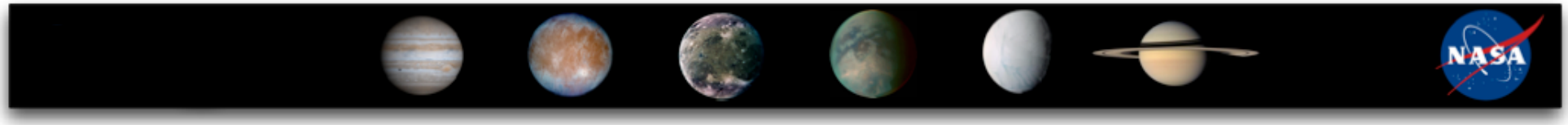
19 January 2012



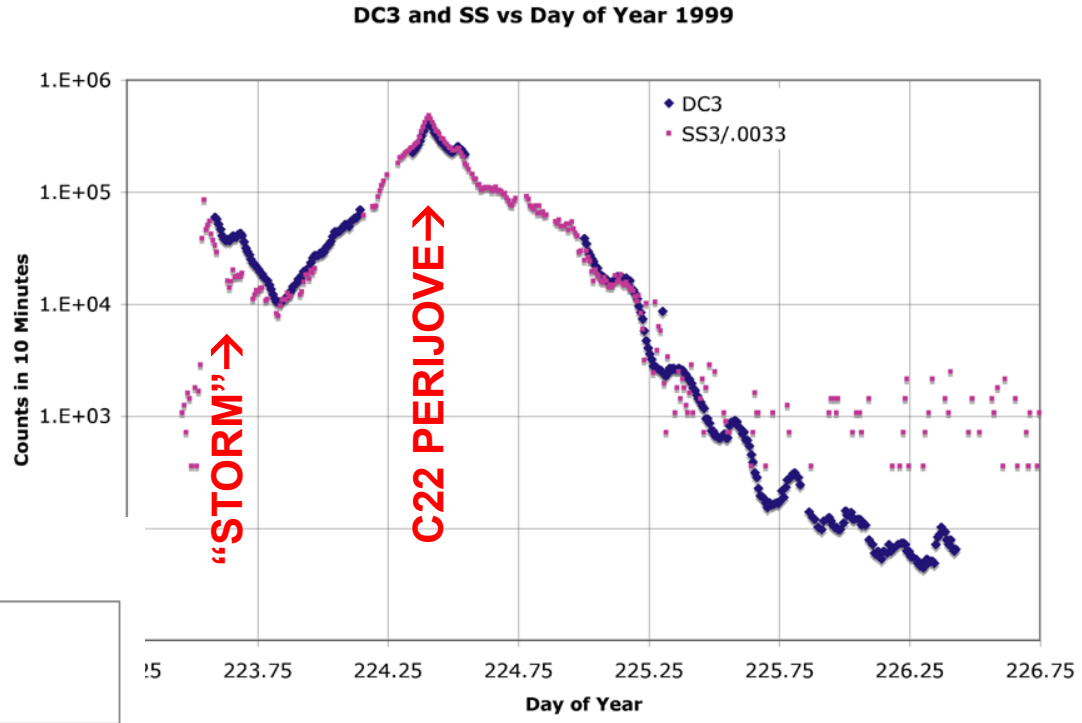
Solar Wind Effects on the Jovian Radiation Environment

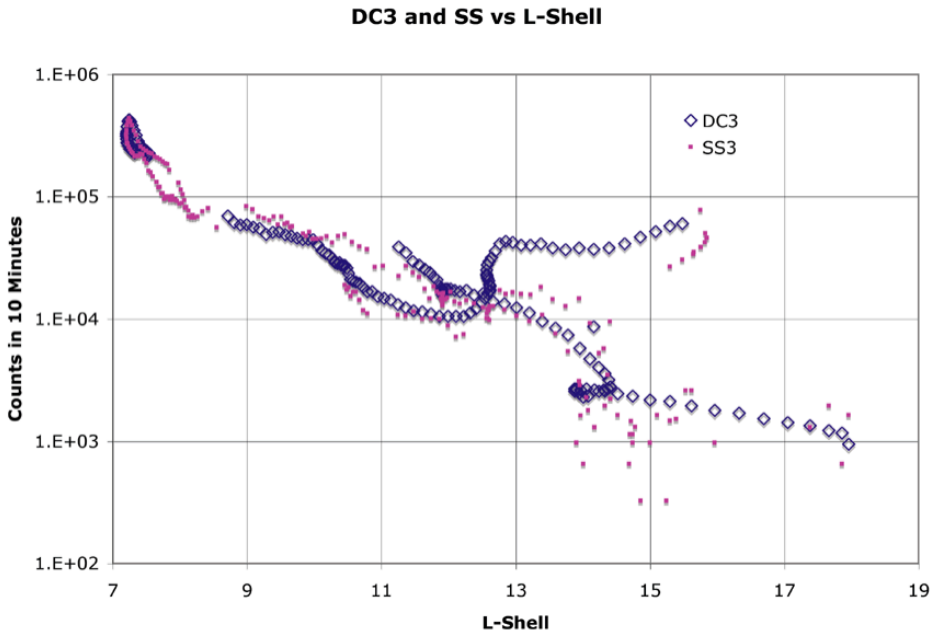
- ***Our Objective:***
  - Determine if space weather (solar wind) can affect the jovian electron environment (E>1 MeV) inside ~15 Rj
- ***Agenda:***
  - Present example of a “solar wind effect”
  - Describe the Galileo APL EPD electron high energy particle measurements
  - Fit the count rate measurements in terms of L-Shell for each orbit
  - Compare the fitted parameters with the solar wind as predicted at Jupiter by the CCMC (P. MacNeice)



Example of Jovian "Space Weather"

