

Review of Jupiter Trapped Radiation Model

Juno Radiation Working Group,
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Topics to be covered in the Discussion:

- 1) “Double counting” and potential errors in the model.
- 2) Assessment of expected radiation dose over sample JUNO orbits (relative contribution from high and low L).
- 3) When during Jupiter orbit operations we are likely to have radiation events.
- 4) Discussion of B field model used.
- 5) Summary of the data sources used to construct the current model and assessment of recent updates.
- 6) Comparison of model with available data (Pioneer, Voyager, Galileo etc).

Items 1, 2, 3 and 4 will be addressed individually.

Items 5 and 6 will be covered as part of the model descriptions.



Prologue:

In the course of several iterations of Juno proposal studies, different variations and implementations of a Jupiter radiation model were used.

Near-Term Plans:

If the RWG agrees, implement radiation model of Divine, modified to include sychrotron and GIRE model adjustments. Omit all pitch angle clipping, and omit $L > 16 R_j$ radiation. Use magnetic field model “VIP4 +CurrentSheet”.

Implement this model in documented codes and a well-defined process for producing a Juno radiation estimate.



1a) “Double Counting”.

An oversight we made in some model runs came to be known as “double counting”. The radiation model provides flux at a requested B,L position in the magnetosphere. The physical positions of the spacecraft along the Juno trajectory have to first be converted to B,L coordinates before the radiation model can be used to produce a flux spectrum for each position.

The VIP4+CurrentSheet field model was used to obtain B&L. Where the VIP4+cs model provided an L value greater than 16R_j, the B&L values from the OTD were used.

Because, most latitudes, a given L shell is smaller in the VIP4+cs model than it is in the OTD model, the spacecraft would seem to go through the OTD version of the outer edge of the belts, and then pass through that same region as determined by the VIP4+cs. (See graph on next slide).

Now we are using only one mag field model, the VIP4+CS, to determine B&L positions.

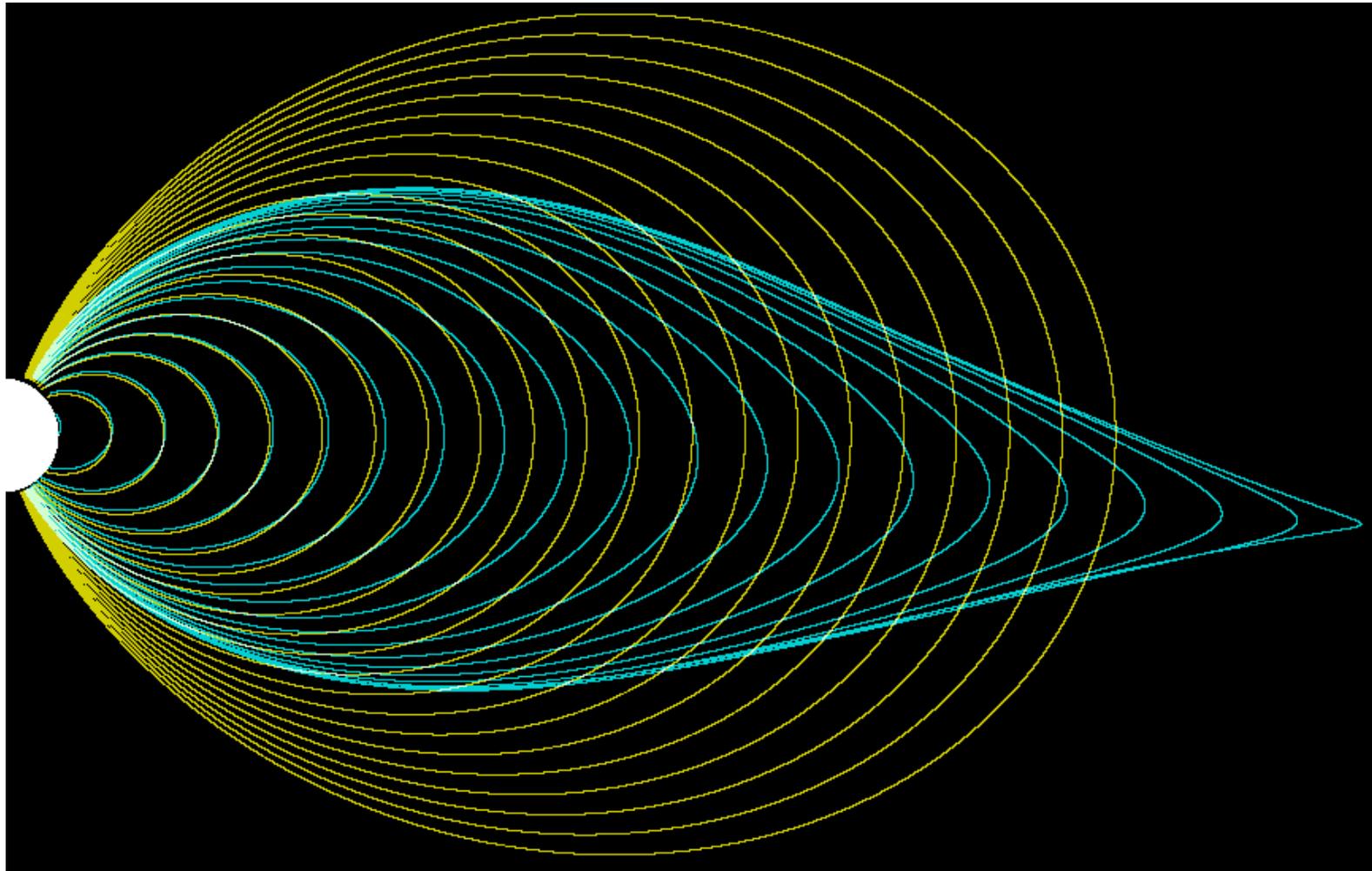


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Topic 1a

Comparison of field lines for VIP4 + current sheet model, and OTD model.
Lines of integer L to $L = 21 R_j$ are shown. {110degree long, SysIII}





1b) Potential errors in the model.

Things to Check for Correctness:

- Coefficients in synch version
- Calculation of magnetic field values
- Calculation of Bcrit parameters
- Pitch angle clipping is correct (on or off?)
- Radiation model needed for $L > 16R_j$?
- Enough significant digits in input file values



2) Assessment of expected radiation dose over sample JUNO orbits (relative contribution from high and low L).

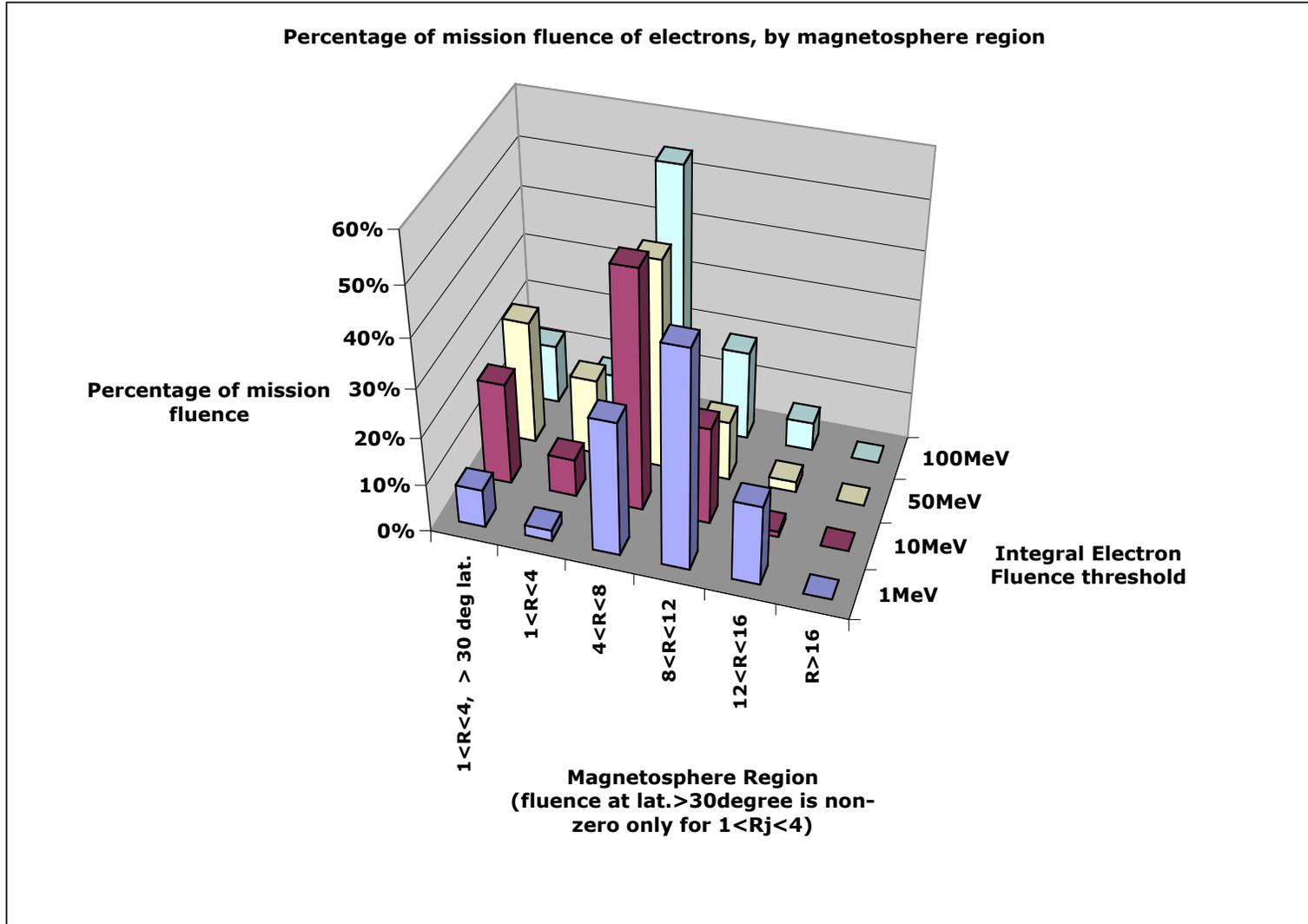
The following graph indicates the percentage contribution to the Juno mission's electron fluence (a proxy for dose) from different regions of the magnetosphere.



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Topic 2





3) When during Jupiter orbit operations are we likely to have radiation events?

The following graph indicates how the flux is expected to vary over the course of an orbit. The highest flux levels occur near the poles, for relatively short durations.



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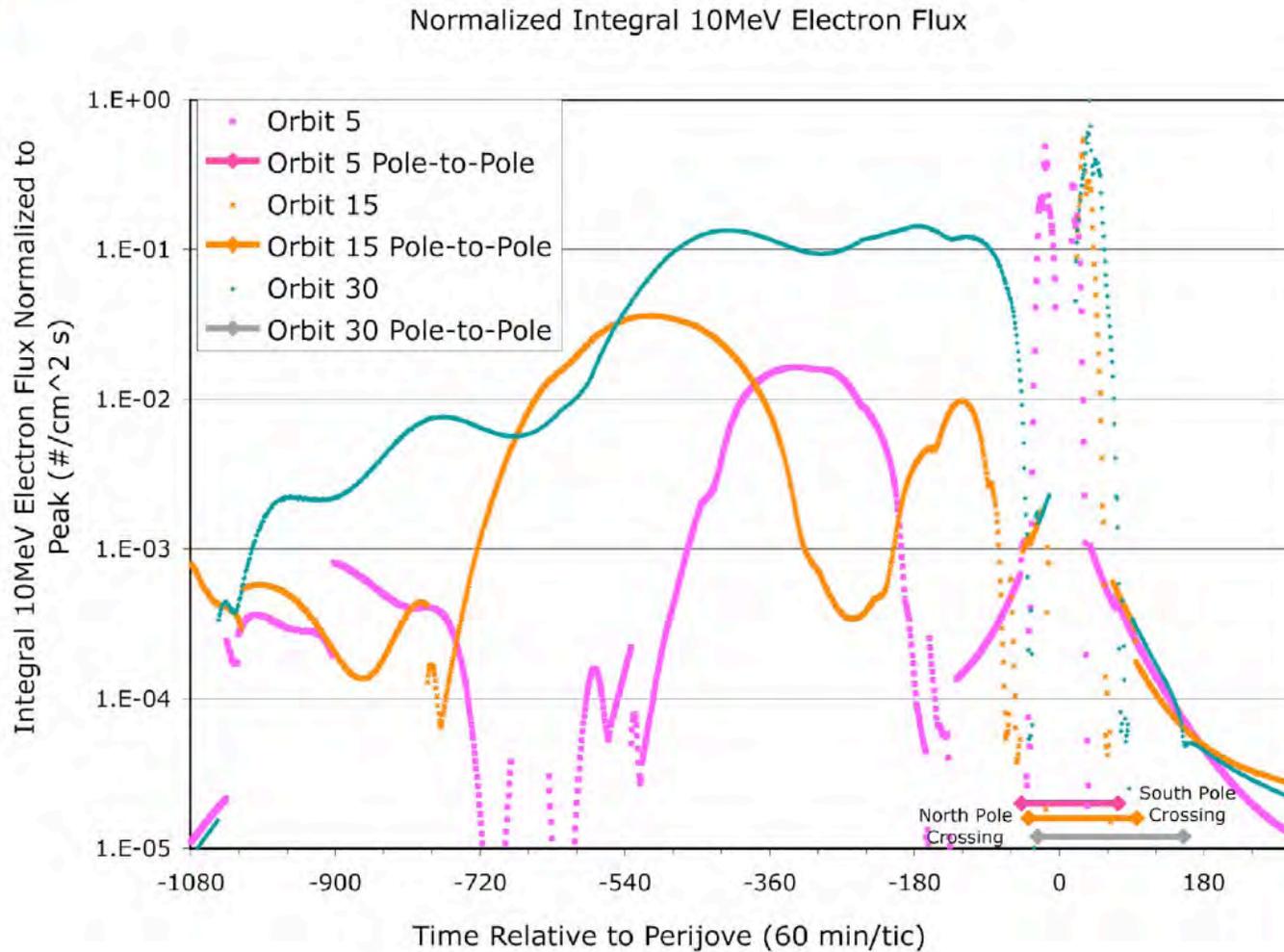


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Topic 3

Timeline of flux in various orbits

(from Juno Concept Study Report, submitted to NASA)





Topic 4: Discussion of B field model used.

Magnetic Field Choices

- original DM field, O4
- Latest/Greatest, VIP4
- Current Sheet (currently included)



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Topic 4 - Mag Field

- Magnetic Field Model:
- The Divine model provides fluxes at specified magnetic field coordinates; the assignment of flux to a particular position in physical space is then determined by transforming magnetic coordinates to physical coordinates. To organize the particle data and construct a functional fit, Divine used the 15-coefficient O4 magnetic field model derived from the flux gate magnetometer on Pioneer 11 [Acuna and Ness, 1976]. Divine suggested to users evaluating spacecraft radiation exposure, that the more easily usable "D4" offset tilted dipole (OTD) model would provide "...adequate accuracy for evaluating model parameters for many applications". Everyone would probably agree that the Juno trajectory is NOT one of those applications; the OTD model is probably too much of an approximation.
- While it can be argued that the most accurate magnetic field model should give the best estimate of a spacecraft's mission fluence of radiation, it is probable that some error will be introduced by using a field model other than the O4 model from which the radiation flux model was constructed. The difference in fluences as produced by the O4 model and the field model of choice (e.g. VIP4 + current sheet) might give a rough indication of the error introduced by magnetic field model inconsistency.



