Mars Atmosphere and Volatile EvolutioN (MAVEN) Mission

Langmuir Probe and Waves (LPW)

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LPW Level 1 Science

4.1.5 Electron Density and Temperature

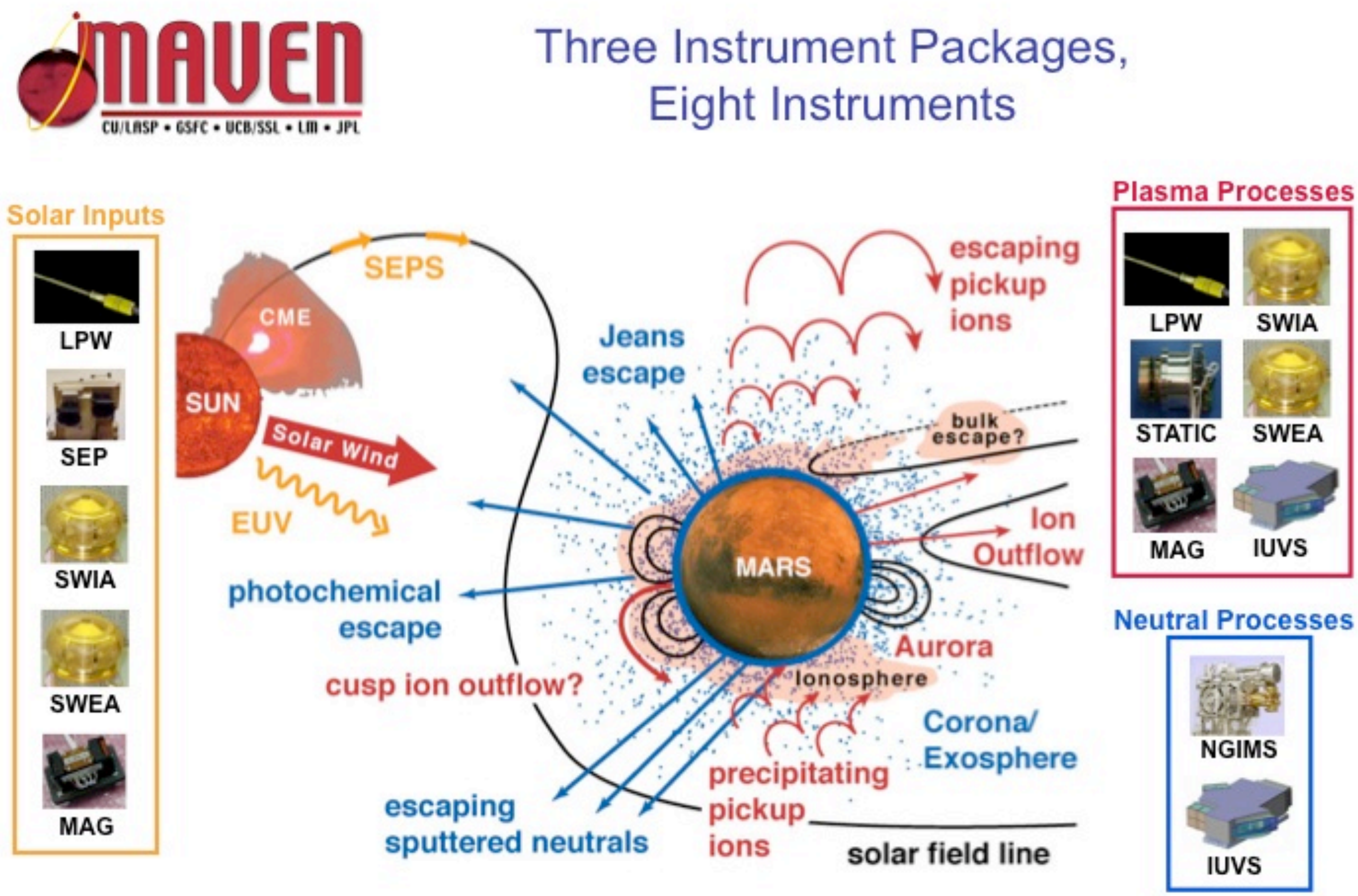
- **Baseline:** MAVEN shall determine thermal electron density (100 to 10^6 cm^{-3}) and electron temperature (500-5000K) with absolute precision better than 20% and relative precision of 5% from within the main ionospheric peak to the nominal ionopause (400 km) with a vertical resolution better than 60 km.
- **Threshold:** MAVEN shall determine thermal electron density (100 to 10^6 cm^{-3}) and electron temperature (500-5000K) with precision better than 20% from within the main ionospheric peak to the nominal ionopause (400 km) with a vertical resolution better than 60 km.
- **Rationale:** Profiles of electron number density and temperature provide important constraints on ionospheric, photochemical, and solar-wind-related processes.

4.1.6 Electric Field Wave Power

- **Baseline:** MAVEN shall determine electric field wave power at frequencies between 0.05 Hz and – 10 Hz and altitudes from 200 km (nominal exobase) to 600 km (above the nominal ionopause) with an instrumental sensitivity of 10^{-8} $(V/m)^2/Hz$ $(fo/f)^2$ with f_o = 10 Hz and at 100% bandwidth.
- **Threshold:** Not a necessary measurement for a minimum mission.

