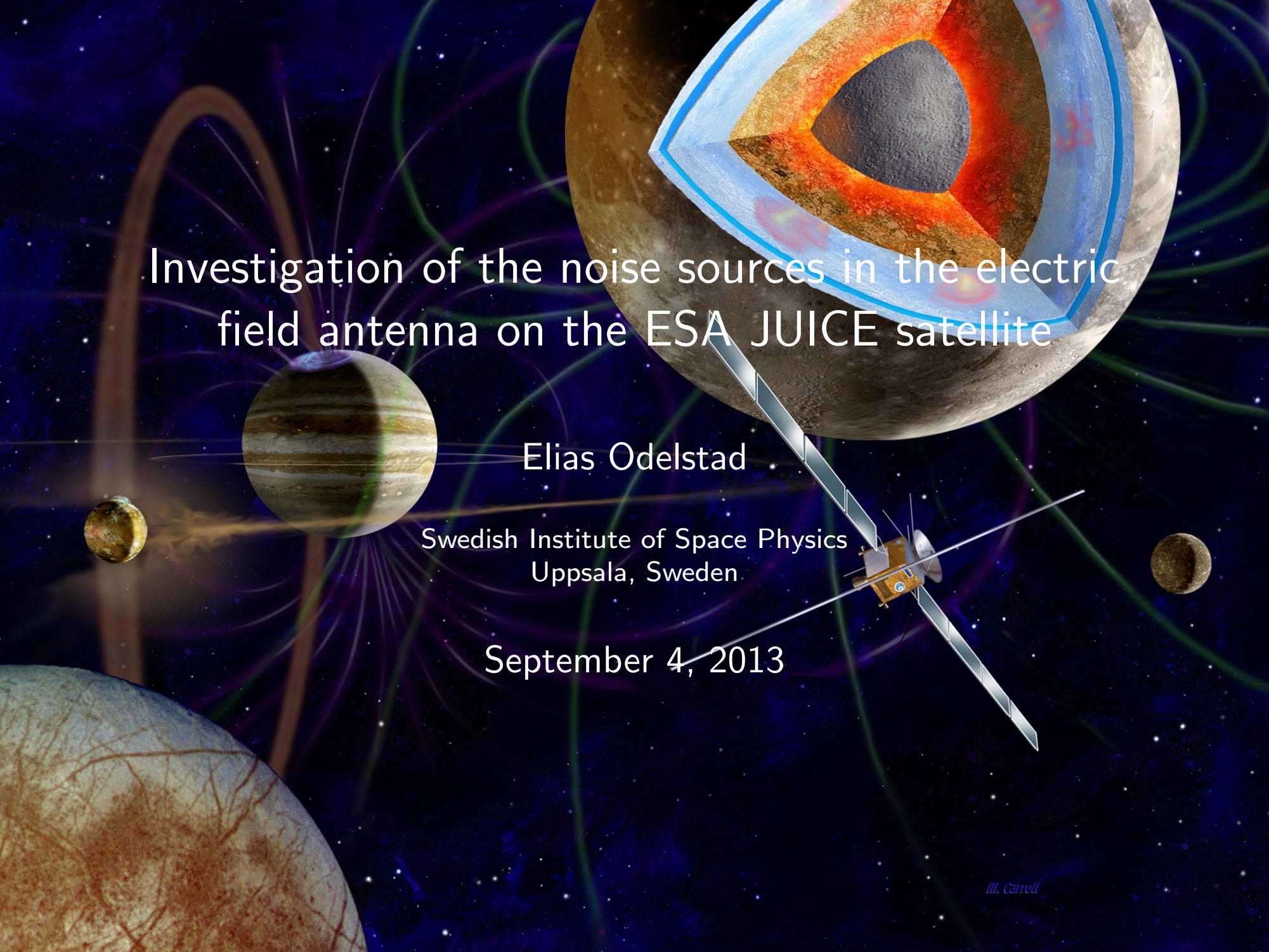


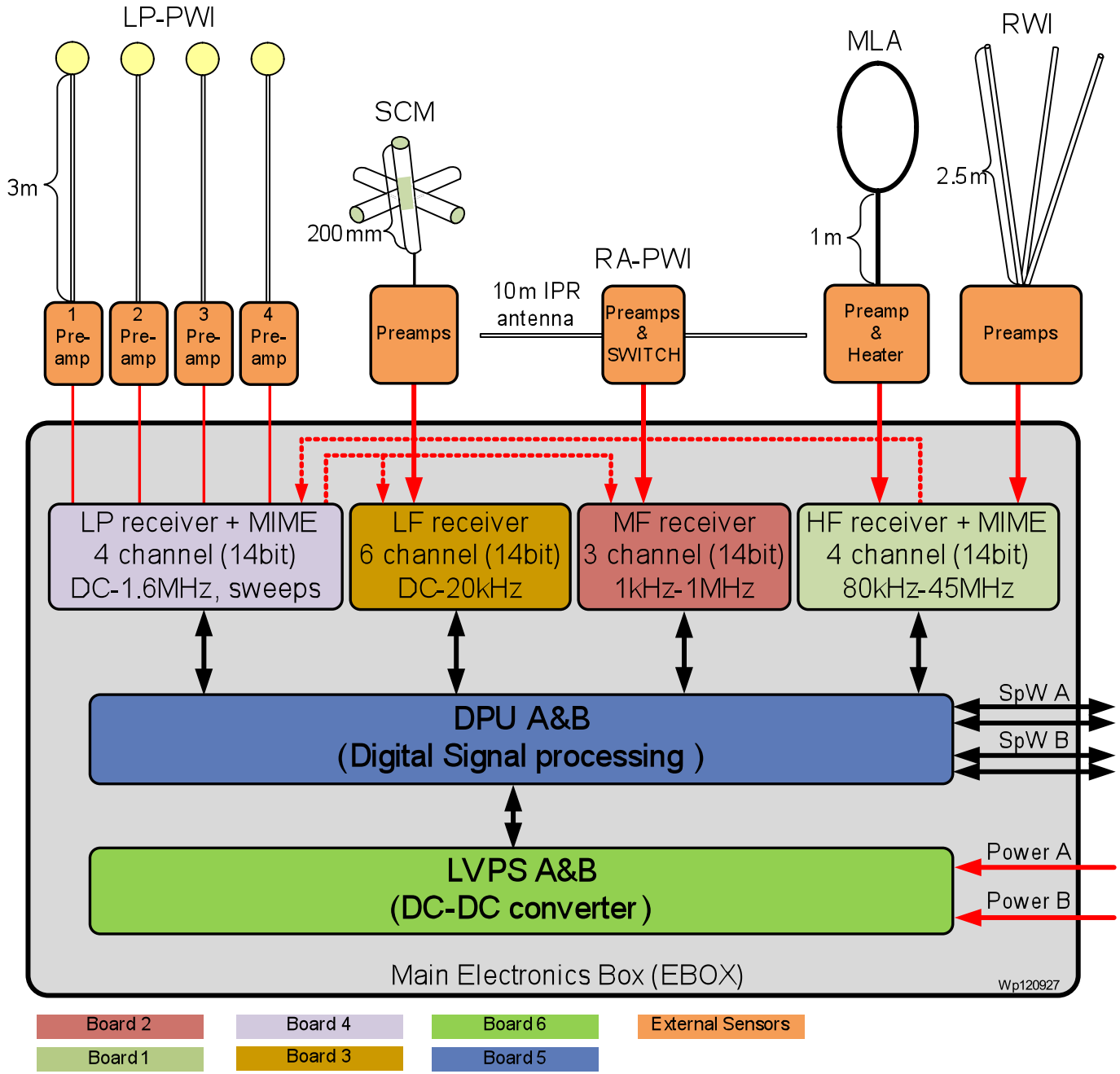
Investigation of the noise sources in the electric field antenna on the ESA JUICE satellite