GALILEO EPD DC3 (E>11 MeV) AND STAR SCANNER MEASUREMENTS

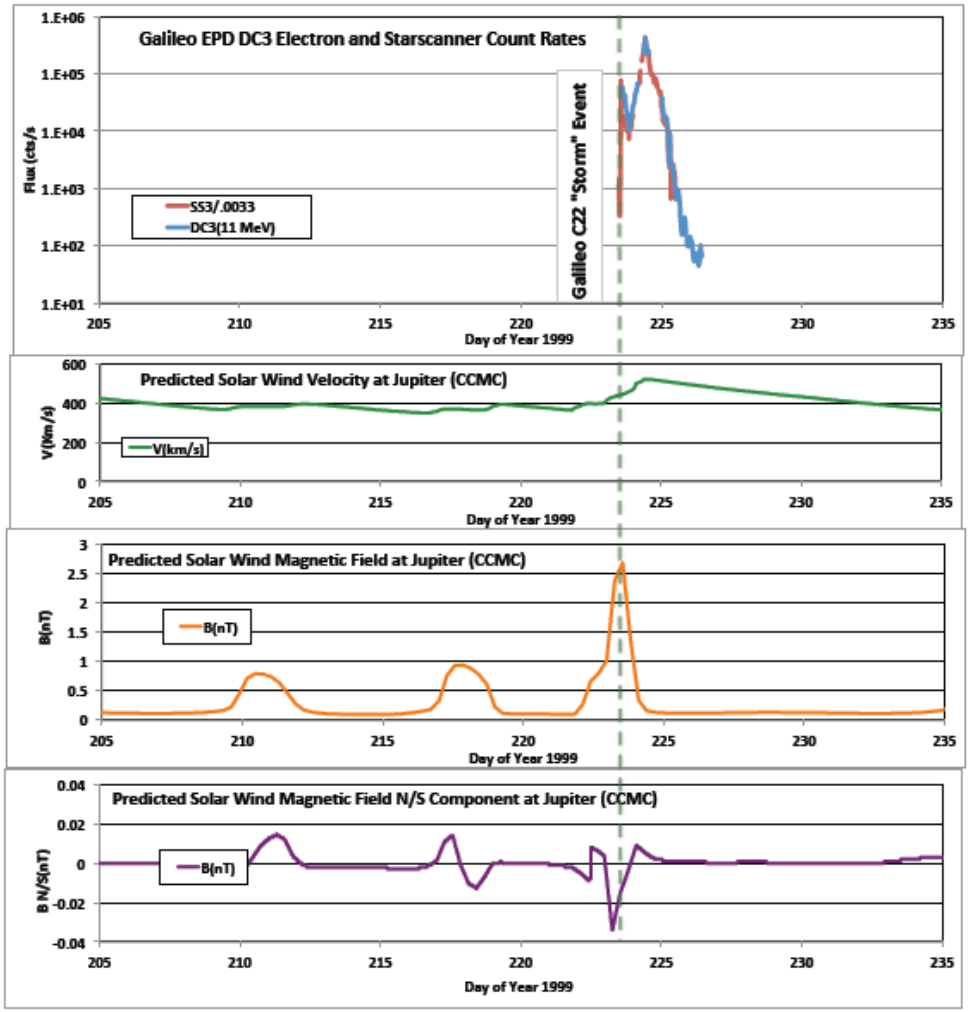


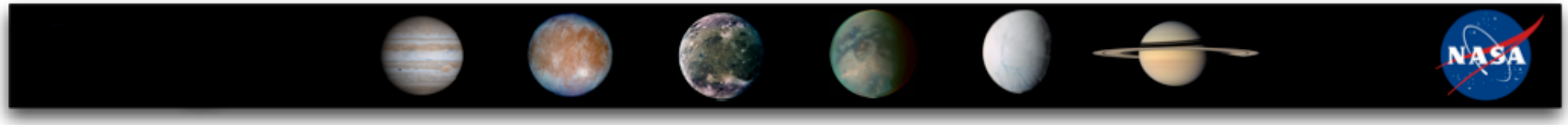


GALILEO ORBIT C22

First, could the Solar Wind actually affect the inner jovian magnetosphere?

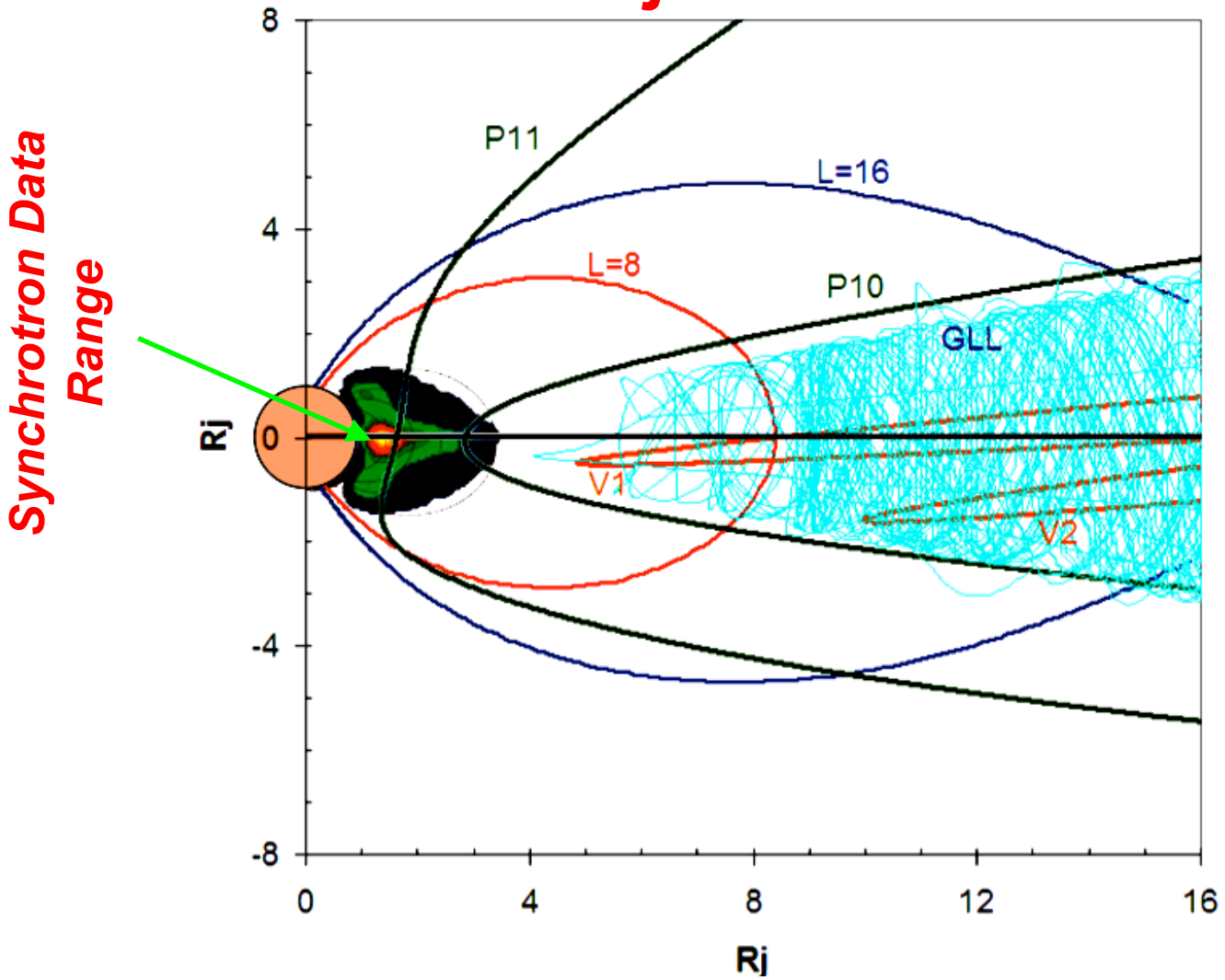
Maybe! CCMC estimates of solar wind during the Galileo orbit C22 storm imply a correlation:



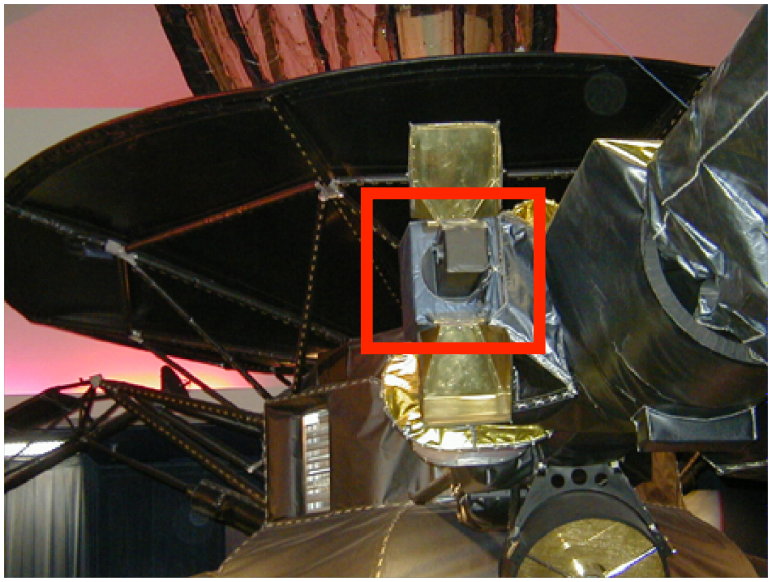


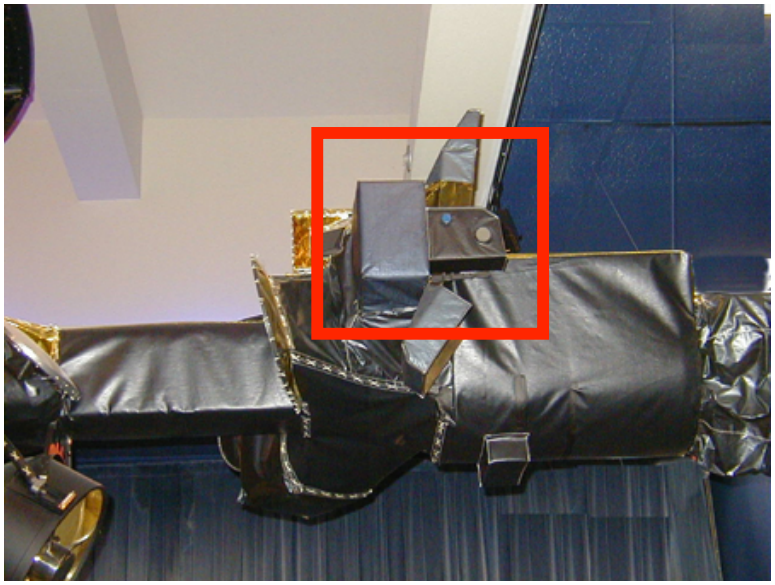
Galileo Mission and Radiation Measurements