4.1.12 EUV – See next talk.

MAVEN Science



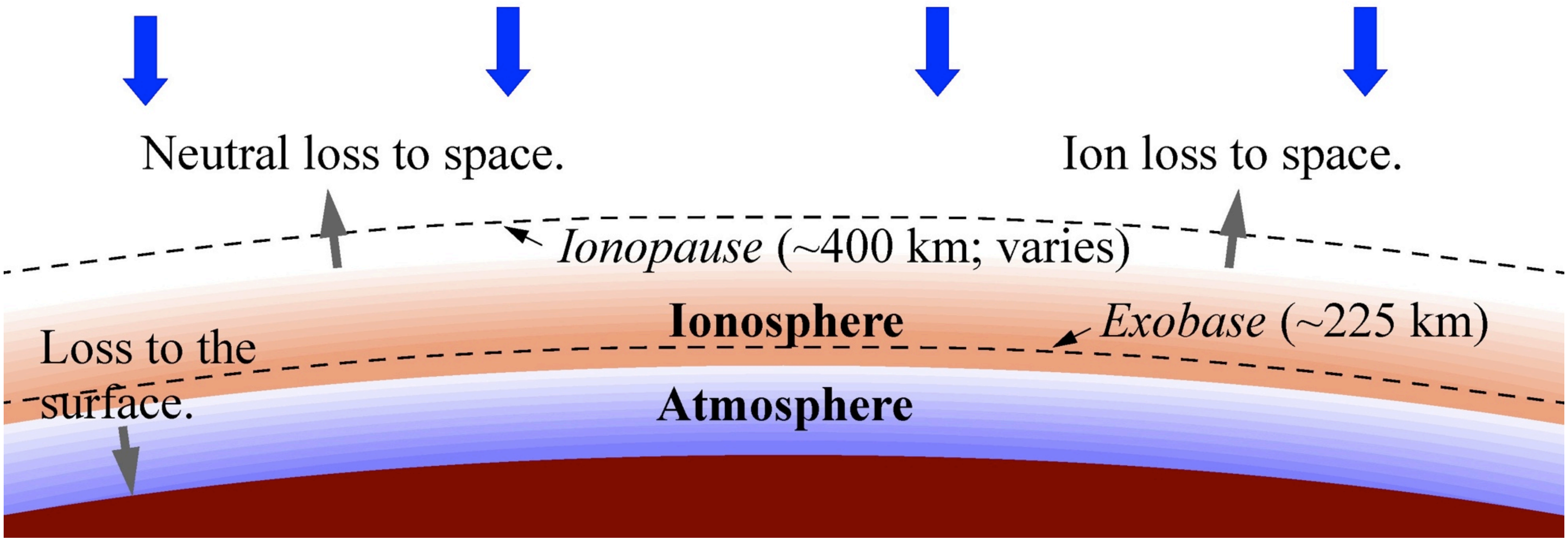
Energy Sources

UV Flux: ~10^{-4} W/m^2 (10^{14} γ/s) at 10 eV.

SW Protons: ~10^{-6} - 10^{-5} W/m^2 [*Brecht et al.*, 1997]

O^+ (Picked Up): ~10^{-6} - 10^{-5} W/m^2 [*Luhman and Kozyra*, 1991]

Poynting Flux: ~10^{-8} to 10^{-7} W/m^2 [*Ergun et al.*, 2006]



Atmospheric Loss

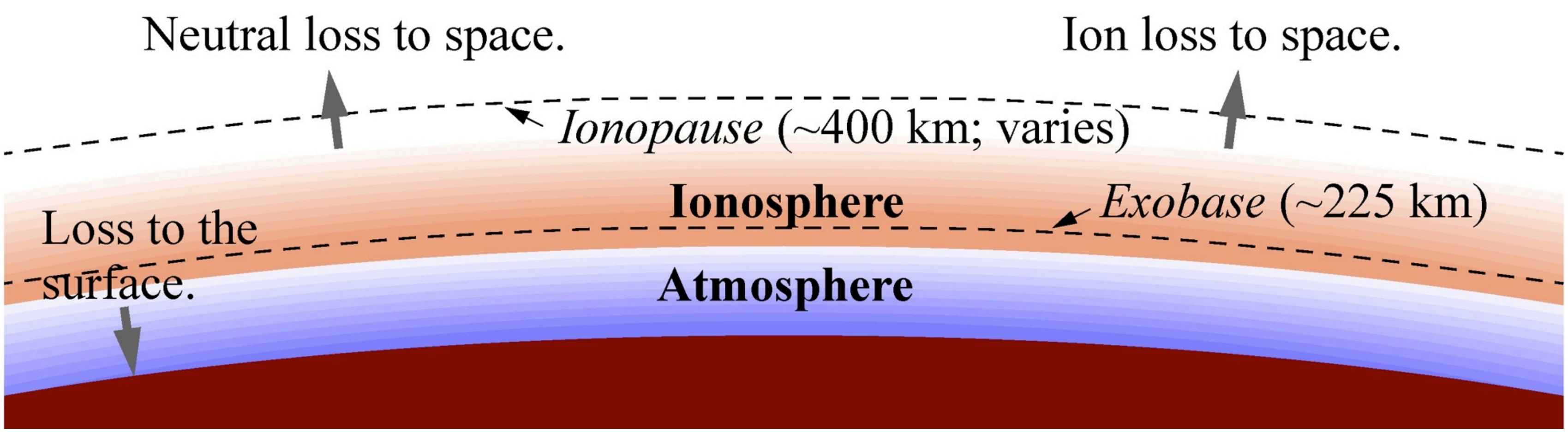
Dissociative Recombination,

$$O_2^+ + e^- \rightarrow O + O + W$$

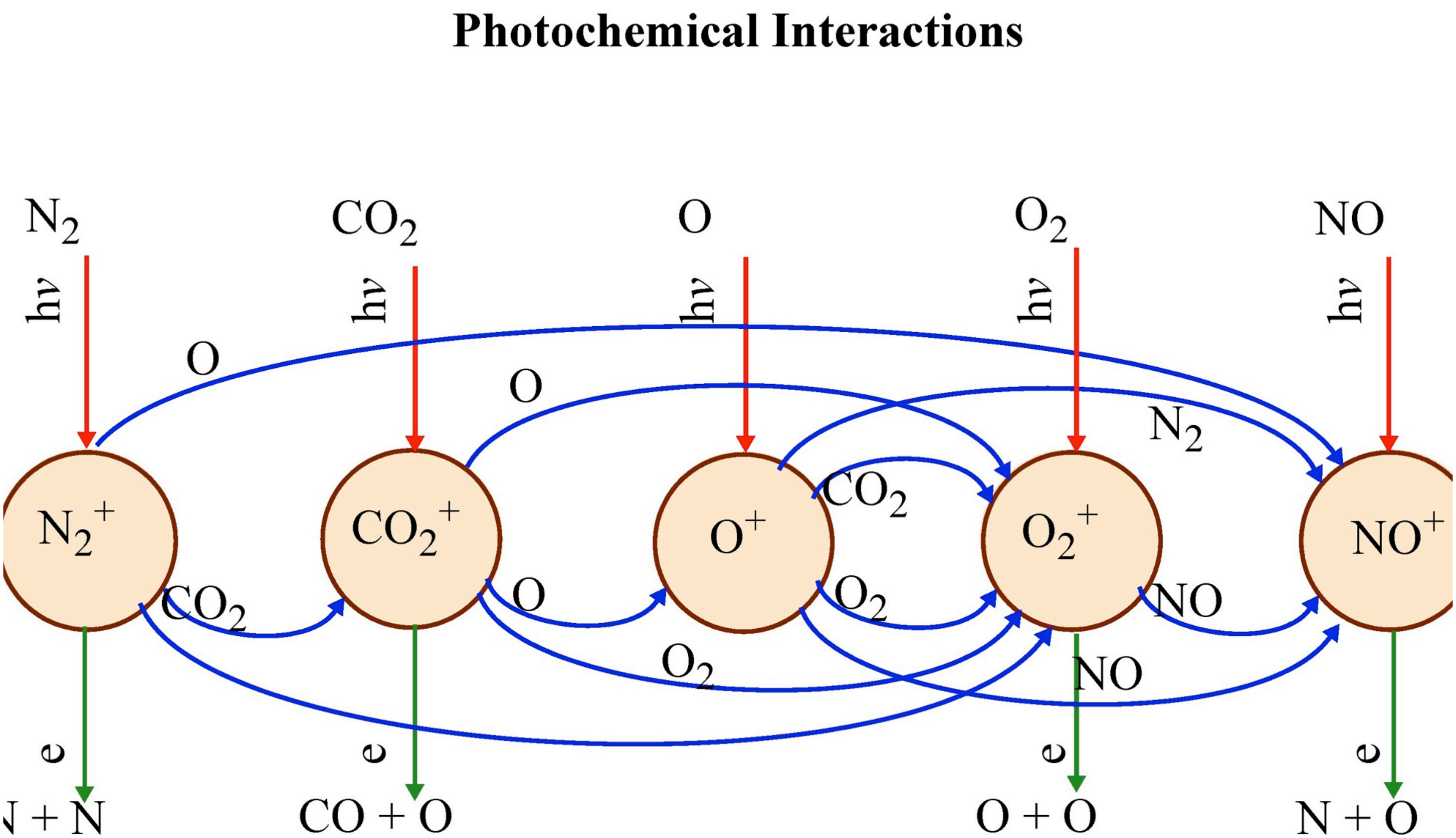
where W is the free energy between 0.8 and 7.0 eV, can account for $\sim10^{25\text{-}26}$ atoms/s in the present-day environment. The gravitational binding energy of O is ~2.1 eV.

