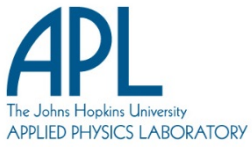
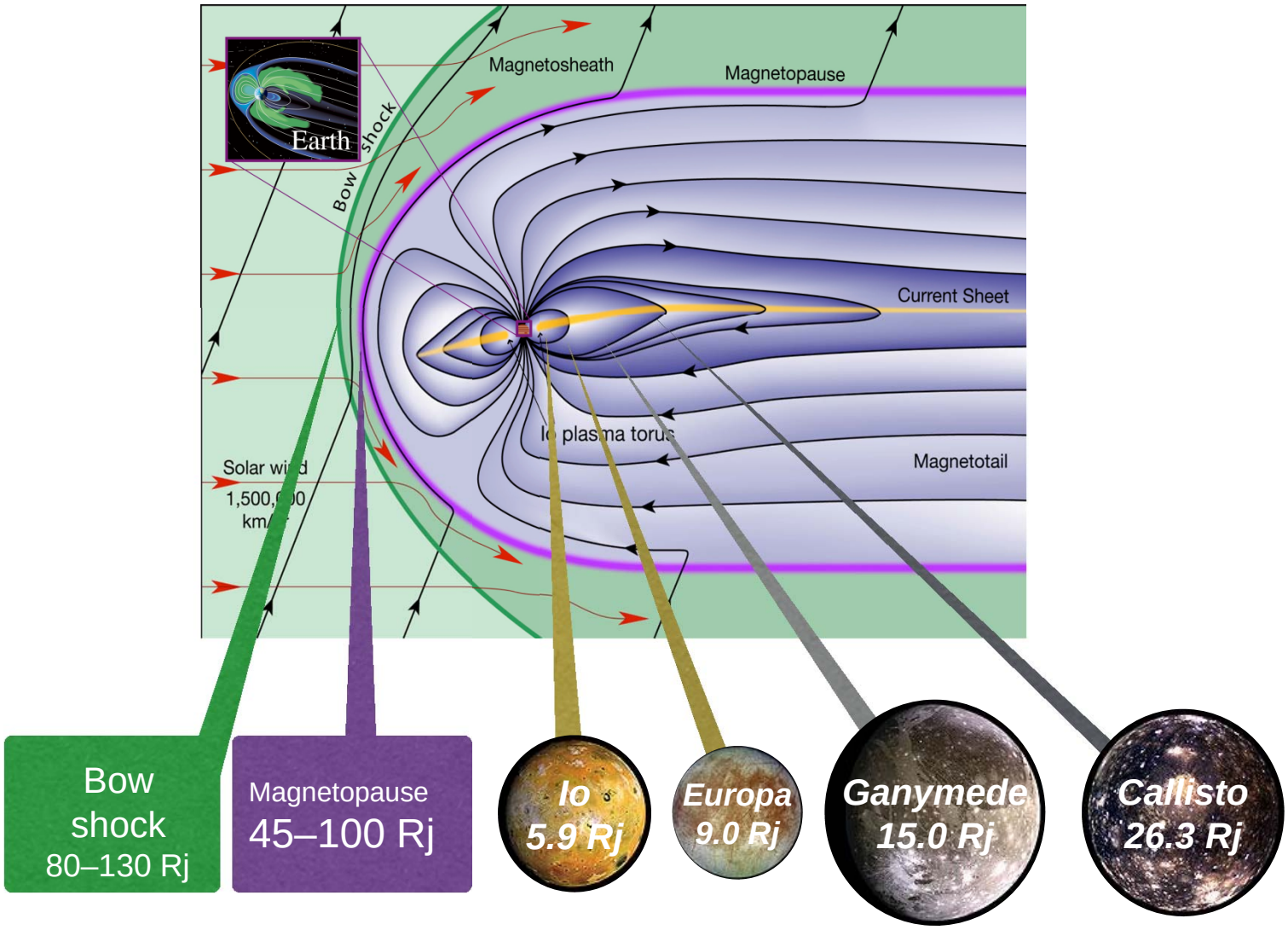
Environment models for JCAT
(Jupiter Charging Analysis Tools)

E. Roussos[1], Y. Futaana[2], X-D. Wang[2], P. Kollmann[3], J.-E. Wahlund[4], M. Fränz[1], N. Krupp[1], S. Barabash[2]

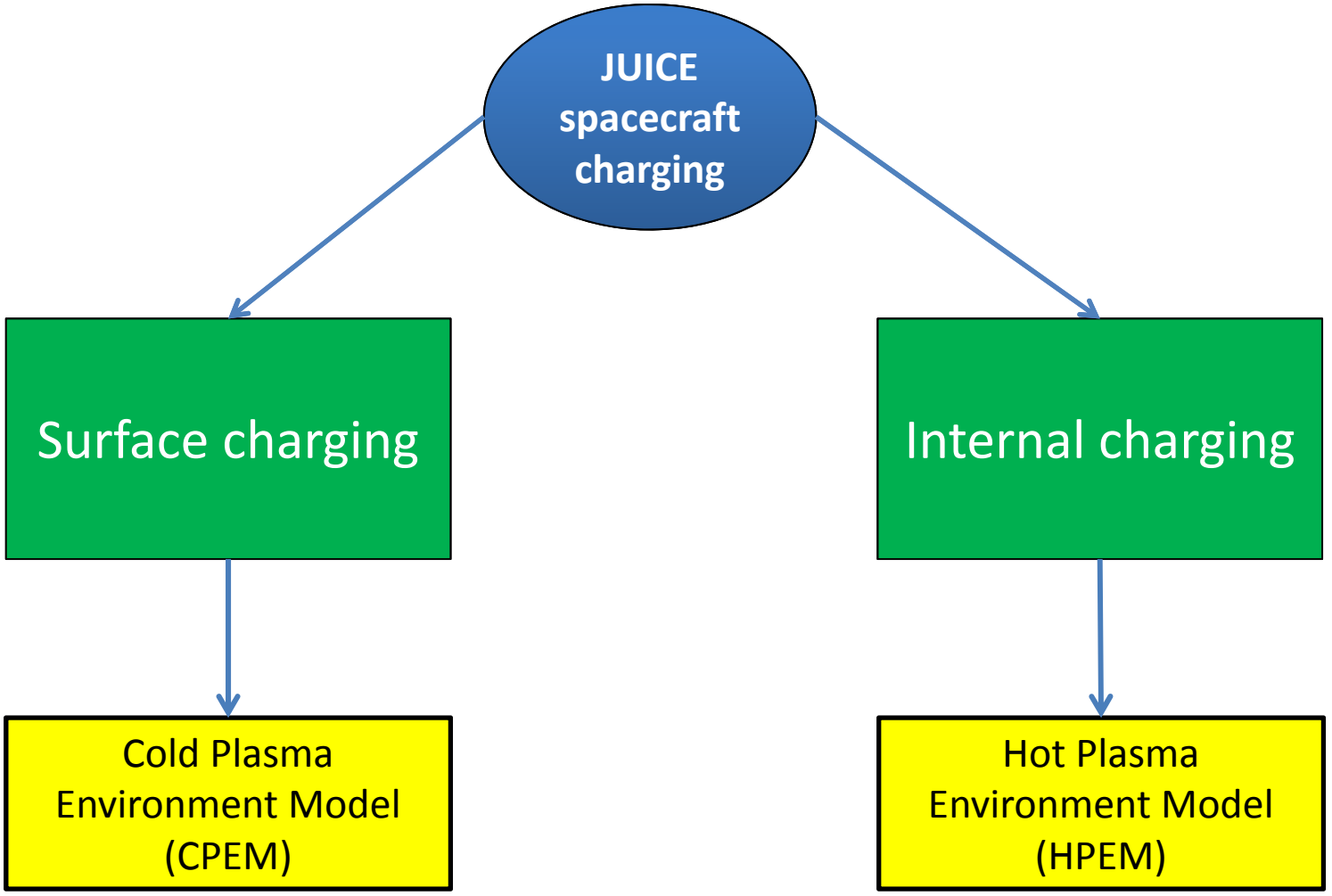
1: Max Planck Institute for Solar System Research, Göttingen, Germany
2: Swedish Institute for Space Physics, Kiruna, Sweden
3: Applied Physics Laboratory, Laurel, USA
4: Swedish Institute for Space Physics, Uppsala, Sweden