Elias Odelstad

Swedish Institute of Space Physics
Uppsala, Sweden

September 4, 2013

The Radio and Plasma Wave Investigation (RPWI)



Outline

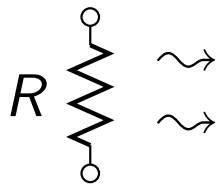
- Noise sources
  - Nyquist (Thermal) noise
  - Shot noise
  - Quasi-thermal noise (QTN)
- Small signal equivalent circuit model
- Results
  - Ganymede's ionosphere
  - Jupiter's magnetosphere
- Discussion

Nyquist (Thermal) noise

Thermal noise/Nyquist noise/Johnson noise

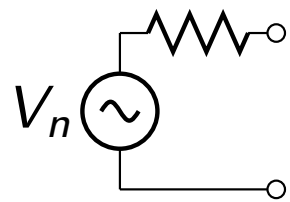
Thermal agitation of charge carriers

dissipative element



$\Longrightarrow$

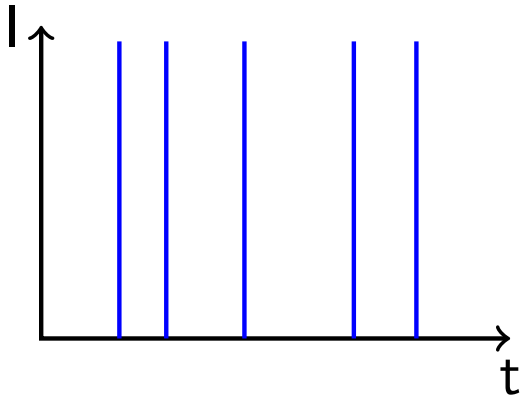
R (noiseless)



$$\boxed{V_\omega^2 = 4k_B TR} \quad = \quad \mathcal{F}\{ < V(t)V(t+\tau) > \}$$