Ion escape of O^+, O_2^+, and CO_2^+ can account for $\sim10^{24}$ atoms/s in the present-day environment [*Lundin et al.*, 1991-2009].

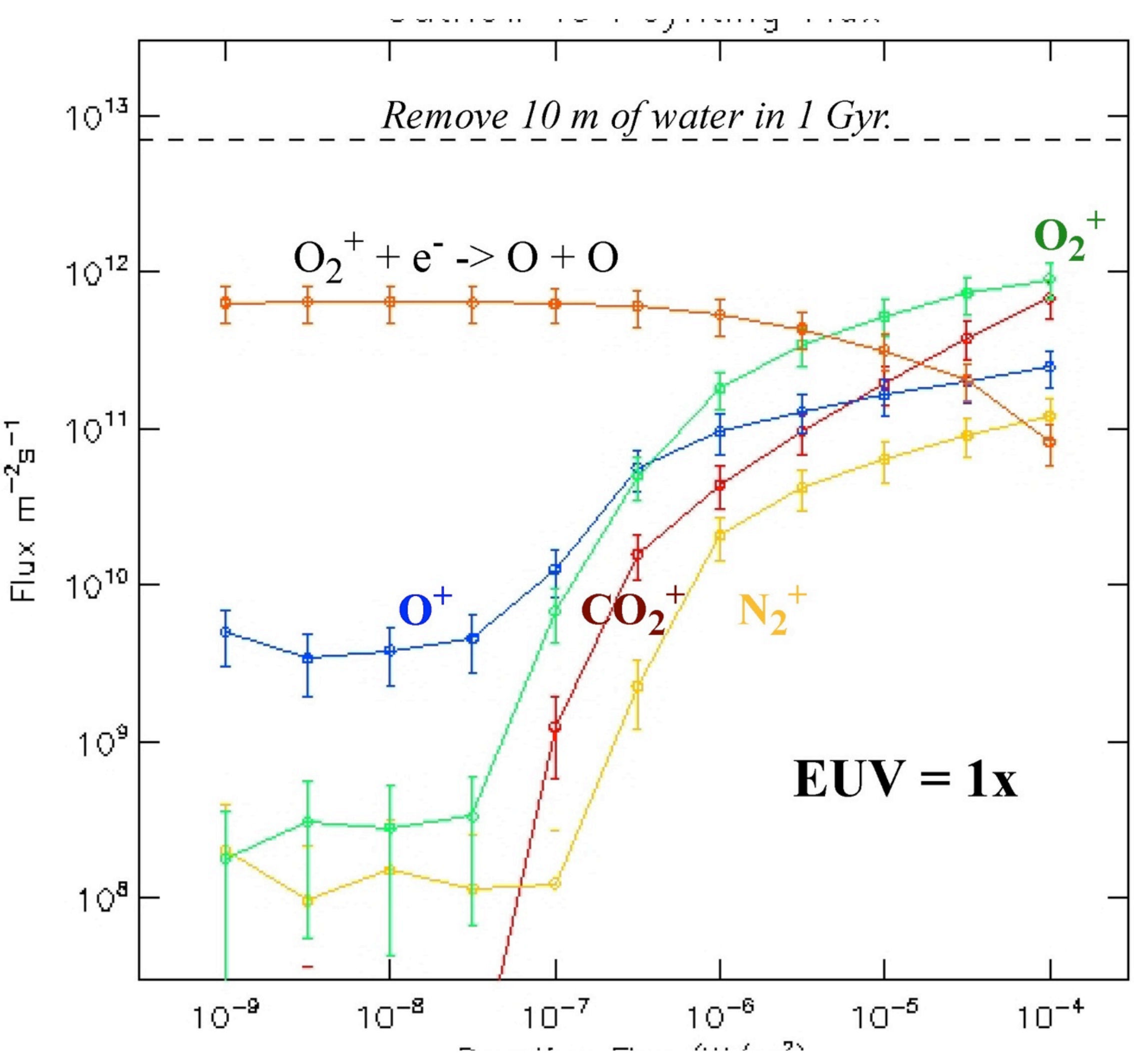
We examine the role of ion heating in ion loss.