Radiation Model Components:

- original DM (Divine Model of Jupiter's rad belts)
- Synchrotron modification to DM $\{2 < L < 4R_j\}$
- GIRE (GLL Interim Radiation Electrons) $\{L > 8R_j\}$
- Pitch angle clipping of DM [now obsolete?]



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Topics 5&6

Topics:

- 5) Summary of the data sources used to construct the current model and assessment of recent updates.
- 6) Comparison of model with available data (Pioneer, Voyager, Galileo etc).



Core model ("Divine model", or DM):

protons and electrons as described in

N. Divine and H. B. Garrett, "Charged Particle Distributions in Jupiter's Magnetosphere", JGR 88(A9), pp. 6889-6903, 1983.

Region of trapped particles:

Electrons $1.089 < L < 16$

Protons $1.089 < L < 12$

(L in units of R_j , where $R_j = 41,700.km$)



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Data Sources for Divine Jovian Radiation Model

TABLE 1. Data Sources for Jupiter Charged Particle Models

Instrument	Data Type	References
<i>Pioneers 10 and 11</i>		
Helium vector magnetometer (HVM)	vector magnetic field	<i>Smith et al.</i> [1976]
Flux gate magnetometer (FGM)	vector magnetic field	<i>Acuna and Ness</i> [1976a, b]
Plasma analyzer (PA)	electrons and protons, 0.1 to 4.8 keV	<i>Frank et al.</i> [1976]
Geiger tube telescope (GTT)	electrons >0.06, 0.55, 5, 21, 31 MeV protons 0.61–3.41 MeV	<i>Van Allen et al.</i> [1974, 1975], <i>Van Allen</i> [1976], and <i>Baker and Van Allen</i> [1977]
Trapped radiation detector (TRD)	electrons >0.16, 0.26, 0.46, 5, 8, 12, 35 MeV protons >80 MeV	<i>Fillius and McIlwain</i> [1974], <i>Fillius et al.</i> [1975], and <i>Fillius</i> [1976]
Low-energy telescope (LET)	protons 1.2–2.15 and 14.8–21.2 MeV	<i>Trainor et al.</i> [1974, 1975] and <i>McDonald and Trainor</i> [1976]
Electron current detector (ECD)	electrons >3.4 MeV	<i>Simpson et al.</i> [1974, 1975]
Fission cell (F1)	protons >35 MeV	<i>Simpson and McKibben</i> [1976]
<i>Voyagers 1 and 2</i>		
Flux gate magnetometer (MAG)	vector magnetic field	<i>Ness et al.</i> [1979a, b]
Planetary radio astronomy (PRA)	electric vector, 1.2 kHz to 40.5 MHz	<i>Warwick et al.</i> [1979a, b] and <i>Birmingham et al.</i> [1981]
Plasma wave (PWS)	10 Hz to 56 kHz	<i>Scarf et al.</i> [1979] and <i>Gurnett et al.</i> [1979]
Plasma science (PLS)	electrons 10–6000 eV ions 10–6000 V	<i>Bridge et al.</i> [1979a, b], <i>Bagenal and Sullivan</i> [1981], and <i>Scudder et al.</i> [1981]
Low-energy charged particle (LECP)	electrons >15 keV ions >30 keV	<i>Krimigis et al.</i> [1979a, b, 1981]
Cosmic ray telescope (CRT)	electrons 3–110 MeV ions 1–500 MeV/nucleon	<i>Vogt et al.</i> [1979a, b]
<i>Earth</i>		
Radio telescopes	UHF intensity and polarization	<i>Berge and Gulkis</i> [1976] and <i>dePater and Dames</i> [1979]



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Model Details- Divine Model

DM comparison with
data:

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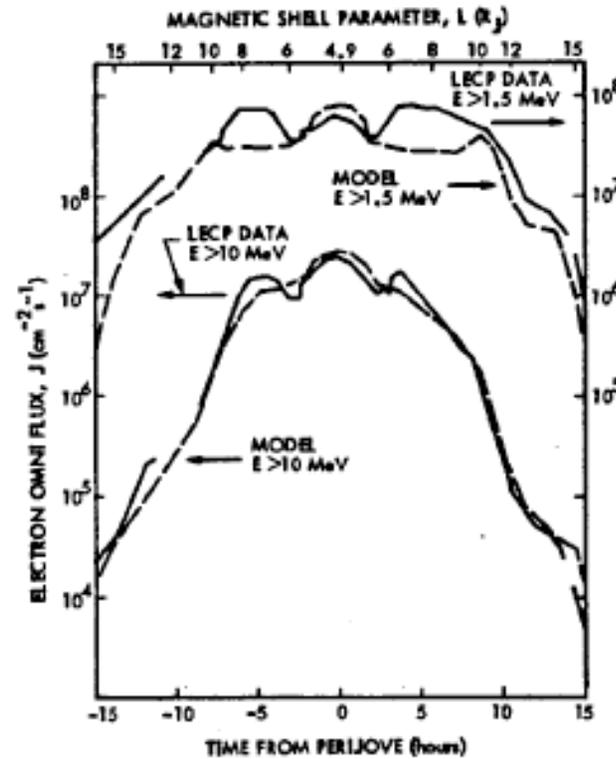


Fig. 12. Comparison of Voyager 1 LECF electron flux profiles with predictions from the Jupiter energetic electron model. Arrows indicate left or right flux scales.



Outside the Belts:

The DM contains a description of a population of electrons outside the trapped-particle region (i.e. for $L > 16R_j$).

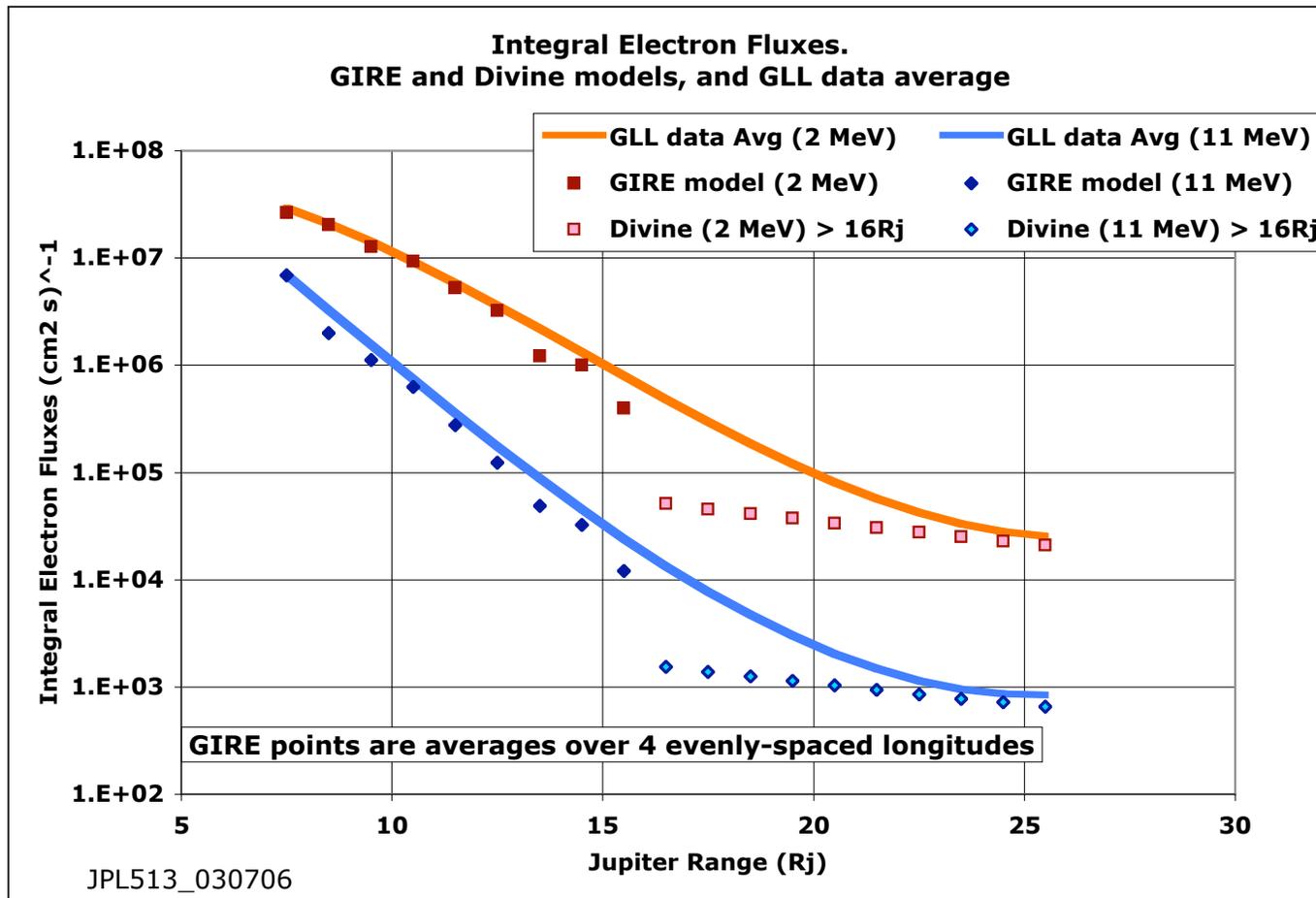
The accuracy of this component of the model is highly speculative. Fortunately, the flux levels are relatively low, so this untrapped electron component will not substantially contribute to the mission fluence for most missions.

We may be able to show that, for Juno, this component can be ignored, so that the radiation exposure to a spacecraft need only be considered for trajectory segments within a planetary range below an L-shell of 16 R_j.

The Galileo EPD data have provided some information about the >16R_j environment near the equator (see plot that follows). This could be used as a bound on the environment at all latitudes.



Outside the Belts:





Model Details > 16 R_J

1.5 MeV:

$$\text{Log}_{10}(I_{1.5\text{MeV}}) = 5.90 \times 10^{-4} R_J^3 - 2.72 \times 10^{-3} R_J^2 + 2.05 \times 10^{-1} R_J + 7.31$$

$$R^2 = 0.99759$$

2 MeV:

$$\text{Log}_{10}(I_{2.0\text{MeV}}) = 5.58 \times 10^{-4} R_J^3 - 2.45 \times 10^{-3} R_J^2 + 1.38 \times 10^{-1} R_J + 7.57$$

$$R^2 = 0.99746$$

11 MeV:

$$\text{Log}_{10}(I_{11\text{MeV}}) = 3.69 \times 10^{-4} R_J^3 - 8.89 \times 10^{-3} R_J^2 - 2.55 \times 10^{-1} R_J + 9.10$$

$$R^2 = 0.9573$$

Where: R_J = Radial distance from Jupiter in units of 1 jovian radius

I_E = Integral omni-directional electron flux ($\text{cm}^{-2} \text{s}^{-1}$)

from Jun et al. "Statistics of the variations of the high-energy electron population between 7 and 28 jovian radii as measured by the Galileo spacecraft", ICARUS 178 (2): 386-394, 15 Nov 2005

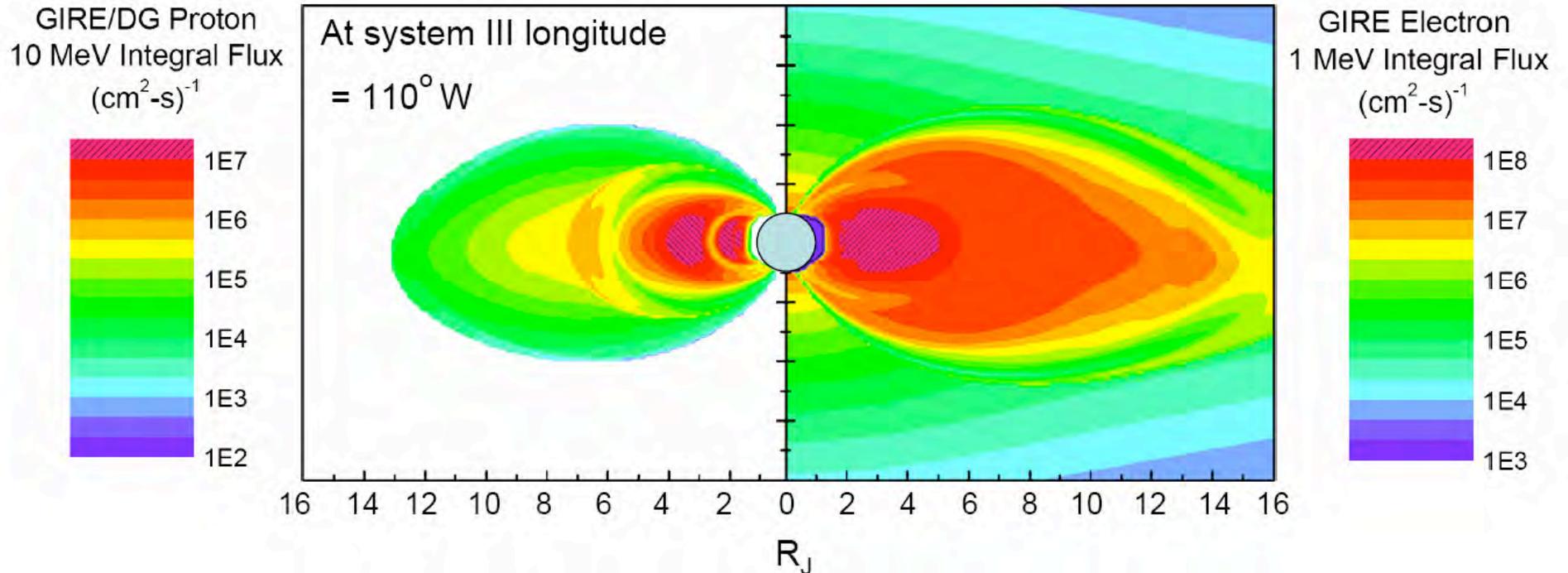


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Divine/GIRE Jovian Trapped Radiation Models



Contour plots of ≥ 1 MeV electron and ≥ 10 MeV proton integral fluxes at Jupiter. Coordinate system used is jovi-centric. Models are based on Divine/GIRE models. Meridian is for System III 110° W.



GIRE modification:

The Galileo Interim Radiation Electron model (GIRE model) is a representation of the electron data from the Galileo Energetic Particle Detector (EPD) instrument.

The “VIP4 + current sheet” magnetic field was used to organize the flux data as a function of magnetic field B,L coordinates.

The model describes the average omnidirectional flux of electrons on the magnetic equator between $8 < L < 16$, and energy range 0.174 to 31 Mev.

This flux replaces the Divine model's electron flux at the magnetic equator.

The flux at non-zero latitudes is determined by applying the pitch-angle dependence of the Divine model to the GIRE equatorial flux.



GIRE modification:

Reference: Garrett, et al., “Galileo Interim Radiation Electron Model”,
JPL Publication 03-006, February 2003.

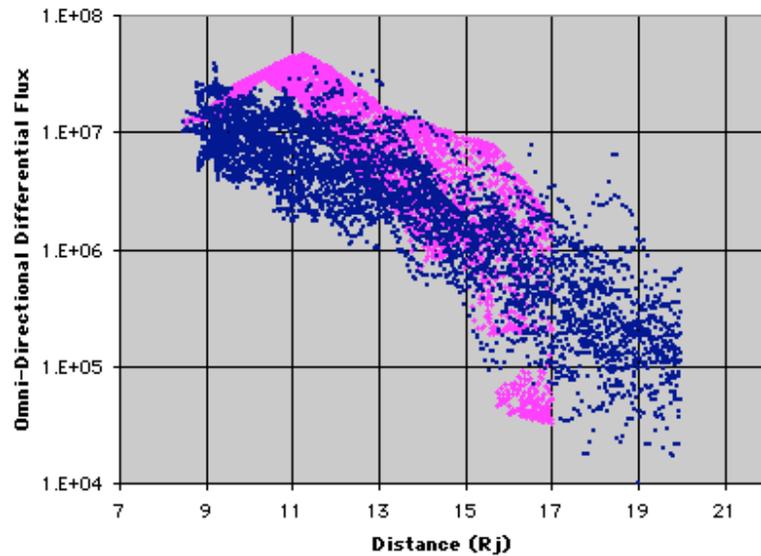
We can email you a copy on request.