The Data: Pioneer 10-11, Voyager 1-2, and Galileo Trajectories

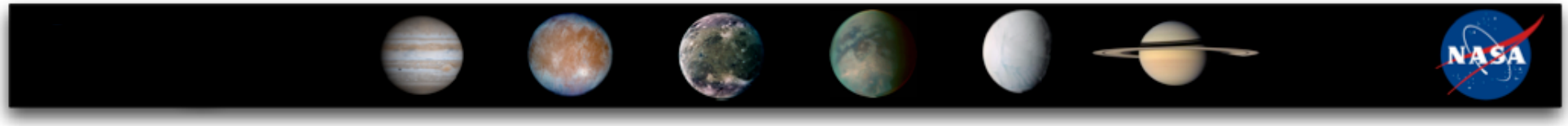


APL EPD (LEMMS) EXPERIMENT

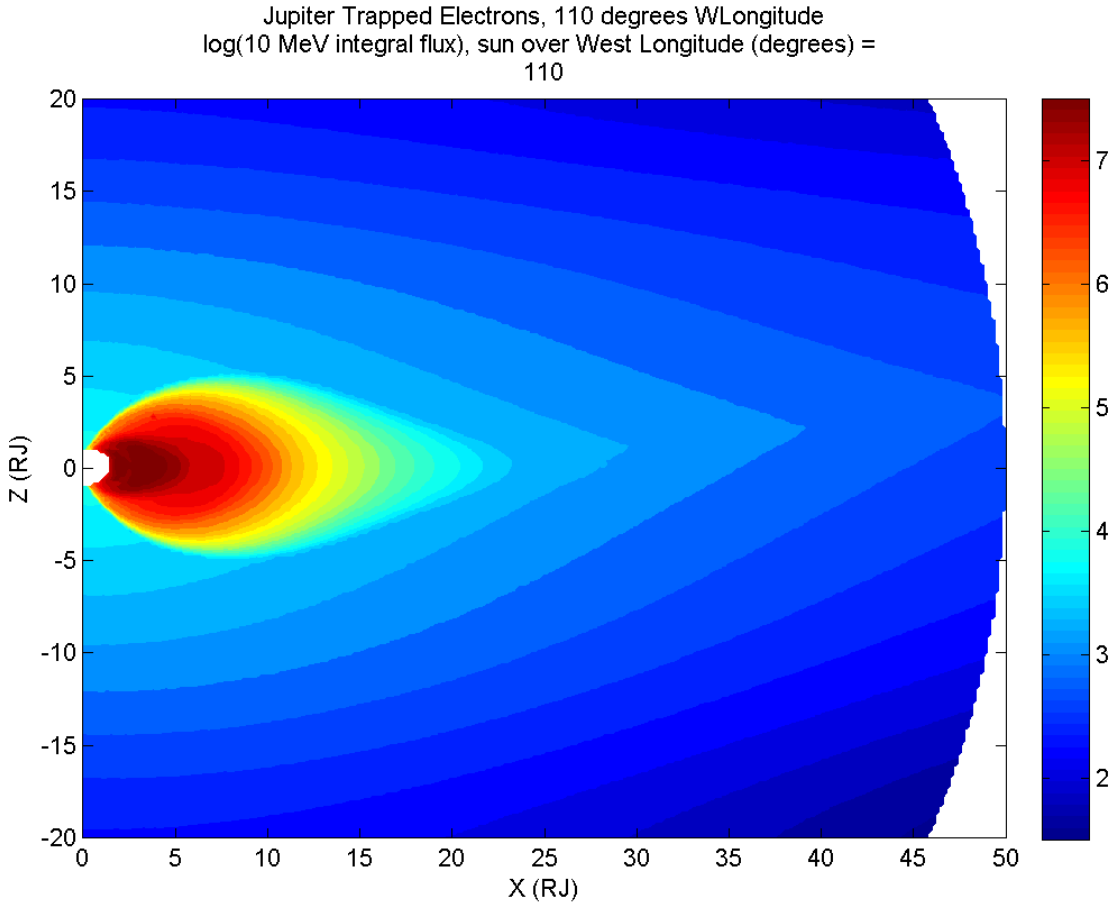




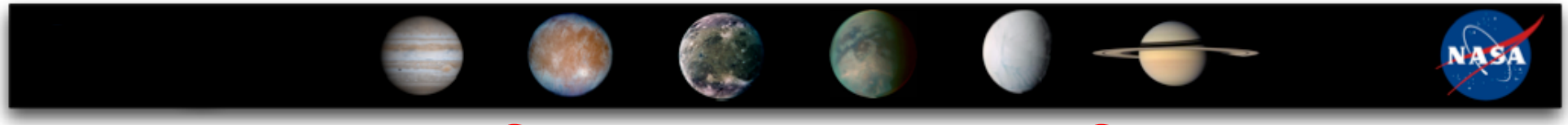
Electron Channel Name	Nominal Energy Range (MeV)
F1	0.174-0.304
F2	0.304-0.527
F3	0.527-0.83
B1	1.5 – 10.5
DC2	≥ 2.0
DC3	≥11.0