Photochemical Processes depend on T_e



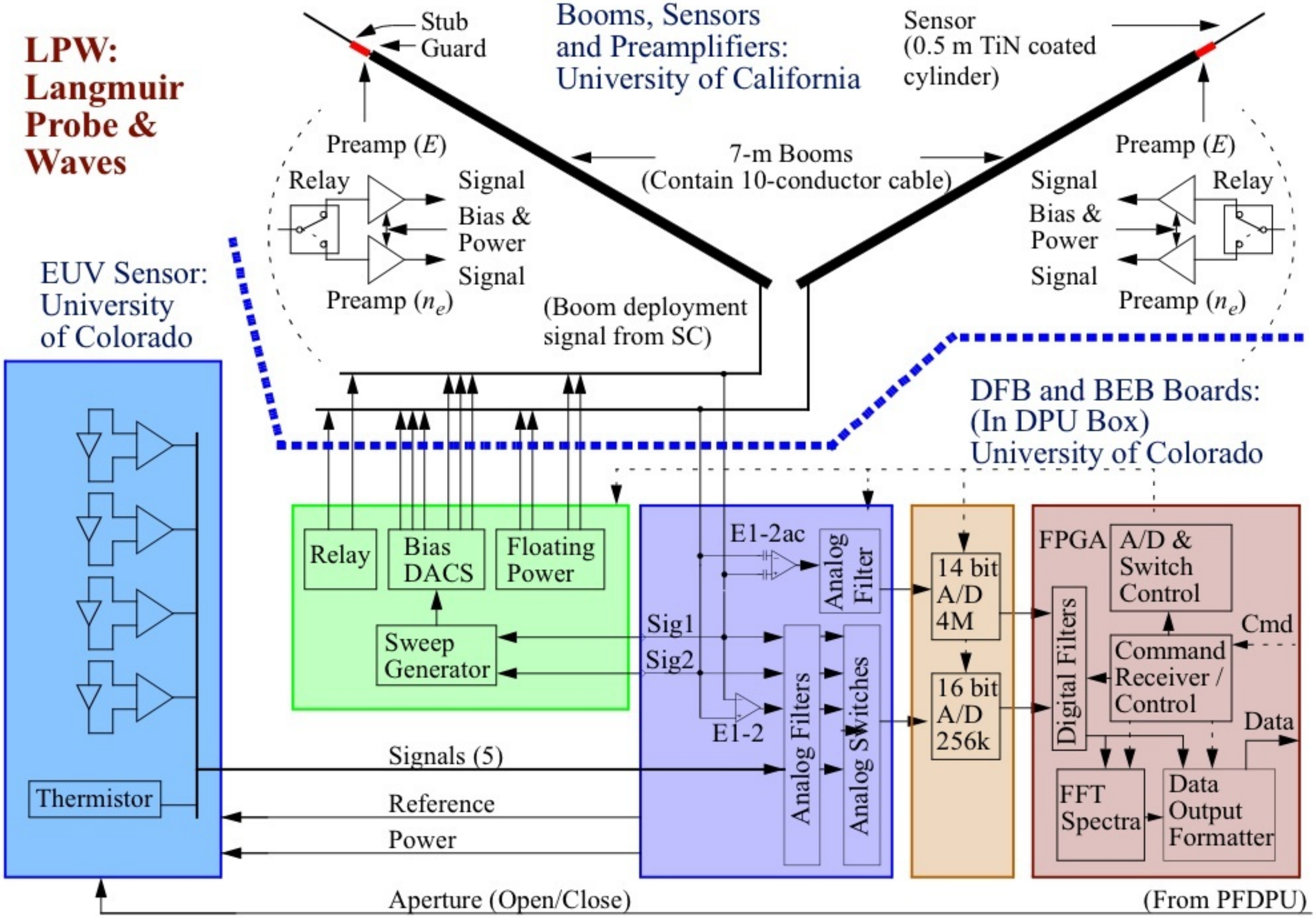
Observation of O+, OCO2+, and O



Main conclusions:

- O_2^+ and CO_2^+ loss rapidly increases (more than linear) with increasing Poynting flux.
- Dissociative recombination slightly decreases due to the extraction of O_2^+ by ion heating and due to enhanced electron temperatures.
- O_2^+ loss can dominate over O^+ loss and dissociative recombination.

LPW Instrument



LPW Design

Key Drivers

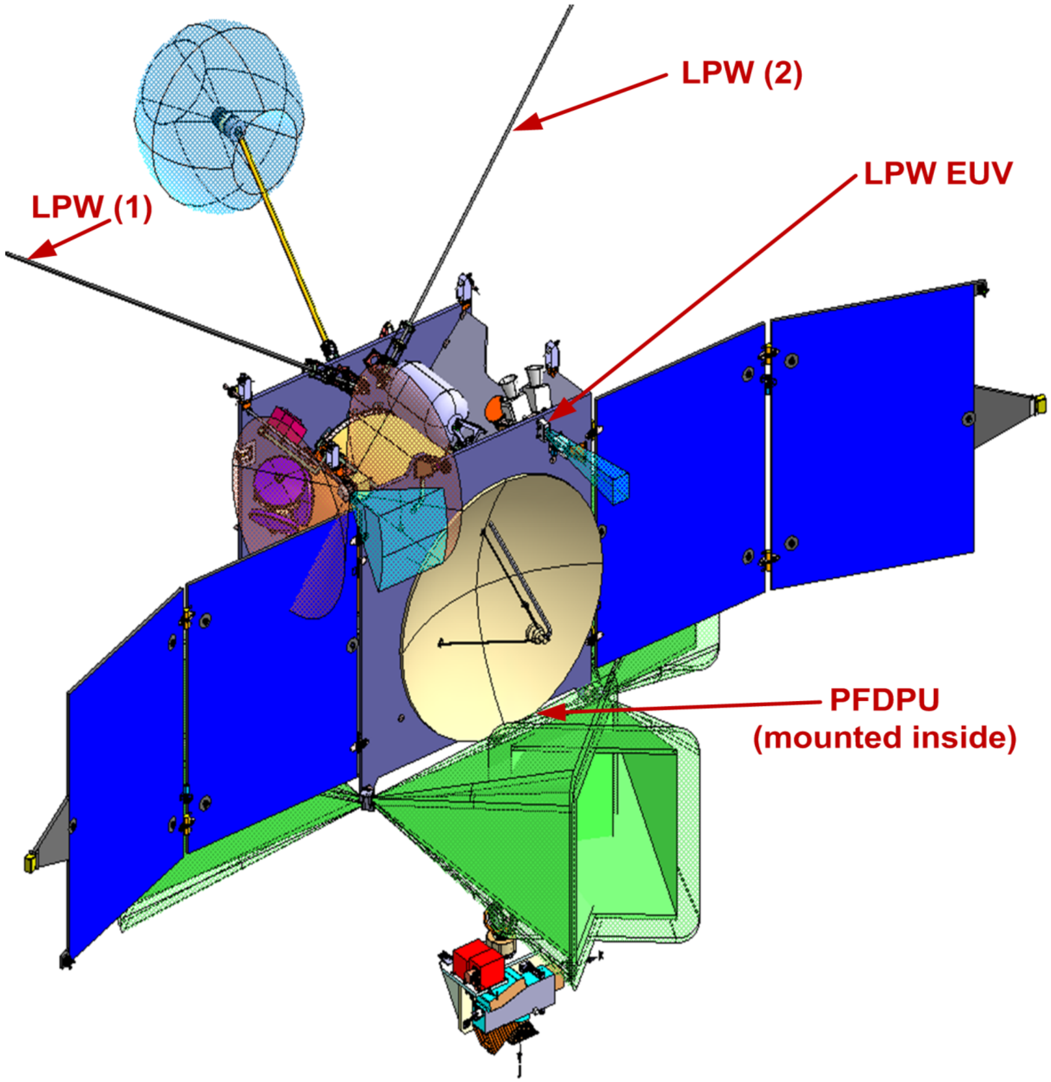
- Payload-to-plasma potential: Expected range $\pm$40 V.
- Sweep Range: $\pm$ 50V.
- Number of points per sweep: 128.
- Range of current measurement: 0.2 mA.
- Resolution of current measurement: 3.1nA.
- Range of Electric Field Measurement: $\pm$1 V/m.
- Resolution of Electric Field Measurement: 0.3 mV/m
- Low-Frequency Electric Field Measurement: 0.05 Hz – 10 Hz.
- High-Frequency Electric Field Measurement: 90 kHz – 1.6 MHz (represents densities of 10^2 cm^{-3} to $2x10^5$ cm^{-3}).