It can also be obtained at <http://www.openchannelfoundation.com/projects/GIRE>

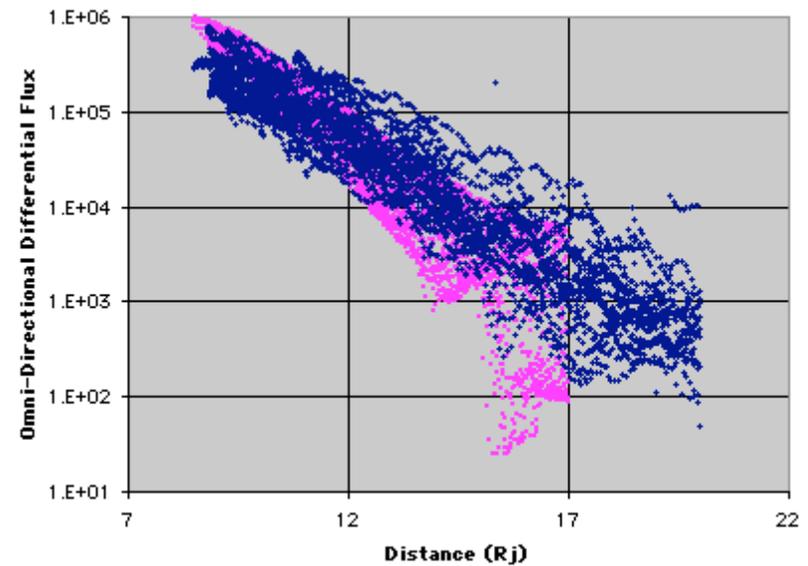


Model Details- Model Comparisons

Divine Model Estimates vs EPD Calibrated Data



1.5 MeV ELECTRONS



11 MeV ELECTRONS

Pink = Divine; Blue = EPD calibrated data

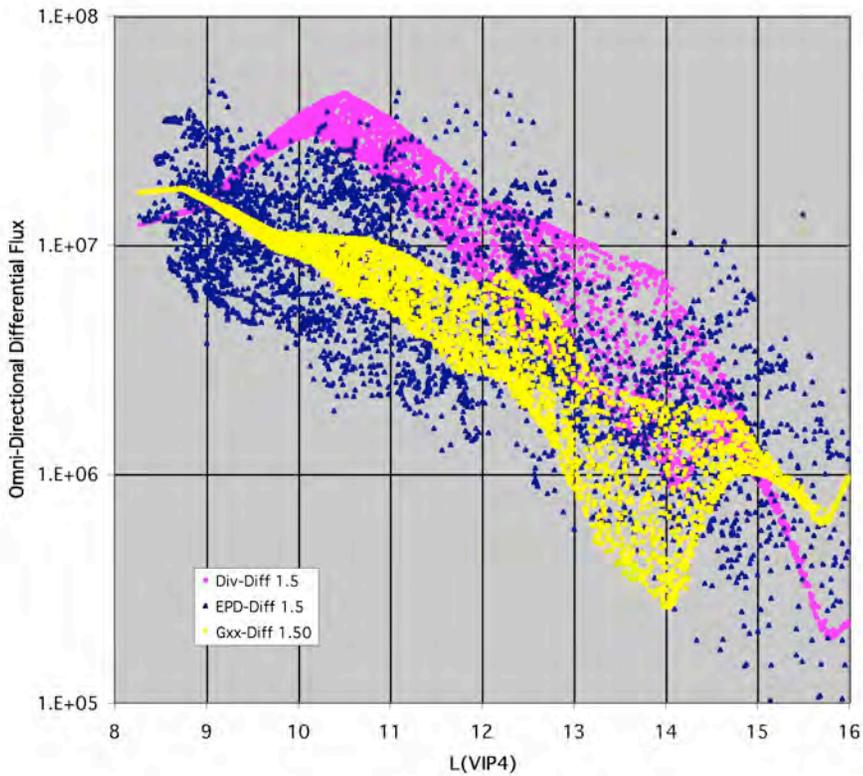


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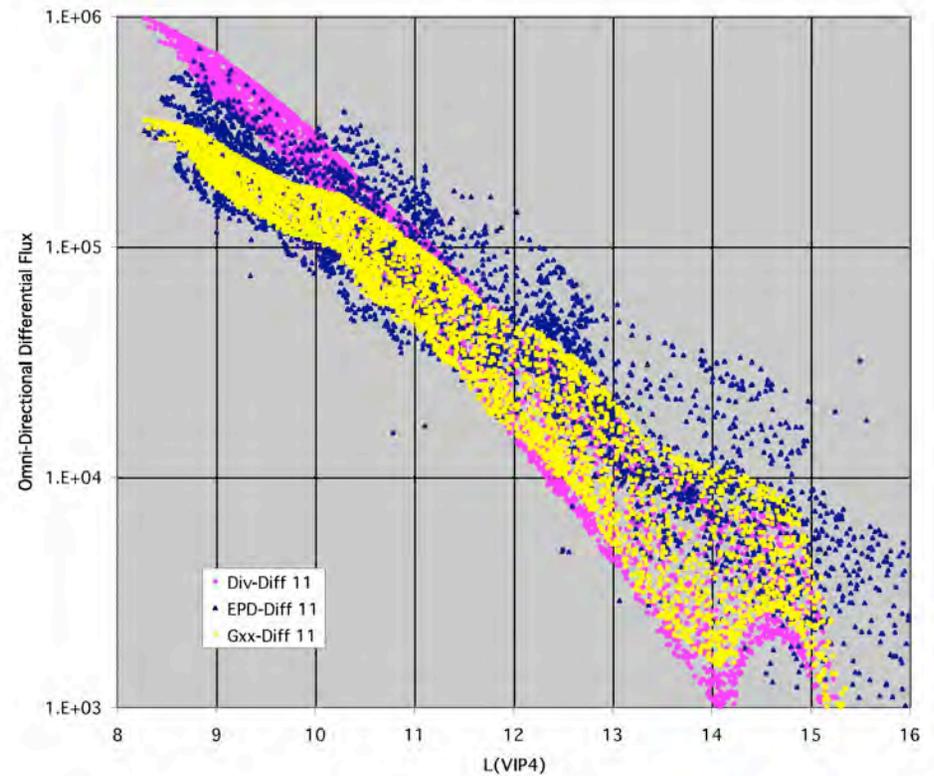
Model Details- Model Comparisons

Divine Model, GIRE Model, & EPD data



1.5 MeV ELECTRONS

Pink = Divine; Yellow = GIRE; Blue = EPD data



11 MeV ELECTRONS



Model Details- Model & Data Comparisons

Comparison of electron in situ measured fluences with Divine Model and GIRE+synch fluences:

	<i>Pioneer 10</i>			<i>Pioneer 11</i>	
	21 MeV<E	31 MeV<E		21 MeV<E	31 MeV<E
Scanned	4.95E+11	2.00E+11	Scanned	7.55E+12	5.98E+12
GIRE+Sync	5.24E+11	2.13E+11	GIRE+Sync	1.28E+13	5.45E+12
Divine	5.12E+11	2.01E+11	Divine	1.09E+13	4.49E+12
PDS (Fr)	5.47E+11	4.41E+11	PDS (Fr)	1.36E+13	5.62E+12

- “scanned” data are from published plots (large versions in Divine files)
- “GIRE+Sync” is that model’s estimate of spacecraft fluence
- “Divine” is that model’s estimate of spacecraft fluence
- “PDS (Fr)” is the Planetary Data System’s version of the P10 and P11 data, as provided to us by D. Santos-Costa



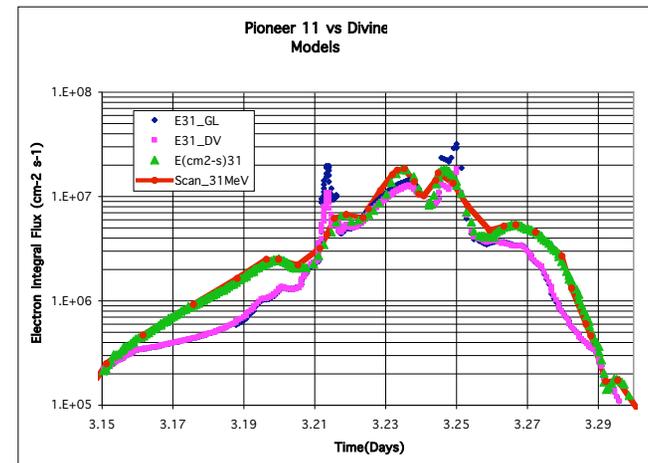
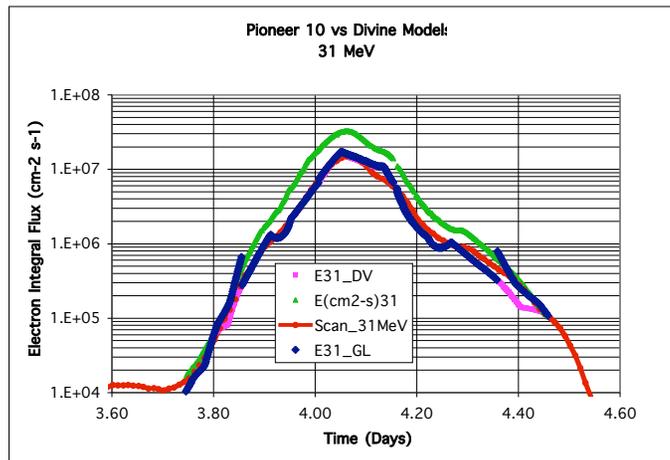
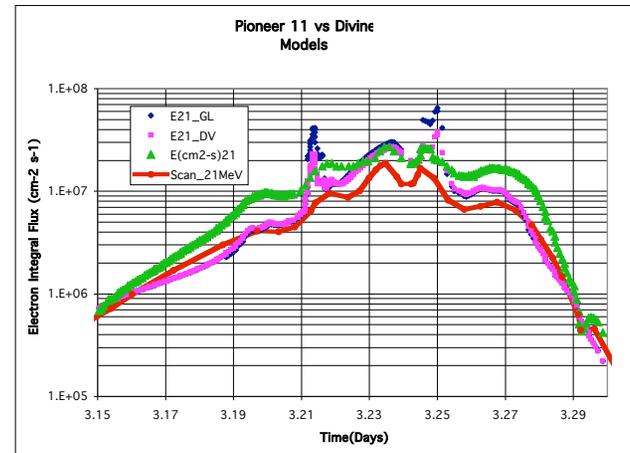
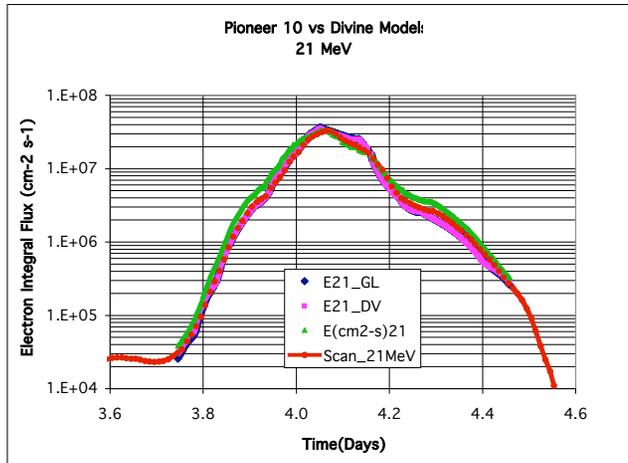
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Model Details- Model & Data Comparisons

Pioneer 10 and 11 Fluxes





Model Details- Sychrotron Correction

Sychrotron radiation:

Changes to the $L < 4 R_j$ region of the electron belt are described in Garrett et al., "A revised model of Jupiter's inner electron belts: Updating the Divine radiation model", GRL 32(L04104) 2005.

For $L < 4.0$,

the Divine model's electron flux is scaled down, and a near-equatorial flux distribution (a "pancake" distribution) is added.

For $2.0 < L < 2.3$,

in addition to the pancake distribution, the electron flux is modified to increase the flux as pitch angle decreases, i.e. a field-aligned component of the flux is added. This increases the flux at high latitudes.



Model Details- Sychrotron Correction

Sychrotron radiation (cont'd):

For $L < 4.0$,

the new flux F_1 is estimated by scaling the Divine model's electron flux F_{DM} , including a pancake distribution:

$$F_1 = F_{DM} (0.48 + 1.80 \sin^{40}(\alpha))$$

For $2.0 < L < 2.3$,

a field-aligned term is included, to produce a flux of the form

$$\begin{aligned} F &= F_1 (1 + 0.6 \sin^{-3}(\alpha)) \\ &= F_{DM} [0.48 + 1.80 \sin^{40}(\alpha)] [1 + 0.6 \sin^{-3}(\alpha)] \end{aligned}$$



Model Details- Sychrotron Correction

Sychrotron radiation (cont'd):

A comparison of the new model with measured synchrotron emission is shown (from Garrett, et al., 2005).

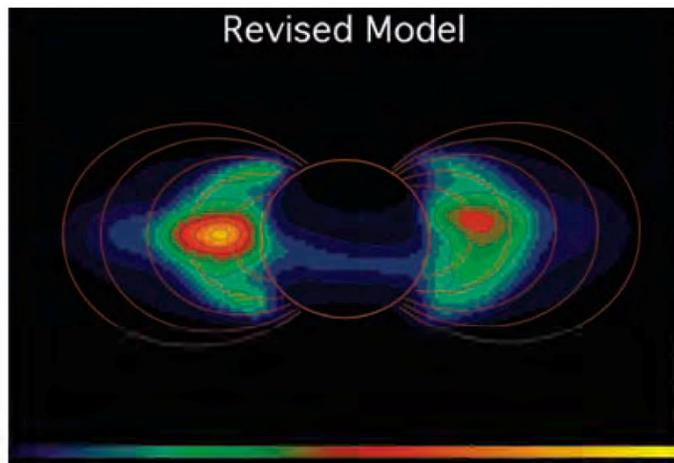


Figure 2. Predicted synchrotron emissions at 1.4 GHz and CML 200° for the modified DM electron radiation distributions for $E > 1$ MeV. The color scale and field lines are identical to those in Figures 1a and 1b.

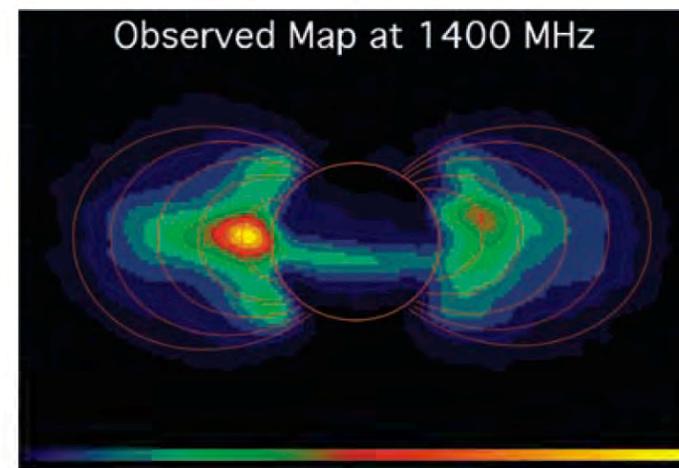


Figure 1a. Observed synchrotron emissions at 1.4 GHz and CML 200° for $E > 1$ MeV [Levin et al., 2001]. The color scale is linear from 0 (black) to 8.74×10^8 Jy/steradian (yellow). Field lines shown correspond to L-shells 1.5, 2.0, 2.5, 3.0, and 3.5 projected onto the meridional plane.



