Radio and Plasma Wave Investigations (RPWI) in Japan

Through the measurement of

Radio:	first	Direction/Polarization obs.	(80kHz – 45MHz)
Wave:	[first	Wave-Particle interaction obs.]	(few – 1MHz/20kHz)
E-field:	first	DC E-field measurement	(Langmuir probe)
Plasma:	first	Low-T plasma measurement	(Langmuir probe)

we will attack the following sciences in the JUICE mission.

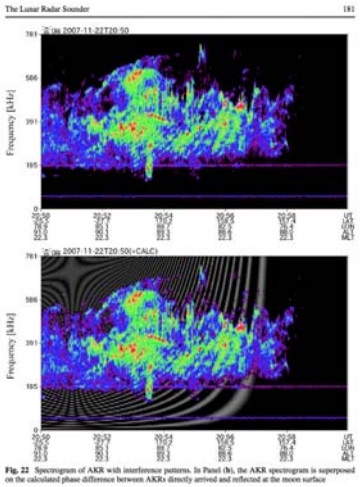
(1) Jovian system: Structure & Variation ～Fast rotating Giant magnetosphere～
(2) Jovian system: Energy release ～System filled with Relativistic particles～
(3) Satellite – Jupiter system ～Electrical coupling of Satellite - Jupiter～
(4) Satellite environment ～Electrical Atmosphere, magnetosphere, and interiors～

LATEST Status – Feb. 2015

* JAXA Pre-project Review: in this week
  18 Feb SRR
  20 Feb Management

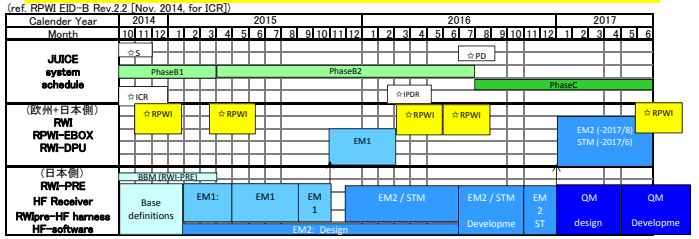
* 'Software-type Wave-Particle Interaction Analyzer (SWPIA)' function will be included, with MAG & PEP teams.

* 'PASSIVE-RADAR' might be possible.
  Detection of 'ICE – WATER boundary'
  = subsurface ocean surface
  by the reflection of Jovian radiation.



ref. AKR reflection from Lunar surface (Ono et al. 2010)

<Development schedule in 2015-2016>



RPWI: Contribution from Japan ---- TEAM

Science Members

Yasumasa Kasaba
Co-PI (overall)
[Tohoku Univ.]

RWI-PRE & HF (Tohoku Univ.)
- (Meisei Elec.) RWI-PRE
- Yoshihiro Sato, Engineer (Electronics)
- (Meisei elec.) HF
- **Hiroaki Misawa** Co-I (RWI-PRE) *[Tohoku Univ.]*
- Keigo Ishisaka, Scientist (ANT-I/F) *[Toyama Pref. Univ.]*
- Fuminori Tsuchiya, Scientist (Soft-HF) *[Tohoku Univ.]*
- **Atsushi Kumamoto** Co-I (HF)

DPU-soft (Tohoku U. Kanazawa U.)
- Fuminori Tsuchiya, Scientist (Soft-HF) *[Tohoku Univ.]*
- Yuto Katoh, Scientist (SWPIA/model) *[Tohoku Univ.]*
- Yoshiya Kasahara, Tomohiko Imachi, Scientist (Soft - HF / SWPIA) *[Kanazawa Univ.]*

LF / SC (Kyoto U., Kanazawa U.)
- **Hirotsugu Kojima** Co-I (LF/SWIPA) *[Kyoto Univ.]*
- **Satoshi Yagitani** Co-I (SC)
- Mitsunori Ozaki, Scientist (SC) *[Kanazawa Univ.]*