LPW Design

Key Design Features

- High impedance preamplifiers.
- Floating ground and floating power supplies. Range: ±90 V.
- Biased surfaces near the sensor.
- 16 bit A/D converter (up to 64 ksamples/s).
- 14 bit A/D converter (up to 4 Msamples/s).
- Digital signal processing (including FFT) in FPGA.

LPW Instrument



Langmuir **P**robe and **W**aves (LPW) – LASP / SSL

SSL: Boom, Pre-Amp

LASP: LPW Electronics

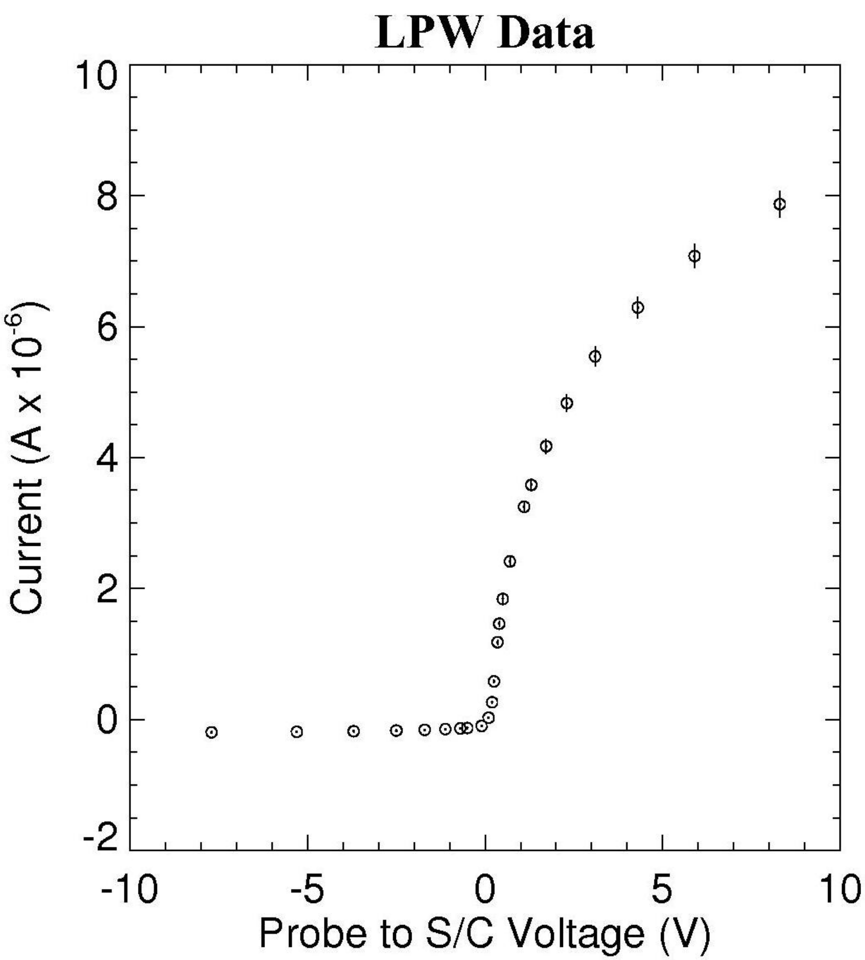
LPW/**E**xtreme **U**ltra-**V**iolet (LPW-EUV) – LASP

LASP: Mechanical & Electrical

n_e and T_e Measurement

(1) LPW measures the I-V characteristic every 2 s near periapsis. The current to the sensor is measured as it is stepped through 128 pre-determined voltages.

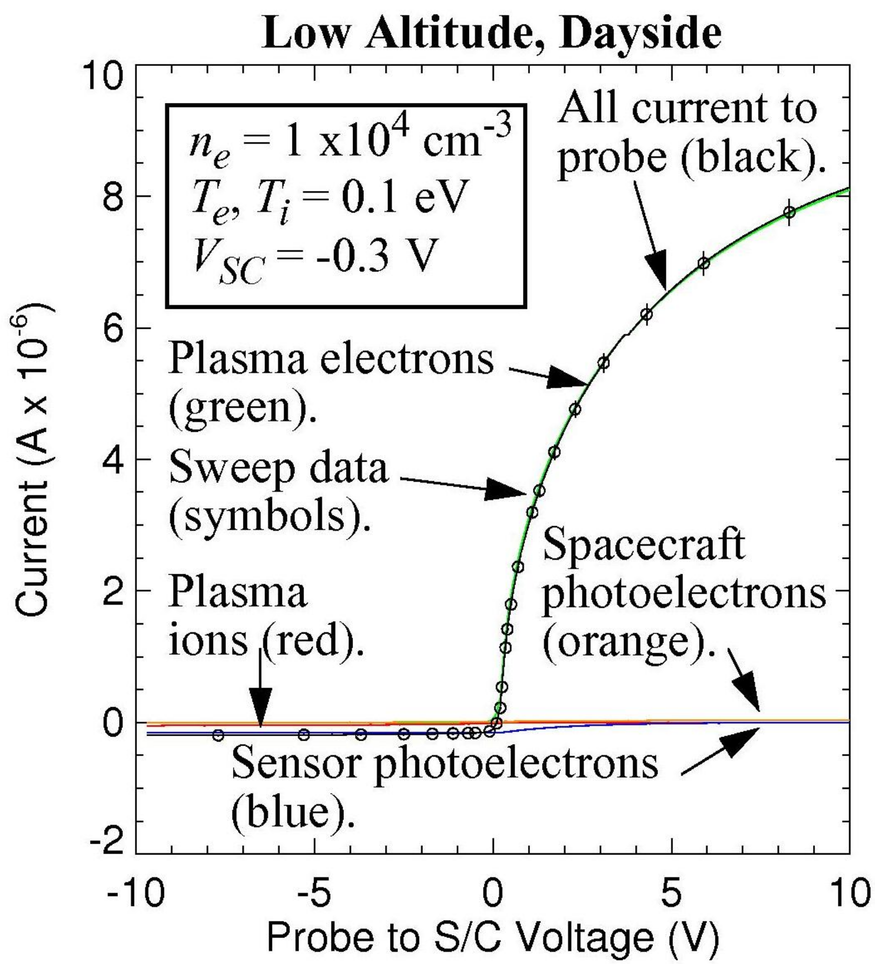
(2) The I-V characteristic data are transmitted.