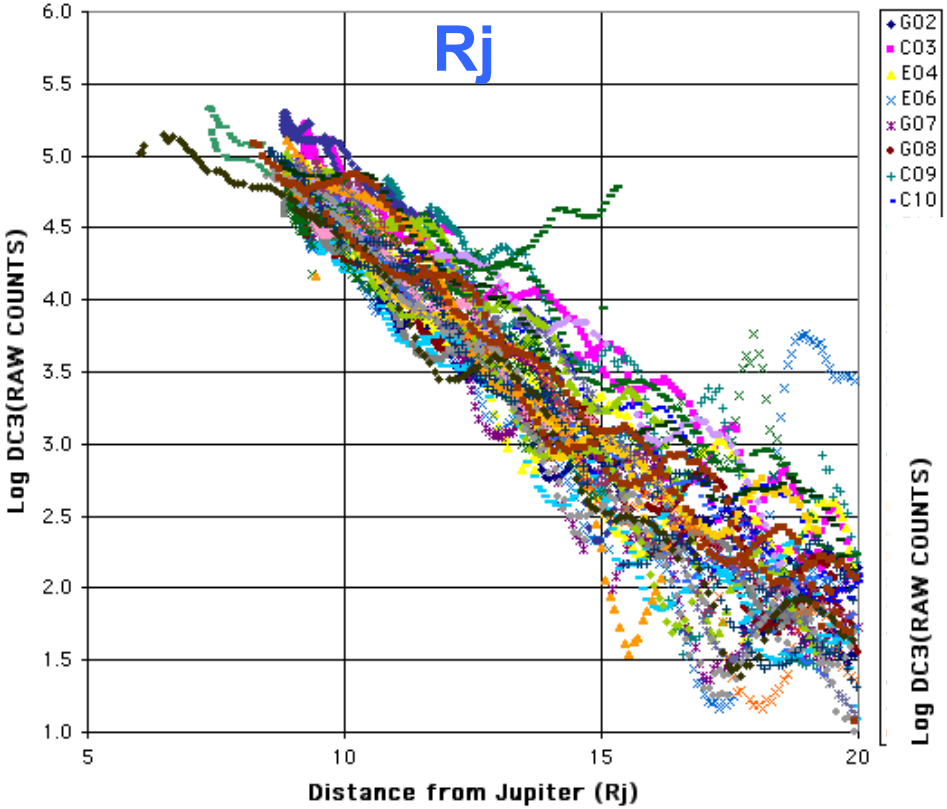
GIRE2 Jovian Trapped Radiation Model

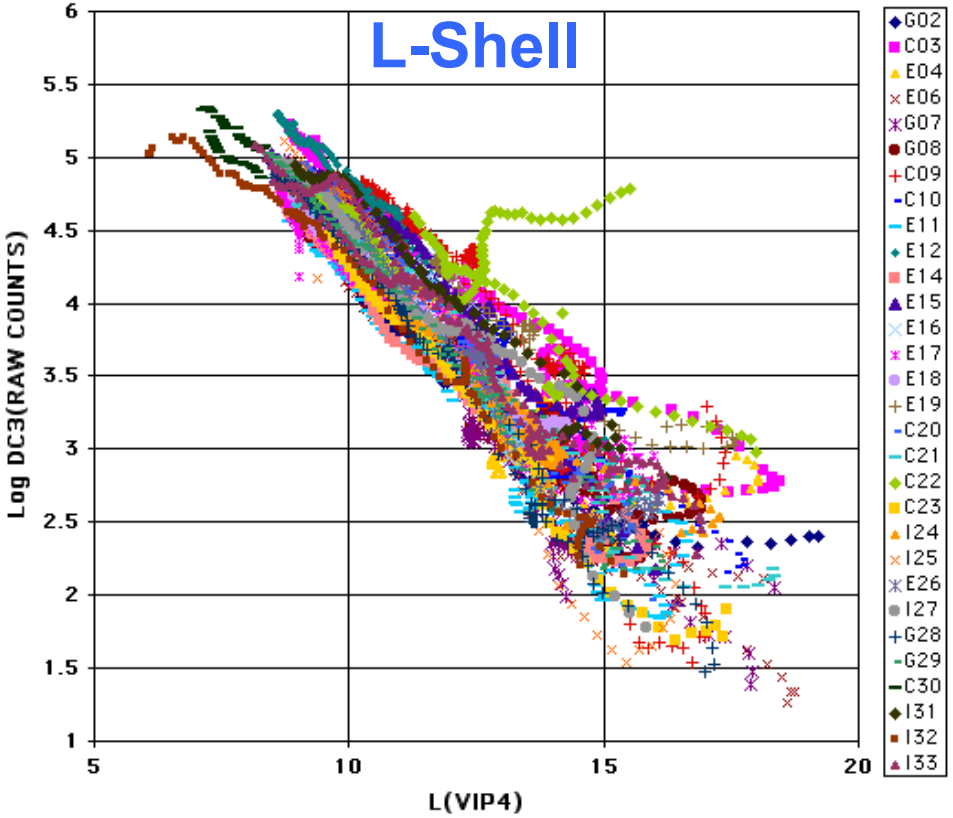


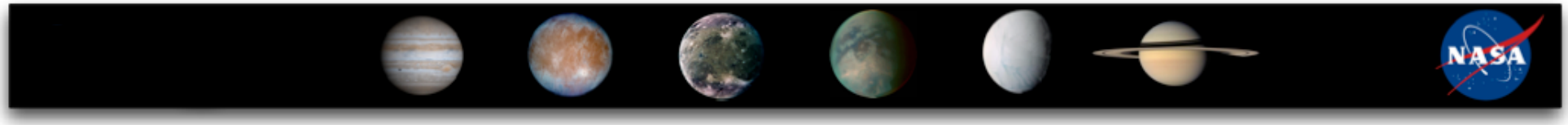
Contour plot of ≥10 MeV electron integral fluxes at Jupiter. Coordinate system used is jovi-centric. GIRE2 model based on the Divine/GIRE models. Meridian is for System III 110° W.



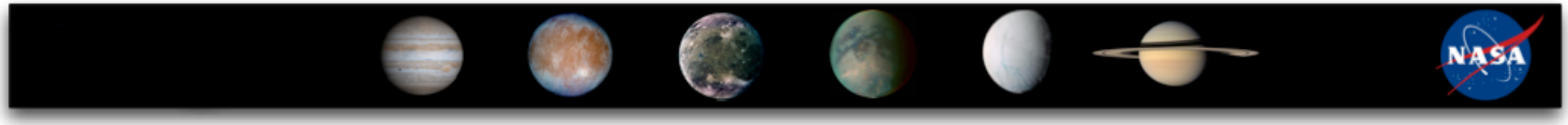
Plotting flux in terms of L-shell organizes the data:







Fitting the Galileo Electron Data inside 15 L



Assumptions

- ***The Galileo data imply that the high energy electron fluxes can be divided into two regions: The trapped environment inside ~15-20 L and the "plasma sheet" outside***
- ***The 35 Galileo orbits provided excellent in-situ measurements of the jovian equatorial radiation environment :***
  - Each orbit can be fit in terms of L-shell:

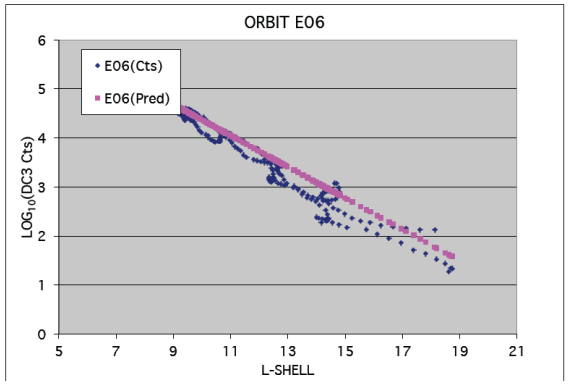
    $$Log_{10}(Electron\ Flux) \sim A + B * L\text{-}shell$$

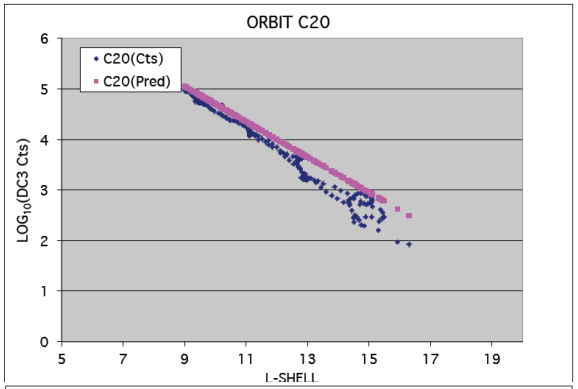
  - Only energies above ~1 MeV are considered
- ***The CCMC has provided estimates for the solar wind at Jupiter for the Galileo mission duration***
- ***May be able to correlate the A and B parameters with the solar wind characteristics***

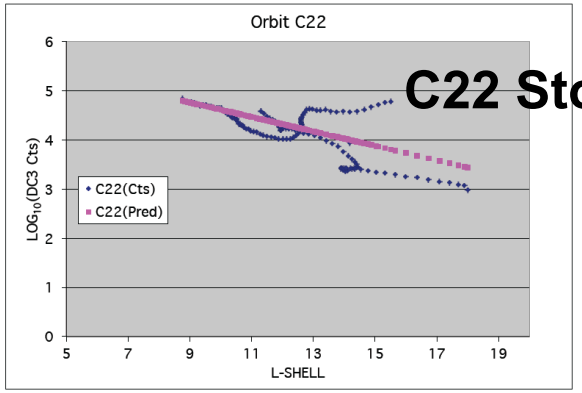
Fitting the Galileo Data (>11 MeV)

Regression Analysis Results by Orbit

Orb	Perijove	N#	Pnts	A	B
G02	1996.68378	3	222	7.00E+00	-2.75E-01
C03	1996.84805	4	203	7.50E+00	-2.62E-01
E04	1996.96578	5	219	7.74E+00	-3.25E-01
E06	1997.13826	7	232	7.55E+00	-3.19E-01
G07	1997.25599	8	242	8.03E+00	-3.50E-01
G08	1997.34908	9	236	7.15E+00	-2.79E-01
C09	1997.48597	10	239	8.58E+00	-3.49E-01
C10	1997.71321	11	243	7.01E+00	-2.50E-01
E11	1997.8501	12	185	7.71E+00	-3.39E-01
E12	1997.95688	13	162	8.56E+00	-3.66E-01
E14	1998.23888	15	206	7.43E+00	-3.02E-01
E15	1998.4141	16	221	7.30E+00	-2.63E-01
E16	1998.55099	17	74	8.50E+00	-3.74E-01
E17	1998.73443	18	219	6.86E+00	-2.46E-01
E18	1998.89049	19	85	7.40E+00	-2.94E-01
E19	1999.08487	20	64	6.74E+00	-2.04E-01
C20	1999.33402	21	202	8.20E+00	-3.50E-01
C21	1999.49829	22	158	7.66E+00	-3.13E-01
C22	1999.61054	23	135	6.09E+00	-1.47E-01
C23	1999.70089	24	71	7.72E+00	-3.33E-01
I24	1999.77481	25	89	7.23E+00	-2.86E-01
I25	1999.8898	26	70	9.26E+00	-4.46E-01
E26	2000.02669	27	67	7.93E+00	-3.34E-01
I27	2000.16085	28	72	7.73E+00	-3.09E-01
G28	2000.38535	29	128	8.11E+00	-3.64E-01
G29	2000.99316	30	145	7.64E+00	-3.14E-01