Model Details- pitch angle clipping

Clipping of presumably non-physical, field-aligned flux:

For certain combinations of fitting coefficients used to describe the pitch-angle variation of the flux, the analytic functions reach a minimum at some intermediate pitch angle, and then rise again as the pitch angle approaches zero. These field-aligned fluxes are thought to be artifacts of a functional fit to limited data, so the analytic functions were clipped to be zero for pitch angles smaller than the angle of minimum flux.

The specifics of this modification have not been formally documented.

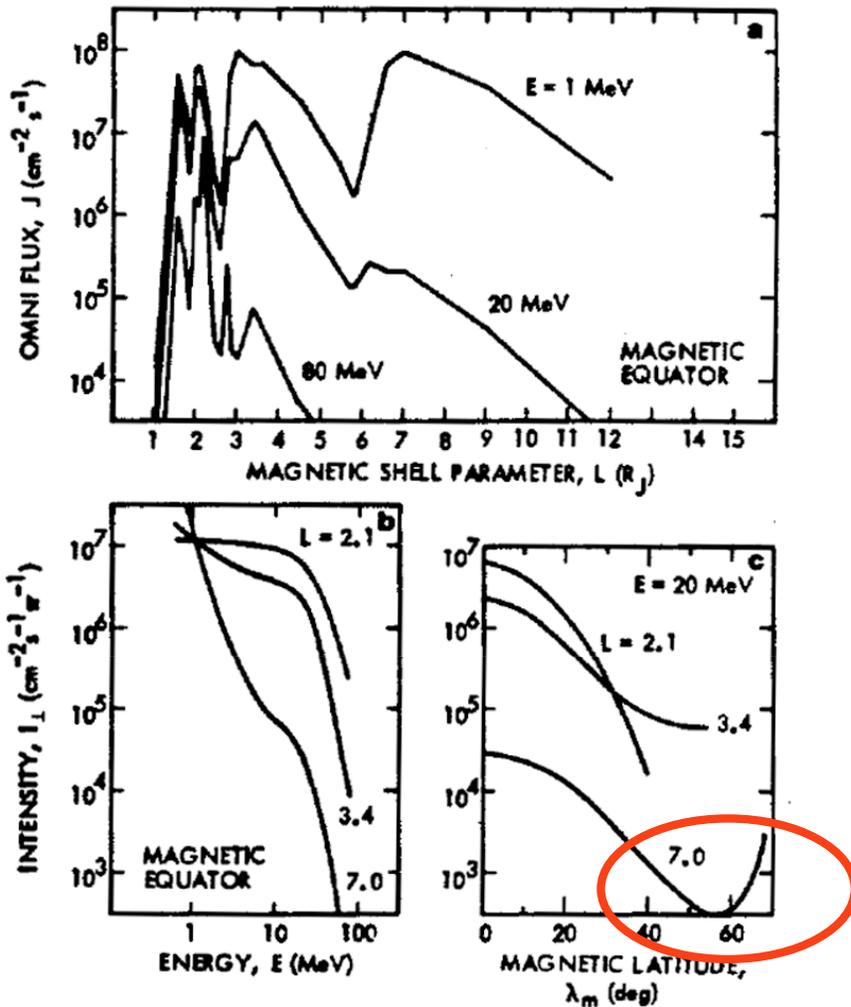
Note: This clipping correction for electrons at $L < 4 R_j$ is not to be used when the synchrotron corrections are implemented. (TBR?)



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Model Details- pitch angle clipping



Example of “unphysical” pitch angle variation:

- “Fig. 3.....In Figure 3c the increase of the intensity at $L=7.0$ and $\lambda_m > 55^\circ$ illustrates the kind of model defect that can occur when carefully crafted algebraic forms are used to extrapolate beyond the range of available data, this increase is unphysical.” (Divine and Garrett, 1983)



Model Details- pitch angle clipping

“Unphysical” Electron Pitch Angle Cutoff Table

L-Shell	Energy(MeV)													
	1	2	3	4	6	10	16	25	40	63	100	159	251	398
1.089	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.55	0	0	0	0	0	0	0	38	38	38	38	38	38	38
1.60	0	0	0	0	0	0	35	36	37	37	37	37	37	36
1.75	0	0	0	0	0	0	31	33	33	33	33	33	32	32
1.80	0	0	0	0	0	30	32	33	33	33	33	32	32	31
1.85	0	0	0	0	28	30	32	33	34	33	33	32	32	31
1.90	0	0	0	26	30	32	34	35	35	34	33	33	32	31
2.00	0	0	0	0	0	83	86	87	86	27	27	27	26	26
2.10	0	0	0	0	22	24	26	26	27	26	26	25	25	24
2.20	0	0	0	0	83	87	87	88	87	87	82	0	0	0
2.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.70	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.80	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.85	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.20	0	0	0	0	0	0	0	0	0	0	0	0	0	10
5.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.80	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.00	0	0	0	0	0	0	0	0	0	0	0	13	25	49
10.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14.00	0	0	0	4	5	6	6	6	6	6	6	6	6	6
16.00	37	24	18	15	13	11	10	10	10	10	10	10	10	10



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Model Details- pitch angle clipping

“Unphysical” Proton Pitch Angle Cutoff Table

L-Shell	Energy(MeV)													
	1	2	3	4	6	10	16	25	40	63	100	159	251	398
1.089	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.80	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.85	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.90	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.60	36	84	86	86	86	87	86	86	85	75	0	0	0	0
2.70	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.80	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.85	0	0	0	0	0	0	0	0	0	86	88	88	88	89
3.00	0	0	0	0	0	0	0	0	0	84	88	88	89	89
3.20	0	0	0	0	0	0	11	13	17	23	32	45	69	86
3.40	0	0	0	0	0	0	0	0	11	17	25	37	64	86
3.60	0	0	0	0	0	0	0	9	11	14	25	84	87	88
4.50	0	0	0	0	0	0	8	11	16	23	35	54	84	87
5.20	0	0	0	0	0	0	0	6	11	19	31	54	83	87
5.40	0	0	0	0	0	0	0	5	10	19	34	64	85	87
5.80	0	0	0	0	0	0	0	0	0	10	28	73	85	87
6.20	0	0	0	0	0	0	0	0	0	0	0	79	86	87
6.60	0	0	0	0	0	0	0	0	0	0	6	22	70	83
7.00	0	4	5	6	6	5	5	5	5	6	7	87	88	88
7.20	0	4	5	6	6	6	6	6	7	8	11	18	74	86
9.00	0	0	0	0	0	0	0	6	10	13	17	21	25	29
10.50	0	0	0	0	0	0	0	0	0	8	14	20	26	34
11.00	0	0	0	0	0	0	0	0	0	9	17	24	32	42
12.00	0	0	0	0	0	0	0	0	0	0	7	12	17	23
14.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Additional Material

- **Time Variability of Electrons as seen in GLL data**
- **GIRE.ppt slide presentation (sent separately)**



National Aeronautics and Space Administration
 Jet Propulsion Laboratory
 California Institute of Technology
 Pasadena, California

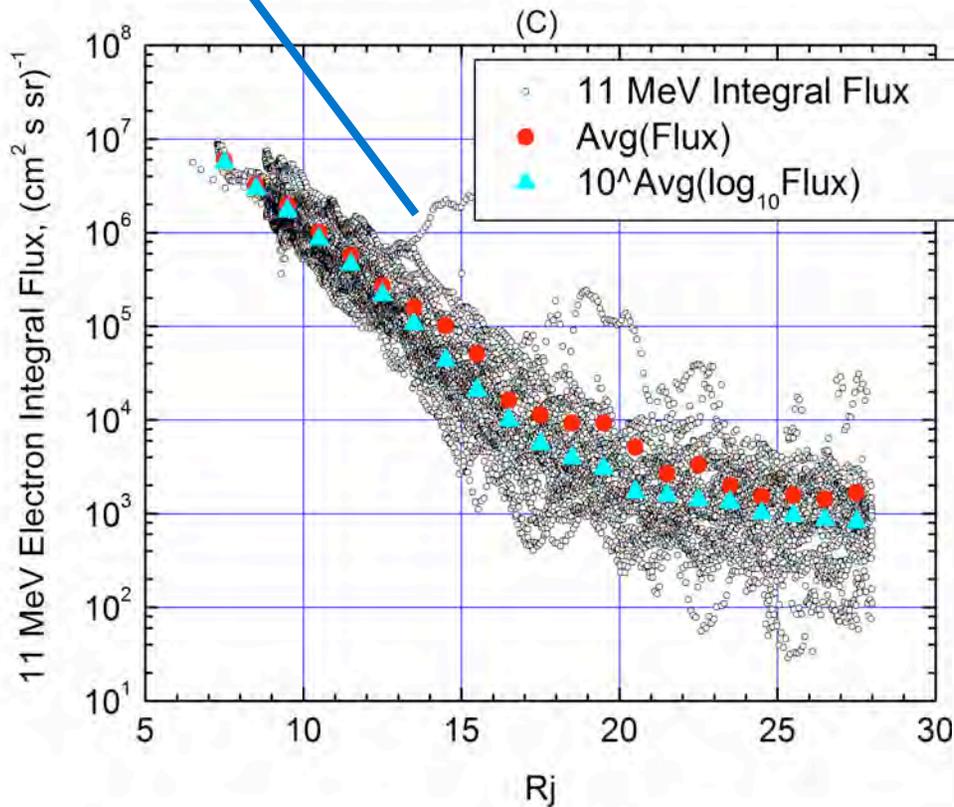


Juno

Time Variability of Electrons as seen in GLL data

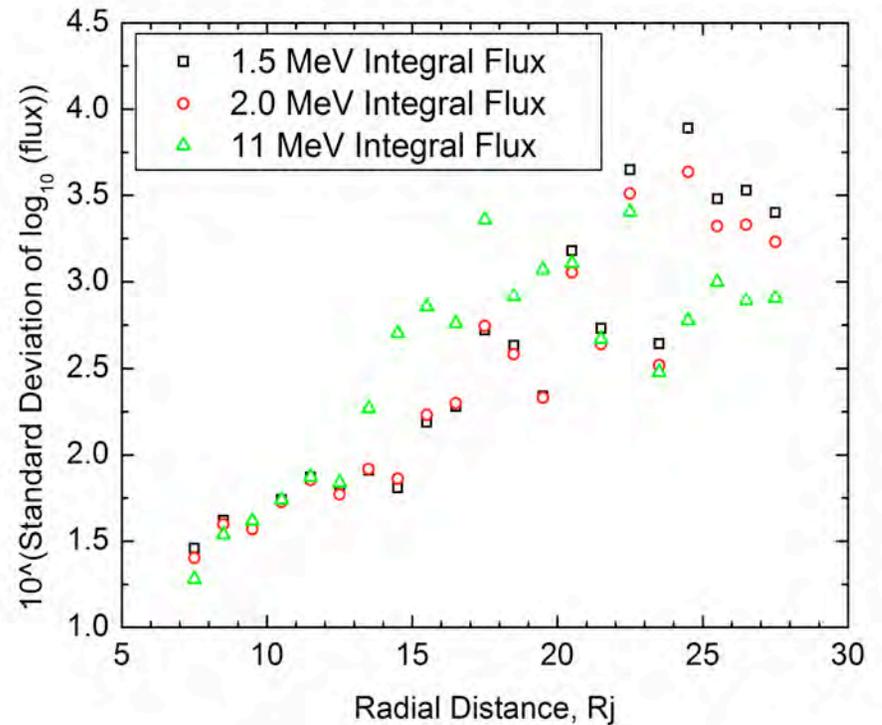
Standard deviation of Electron Flux

C22 Storm



Galileo 11 MeV particle fluxes vs radial distance

Galileo estimates of the STD (~RDF) vs radial distance





Galileo Interim Radiation Electron Model **JPL**

GALILEO INTERIM RADIATION ELECTRON MODEL

H. B. Garrett^a, I. Jun^a, J. M. Ratliff^a,
R. W. Evans^b, G.A. Clough^c,
and R. W. McEntire^d

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^bGibbel Corp., 2550 Honolulu Blvd., Montrose, CA 91020

^cBates College, Lewiston, Maine 04240

^dJohns Hopkins University Applied Physics Laboratory, Laurel, Maryland 20723



Galileo Interim Radiation Electron Model **JPL**

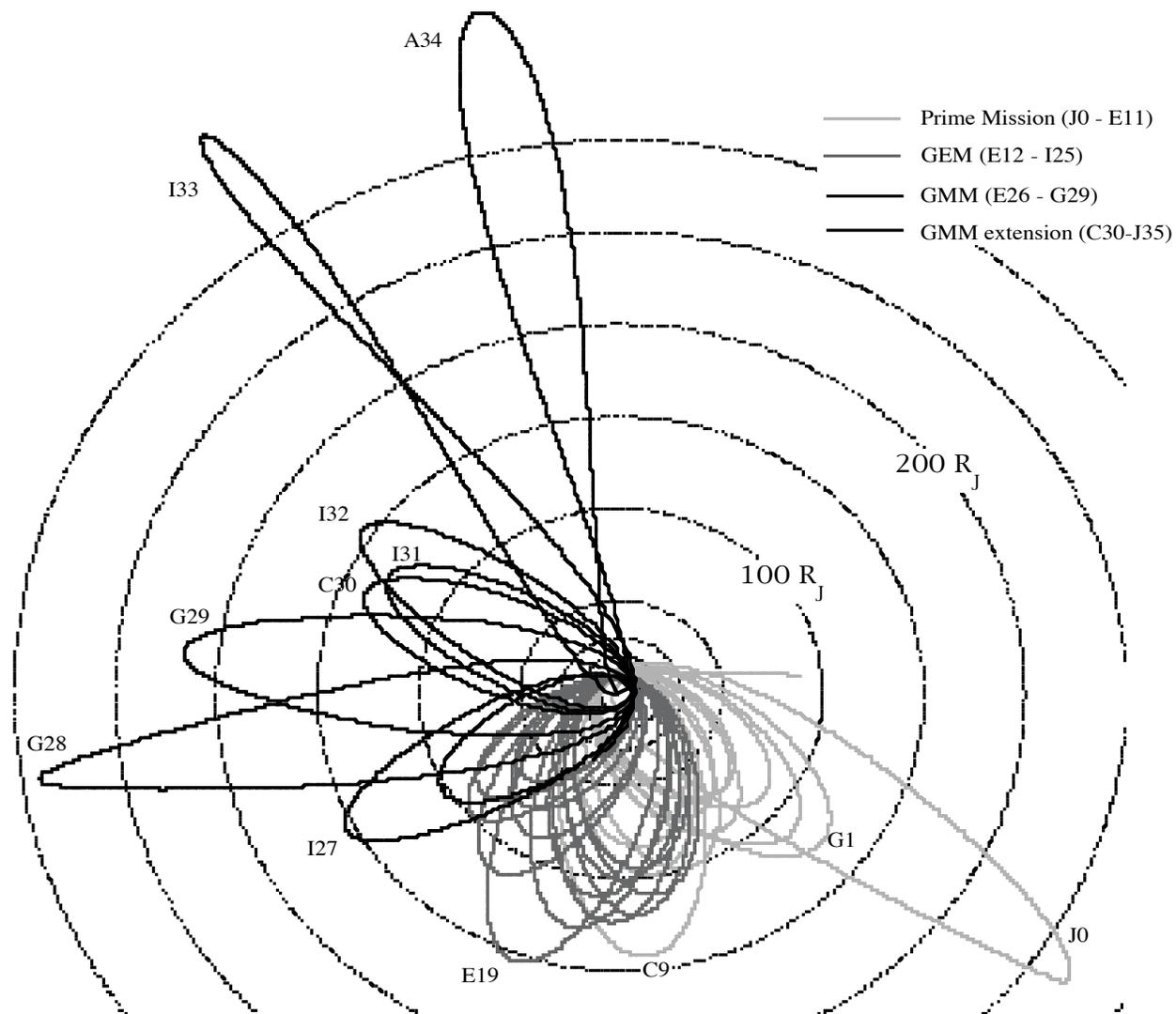
AGENDA

- APL/JHU ENERGETIC PARTICLE DETECTOR**
- OMNI-DIRECTIONAL, EQUATORIAL FLUX MODEL**
- PITCH ANGLE VARIATIONS**
- GIRE FLUX MODEL**
- APPLICATIONS**
- CONCLUSIONS**