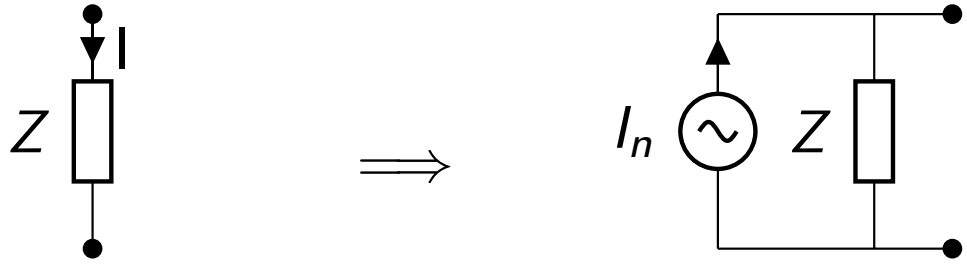
Shot noise

Discrete nature of charge



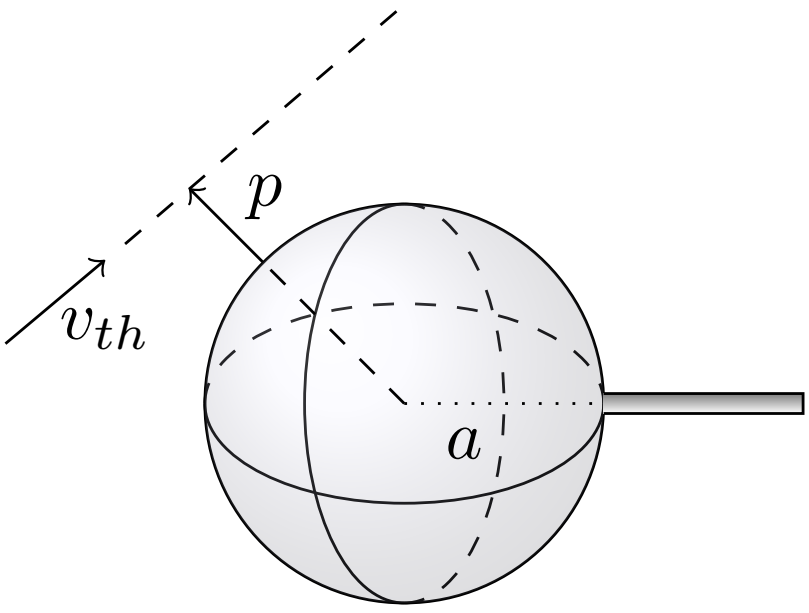
$$I(t) = q \sum_k \delta(t - t_k)$$

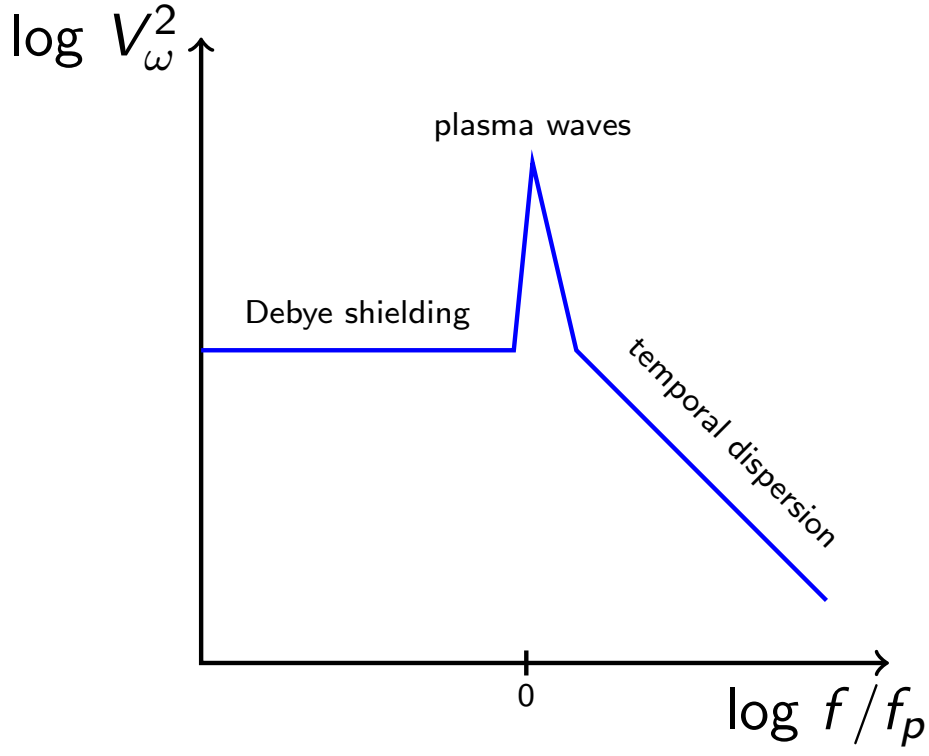
$$\boxed{I_\omega^2 = 2q\bar{I}} \qquad (\Rightarrow V_\omega^2 = 2q\bar{I}|Z|^2)$$



Quasi-thermal noise (QTN)

Electric field fluctuations





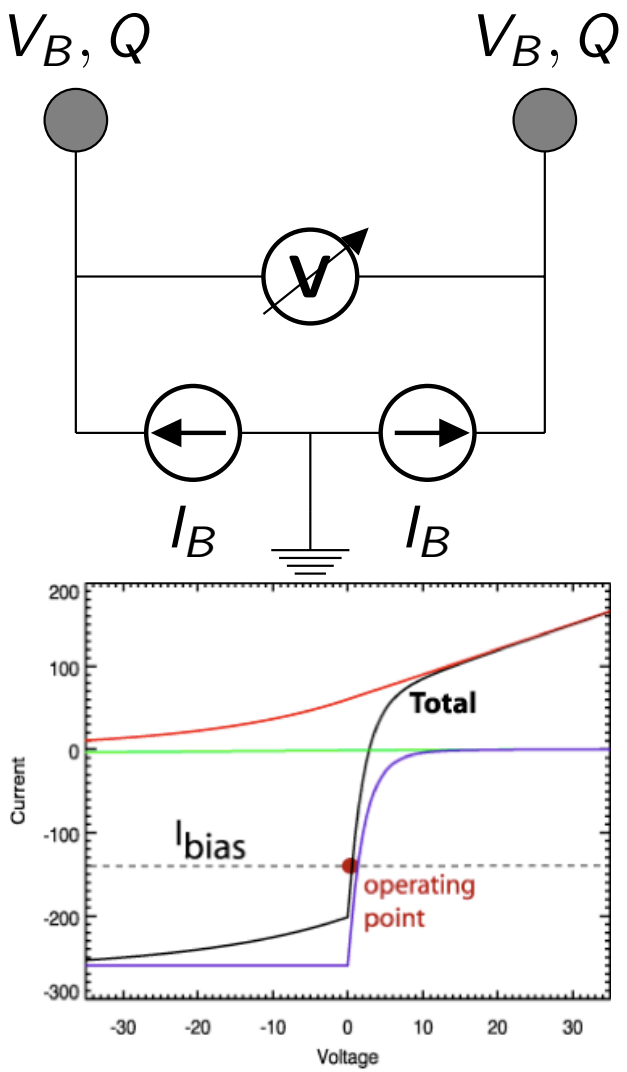
$$V_\omega^2 = \frac{1}{(2\pi)^3} \int_{\Re^3} \mathbf{J}_i(\mathbf{k}) \cdot \mathbf{E}_{ij}(\mathbf{k}, \omega) \cdot \mathbf{J}_j(\mathbf{k}) \mathrm{d}\mathbf{k}$$