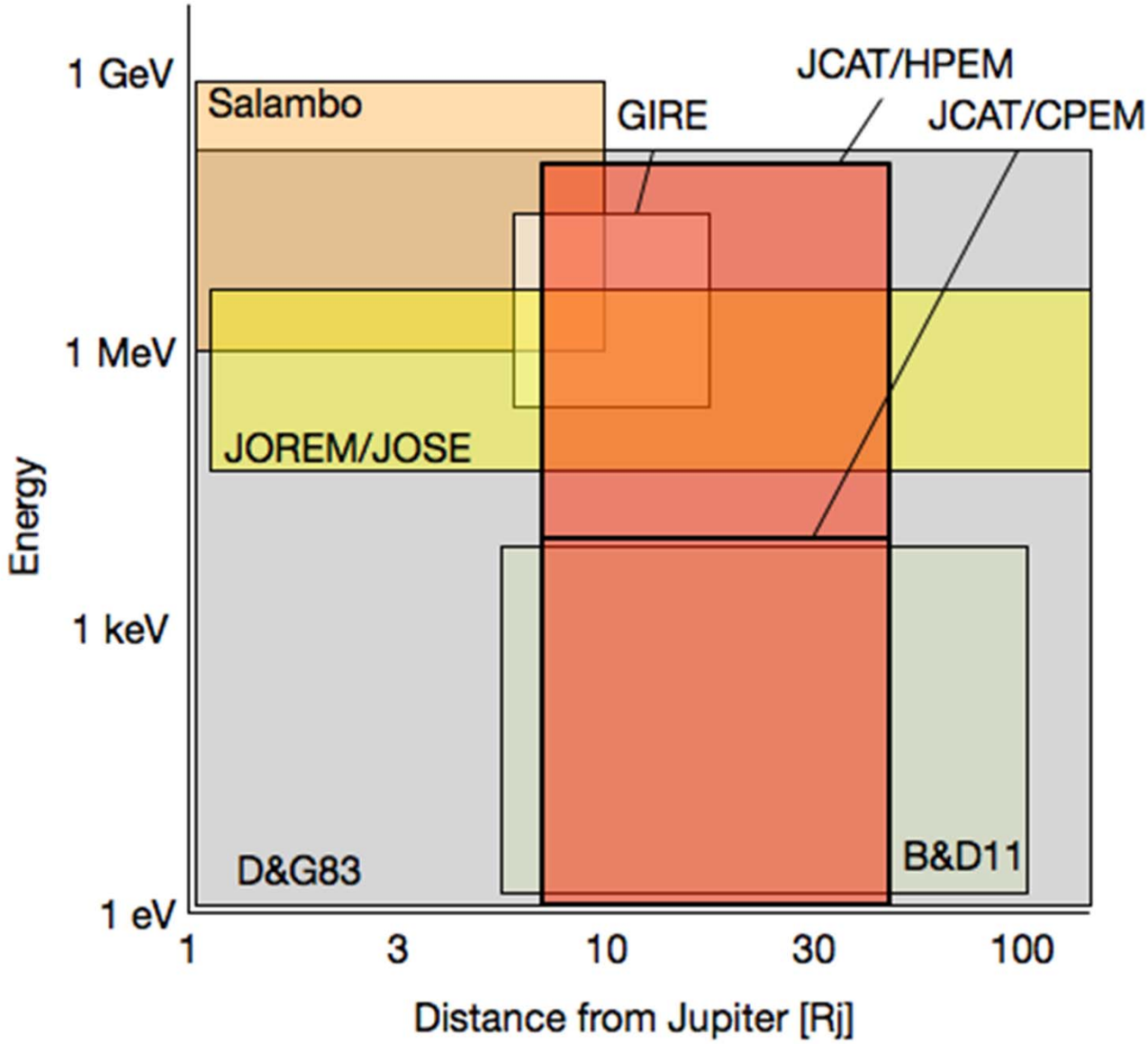
Introduction: Jupiter's magnetosphere



Motivation


JUICE spacecraft charging
Surface charging
Internal charging
Cold Plasma Environment Model (CPEM)
Hot Plasma Environment Model (HPEM)

Earlier models



Earlier model limitations

Cold plasma

- Based mostly on Pioneer 10/11 data
- Only mean models
- Limited distance/latitude applicability
- No temporal variations

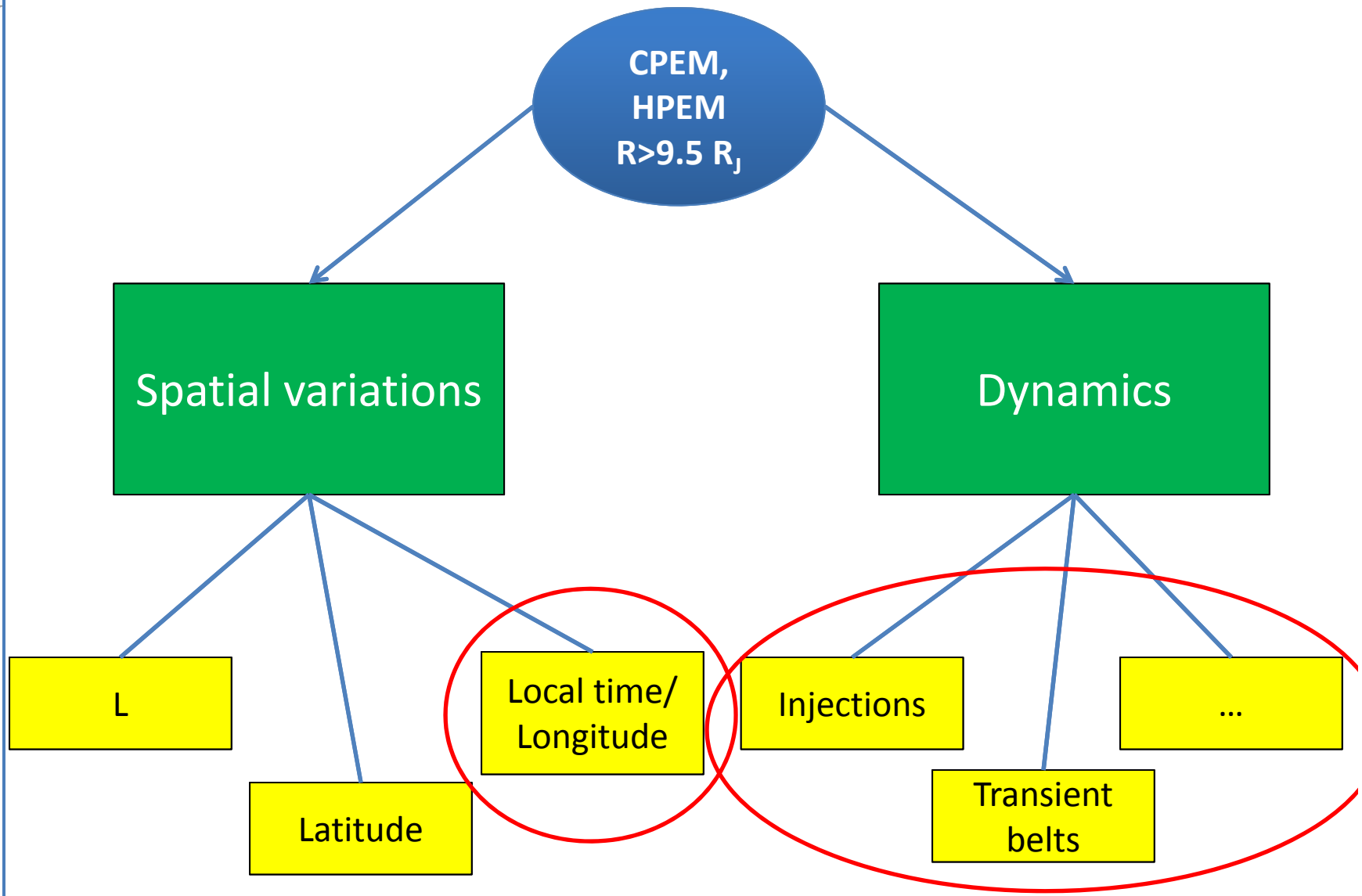
Energetic particles

- No temporal variations
- Mostly mean models

Both

- Data analysis challenges (penetrating radiation, corrupted data, saturation etc.)