Science (Obs / Model)
- **Tomoki Kimura** Co-I (Obs)
- Takumi Abe, Sci. (Obs)
- Chihiro Tao, Sci. (Model) *[IRAP]*
- **Yoshizumi Miyoshi** Co-I (Obs) *[Nagoya Univ.]*
- Masato Kagitani, Sci. (Obs)
- Akira Morioka, Sci. (Obs)
- Hiromu Nakagawa, Sci. (Obs)
- Hiroshi Oya, Sci. (Obs)
- Takeshi Sakanoi, Sci. (Obs)
- Naoki Terada, Sci. (Model) *[Tohoku Univ.]*
- Shigeto Watanabe, Sci. (Obs) *[Hokkaido Univ.]*
- Vladimir B. Riabov, Sci. (Obs) *[Future Univ. Hakodate]*
- Tomoyuki Nakajo, Sci. (Obs) *[Fukui Univ. Tech.]*
- Kazumasa Imai, Sci. (Obs) *[Kochi National Coll. Tech.]*
- Shoichi Okano, Sci. (Obs) *[Univ. Hawaii]*
- Yukitoshi Nishimura, Sci. (Obs) *[UCLA]*

Schedule / Models / Tests

When, Where,

EM1 to Europe	2015 Summer →	Nov. 2015	(X-7 years)
EM2 to Europe	2016 Summer →	Jan. 2017	(X-5 years)
QM to Europe	2017 Summer →	Nov. 2017	(X-5 years)
FM to Europe	2018 Summer →	Mar. 2018	(X-4 years)

Launch: Summer 2022 (or later)

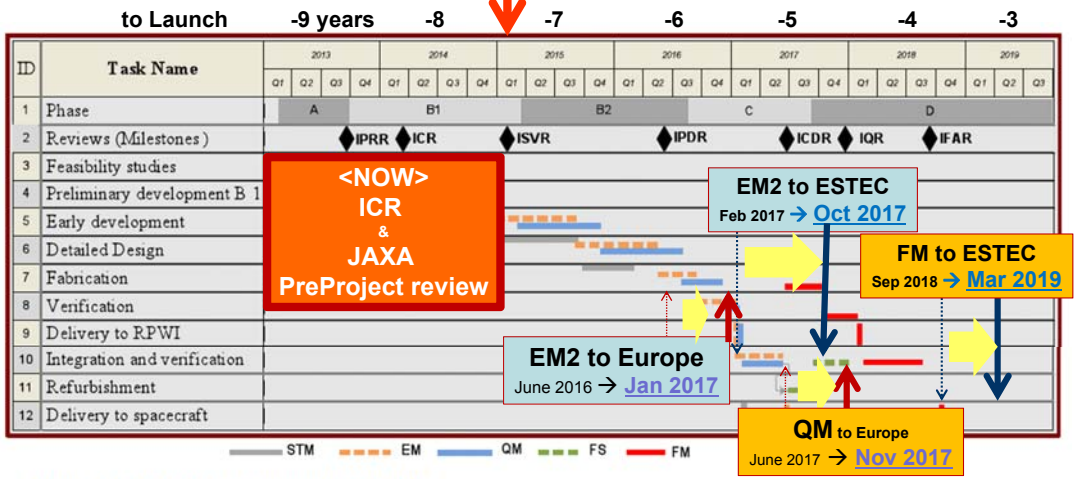
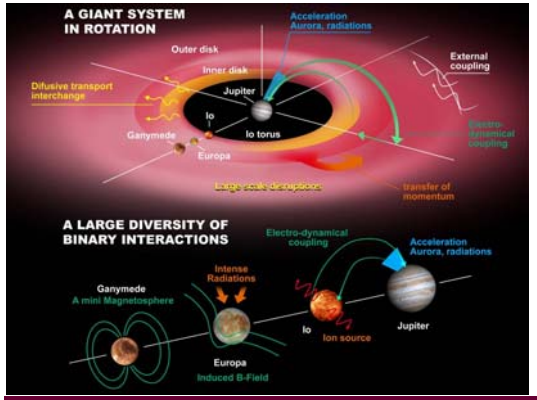


Figure 3-4 RPWI System engineering schedule

● Jovian – Satellite 'electromagnetic' System : !!! Uniqueness !!!