Two different models

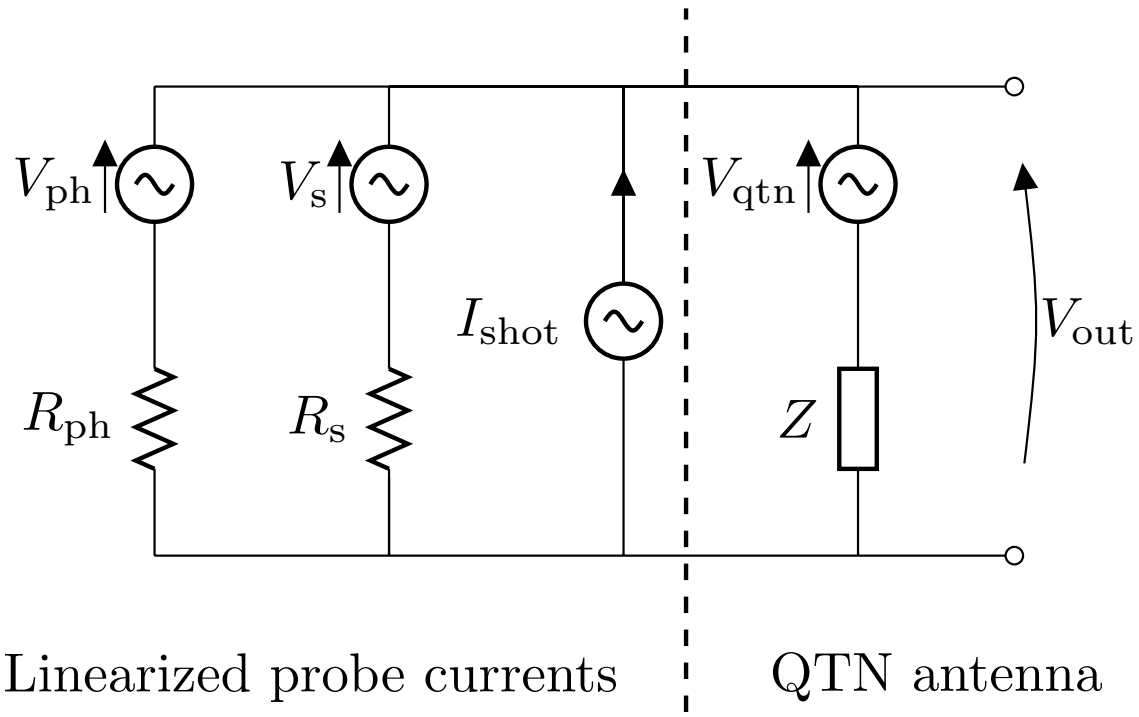
QTN dipole antenna

$$Z = -\frac{1}{I_T^2(2\pi)^3}\int_{\Re^3} \mathbf{E}_A(\mathbf{k})\cdot\mathbf{J}_A(-\mathbf{k})d\mathbf{k}$$