Introducing temporal variations

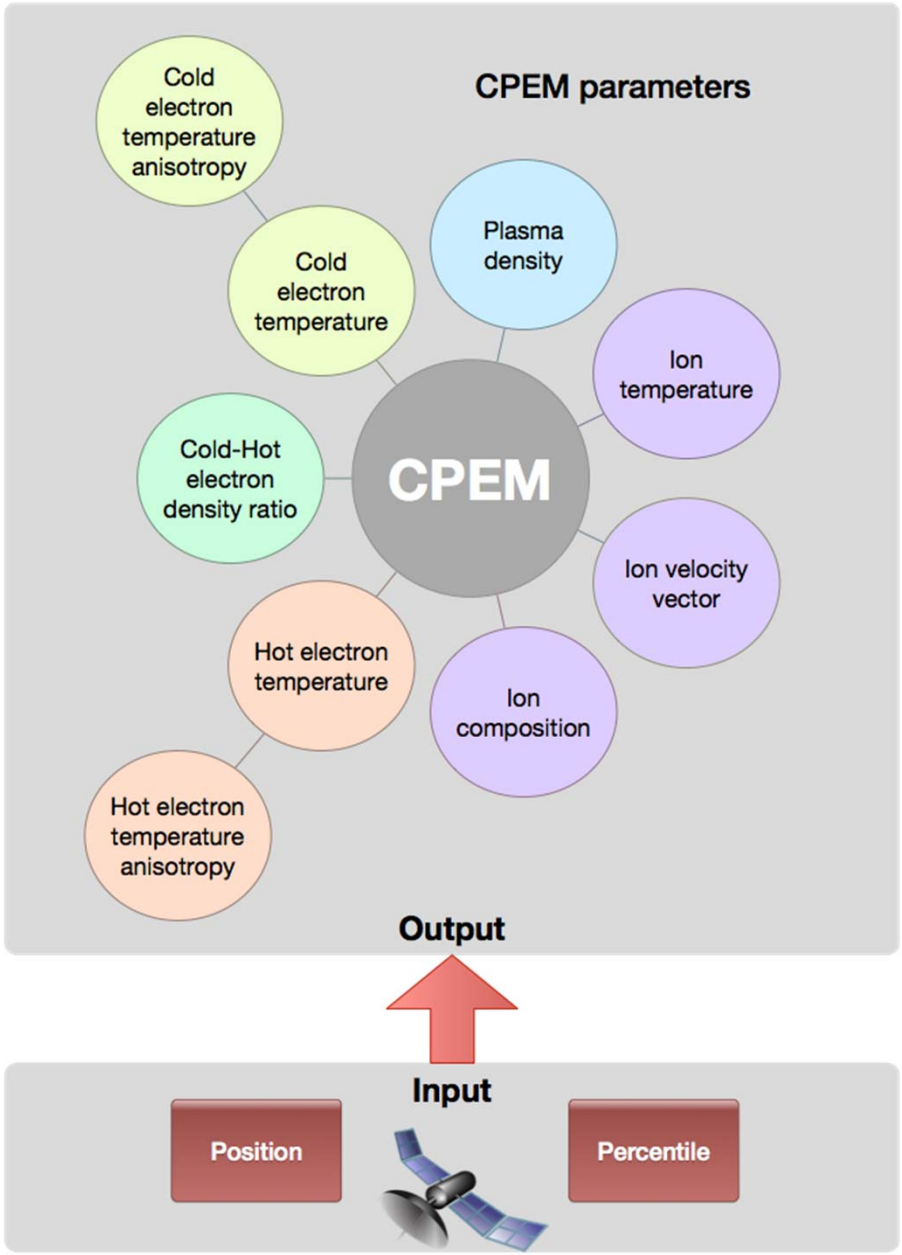


Cold Plasma Environment Model (CPEM)

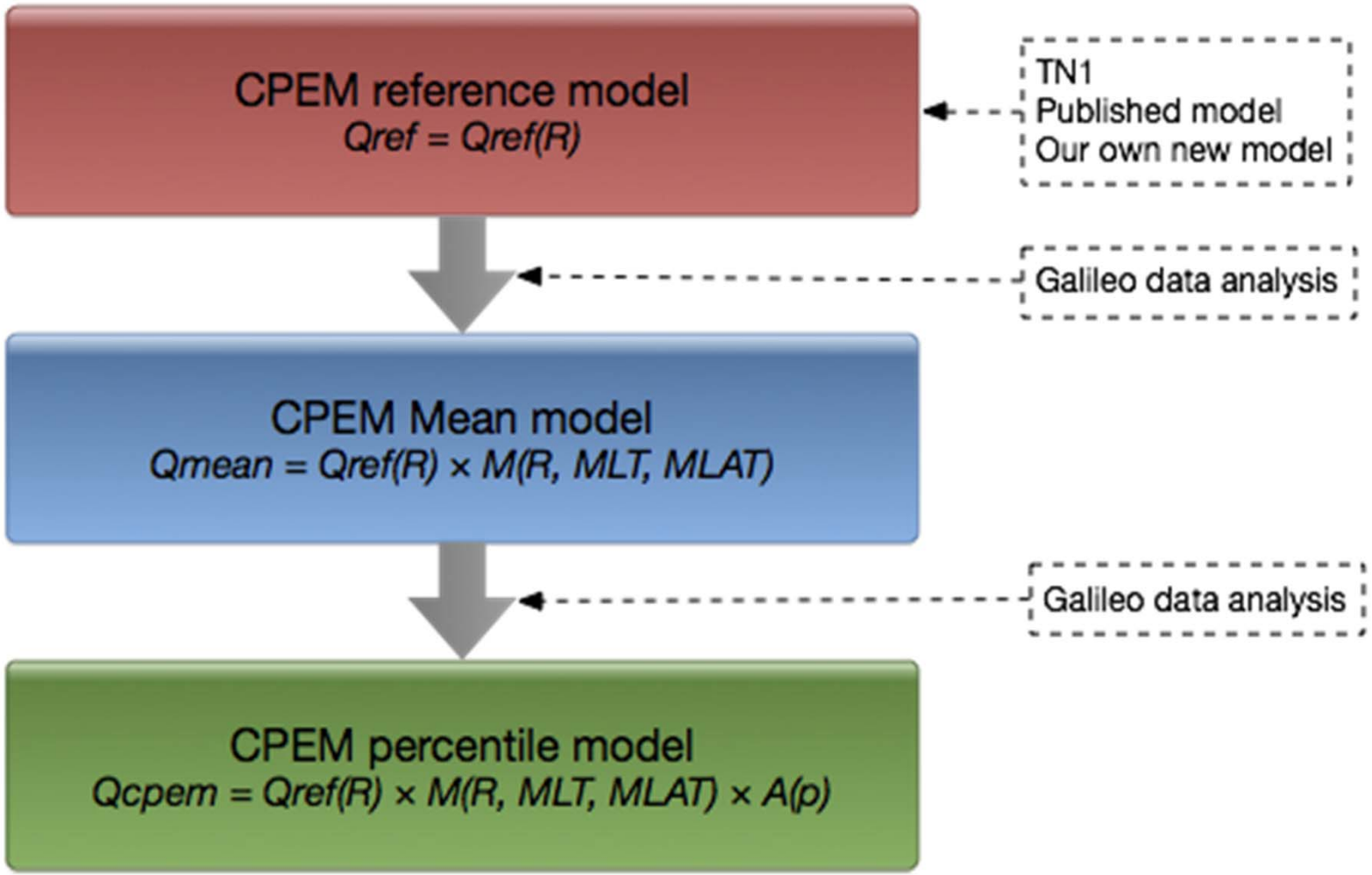
- Empirically derived
- All MHD parameters
- Distance, magnetic longitude and latitude (3-D)
- Probability model

  $$Q = Q(x, y, z; p)$$

- Based on Galileo/PLS electron and ion observations
- Ion moments provided by Fran Bagenal/Rob Wilson
- Electron observations re-analyzed



CPEM development concept



- ***Available magnetic latitude data is limited. Theoretical guess needed.***
- ***No inter-parameter dependence considered.***

CPEM example: plasma density

$$N_{JCAT}(r, MLT, MLAT; p) = N_{BD11}(r) \times A(p) \times M(r, MLT) \times ShM(r, MLAT)$$

reference model

probability coefficient

MLT coefficient

MLAT coefficient

$$N_{BD11}(r) = 1987 \times (R/6)^{-8.2} + 14 \times (R/6)^{-3.2} + 0.05 \times (R/6)^{-0.65}$$