<Jovian system>
- Fast rotating Giant Magnetosphere → Different type to Earth's "Rotation-energized" object
- System filled with Relativistic particles → Largest in solar system planets "High-energy" object

<Satellite system>
- Electromagnetic coupling → like Star-Hot Jupiter system "Electromagnetic binary" object
- Electromagnetic sounding of Satellites → Gas source / Conductive object



These are

→ fundamental phenomena/process expected in exoplanets & stellar magnetospheres

→ no similar activity in other planets ex) Earth / Mecury systems

It is essential to investigate this system by in-situ surveys.

(2) Jovian system: Energy
~System filled with Relativistic particles ~

Particle accelerations along the field lines ?
MEV accerelation by Wave ?
Injection of plasmas into the inner region ?

(1) Jovian system: Structure
Fast rotating Giant magnetosphere ~

MIT Couplings ?
Retraction of rot. Energy to outside?
Effects from outside? SW / EUV

first Direction / Polarization !

first detection !

<Radio: Remote with UV/IR/...>
Global detection of high-E particle activities !

<DC E-field: In-situ>
Grasp the plasma motion & acceleration E-field !

<Wave: In-situ>
Direct detection of Electromagnetic energy exchanges !

<Low-T plasmas: In-situ>
Grasp the plasmas around/from satellites !

[first Wave-Particle interaction]

first detection !

(3) Satellite – Jupiter system
~Electrical coupling of Satellite - Jupiter ~

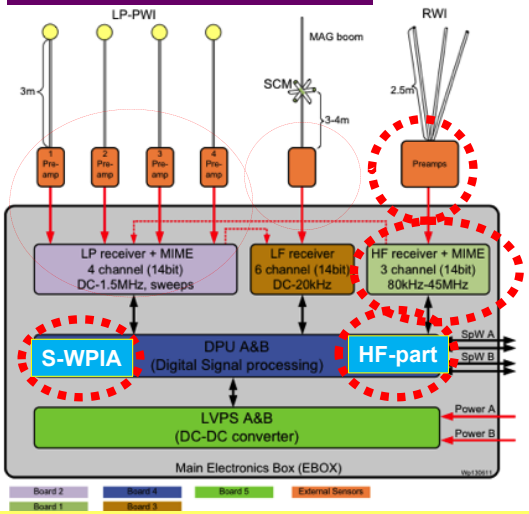
Current connections between them ?
Enhancement by plasma from satellites ?

(4) Satellite environment
~Electrical sounding of Atmosphere / Interior ~

Plasma production: Volcano, Water, ... ?
Conductivity in the satellites ?

RPWI: World-wide consortium

[PI] Jan-Erik Wahlund
(IRF – Uppsala, Sweden)



[Members (Inst.)] Sweden (x2), Austria (x1), Czech(x1), France (x4), Japan (x6+α) USA (x5), Poland (x1), UK (x2)

<Remote sensing: Radio>

[HF-System]
* Ex3(80kHz – 45MHz)

first Direction & Polarization
→ plasma remote sensing package with ENA & UV

<In-situ: Waves, DC E-field, Low-T plasma>

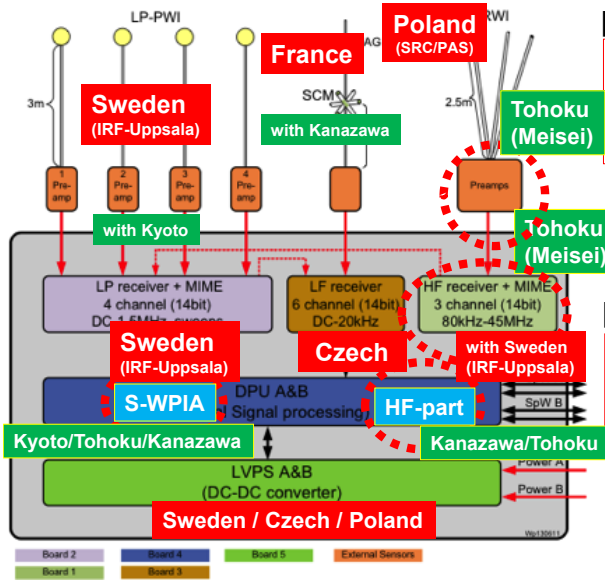
[MF-System]
* *Ex3* *(1kHz – 1MHz)*

[LF-System]
* Ex3 & Bx3 (few – 1MHz / 20kHz)
  [DC-E : < 7 mV/m]
* Electron / Ion (Langmuir probe)
  [10^{-4} ~ 10^{5} cm^{3}]

[first Wave-Particle interaction]
first DC-E field detection
first low-T plasma detection

RPWI: Contribution from Japan

[Co-PI] Y. Kasaba (Tohoku Univ.)