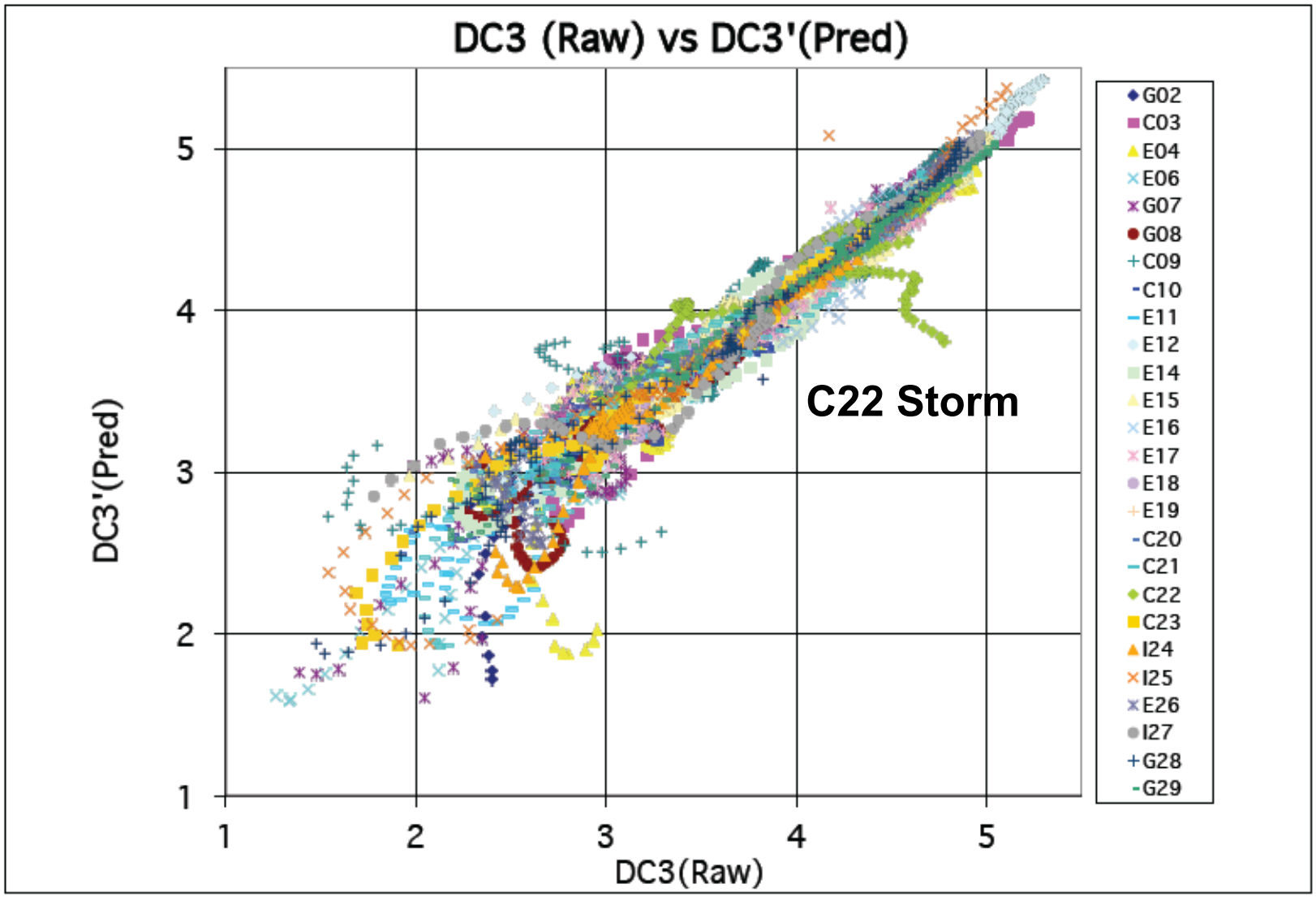




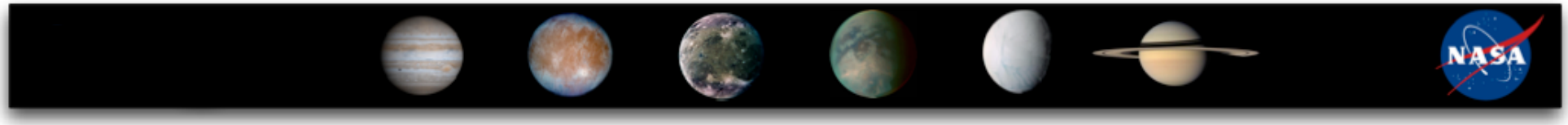


C22 Storm

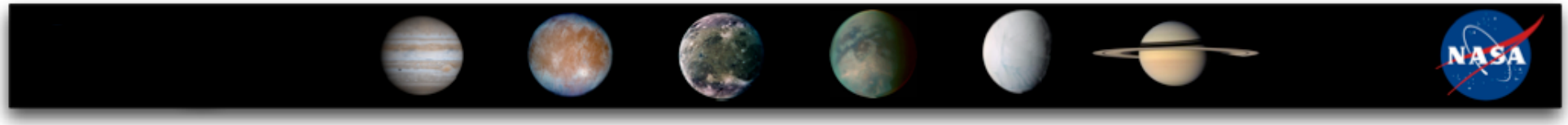
Galileo Count Rate Data (>11 MeV) vs A-B Fit



Regression Predictions by Orbit



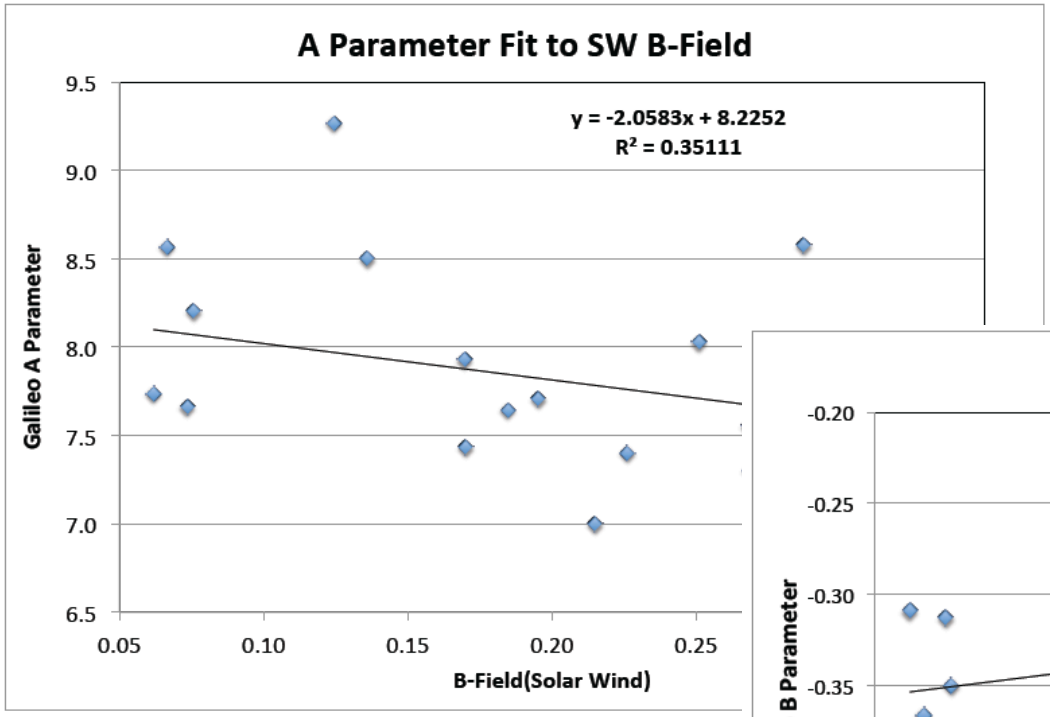
Galileo A-B Correlations with CCMC Solar Wind Predictions