Galileo Interim Radiation Electron Model **JPL**

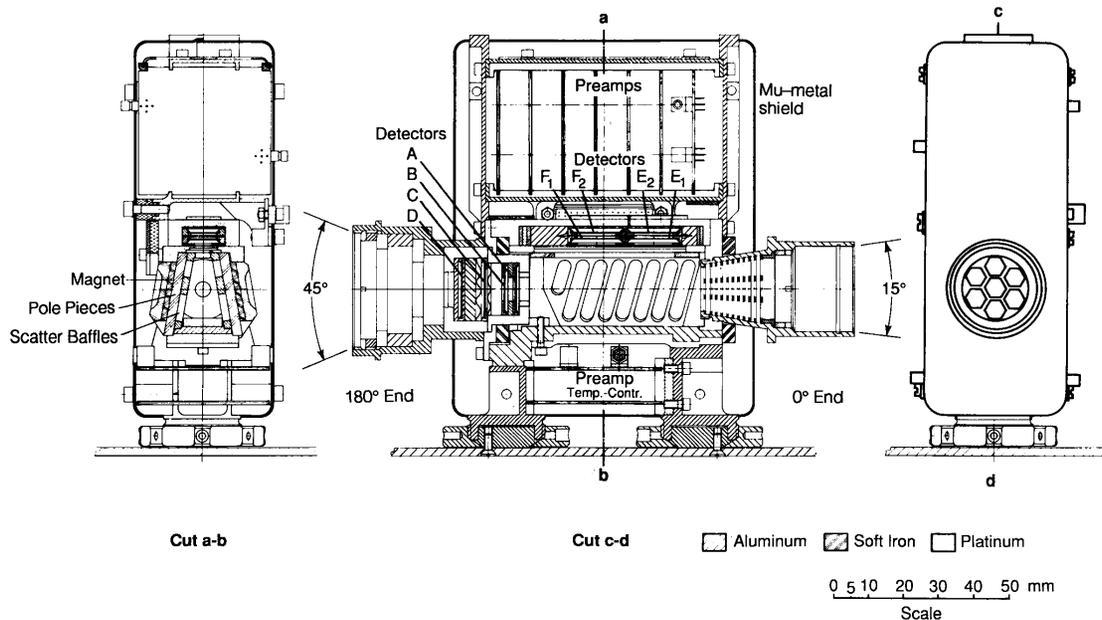
GALILEO ORBITS





Galileo Interim Radiation Electron Model **JPL**

APL/JHU ENERGETIC PARTICLE DETECTOR



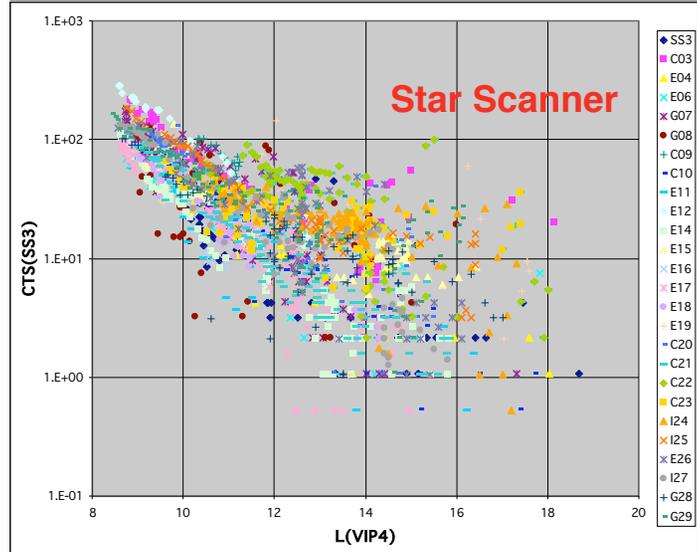
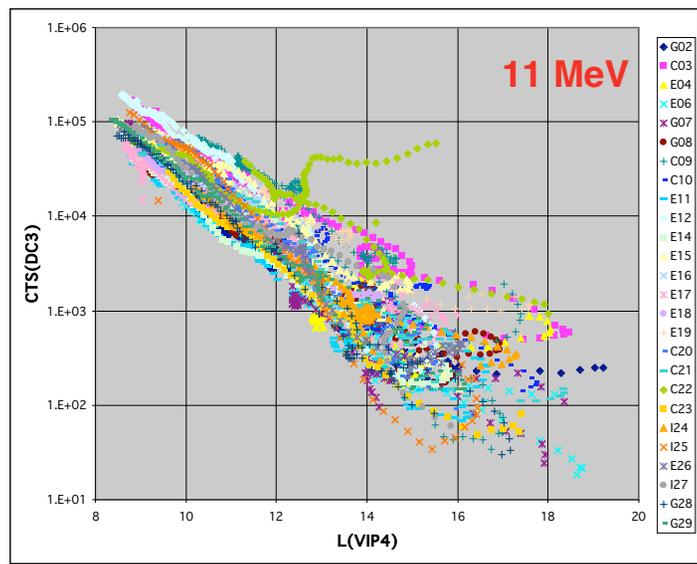
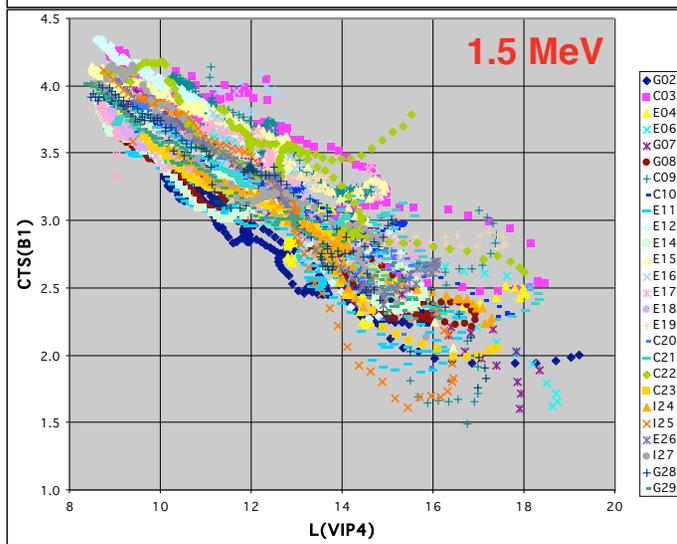
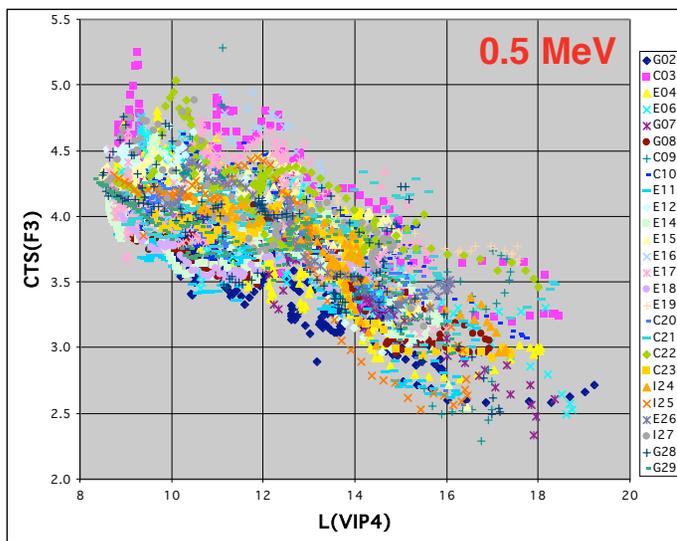
Channel Name	Species	Nominal Energy Range (MeV)	Channel Logic
B0	Z=1	3.20-10.1	A7 B1 NC2
B1	Electrons	1.5-10.5	A2 NA4 B1 NB2 NC2
DC0	Z≥1	14.5-33.5	NB1 D2 NC1
DC1	Z≥1	51-59	NB1 C2 D1
DC2	Electrons	≥2	NB1 D1 ND2
DC3	Electrons	≥11	NB1 C1 NC2 D1

Description of the LEMMS high energy electron and protons channels (Williams et al., 1992).



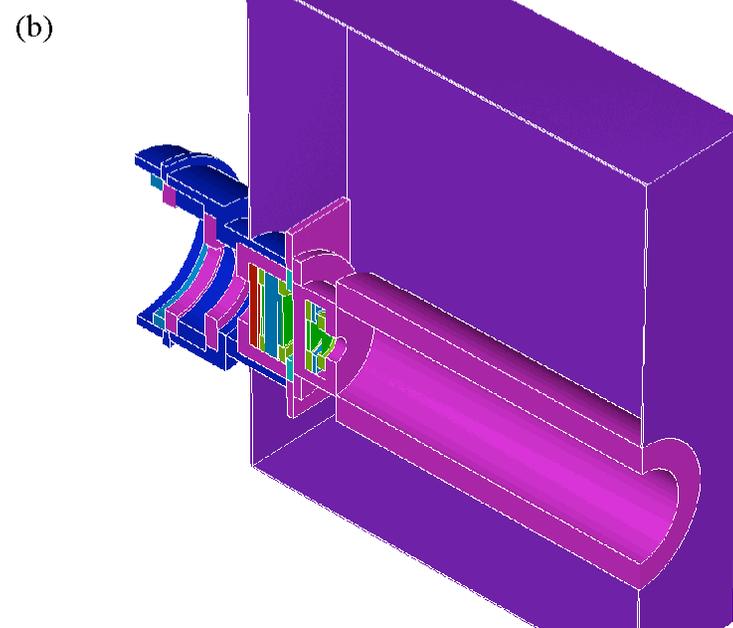
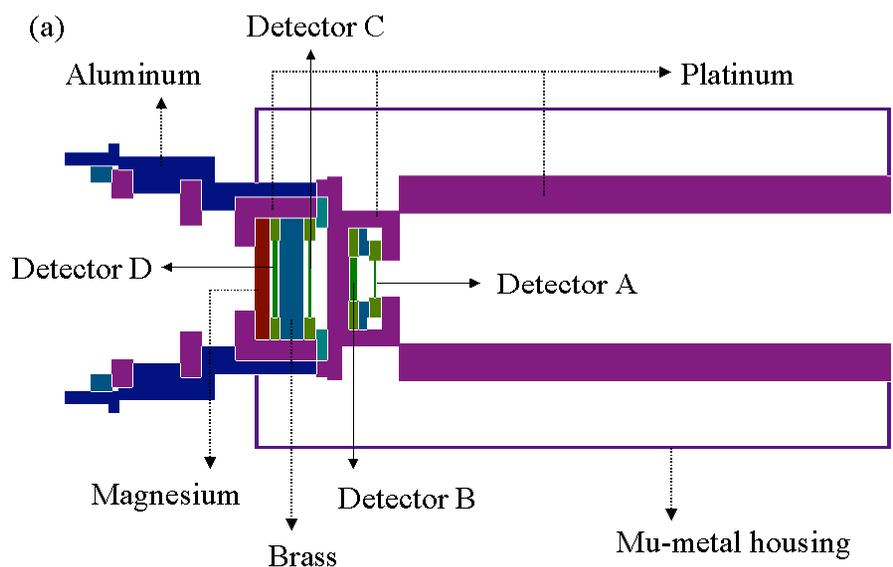
Galileo Interim Radiation Electron Model **JPL**

COUNT RATE VARIATIONS WITH L-SHELL





APL/JHU ENERGETIC PARTICLE DETECTOR

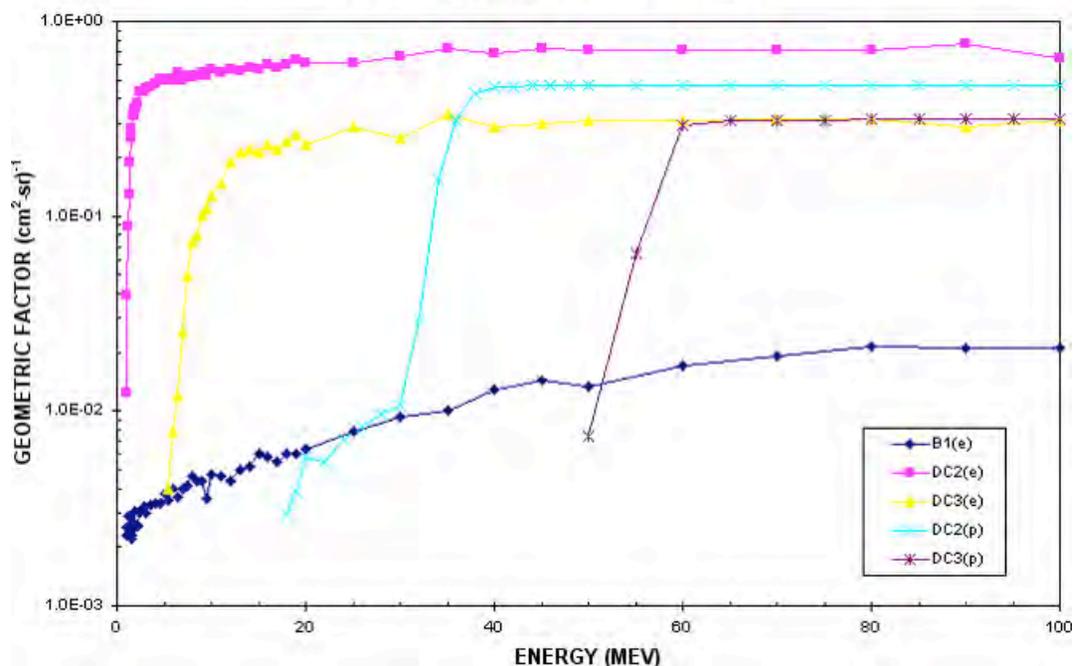


**LEMMS modeling used in the MCNP/MCNPX simulations:
(a) Cross sectional view and (b) Iso-view**



Galileo Interim Radiation Electron Model **JPL**

GEOMETRIC FACTORS



$$(cts / s)_{APL} = \int_0^{\infty} \frac{dI(E)}{dE} G(E) \cdot dE = J_0 \int_0^{\infty} \left(\frac{E_i}{E_0} \right)^{-X} G(E) \cdot dE \cong J_0 \sum_{i=1}^{\infty} \left(\frac{E_i}{E_0} \right)^{-X} G(E_i) \cdot \Delta E_i$$