<Remote sensing: Radio>

[HF-System]
* **Preamp** (Tohoku +Meisei)
* **HF – Receiver** (Tohoku + Meisei + IRF-Uppsala)
* **DPU: HF - Software** (Kanazawa/Tohoku)

<In-situ: Wave, DC-field, Low-T plasma>

[LF-System]
* [option] Software-type WPIA (Kyoto/Kanazawa/Tohoku)
* **Contribution to design: E/B sensor, Langmuir Probe** (Kyoto/Kanazawa/Tohoku)

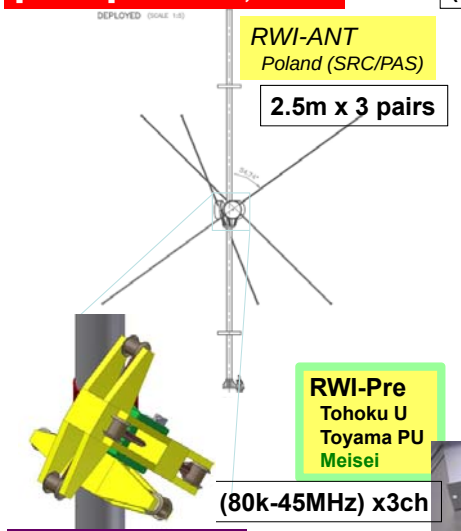
[Science]
Hokkaido, Hakodate FU, Tohoku, Nagoya, Toyama PU, Kanazawa, Fukui IT, Kyoto, Kouchi NCT, JAXA

RPWI: Contribution from Japan ---- (1) HF

[Critical] Radiation, Low-T

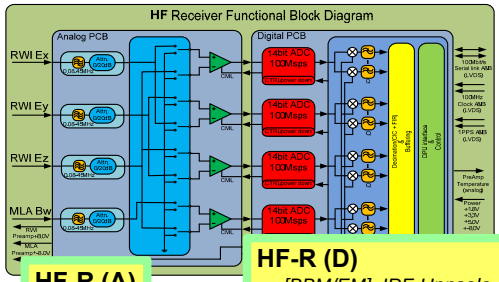
(80k-45MHz) x3ch

[Critical] technical transfer



RWI-ANT
Poland (SRC/PAS)

2.5m x 3 pairs

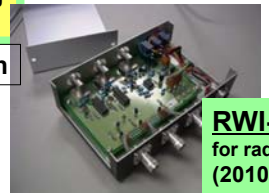


HF-R (A)
Tohoku U
Meisei

HF-R (D)
[BBM/EM] IRF-Uppsala
→ [FM] Tohoku U
Meisei

RWI-Pre
Tohoku U
Toyama PU
Meisei

(80k-45MHz) x3ch



RWI-Pre BBM
for rad. test
(2010-)

HFA BBM
for ERG/HFA
(2012-)