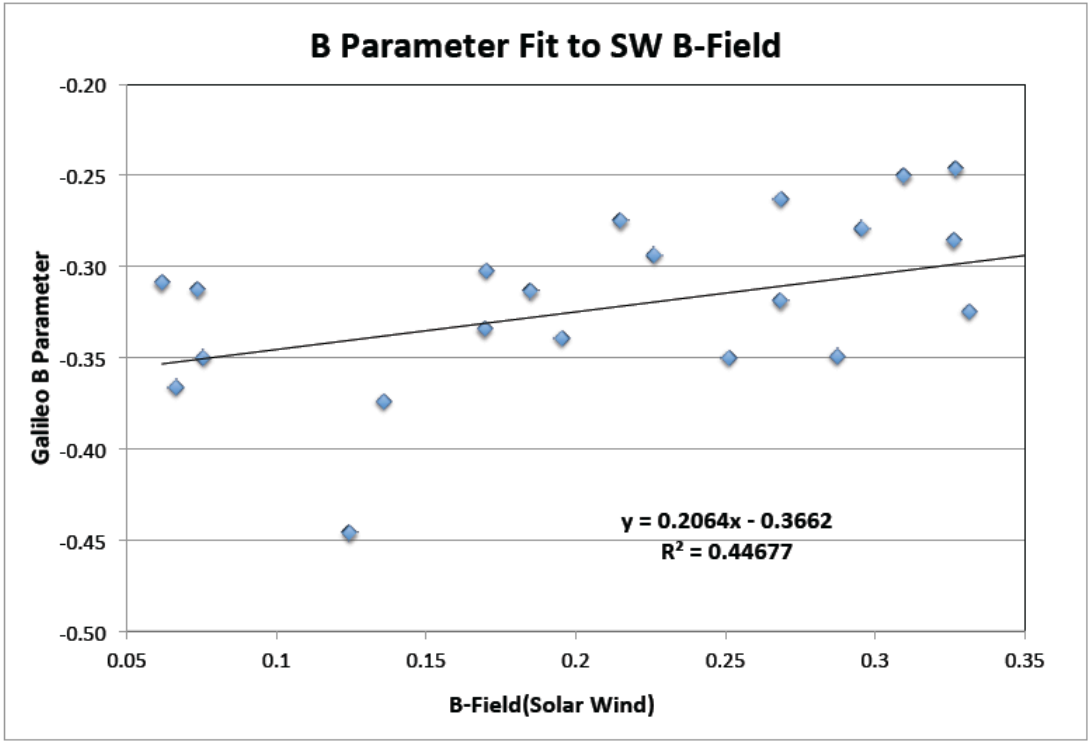


CCMC Solar Wind Predictions

- The CCMC (Dr. Peter MacNeice, NASA GSFC Code 674) provided solar wind predictions (B, V, T, P, rho, etc.) at Jupiter for the Galileo mission (1995-2003).
- The model used by the CCMC was WSA-ENLIL. The developers of the solar wind model are Nick Arge and Dusan Odstrcil.
- Caveat: the WSA-ENLIL results are only for the background solar wind. Transients such as CMEs were not included in the simulations.

CCMC B-Field Correlation with A and B

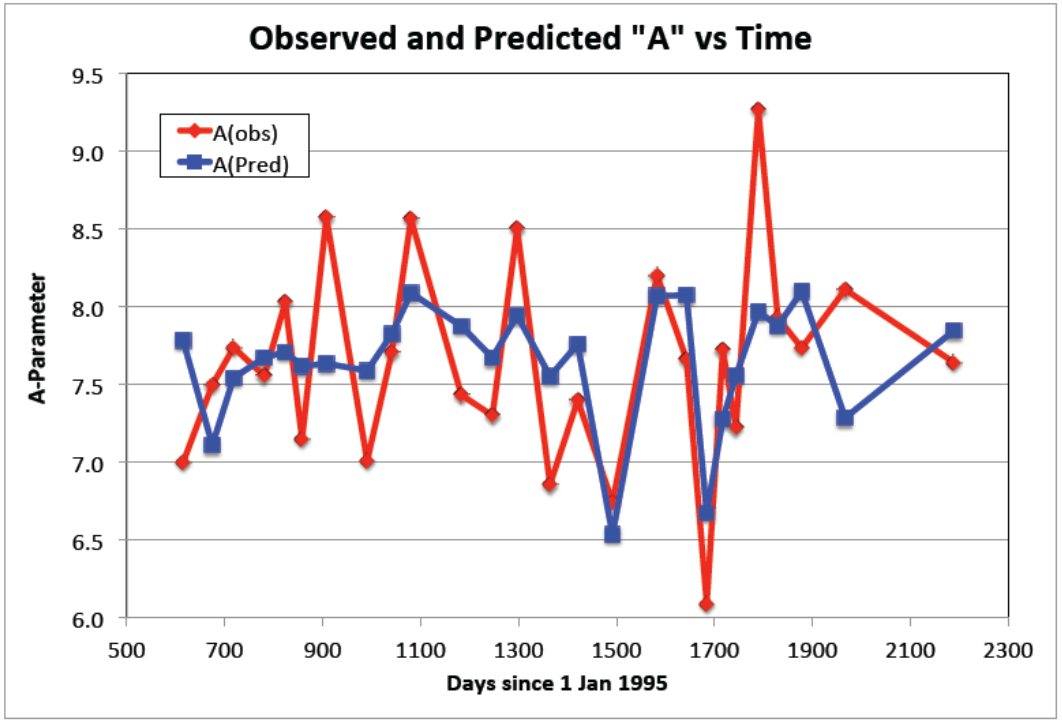


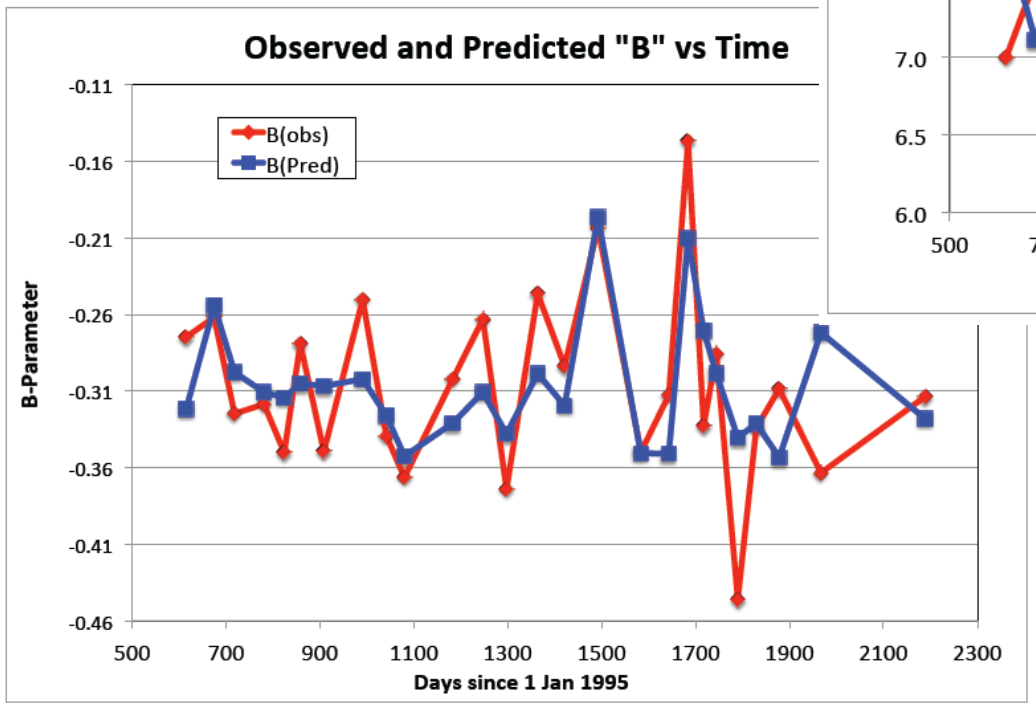


Linear Regressions for A/B on B-Field

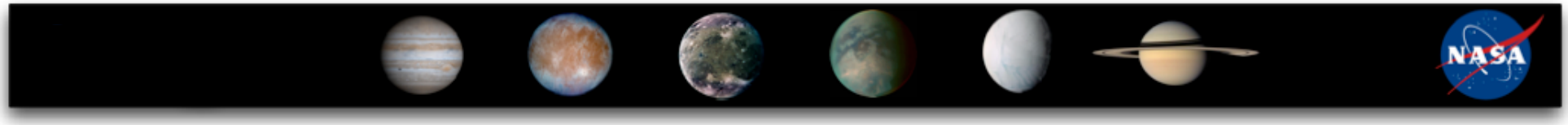
Observed A and B Cts and SW Predictions vs Time

"Predicted" values based on ~4 day SW averages centered on perijove—Correlations 4 days before or after gave ~0 R^2.