DC electrostatic double-probes



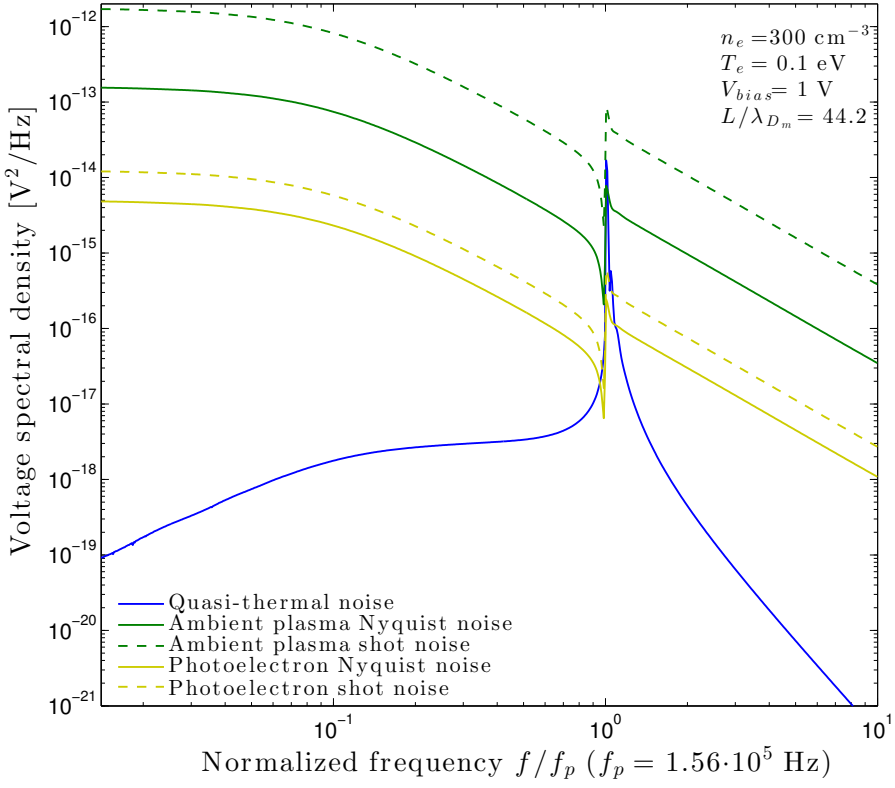
Small signal equivalent circuit model



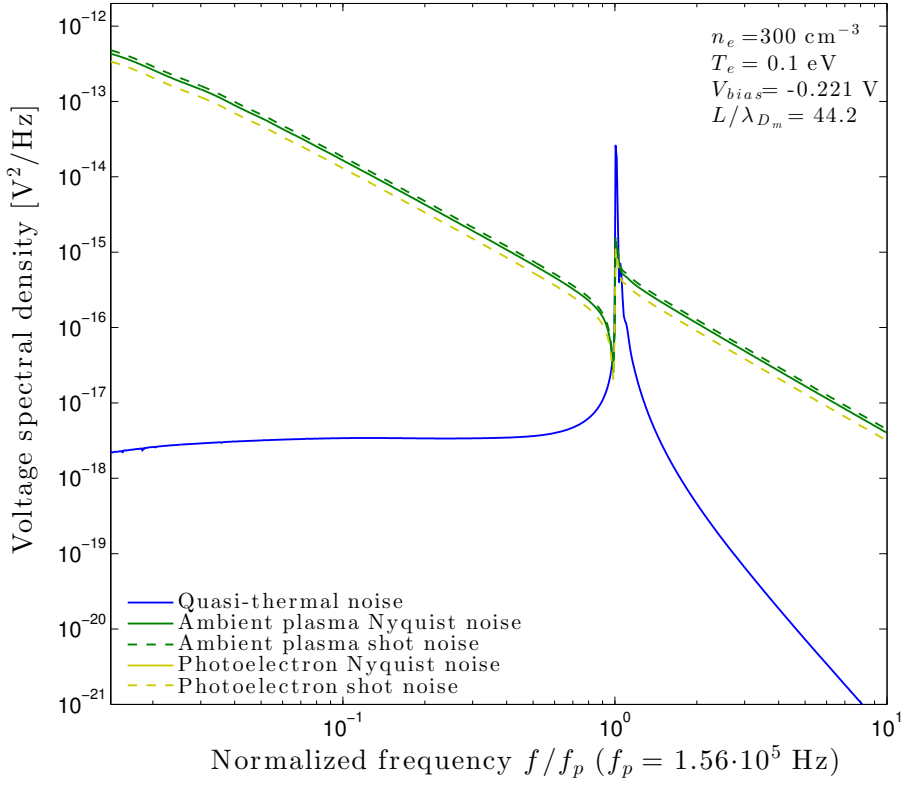
Ganymede's ionosphere

Cold and dense plasma: 300 cm^{-3}, 0.1 eV

$V_{bias} = 1$ V



$V_{float} = -0.221$ V