[Heritage]
MMO/WPT-Pre
Kaguya/PWS-Pre

[Heritage]
Kaguya/LRS
ERG/HFA

RPWI: from Japan High Frequency Receiver system

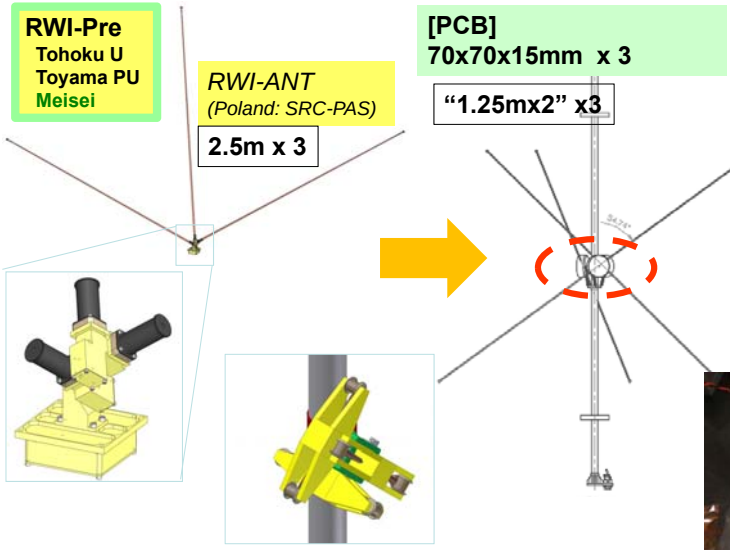
RWI-Pre
Tohoku U
Toyama PU
Meisei

RWI-ANT
(Poland: SRC-PAS)

2.5m x 3

[PCB]
70x70x15mm x 3

"1.25mx2" x3



(80k-45MHz) x3ch

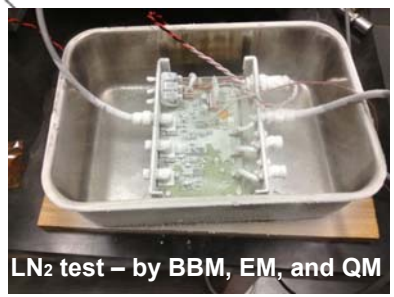
[Heritage]
MMO/WPT-Pre
Kaguya/PWS-Pre

High Radiation

- 880g GET!!
(Al 10mm → Al 3.5mm + Cu 2mm)
→ <100krad

Low Temperature

- LN_2 (-77K) test
→ We need >145K!
- Development of
Low-TEMP chamber
→ Suceeded

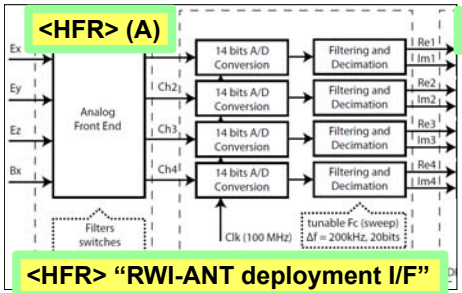


LN_2 test – by BBM, EM, and QM

RPWI: from Japan DPU software

A. DPU – HF data reduction (Kanazawa U / Tohoku U)

<HFR> (A)



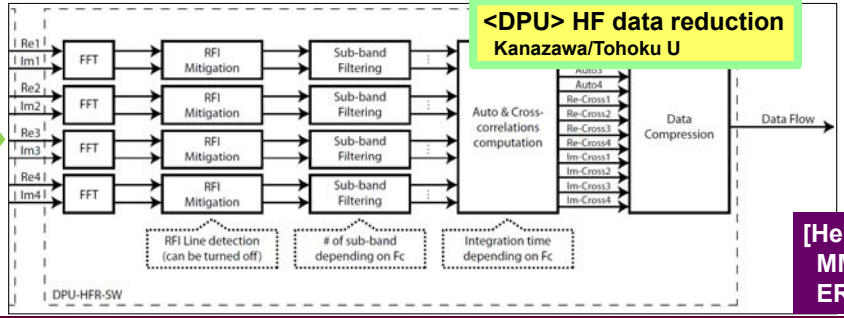
<HFR> "RWI-ANT deployment I/F"

<HFR> (D)

<HF output>
「200kHz x 1~4ch x2(real / imaginary) 」
down-converted waveform

<TLM output> *** SOFTWARE in DPU! ***
80kHz~45MHz x 1~3ch、1-64s resolution
Spectrum data: 0.2 – 1.6kbps