$$A(p) = \exp(-0.802467 + 0.0163519 * p)$$

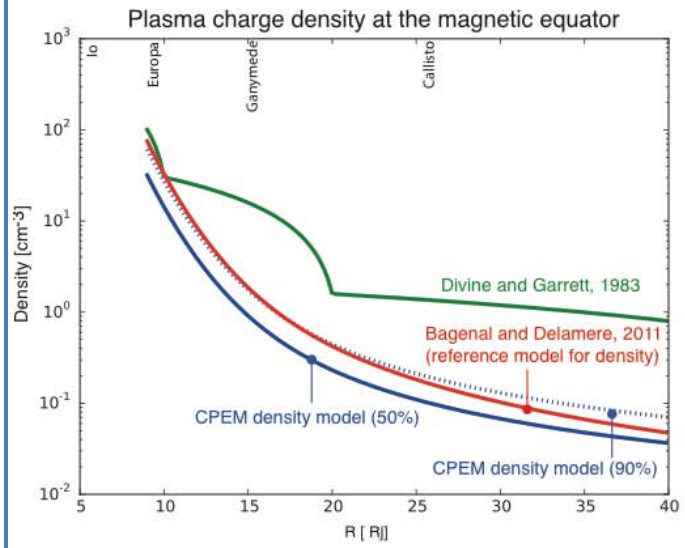
$$M(r, MLT) = c0 + c1 * r$$

$$c0 = 0.1991 \sin(MLT + 3.05hr) + 0.3469$$

$$c1 = -0.01380 \sin(MLT + 3.80hr) + 0.02883$$

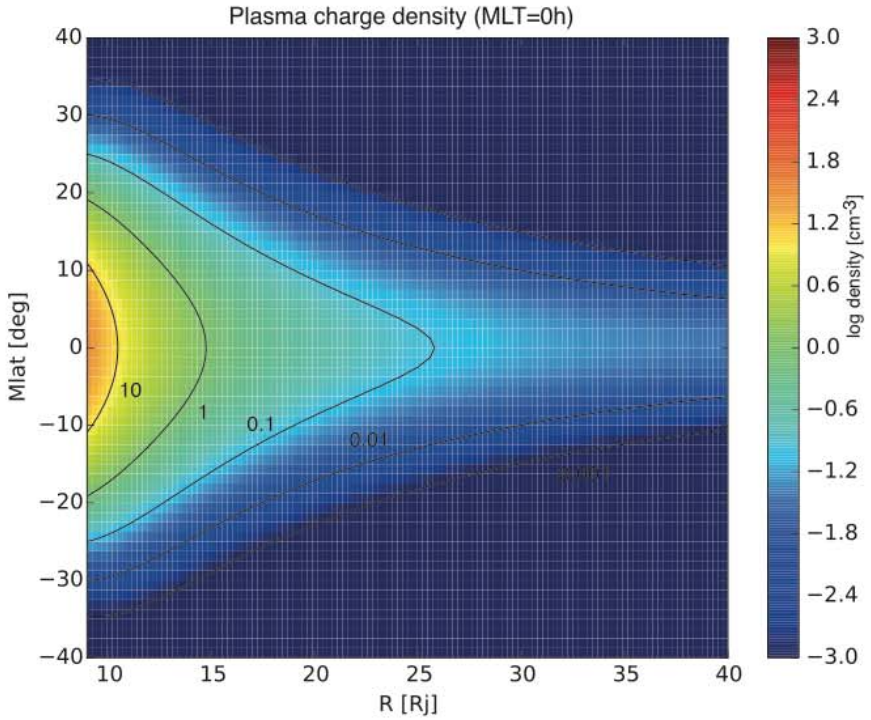
$$ScM(r, MLAT) = \exp(-(r \sin(MLAT)/H)^2)$$

CPEM example: plasma density



(Top) Derived plasma charge density model and its comparison with existing models. Two probability models, 50% (median) and 90% (extreme) are shown.

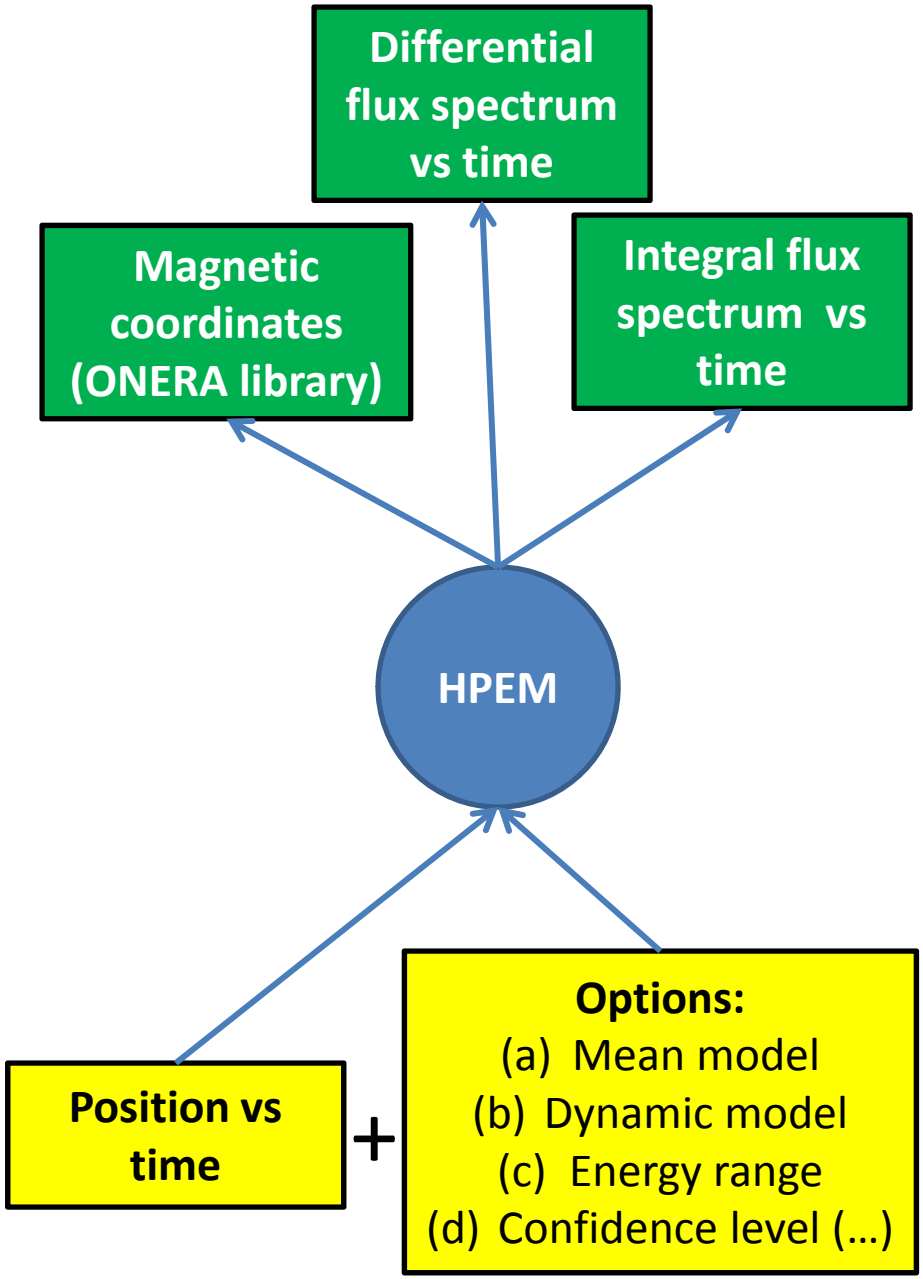
(Right) Median model in 2D representation at MLT=0h.



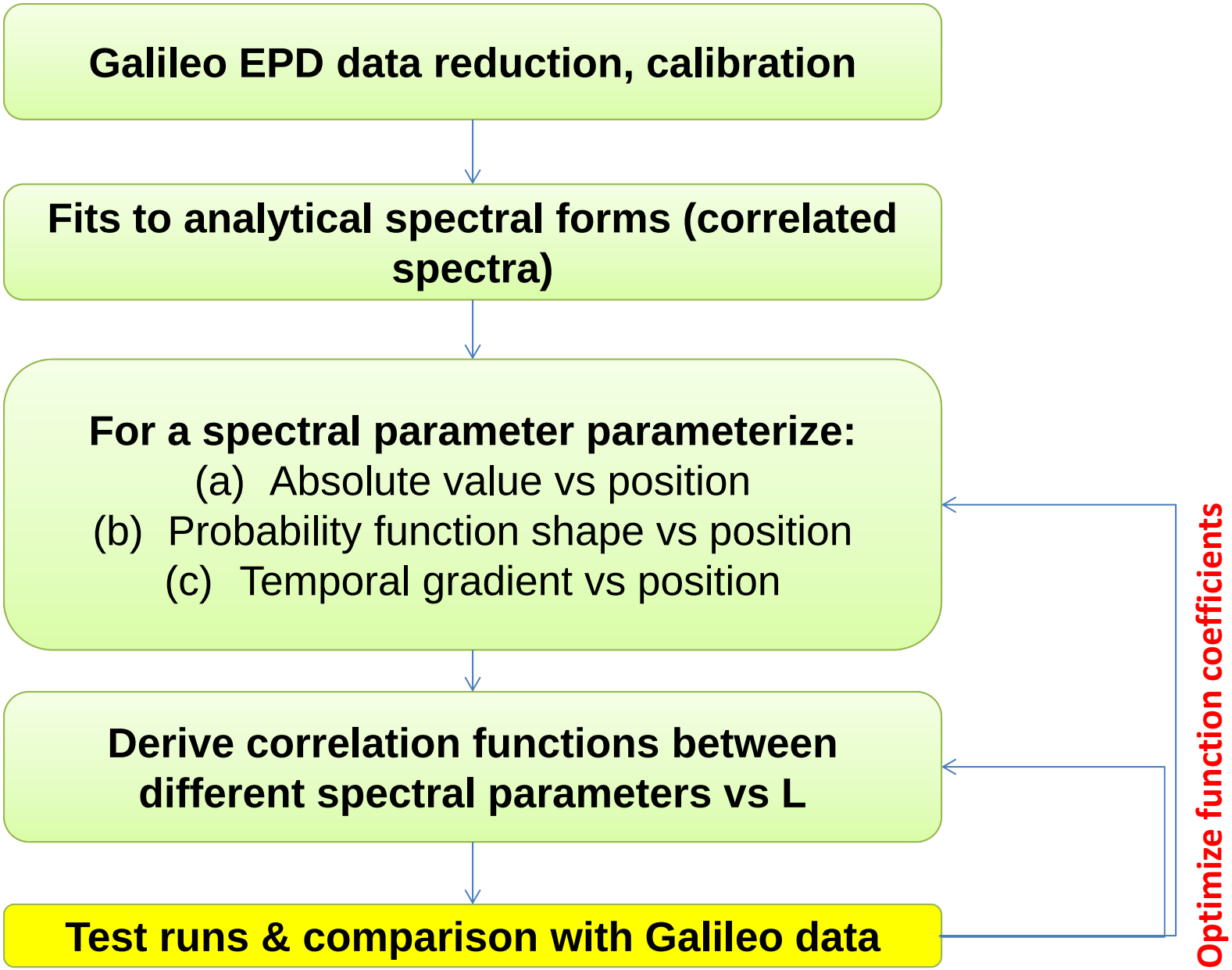
CPEM will be available soon!