Where:

E_i = Energy steps ($E_1 = 1$ MeV here)

E_0 = 1 MeV

$(cts / s)_{APL}$ = Counts per second from EPD channels (B1, DC2, DC3)

$I(E_i)$ = Integral electron flux at E_i

$\frac{dI(E_i)}{dE}$ = $J(E_i)$ = Differential electron flux at E_i

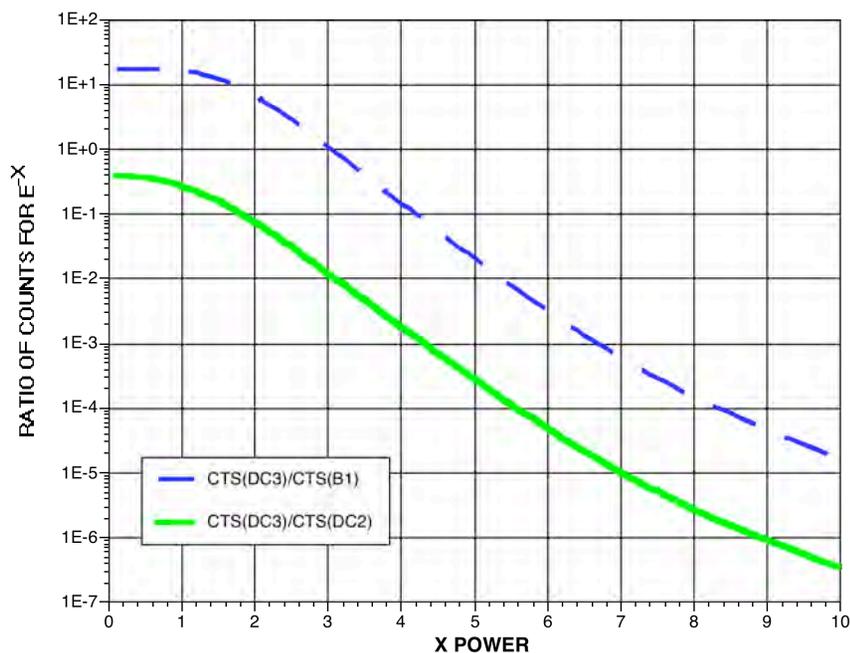
$J(E_i)$ = $J_0 (E_i/E_0)^{-X}$ (units of $(cm^2 \cdot s \cdot sr \cdot MeV)^{-1}$)

$G(E_i)$ = Geometric factor at E_i

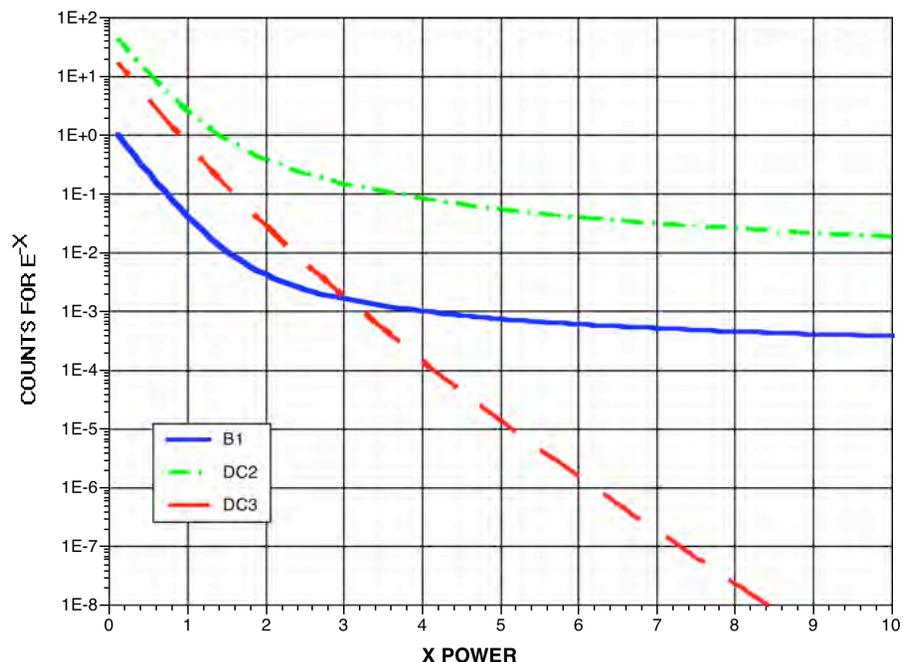


COUNT RATE TO FLUX CONVERSION

$$J(E) \sim J_0 (E/E_0)^{-X}$$



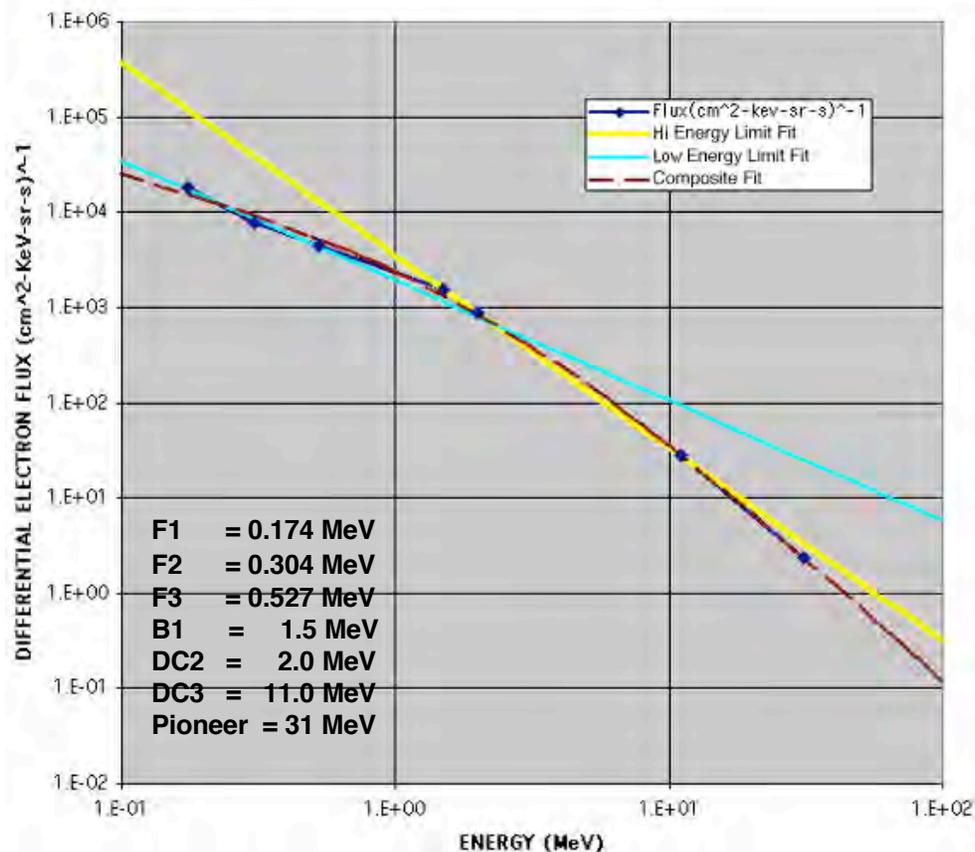
$$\frac{[\text{Cnts}(\text{DC3})/\text{Cnts}(\text{B1})]}{[\text{Cnts}(\text{DC3})/\text{Cnts}(\text{DC2})]} \rightarrow X$$



$$J_0 = [\text{Obs Cnts}]/[\text{Pred Cnts from } X]$$



SPECTRAL FITTING PROCEDURE



$$F(E) = J_o E^{-A} \left(1 + \frac{E}{E_o}\right)^{-B}$$

Where:

F = Differential electron flux as function of E

E = Electron energy (MeV)

J_o = Constant (roughly differential flux at E = 1 MeV)

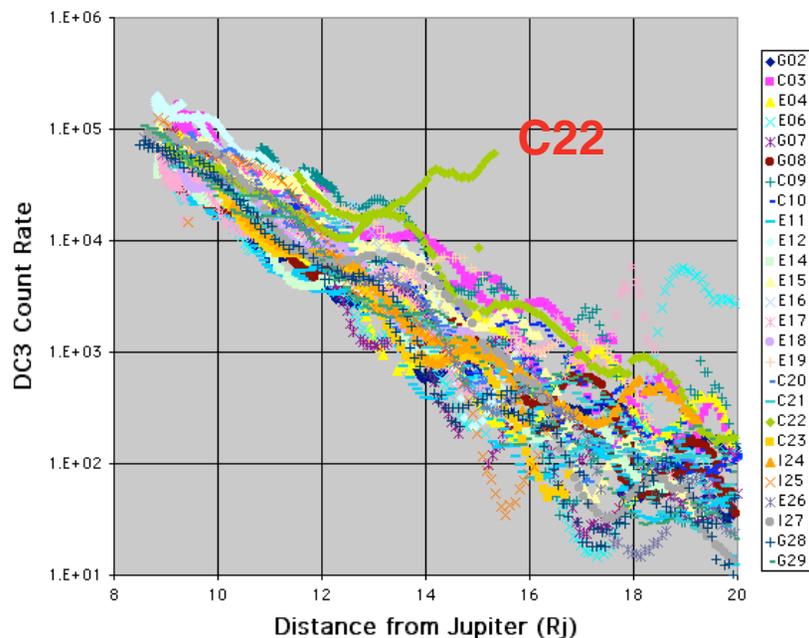
A = Constant (approximately power law index for low energy component)

B = Constant (A+B is approximately power law index for high energy component)

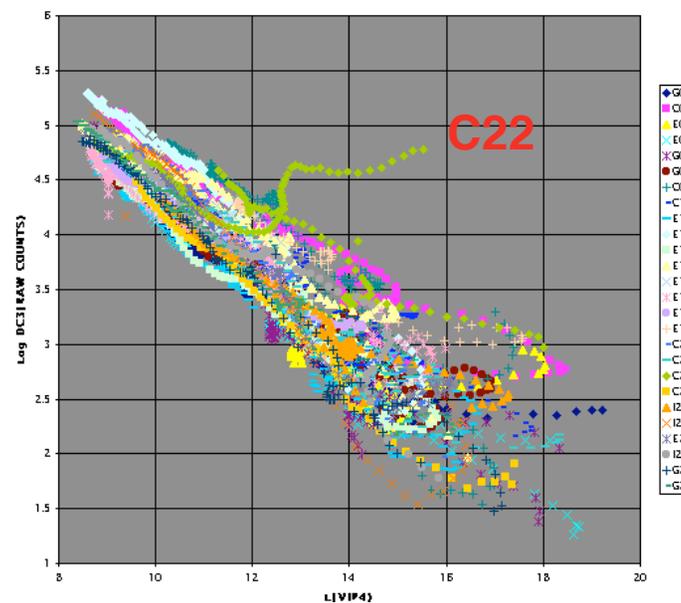
E_o = Constant (approximately breakpoint energy between low and high energy spectra)



RADIAL VS L-SHELL ORBITAL VARIATIONS



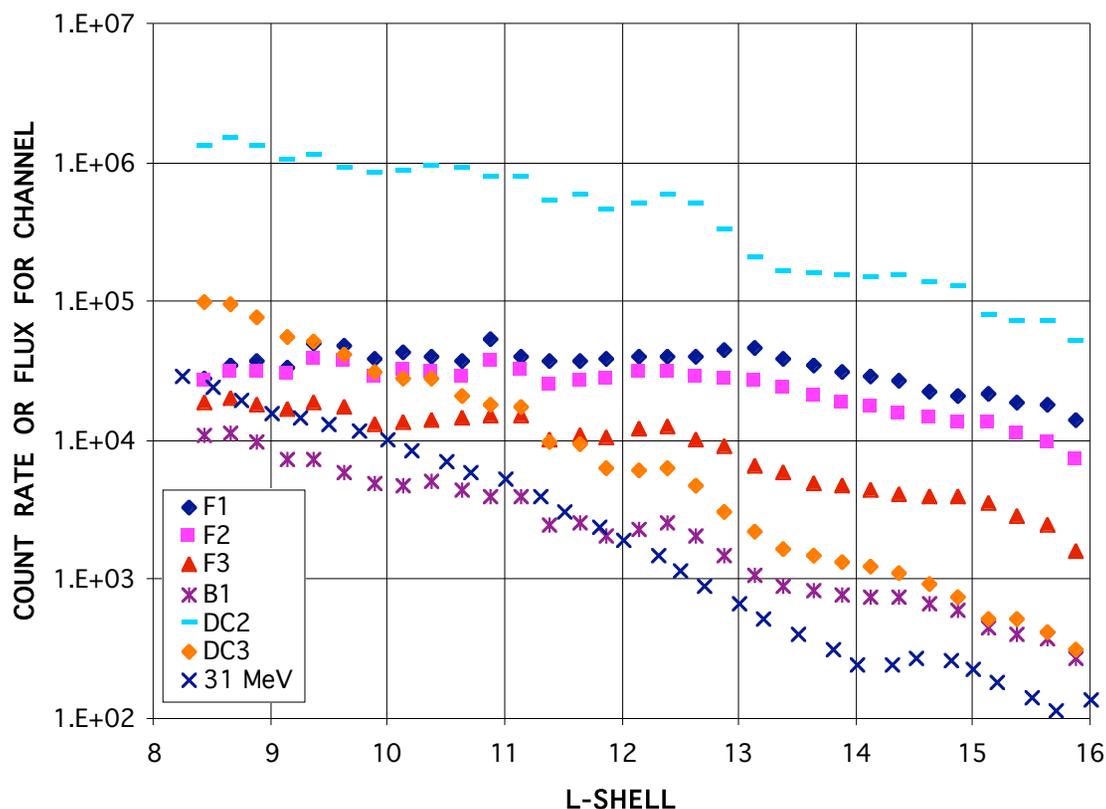
**DC3(11 MeV) Count Rates vs Rj
Orbits G02-G29**