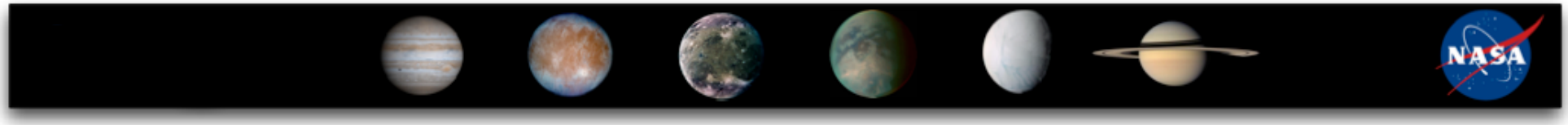




Results: Apparently B-field in Solar Wind may have something to do with variations in the inner jovian electron radiation belts…



CONCLUSIONS

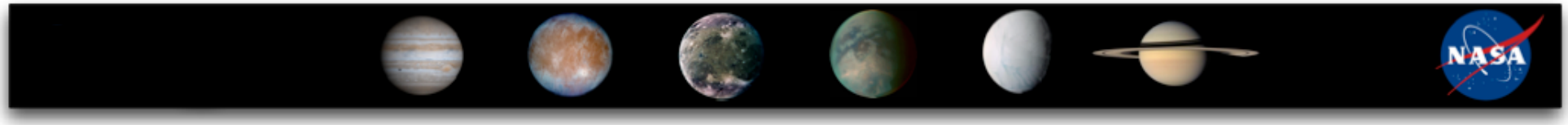


Solar Wind Effects on the Jovian Radiation Environment

- ***Findings:***
  - The variation of the inner electron radiation belt in L-shell at Jupiter can be fit by:

    $$Log_{10}(Electron\ Flux) \sim A + B * L\text{-}shell$$

  - The solar wind can be estimated at Jupiter using the WSA-ENLIL solar wind model
  - The parameters A and B can be fit in terms of the predicted solar wind magnetic field (other parameters TBD)
  - The inner electron radiation belts at Jupiter may be controlled at least in part by the solar wind…



Solar Wind Effects on the Jovian Radiation Environment

- ***Why do we care?***
  - The high energy electron environment (E>1 MeV) provides a major radiation risk for missions to Europa and Io
  - Knowing the radiation levels at Jupiter can allow both improvements in design (better shielding design up front) and, in real time, the possibility of changes in mission operations to maximize data return or to limit radiation effects on sensitive systems*
  - Being able to estimate interplanetary “space weather” and its effects on the jovian radiation belts based on ~1 AU measurements could give up to 2 weeks warning ahead of time at 5 AU!

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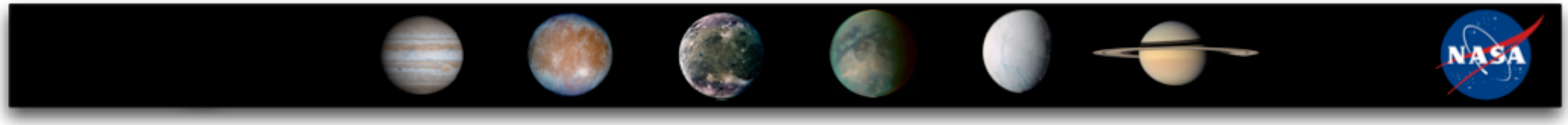
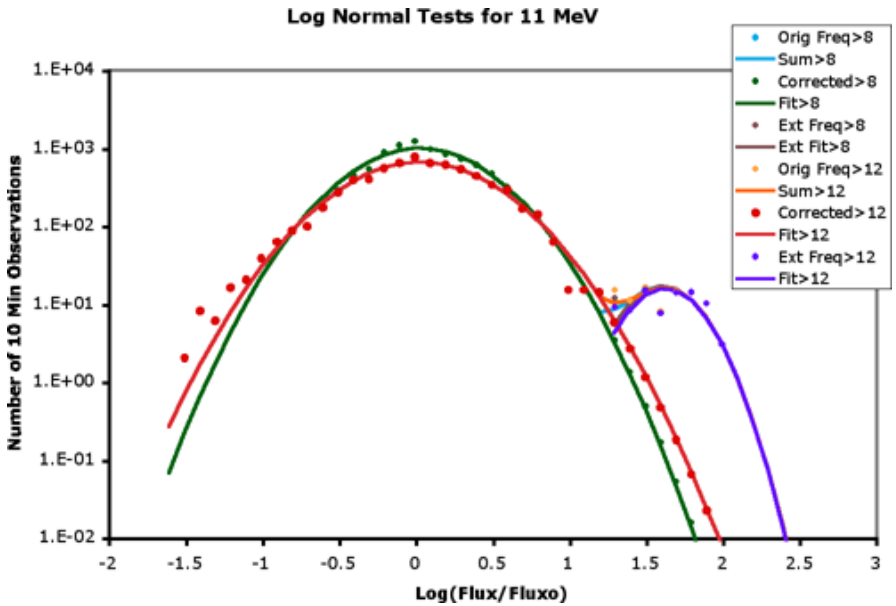
*(e.g., turn something off or move it to a more shielded configuration)



BACKUP SLIDES

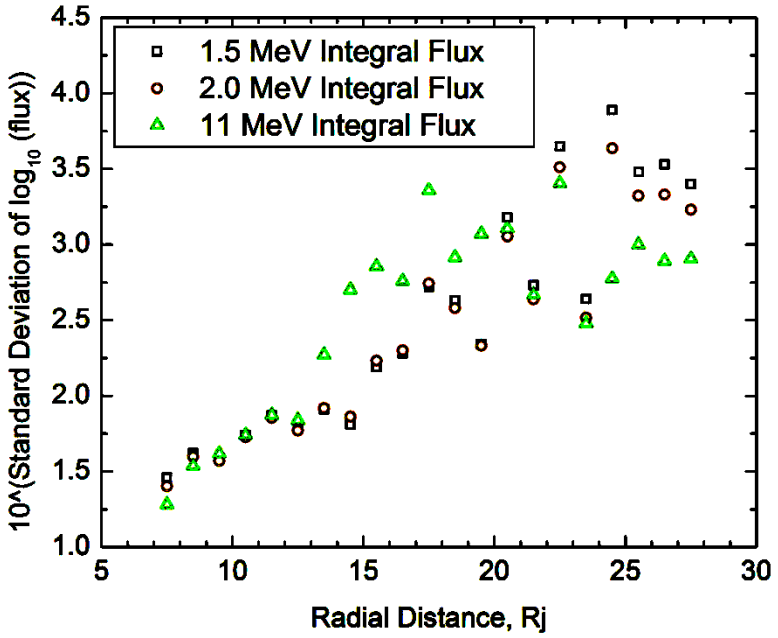
Statistical Variations of Jovian Particle Fluxes