<DPU> HF data reduction
Kanazawa/Tohoku U



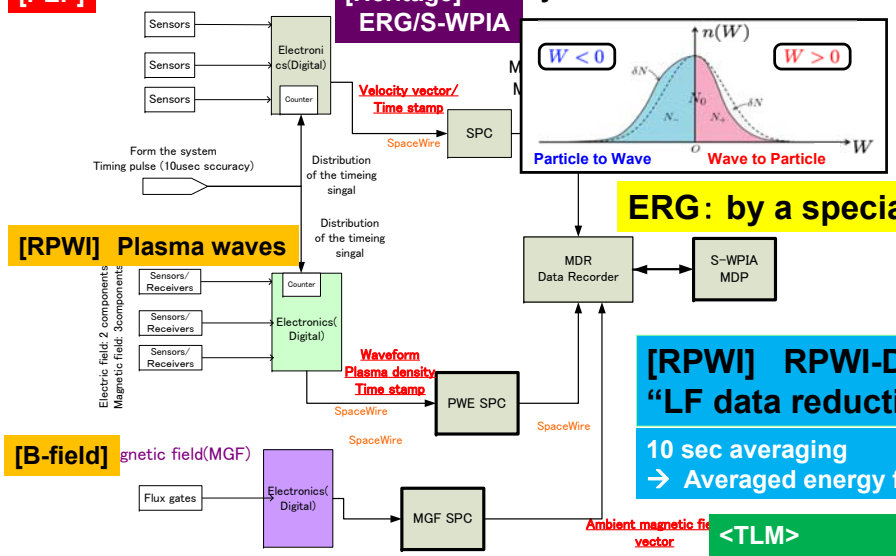
[Heritage]
MMO/MDP - PWI
ERG/PWE - HFA

RPWI: from Japan DPU software

B. Software-type Wave-Particle Interaction Analyzer (S-WPIA)

[PEP] asma instruments(MEP-e/HEP Kyoto / Tohoku / Kanazawa)

[Heritage]
ERG/S-WPIA



[RPWI] RPWI-DPU
"LF data reduction" part

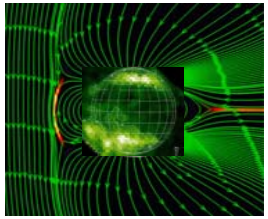
10 sec averaging
→ Averaged energy flow detection

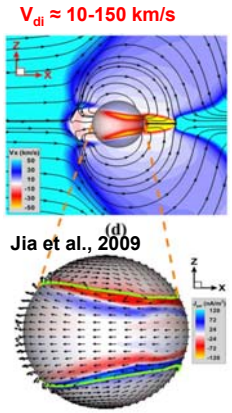
<TLM>
0.02 – 16bps (1/1h case)

Icy Moon Conductivities & Electric Currents

first DC-E field detection
first low-T plasma detection

- **Determine the electric conductivity of the ionospheres**
  - **Assess their role in supporting MHD-dynamo generated current systems induced by the rotating and variable Jovian magnetosphere**
  - **Assess how these currents may couple inductively to sub-surface oceans**
- **Monitor electric acceleration structures at magnetic flux tubes connected to Ganymede's auroral regions.**





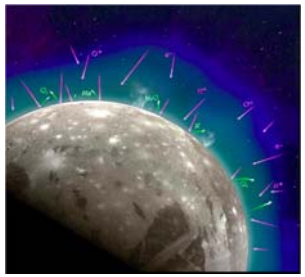
Upward/Downward
j ≈ 0.05-0.1 μA/m²

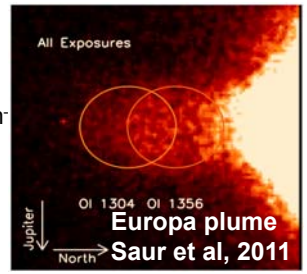
- $\sigma_H \approx -\sigma_P \sim en_e/(2B) \sim 10^{-4}$-$10^{-3}$ mho near surface
- $j \geq \sigma E \sim 0.1$ μA/m² I ≥ 100 kA through ionosphere?
- **Or through salty sub-surface ocean?**