n_e and T_e Measurement

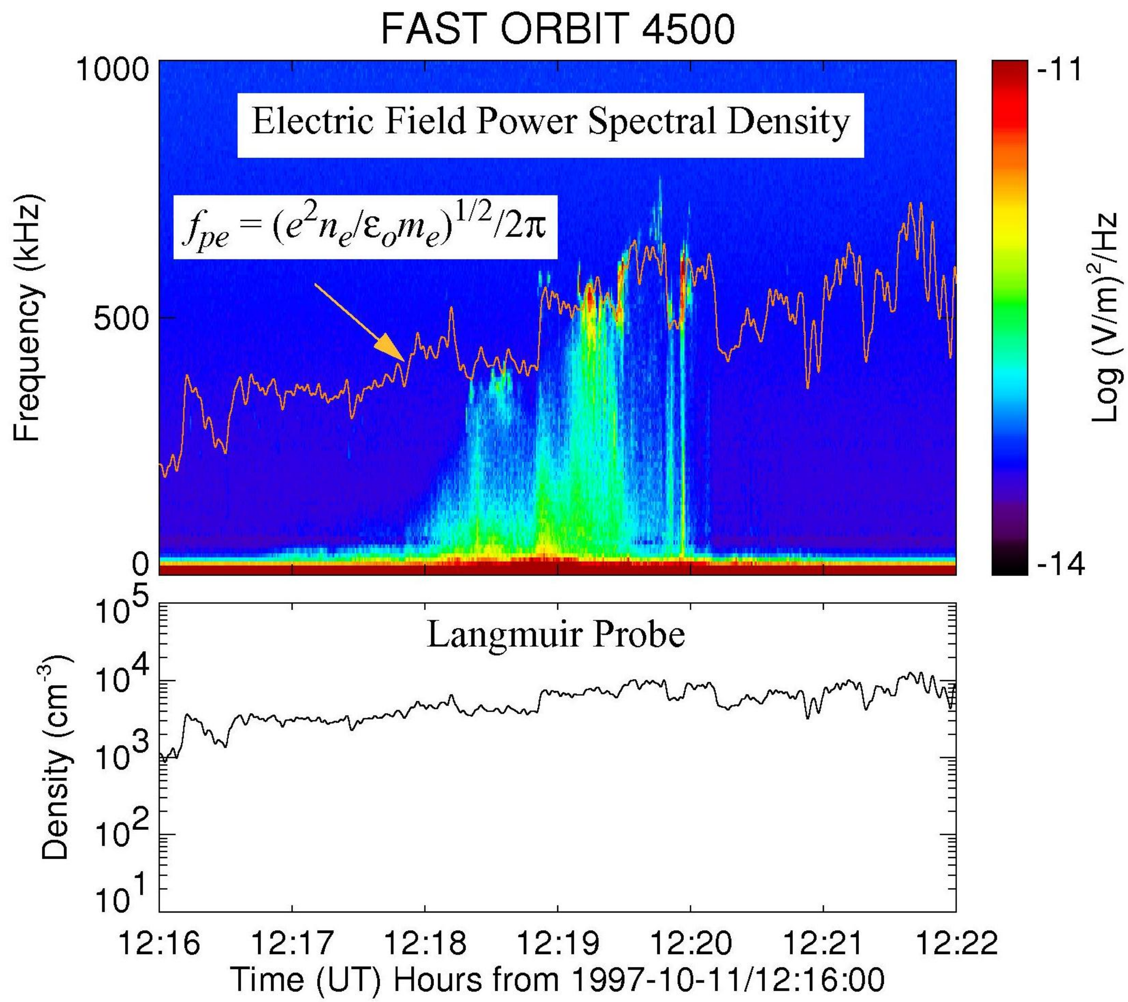
(3) Through data analysis, photoelectron currents are subtracted. Photoelectron currents are determined from I-V characteristics in low-density plasmas elsewhere in the orbit (e.g., solar wind).

(4) T_e and n_e are determined by fit to I-V characteristic. The S/C potential is also determined.



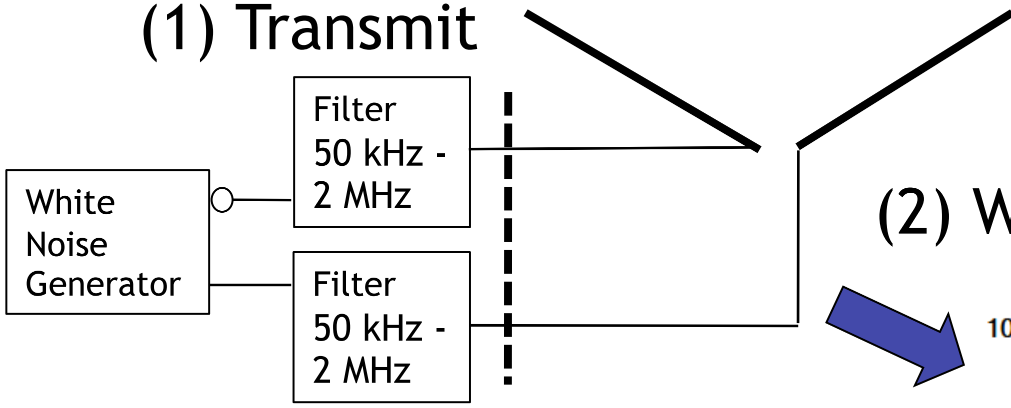
n_e and T_e Measurement

(5) Wave spectra are used to calibrate the sensor's geometric factor and remove other errors (<5%).