Hot Plasma Environment Model (HPEM)

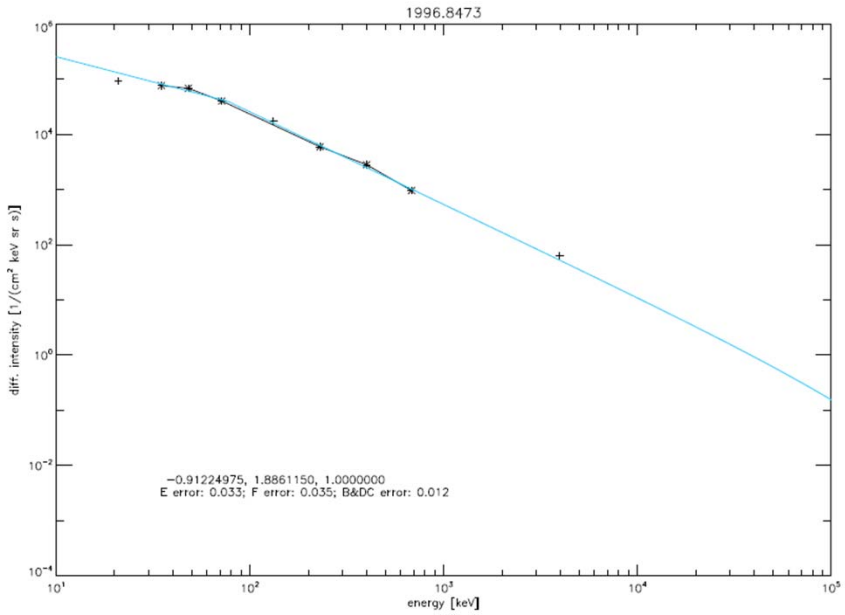
- Empirically derived
- L, local time,latitude (3-D) and time (9.5< R < 100 Rj)
- Electron spectra as a function of time (150 keV – 50 MeV), arbitrary energy resolution, time resolution >11 min
- Correlated electron spectra
- Mean model + Monte Carlo probability code
- Based on Galileo/EPD electron data (+ Pioneer 10/11 for constraints above 20 MeV)



HPEM development concept

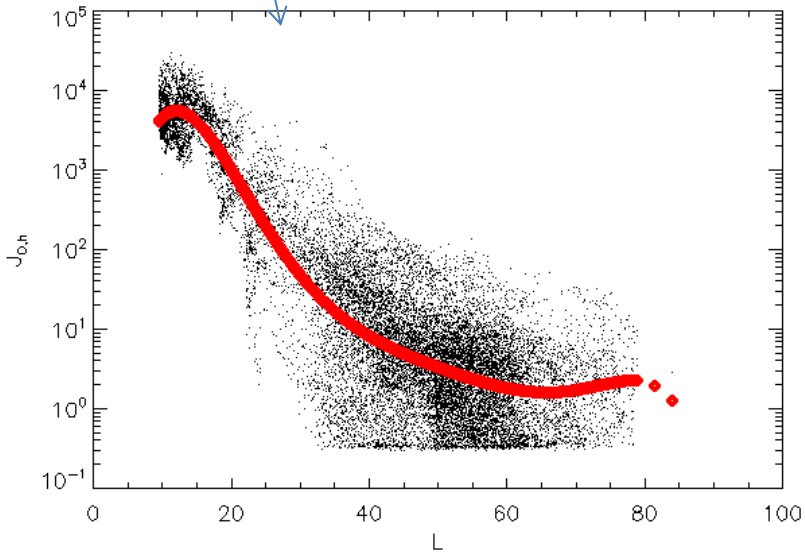


HPEM data analysis (1)



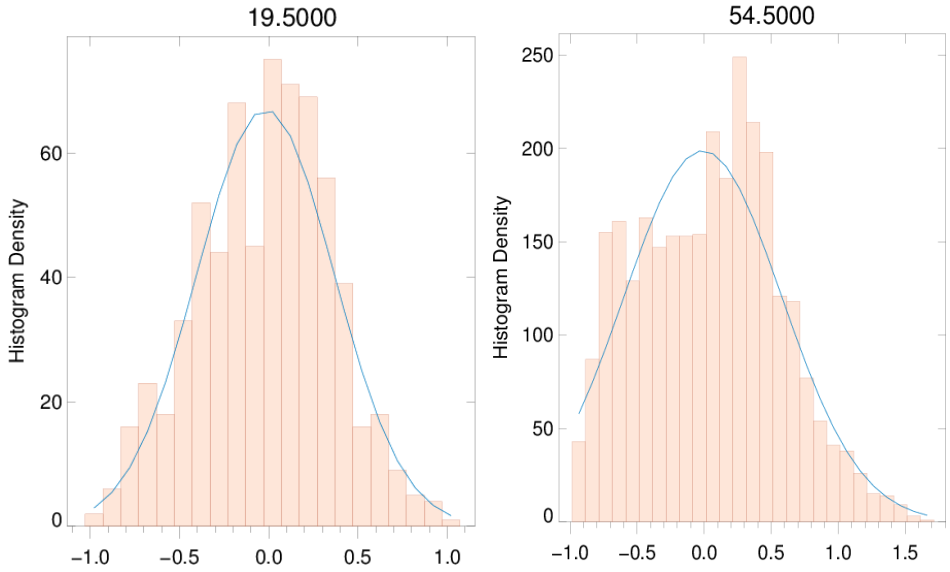
$$j_{high} = j_{Oh} E^{\gamma} \left(1 + \frac{E}{E_c}\right)^{\lambda} \frac{1}{E_o^{\gamma} \left(1 + \frac{E_o}{E_c}\right)^{\lambda}}$$

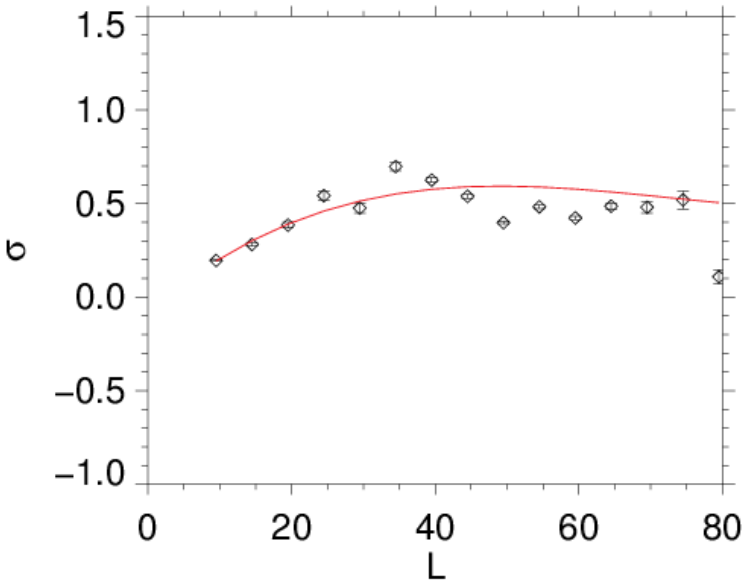
- Use analytical functions to describe $j_{o,h}$ or $log(j_{o,h})$
- Describe local time/latitude variations, where they exist



HPEM data analysis (2)

To quantify dynamics, we model the scatter of $\mathbf{LOG_{10}(j_{o,h})}$ using gaussian distribution fits as a function of L

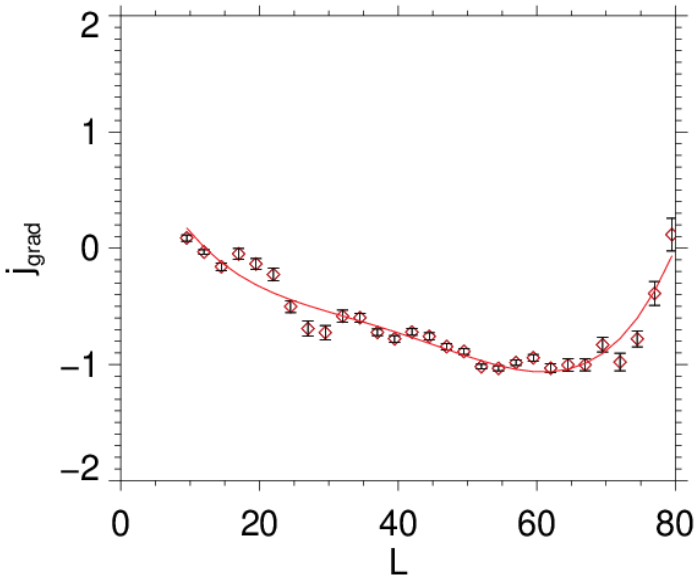


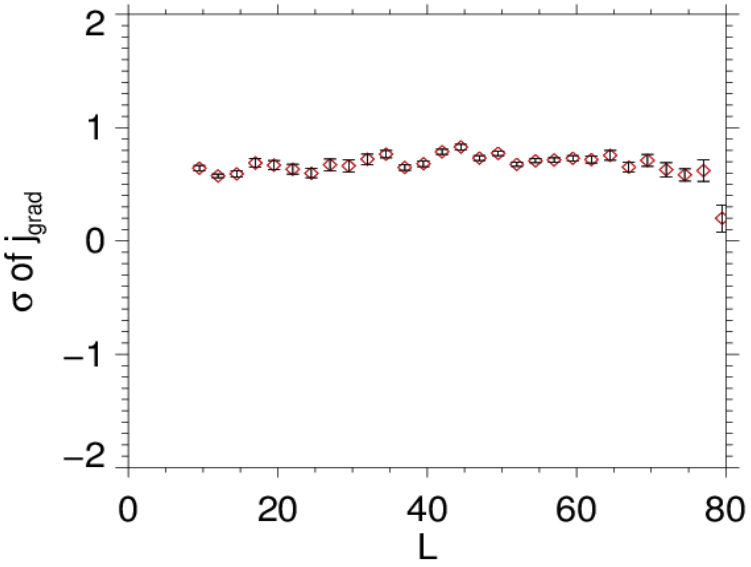


HPEM data analysis (3)