**DC3(11 MeV) Count Rates vs L
Orbits G02-G29**



EPD COUNT RATE* AVERAGES VS L-SHELL

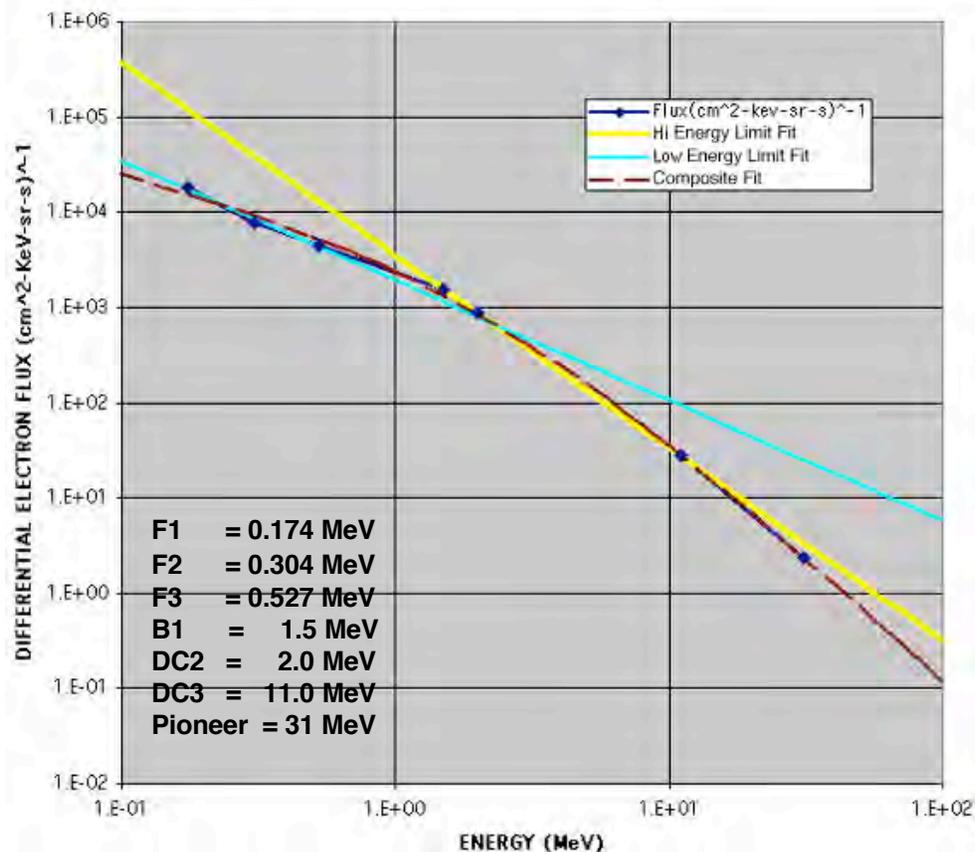


F1 = 0.174 MeV
F2 = 0.304 MeV
F3 = 0.527 MeV
B1 = 1.5 MeV
DC2 = 2.0 MeV
DC3 = 11.0 MeV
Pioneer = 31 MeV

*31 MeV Channel is Omni-Directional Flux



SPECTRAL FITTING PROCEDURE



$$F(E) = J_o E^{-A} \left(1 + \frac{E}{E_o}\right)^{-B}$$

Where:

F = Differential electron flux as function of E

E = Electron energy (MeV)

J_o = Constant (roughly differential flux at E = 1 MeV)

A = Constant (approximately power law index for low energy component)

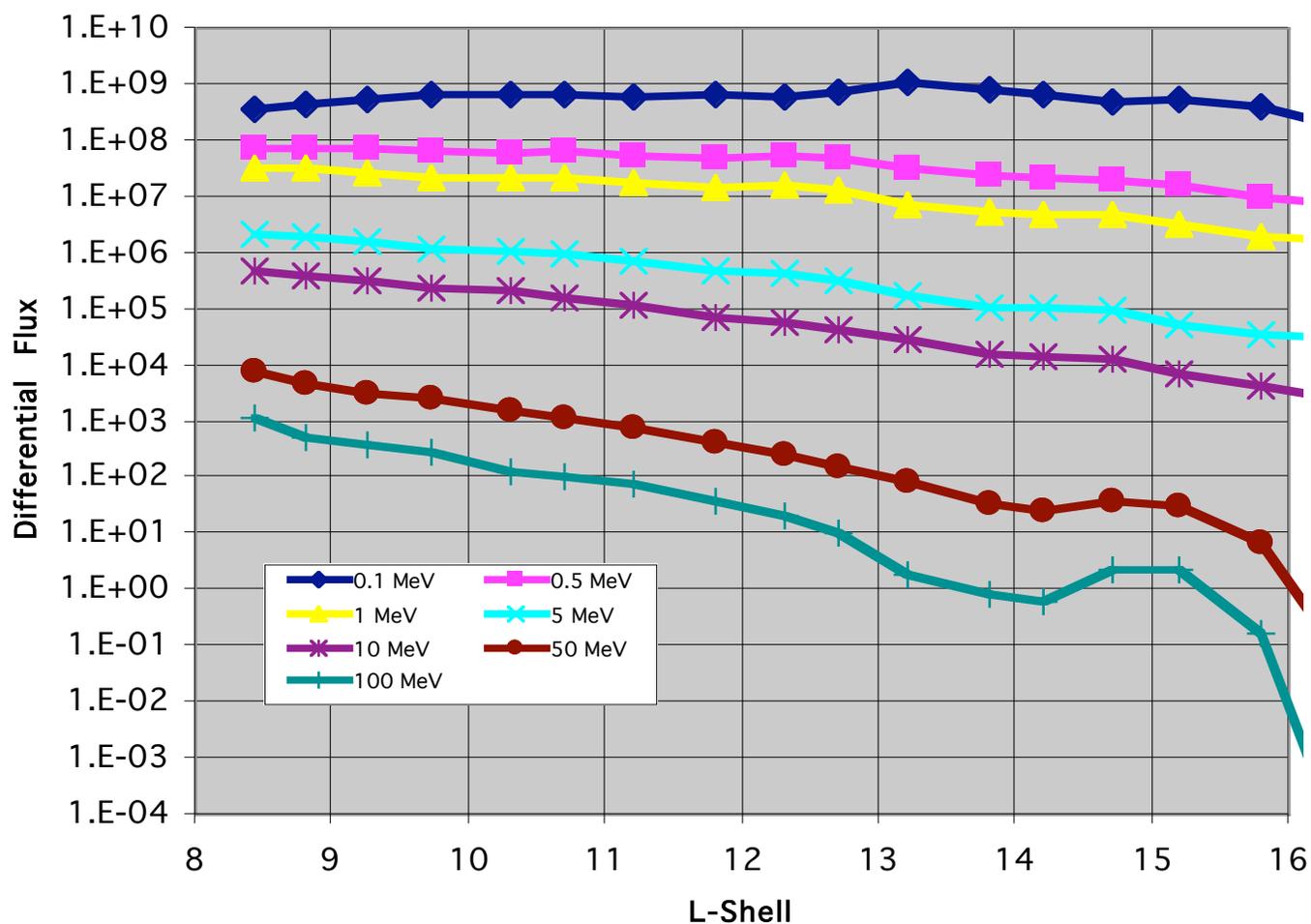
B = Constant (A+B is approximately power law index for high energy component)

E_o = Constant (approximately breakpoint energy between low and high energy spectra)



Galileo Interim Radiation Electron Model **JPL**

EPD OMNI-DIRECTIONAL ELECTRON MODEL FOR THE EQUATORIAL PLANE

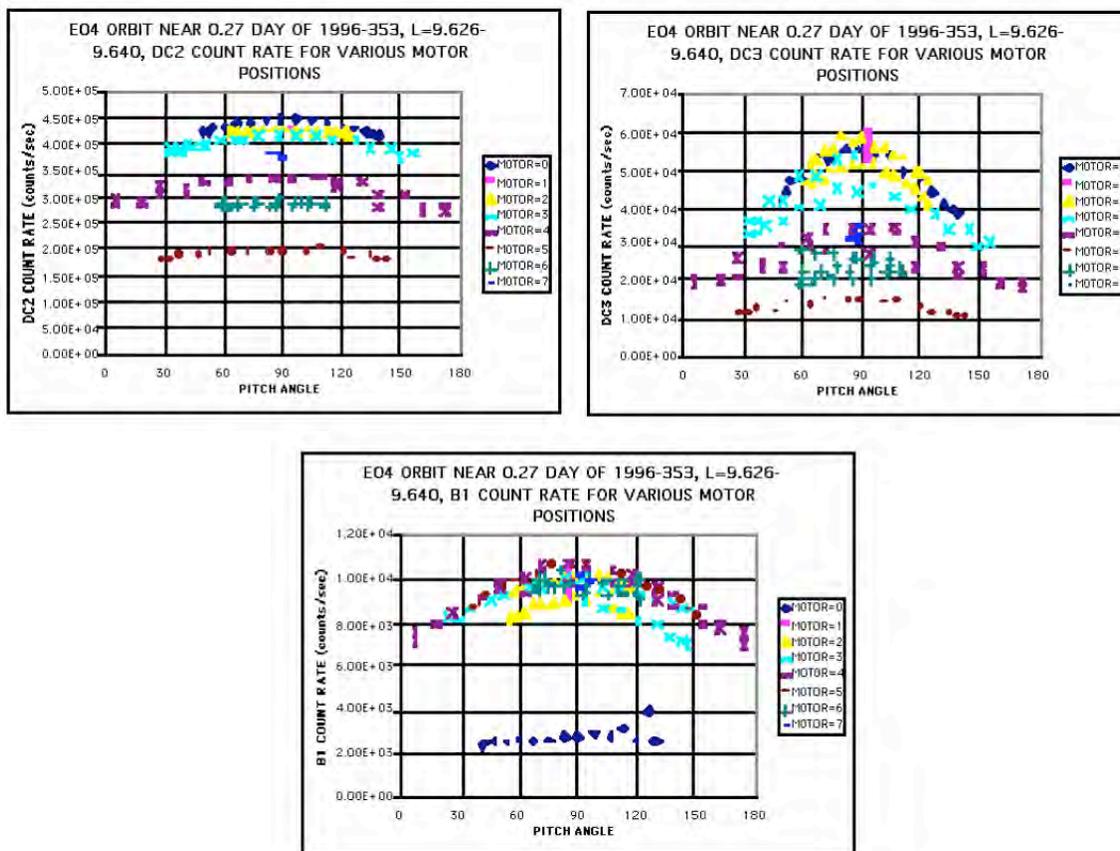


*Units = $(\text{cm}^2 \text{ s MeV})^{-1}$



Galileo Interim Radiation Electron Model **JPL**

PITCH ANGLE DISTRIBUTIONS

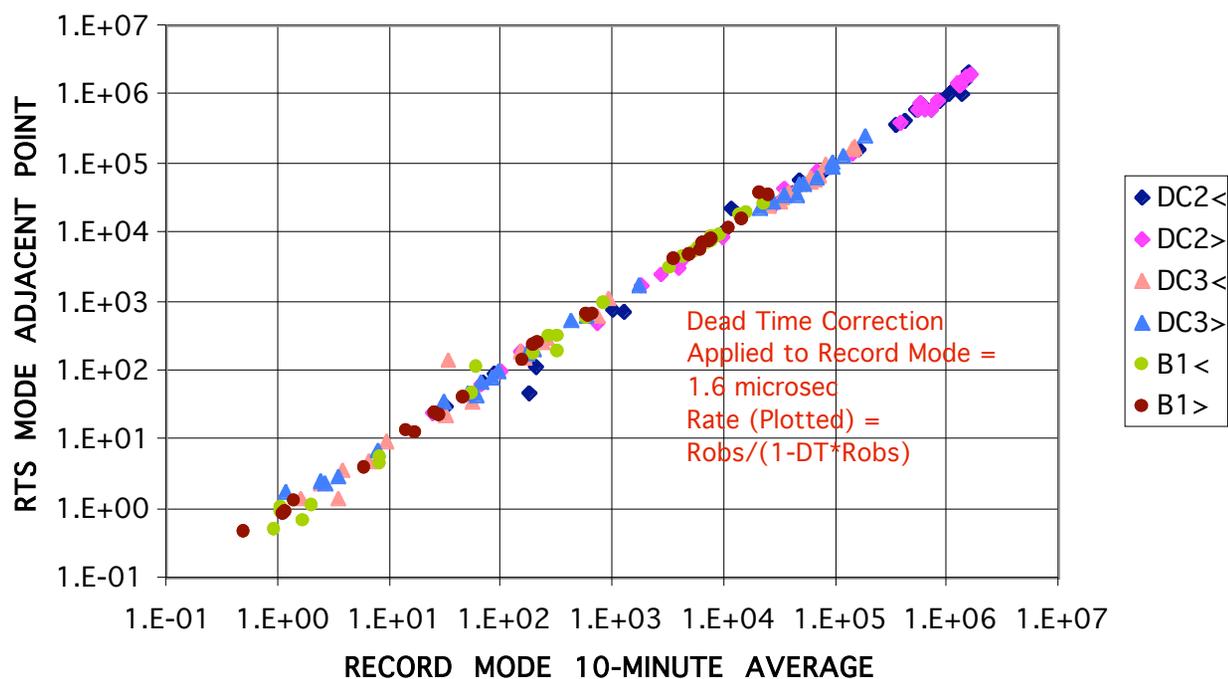


REPRESENTATIVE EXAMPLES OF THE PITCH ANGLE DISTRIBUTIONS FOR B1, DC2, AND DC3 FOR THE PLAYBACK DATA



Galileo Interim Radiation Electron Model **JPL**

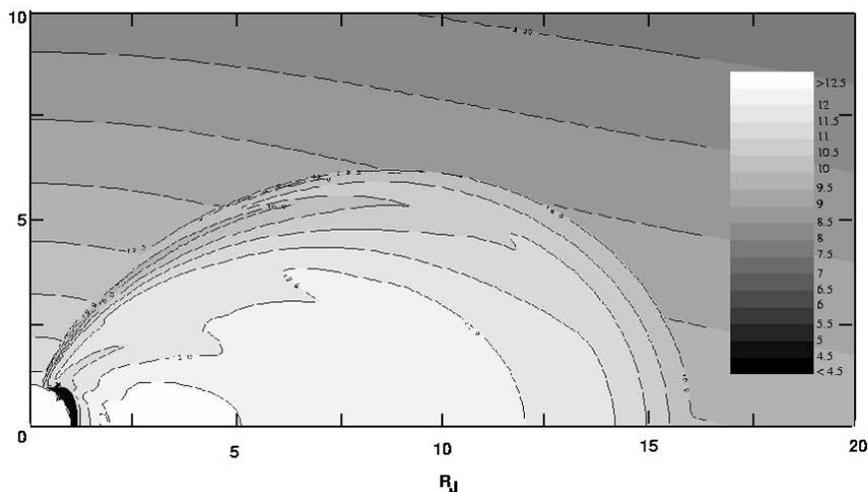
EPD PLAYBACK/RECORD MODE VS REAL TIME DATA





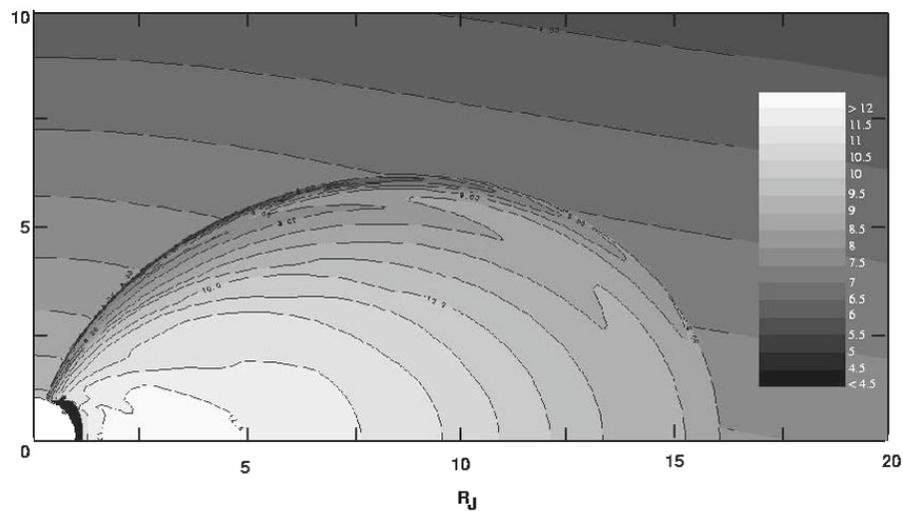
Galileo Interim Radiation Electron Model **JPL**

Divine Model Electron Fluences



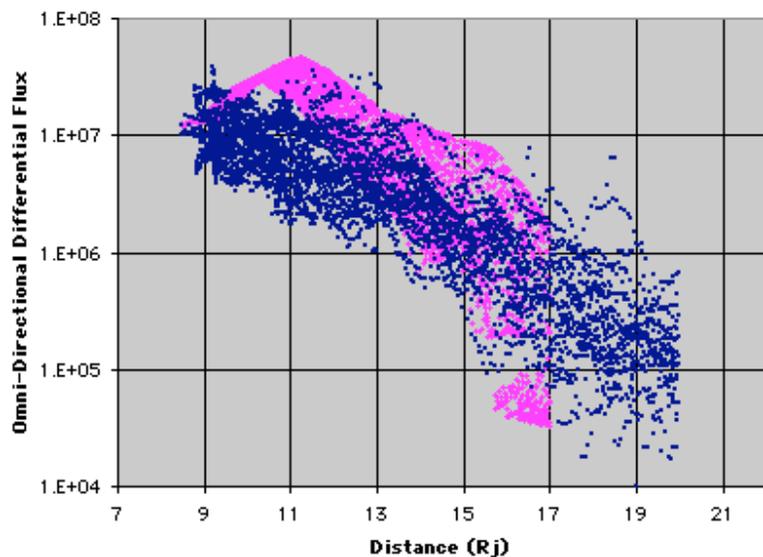
Contour plot of the $E > 1$ MeV high energy electron fluence (Log) at Jupiter as estimated from the Divine model. Fluences (cm^{-2}) are for a 10 hr period.