Ionization, heating and dynamics of exospheres

- H_2O-products released fr. surface:
  - Magnetospheric particle sputtering
  - Sub-surface breaching of oceanic material
  - Diffusion from interior
  - Meteoritic impact evaporation
  - Solar radiation decomposition
- Leads to
  - **O & O_2-rich atmospheres** (10^8 cm^{-3})
  - **O_2^+-rich ionospheres** (500-20000 cm^{-3})
  - **Electrically conducting** layers
- RPWI will:
  - Monitor plasma densities 10^{-4} – 10^5 cm^{-3} (ms resolution)
  - Locate (electron) heating regions in the dense plasma (>0.1 cm^{-3})
  - Determine **ExB** convection and bulk ion drift speed
  - Monitor the size and mass distribution of a possibly existing charged dust component
  - Monitor **dust-plasma** interactions

first low-T plasma detection



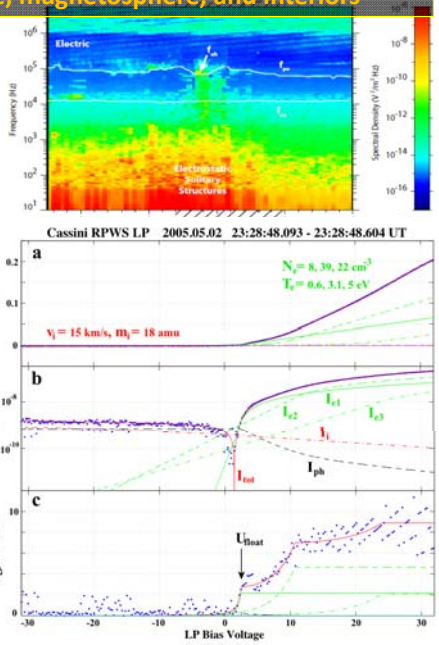


Plasma Density

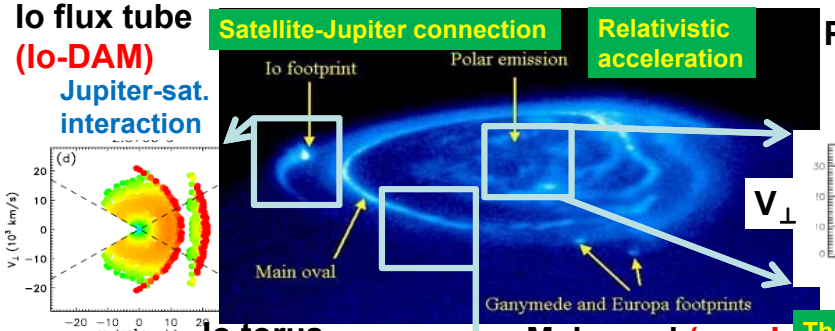
first DC-E field detection
first low-T plasma detection

The number density is determined through several techniques:

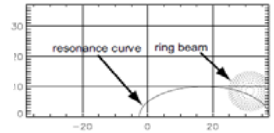
- LP-PWI bias voltage sweeps (for densities > 10 cm^{-3})
- Monitoring the upper hybrid emissions (f_{uh})
- Monitoring the spacecraft potential (U_{SC}) and calibrating toward f_{uh} (or possibly an electron spectrometer on board S/C).
- Continuous sampling of the probe current (allows ms time resolution).
- Active mutual impedance measurements (MIME)



Io flux tube (Io-DAM)
Jupiter-sat. interaction



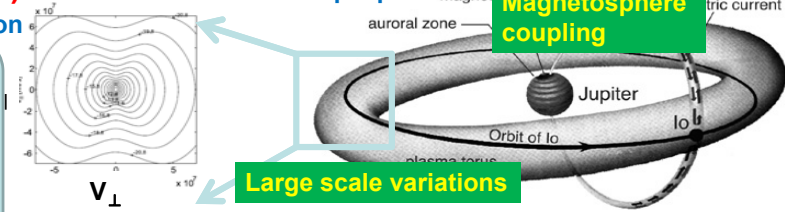
Polar cap (QPB)
Quasi-Periodic Emission



Io torus (nKOM)
injection

Main oval (non-Io)
M-I-T couple process

Themosphere – Ionosphere – Magnetosphere coupling



Large scale variations

Accelerations were rarely observed by in-situ. They can be remotely sensed by radio emissions.