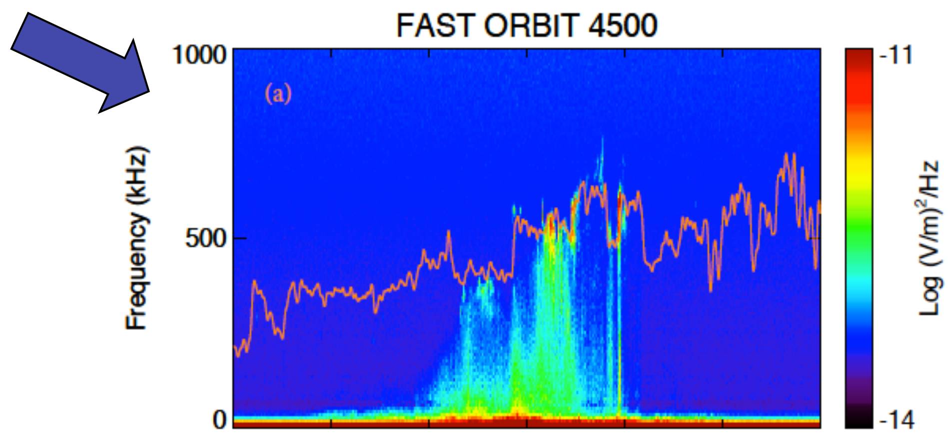
Active Sounding

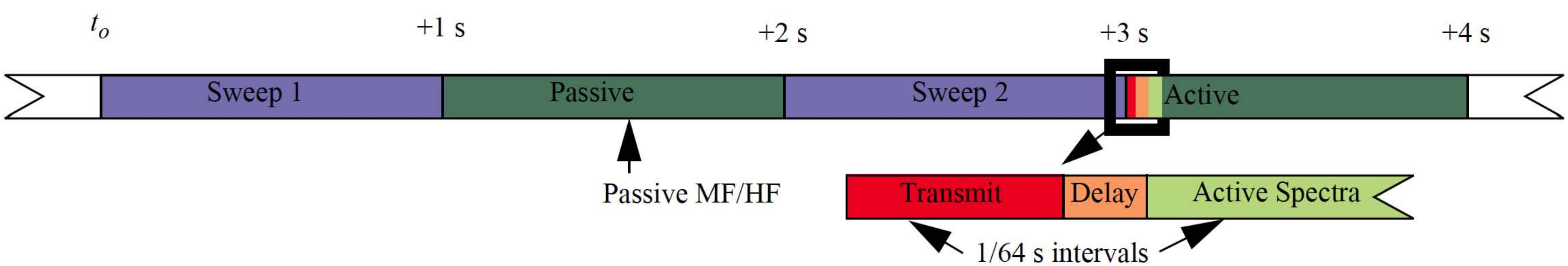
(1) Transmit



(2) Wait

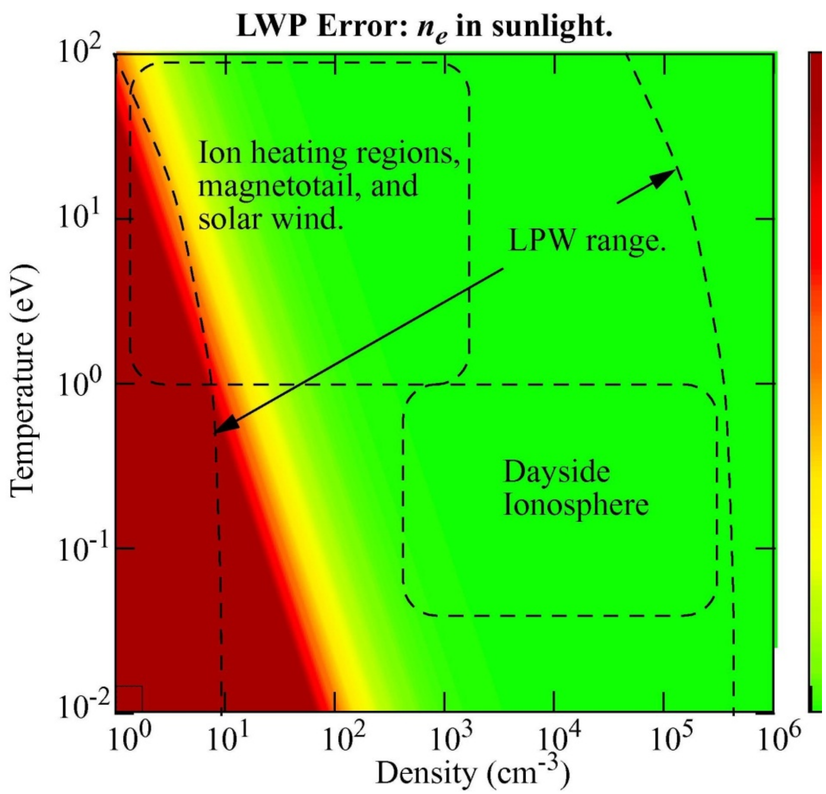
(3) Measure

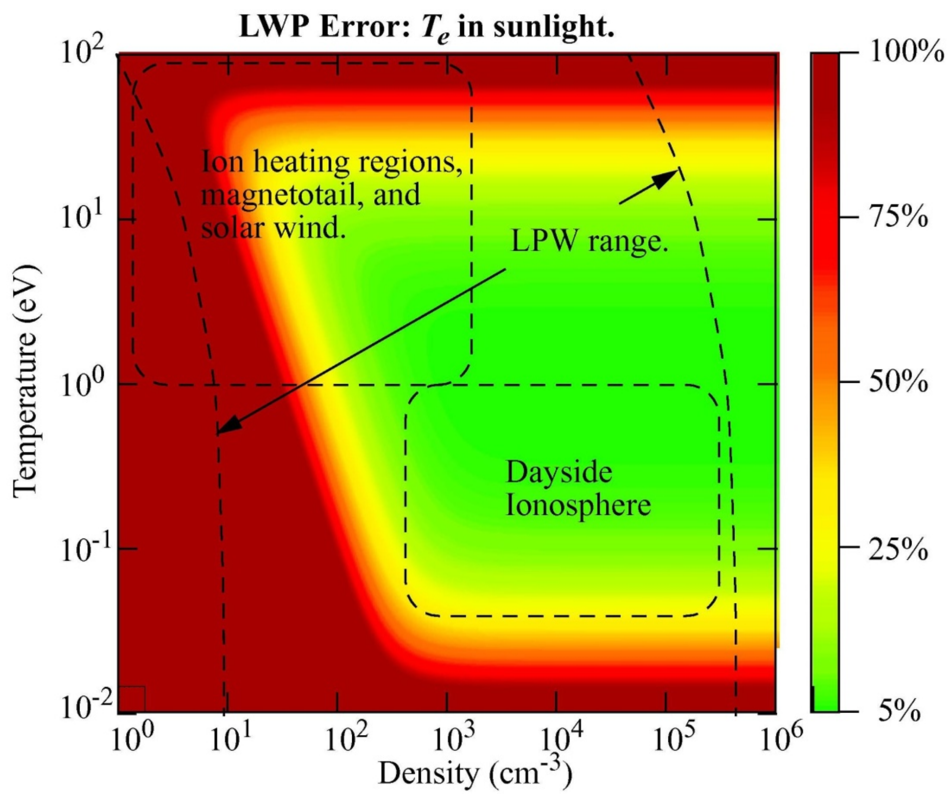




LPW n_e and T_e Accuracy

Relative accuracy of n_e and T_e degrades in low-densities when in sunlight.