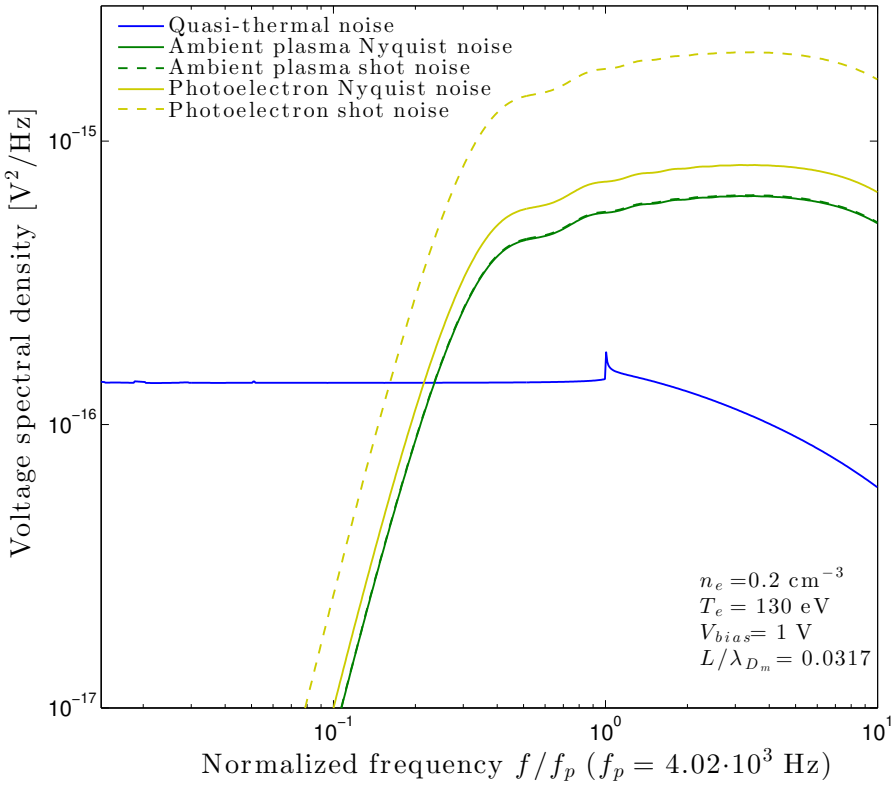


▸ Z ▸ P

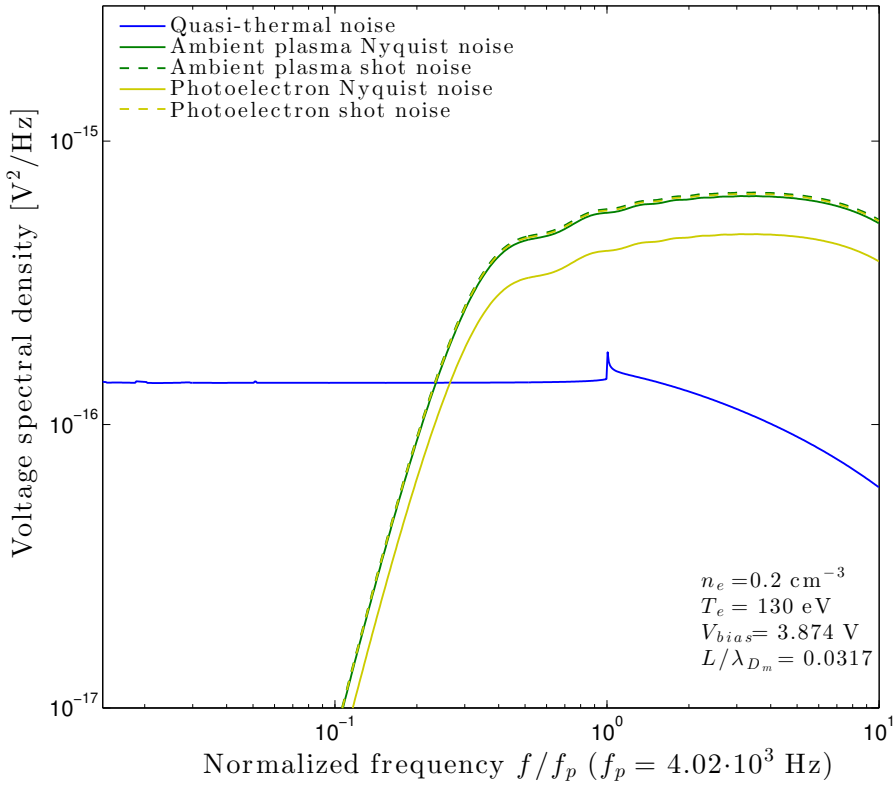
Jupiter's magnetosphere

Hot and tenuous plasma: 0.2 cm^{-3}, 130 eV

$V_{bias} = 1$ V



$V_{float} = 3.874$ V

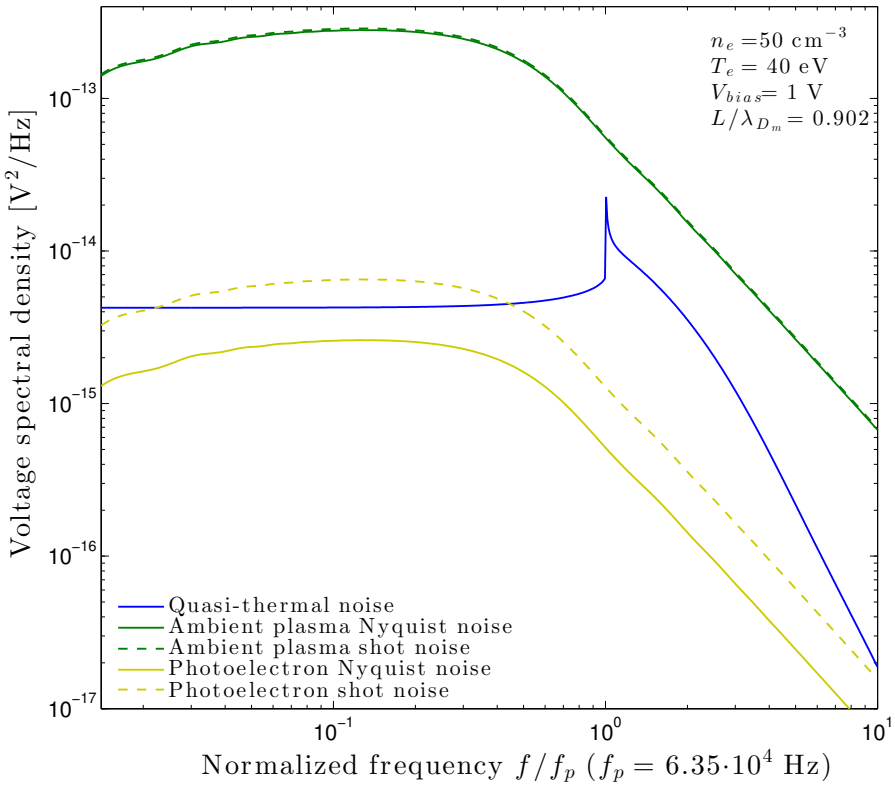


▸ Z ▸ P