- We also constrained the total (temporal and spatial) gradient of $\mathbf{LOG_{10}(j_{o,h})}$. We evaluated it as an L-gradient
- Using the EPD time series we estimated:

$$\boldsymbol{k = \frac{dj_{o,h}}{dL}} \;\&\; \boldsymbol{j_{grad} = LOG(\frac{|k|}{j_{o,h}})}$$

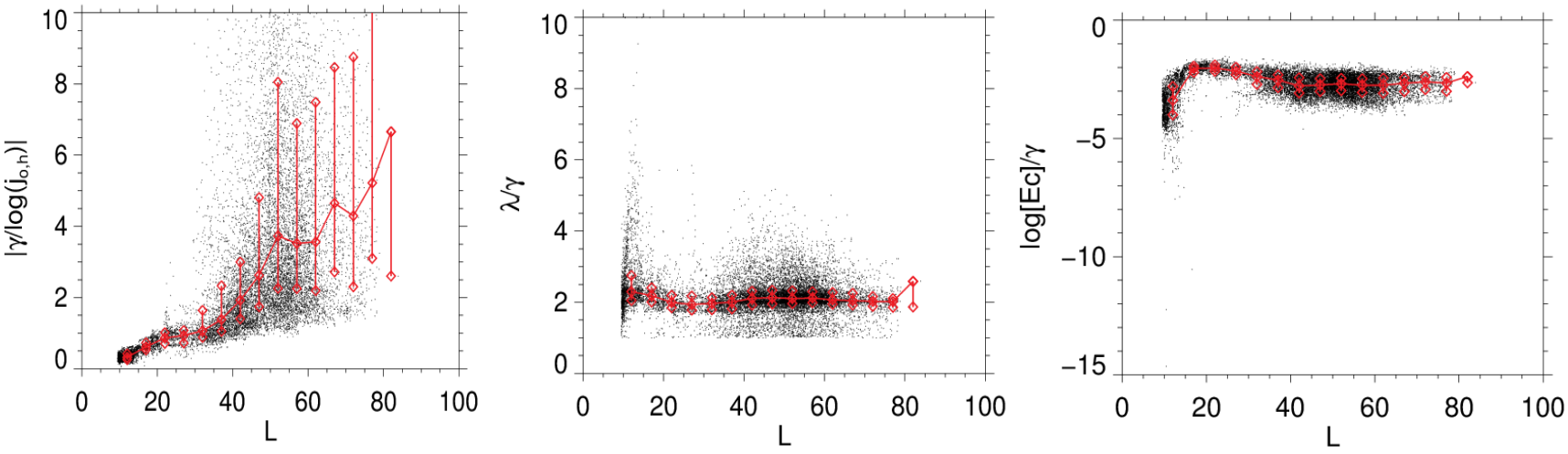




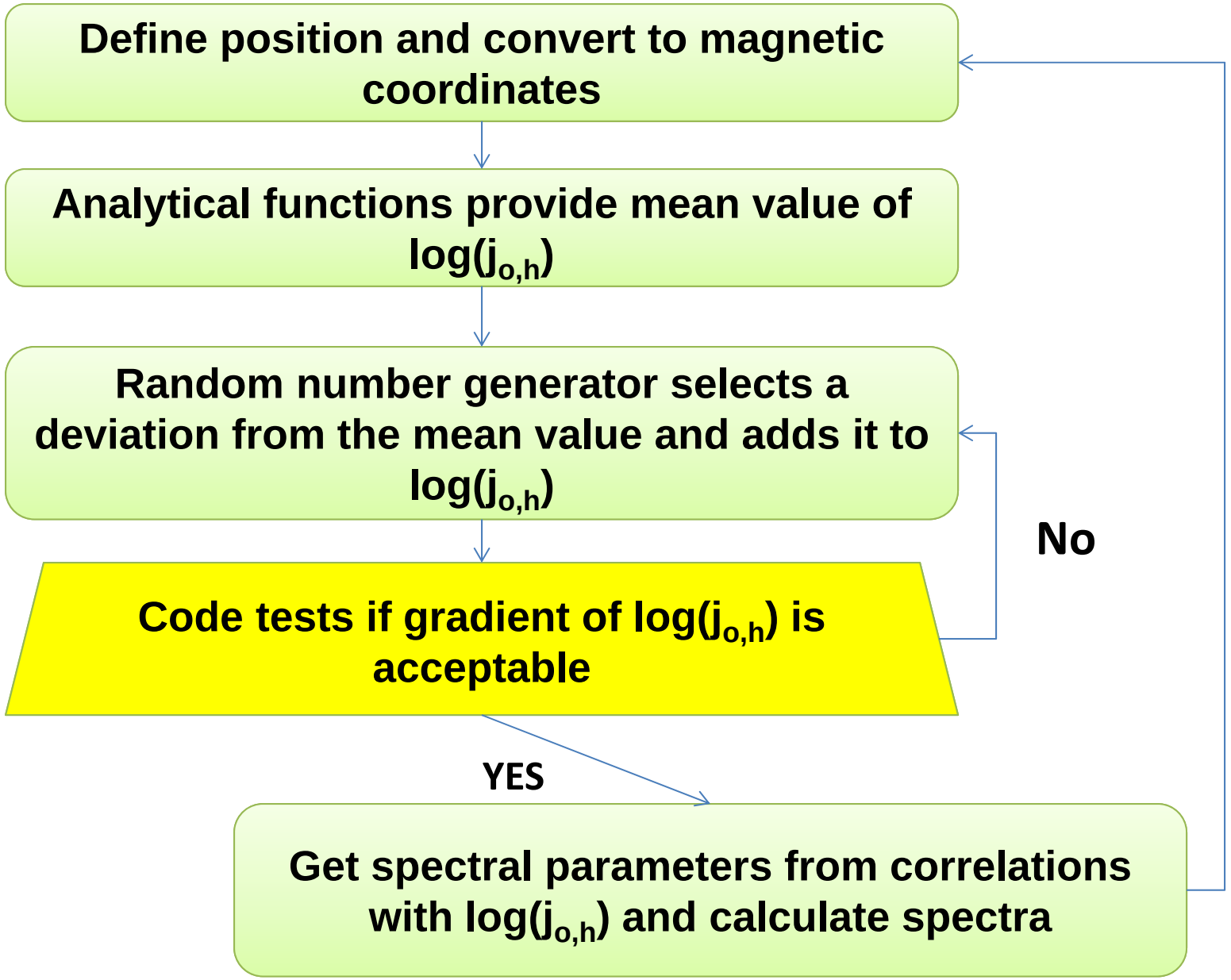
HPEM data analysis (4)

- Using **$LOG_{10}(j_{o,h})$** as a basis, we obtain the other spectral parameters using correlation functions:

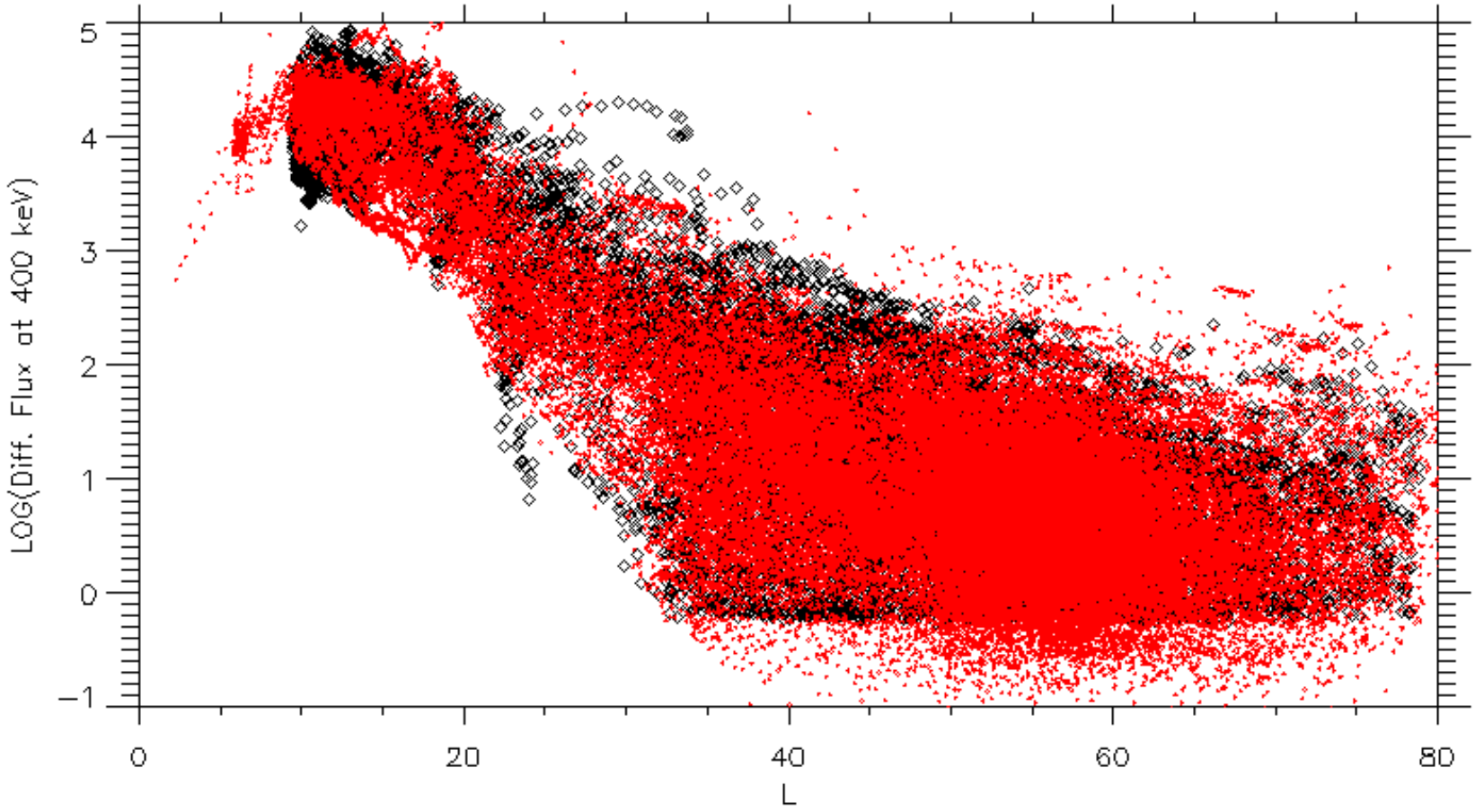
$$j_{high} = j_{OH} E^{\gamma} \left(1 + \frac{E}{E_c}\right)^{\lambda} \frac{1}{E_o^{\gamma} \left(1 + \frac{E_o}{E_c}\right)^{\lambda}}$$



HPEM implementation

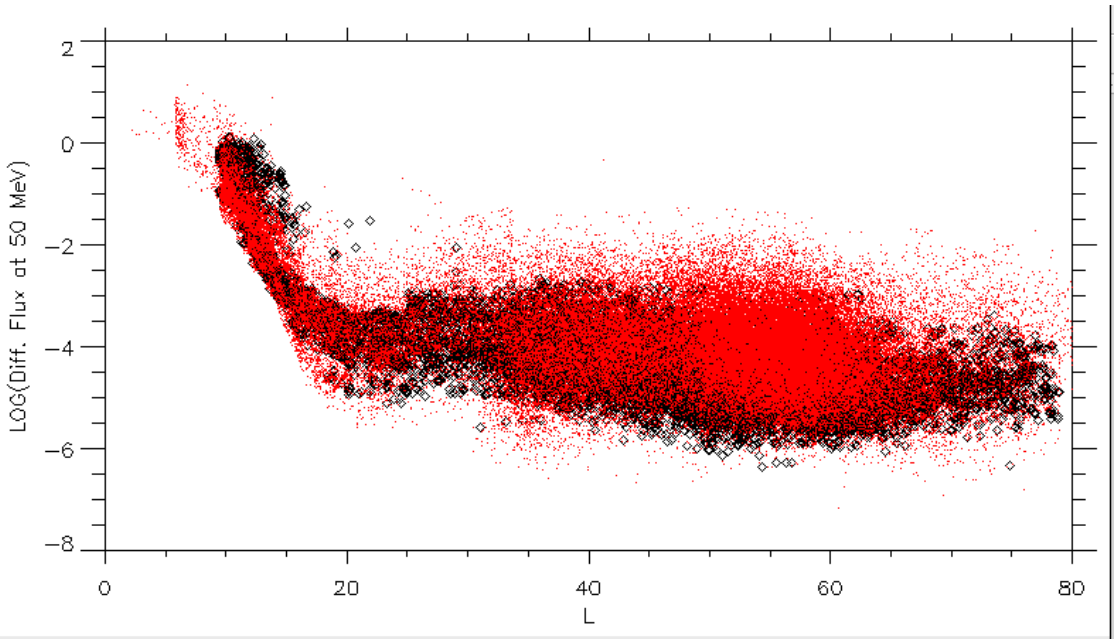


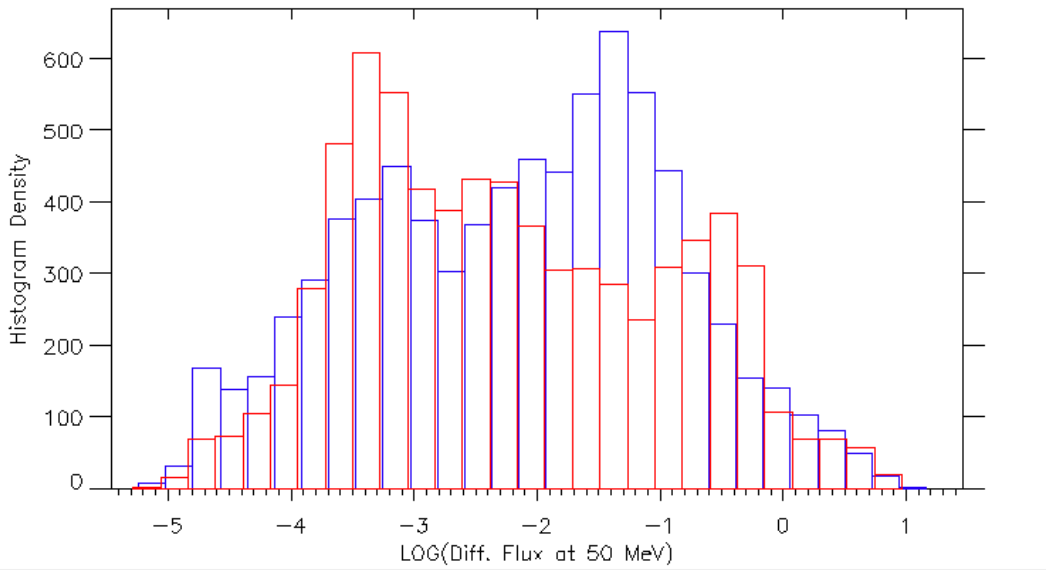
HPEM sample results (Galileo)