Contour plot of the $E > 10$ MeV high energy electron fluence (Log) at Jupiter as estimated from the Divine model. Fluences (cm^{-2}) are for a 10 hr period.

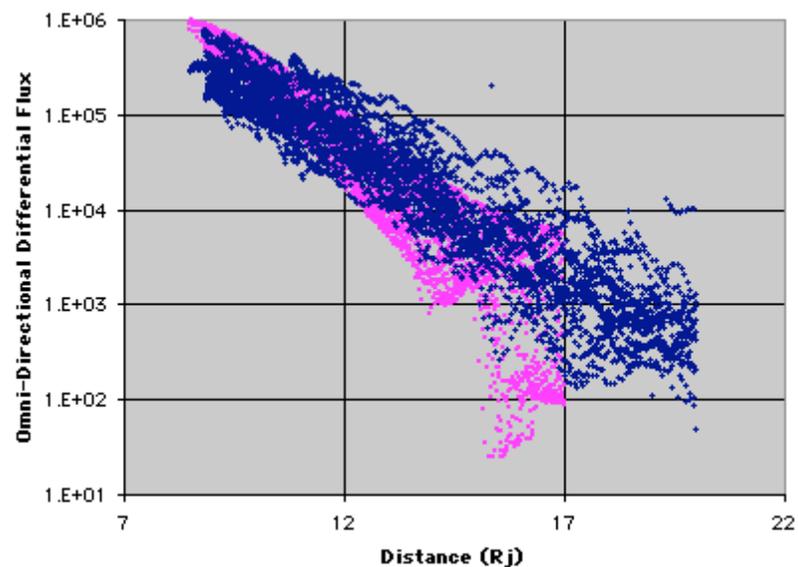




Divine Model Estimates vs GIRE Estimates



1.5 MeV ELECTRONS



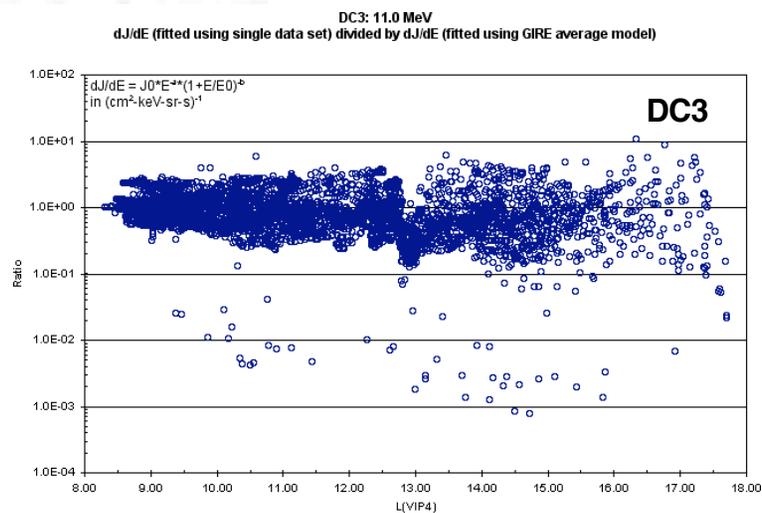
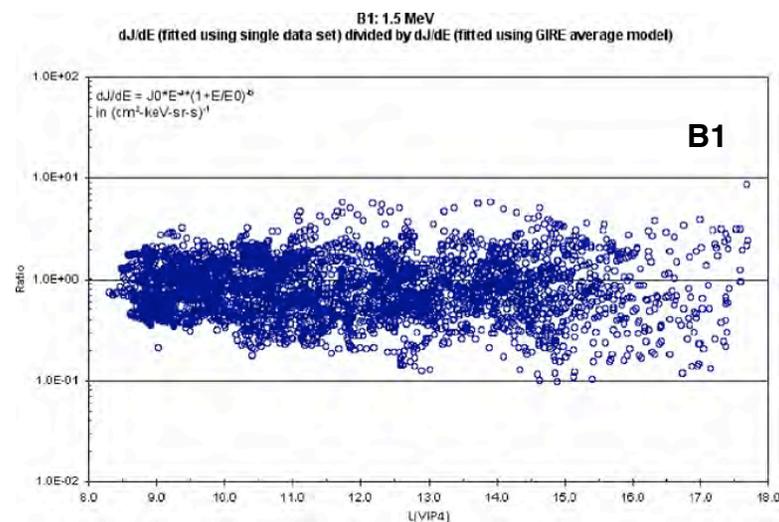
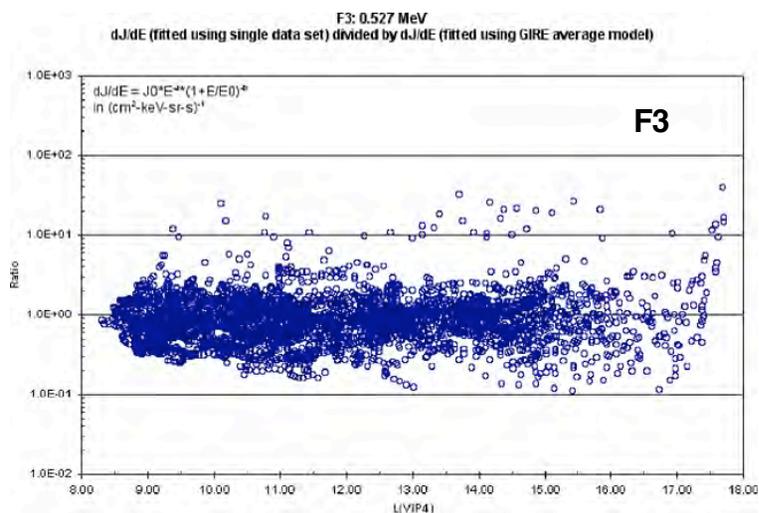
11 MeV ELECTRONS

Pink = Divine; Blue = GIRE



Galileo Interim Radiation Electron Model **JPL**

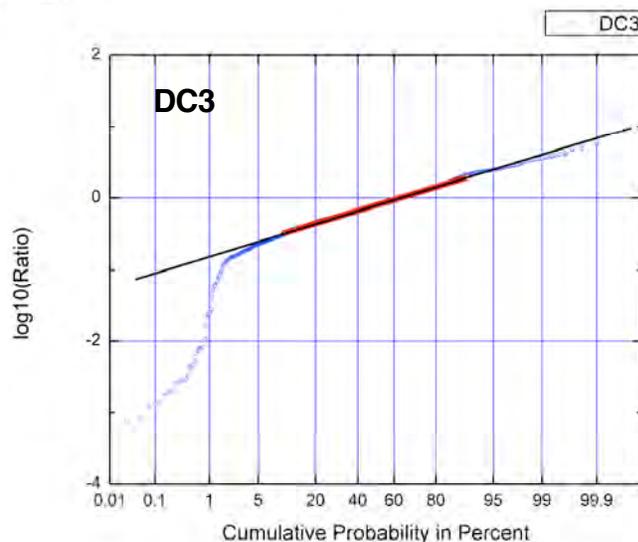
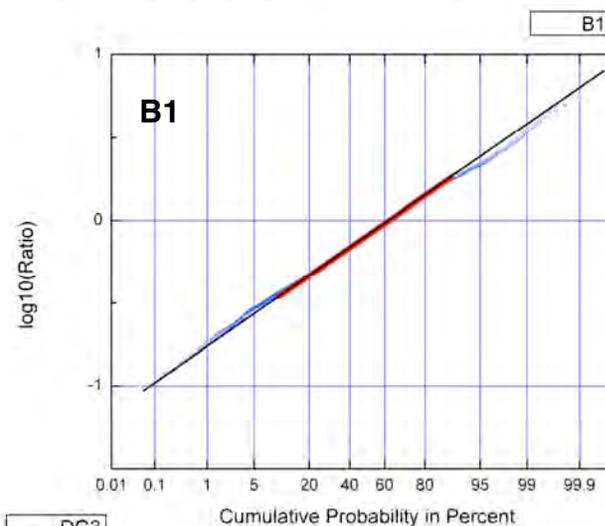
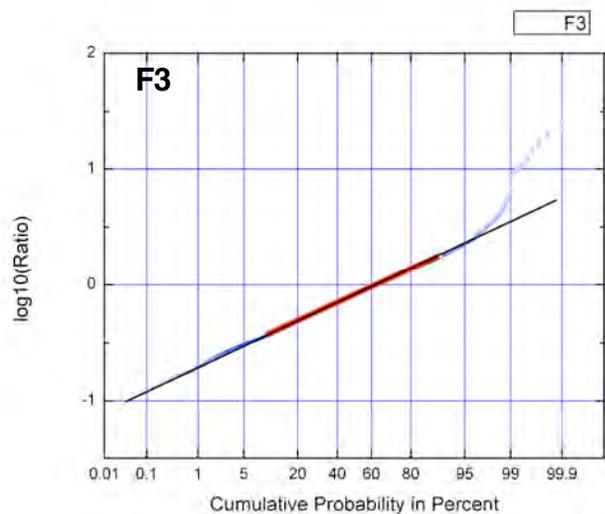
LOGARITHMS OF RATIO OF EPD FLUX OBSERVATIONS DIVIDED BY GIRE MODEL VERSUS L-SHELL





Galileo Interim Radiation Electron Model **JPL**

RATIOS OF EPD FLUX OBSERVATIONS DIVIDED BY GIRE MODEL RANK ORDERED BY FREQUENCY OF OCCURRENCE

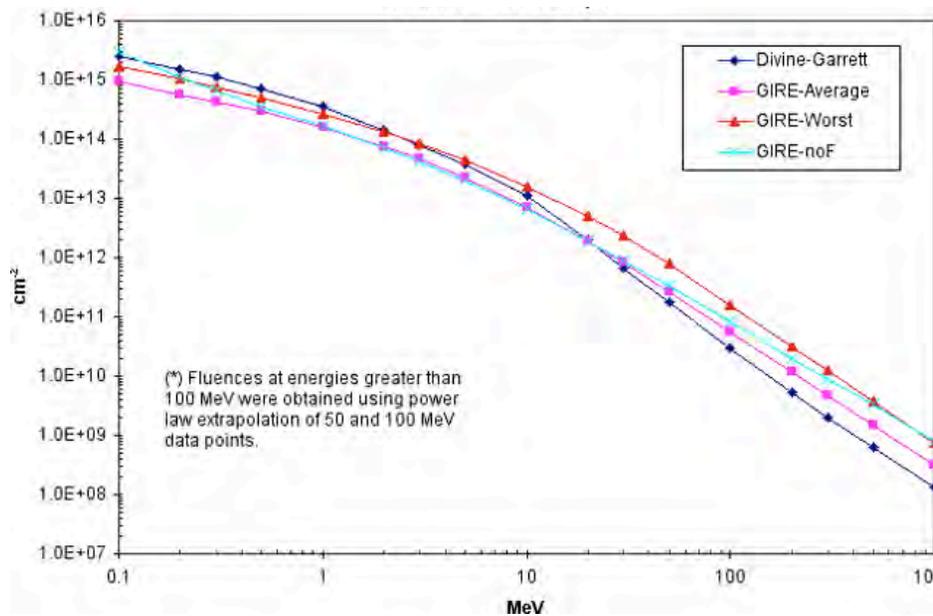


$$P(x) = \int_{-\infty}^x \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} dx$$



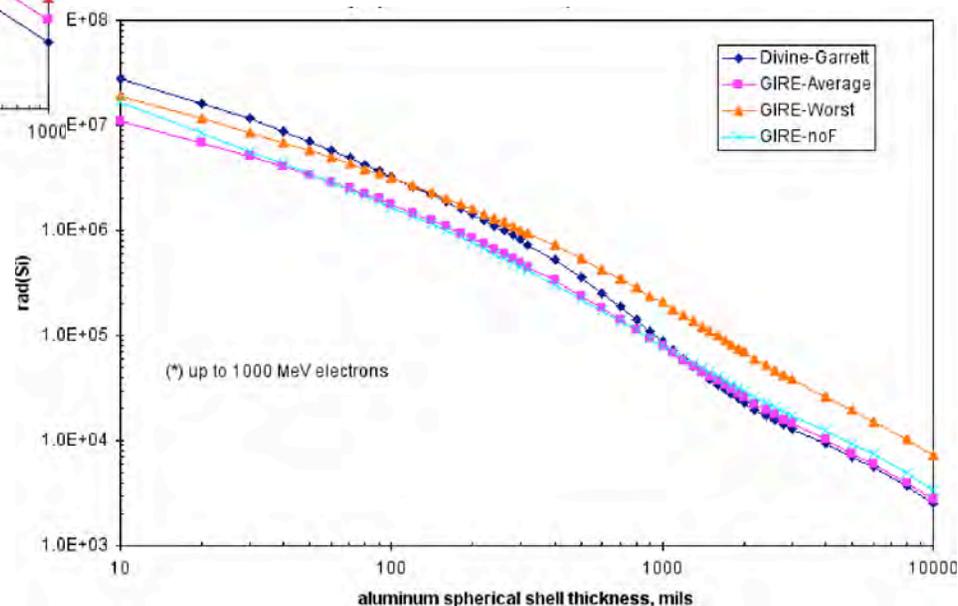
Galileo Interim Radiation Electron Model **JPL**

GIRE MODEL DOSE PREDICTIONS VS DIVINE MODEL FOR EUROPA MISSION



INTEGRAL ELECTRON FLUENCE

EUROPA MISSION DOSE





Galileo Interim Radiation Electron Model **JPL**

CONCLUSIONS

- **APL EPD 1-11 MEV ELECTRON DATA CONVERTED INTO FLUX ESTIMATES USING MODELED GEOMETRIC CROSS SECTIONS**
- **AVERAGE FLUXES FOR L = 8-16 FIT WITH CONTINUOUS SPECTRUM FOR ENERGIES 0.174-31MEV (EPD OMNI-DIRECTIONAL EQUATORIAL MODEL)**
- **DIVINE MODEL PITCH ANGLE VARIATIONS COMBINED WITH EPD MODEL TO GIVE GIRE MODEL FOR L=8-16**
- **STATISTICAL COMPARISONS SHOW LOG OF OBSERVED VS PREDICTED FLUXES CLOSELY FOLLOW GAUSSIAN DISTRIBUTION WITH SIGMA=2X**