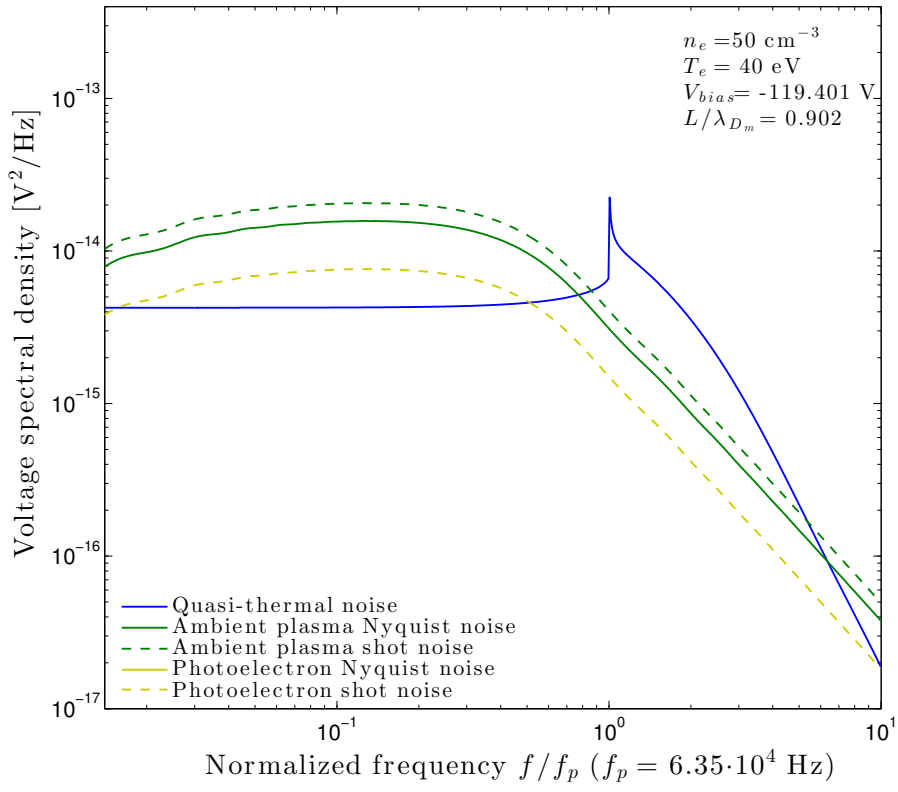
Jupiter's magnetosphere

"Intermediate" conditions: 50 cm^{-3}, 40 eV

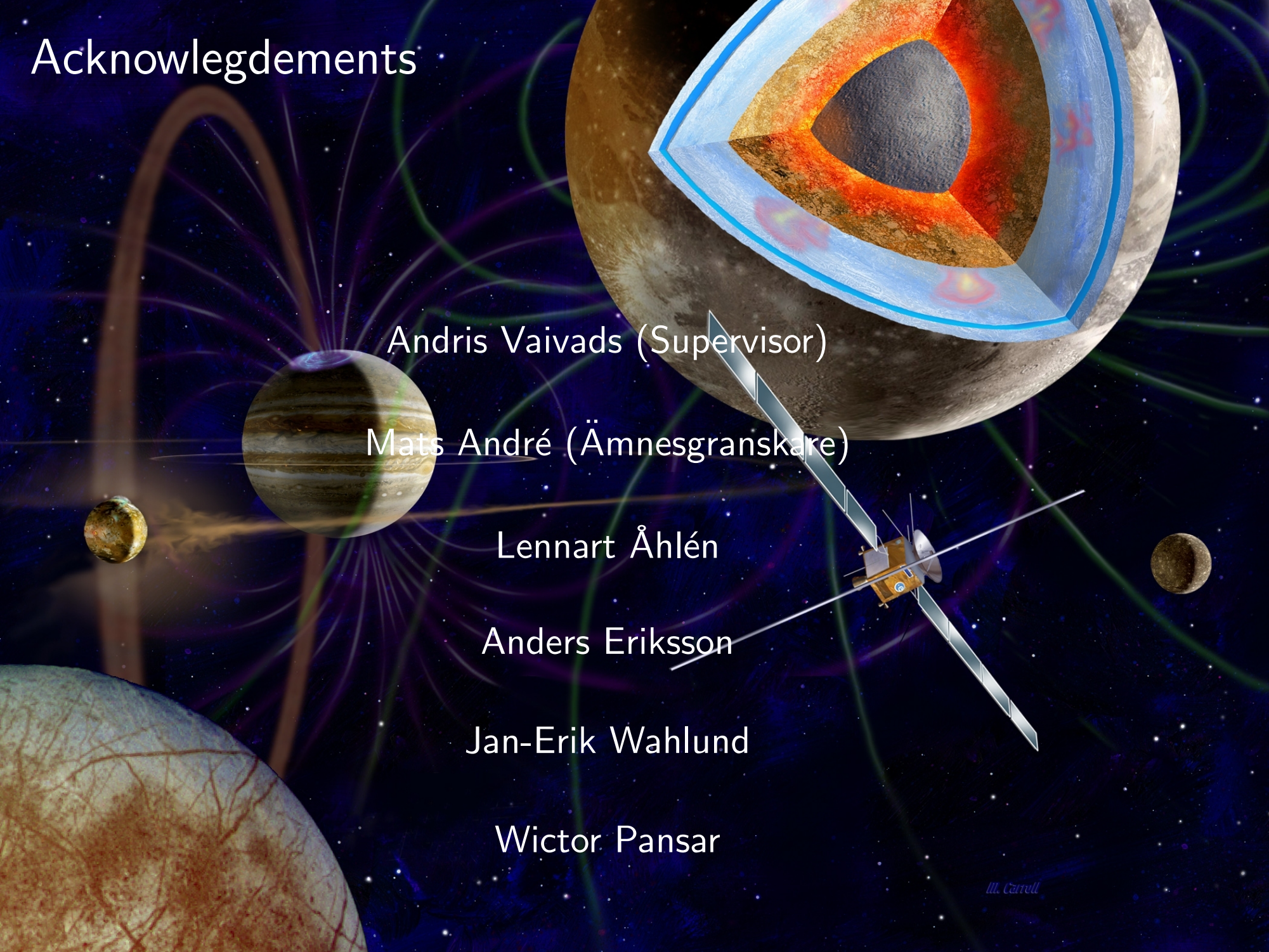
$V_{bias} = 1$ V



$V_{float} = -119.4$ V



Acknowlegdements



Andris Vaivads (Supervisor)

Mats André (Ämnesgranskare)