Examples of log-normal fits to the Galileo electron fluxes



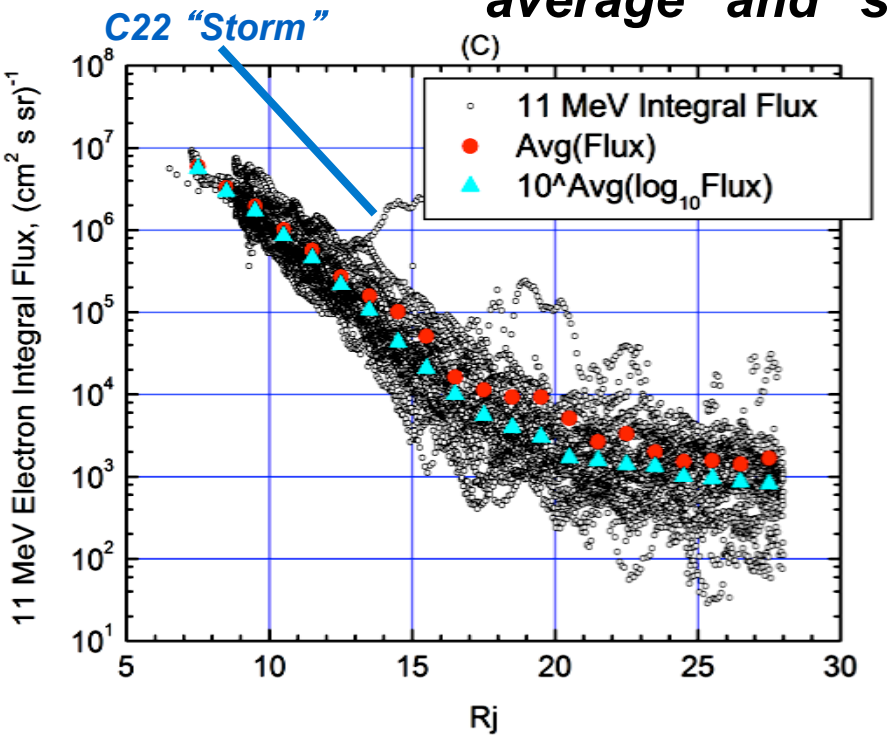
Log-Normal fits to 11 MeV Electrons

Standard Deviations of Electron Fluxes versus Rj



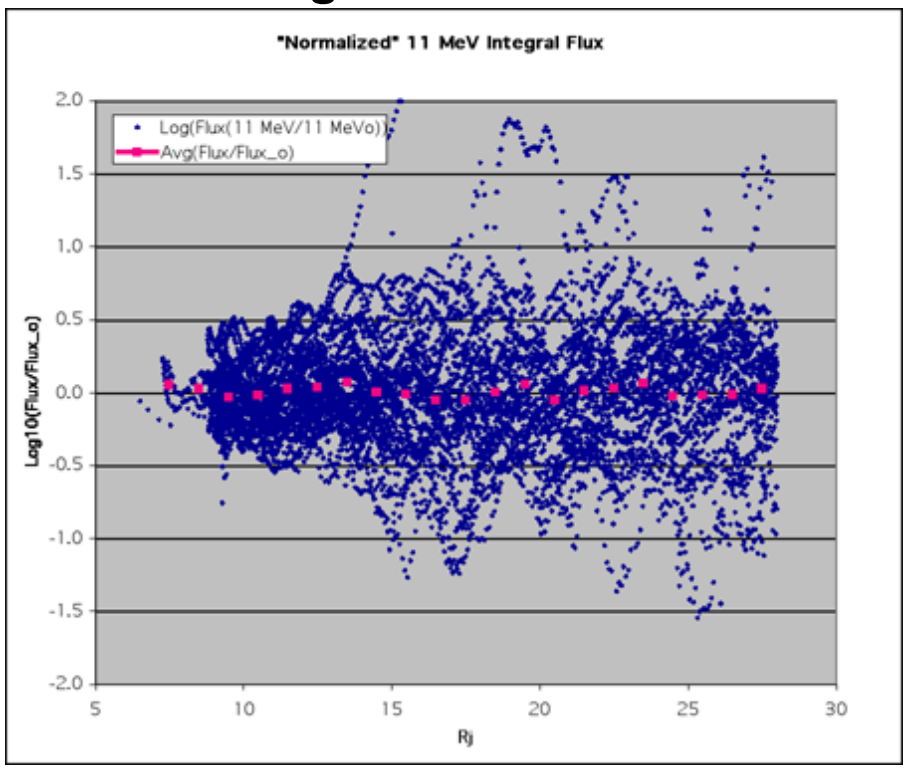
Trapped Electron Radial Variations

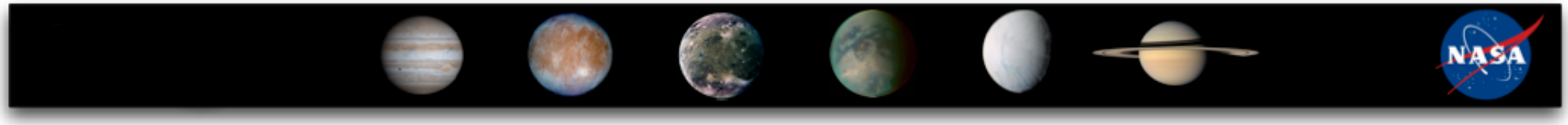
Variations in EPD Fluxes with distance from Jupiter showing "average" and "storm" variations



Galileo EPD 11 MeV particle fluxes vs radial distance

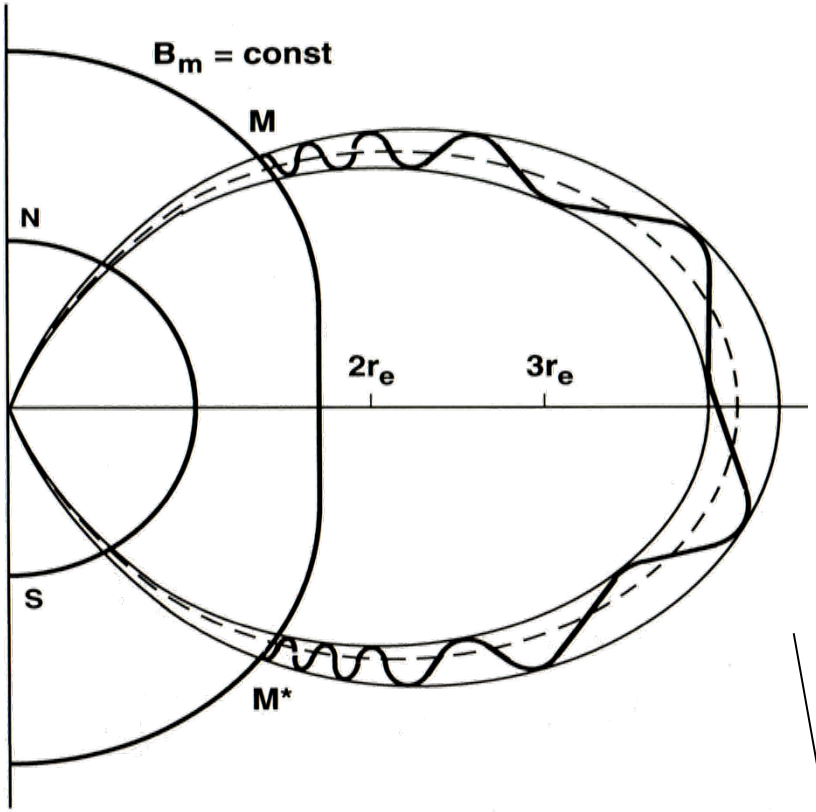
Logarithms Of Ratio Of EPD To Average Flux Vs L-shell

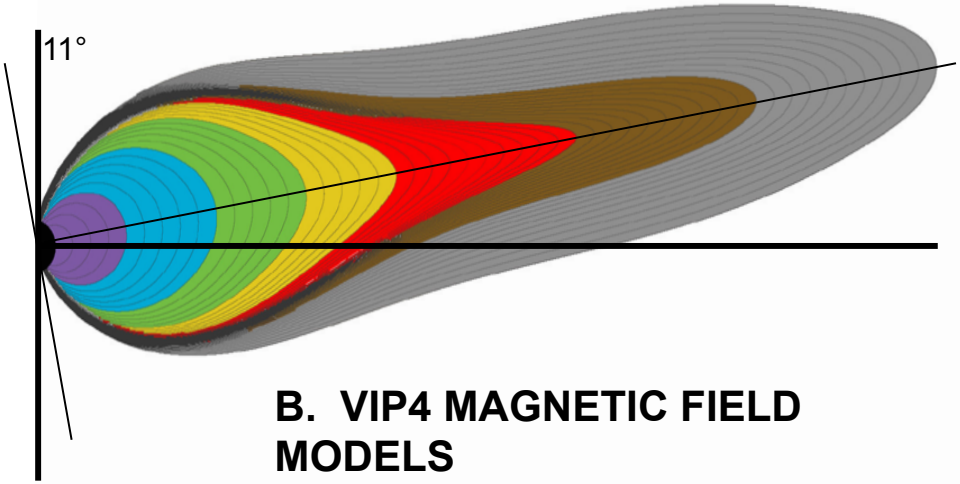




Radiation Particle Trapping at Jupiter

A. PARTICLE TRAPPING





B. VIP4 MAGNETIC FIELD MODELS