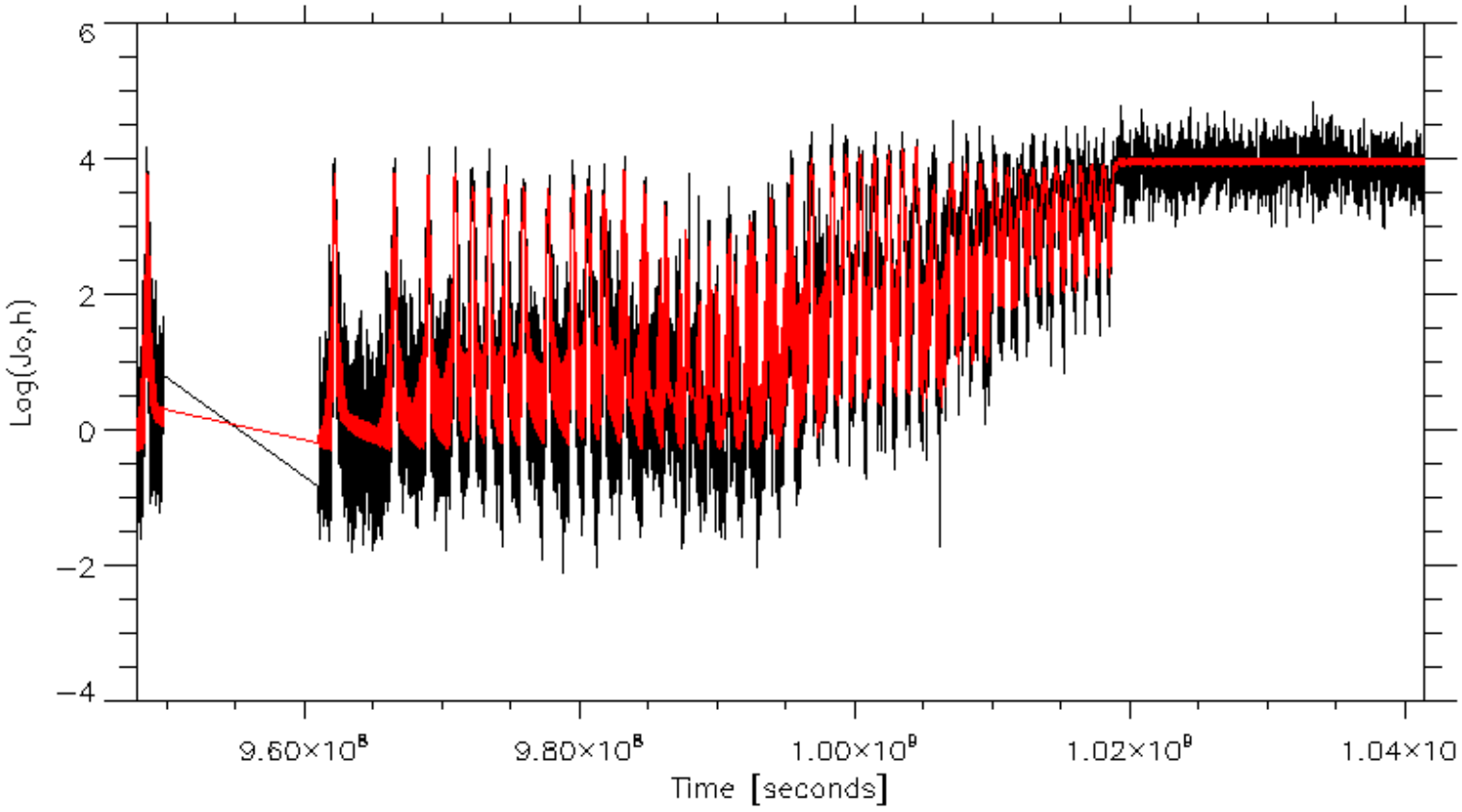
Red: model, black: data

HPEM sample results (Galileo)

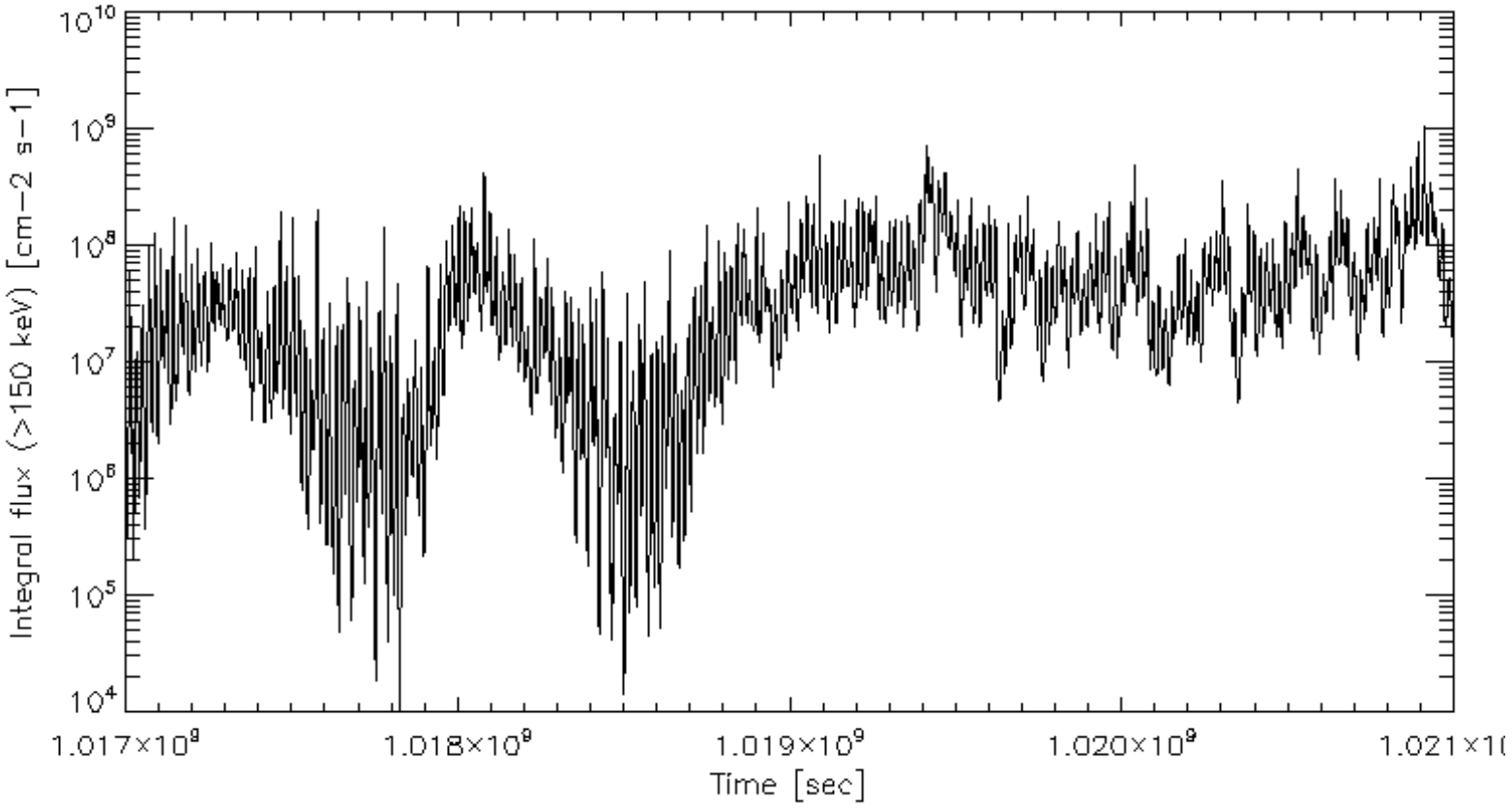




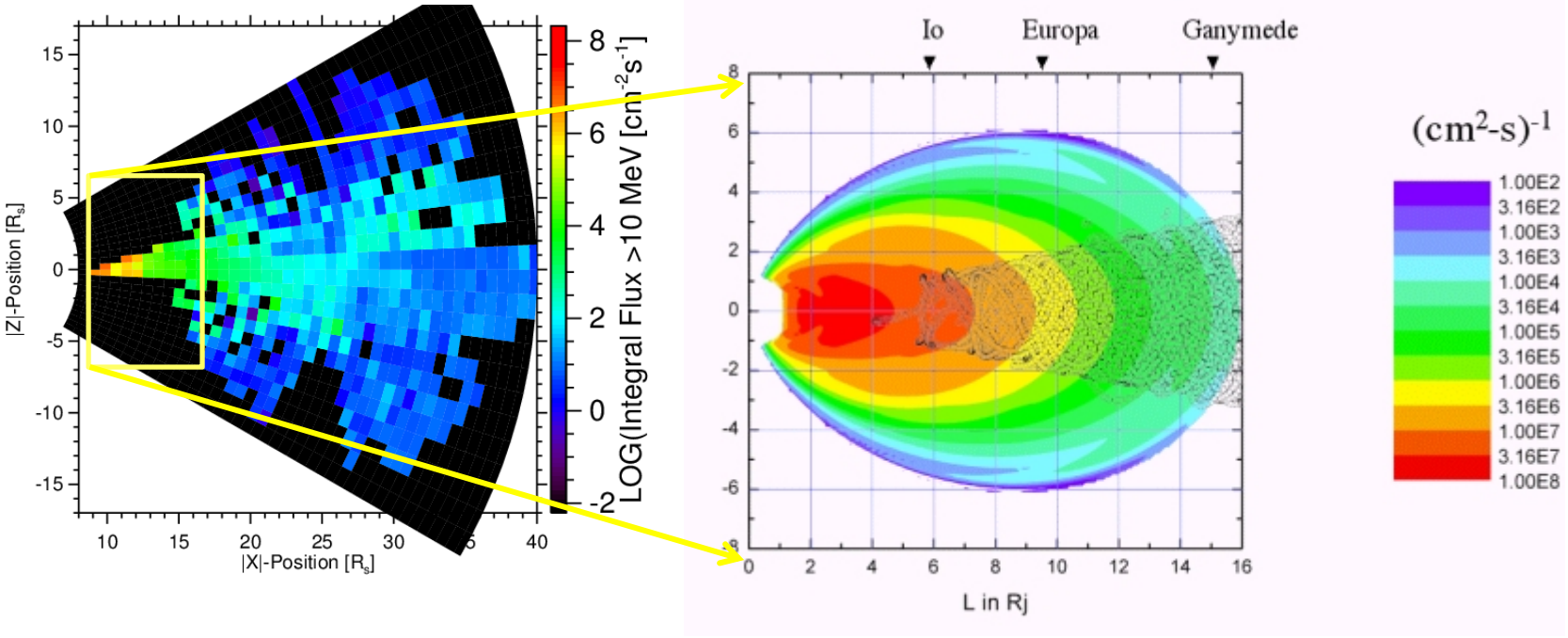
HPEM sample results (JUICE)



HPEM sample results (JUICE)



HPEM: averaging over the JUICE orbit



Summary

- New Jupiter environment models (CPEM and HPEM) for cold plasma and energetic electrons
- Applicable for regions that will be visited by JUICE
- Suitable for describing time variations in the system
- Current status: testing/validation and implementation in JCAT charging codes