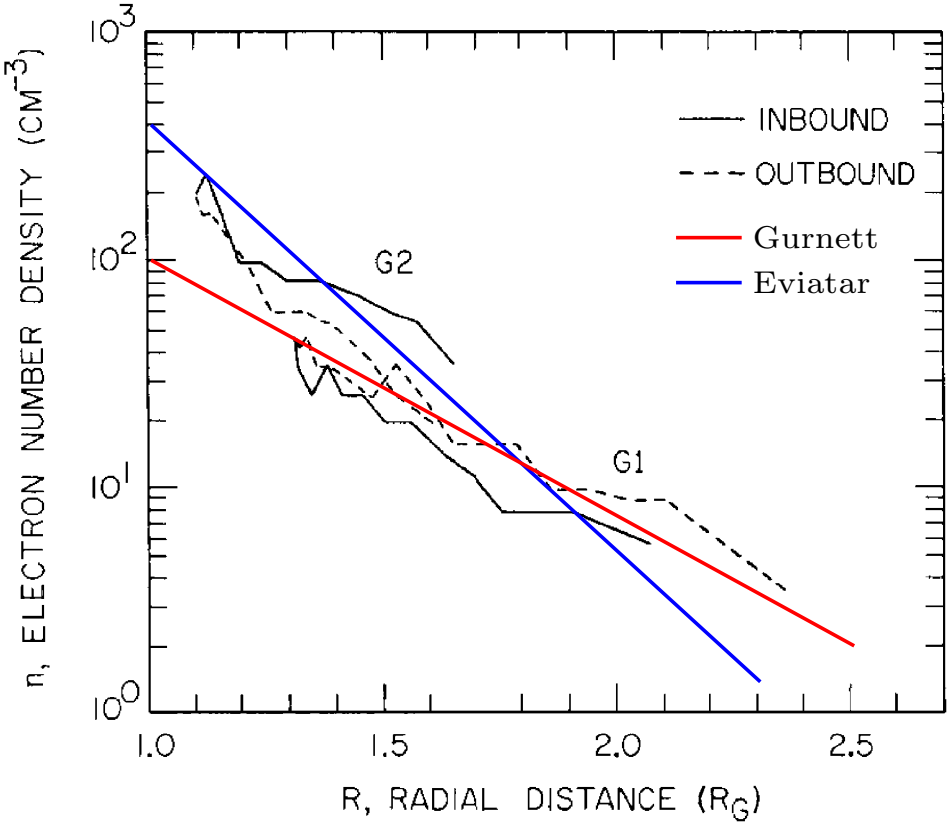
Lennart Åhlén

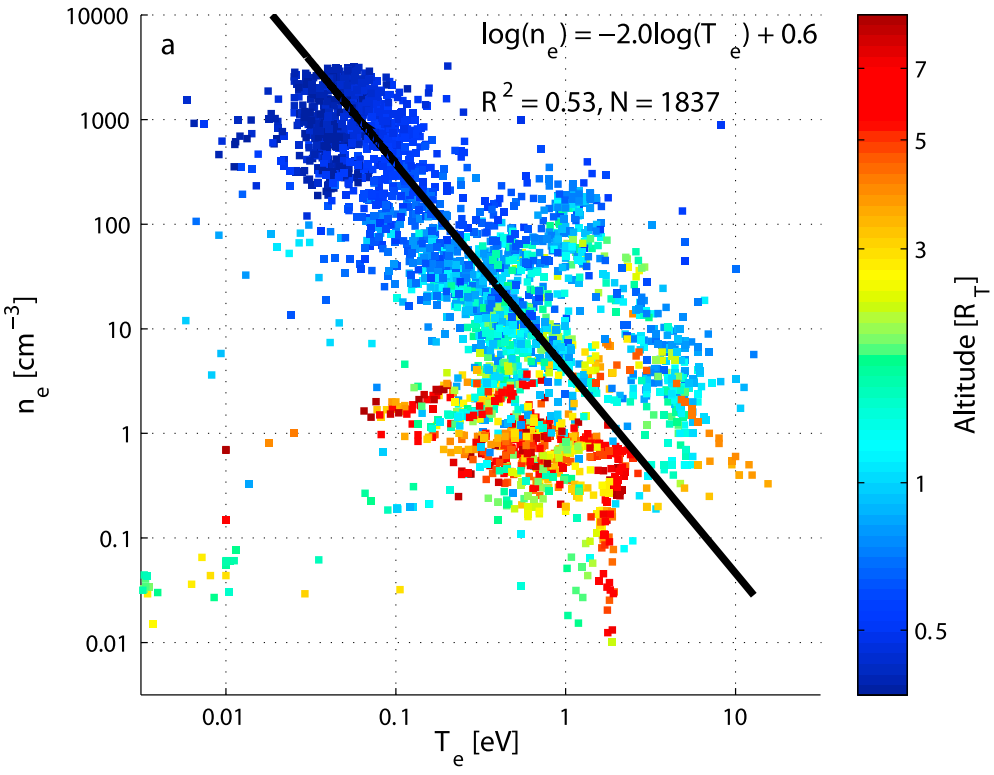
Anders Eriksson

Jan-Erik Wahlund

Wictor Pansar

Ganymede's ionosphere



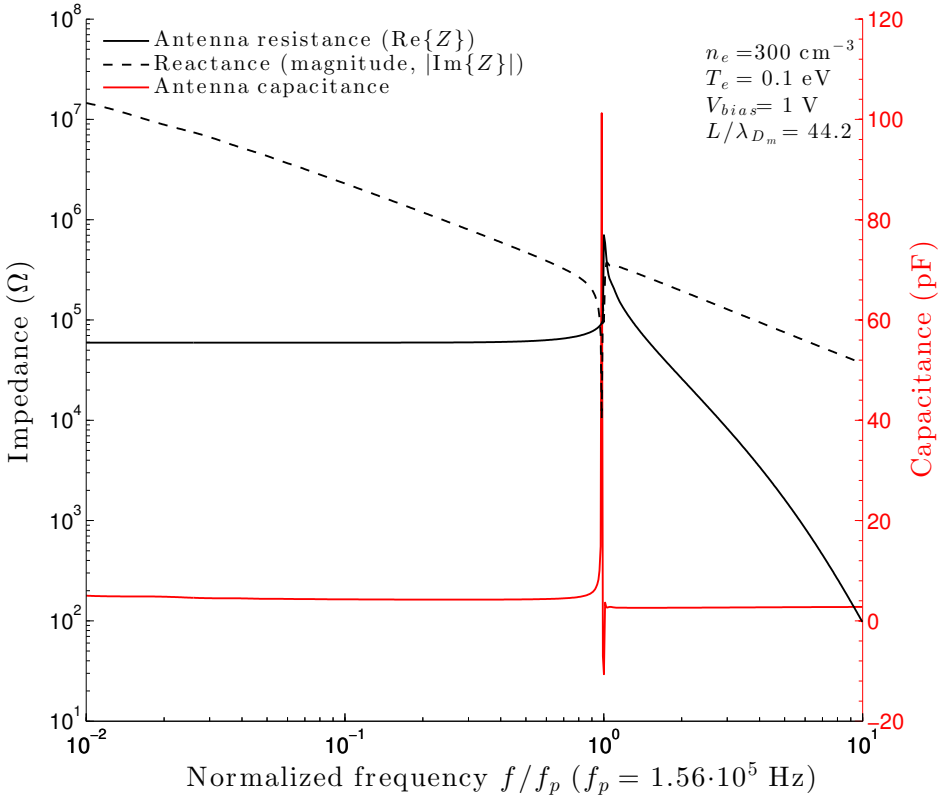


Jupiter's magnetosphere

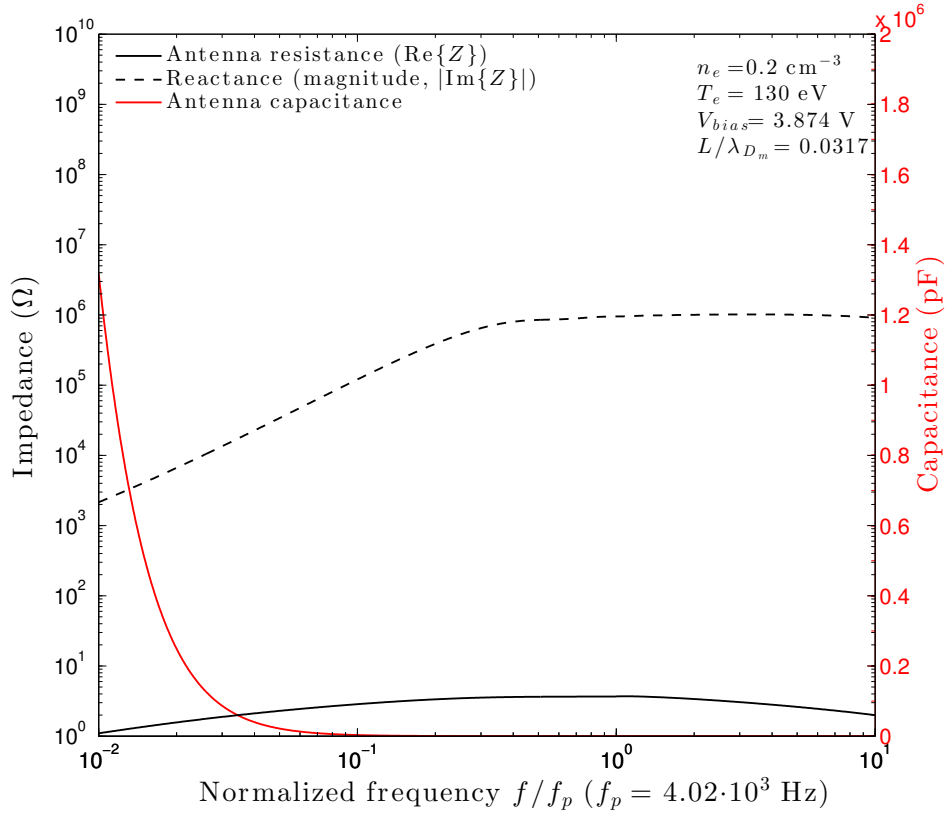
Body	Io	Europa	Ganymede
Radius (km)	1815	1565	2640
Distance from Jupiter (R_j)	5.9	9.4	15.0
Orbital period (days)	1.8	3.6	7.2
Relative co-rotation velocity (km/s)	45–57	84	127
N_e, Jovian magnetosphere (cm^{-3})	4000	50	4
Co-rotational dynamic pressure (nPa)	400	12	2
Average Ionospheric T_e (eV)	4	43	130
Average Ionospheric T_i (eV)	43	52	60
Ionospheric thermal pressure (nPa)	30	0.8	0.1
Jovian magnetic field (nT)	1800	450	100
Intrinsic B field (eq. surface, nT)	1300?	Small	700
Alfvén velocity (km/s)	130	300	250
Acoustic velocity (km/s)	19	26	37
Magnetosonic velocity (km/s)	133	310	250

QTN antenna impedance

300 cm^{-3}, 0.1 eV



0.2 cm^{-3}, 130 eV



◂ G ◂ J