LPW n_e and T_e Accuracy

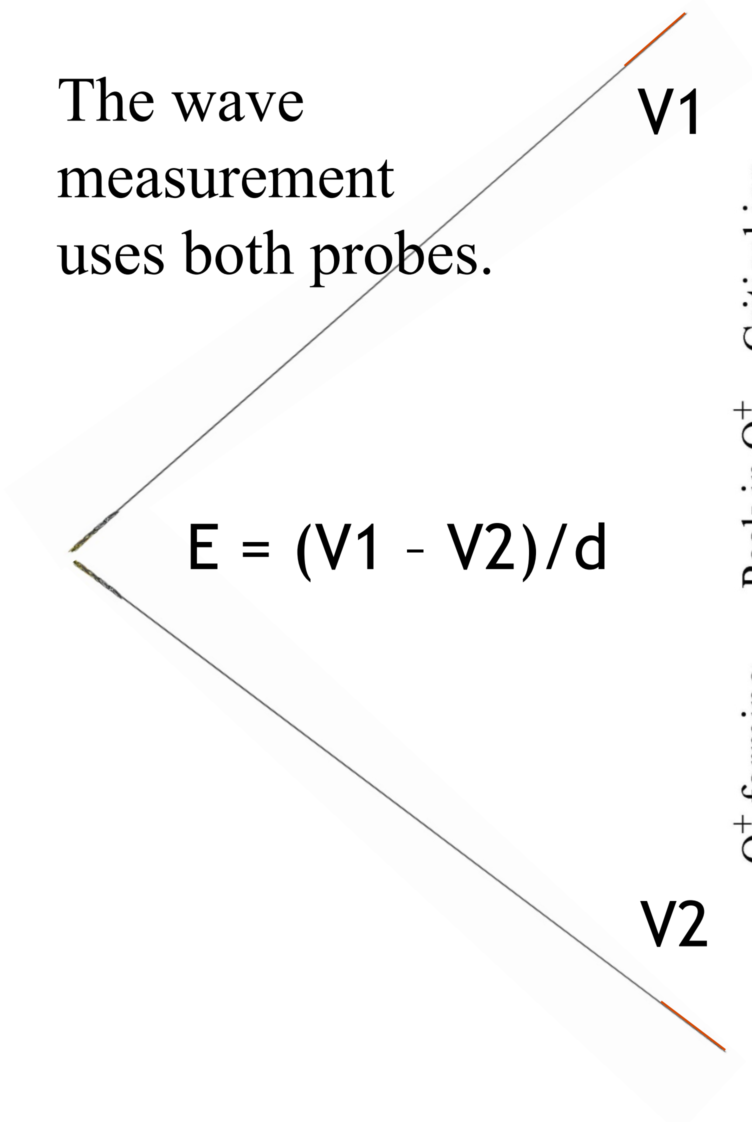
LPW is used for cross-calibration with NGIMS/STATIC.

LPW accuracy degrades if:
- In sunlight.
- In low densities.
- In low temperatures.
- High SC charging (>10 V).

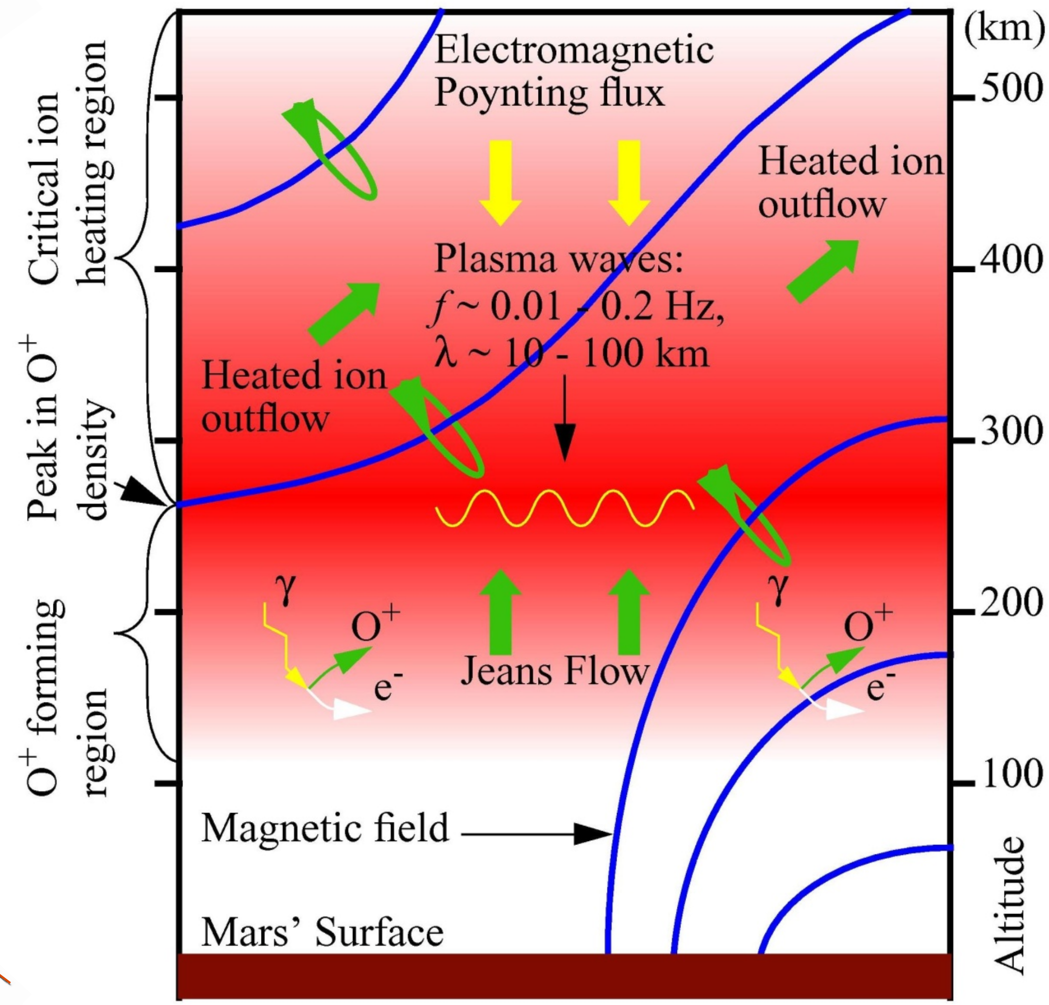
N_e Accuracy		LPW Sweep		Spectra/ Sounding
		Relative Accuracy	Absolute Accuracy	Absolute Accuracy
$n_e \geq 10^3$ cm^{-3} $T_e \geq 0.1$ eV	Daylight/ Shadow	5%	20%	2% - 4% (n_e only)
$n_e \geq 10^2$ cm^{-3} $T_e \geq 0.2$ eV	Daylight	10%	40%	6% - 12% (n_e only)
$n_e \geq 10^2$ cm^{-3} $T_e \geq 0.2$ eV	Shadow	5%	20%	6% - 12% (n_e only)
$n_e \geq 10^1$ cm^{-3} $T_e \geq 0.5$ eV	Daylight	50%	100%	6% - 12% (n_e only)
$n_e \geq 10^1$ cm^{-3} $T_e \geq 0.5$ eV	Shadow	25%	100%	6% - 12% (n_e only)

Waves

The wave measurement uses both probes.



$$E = (V1 - V2)/d$$



Waves

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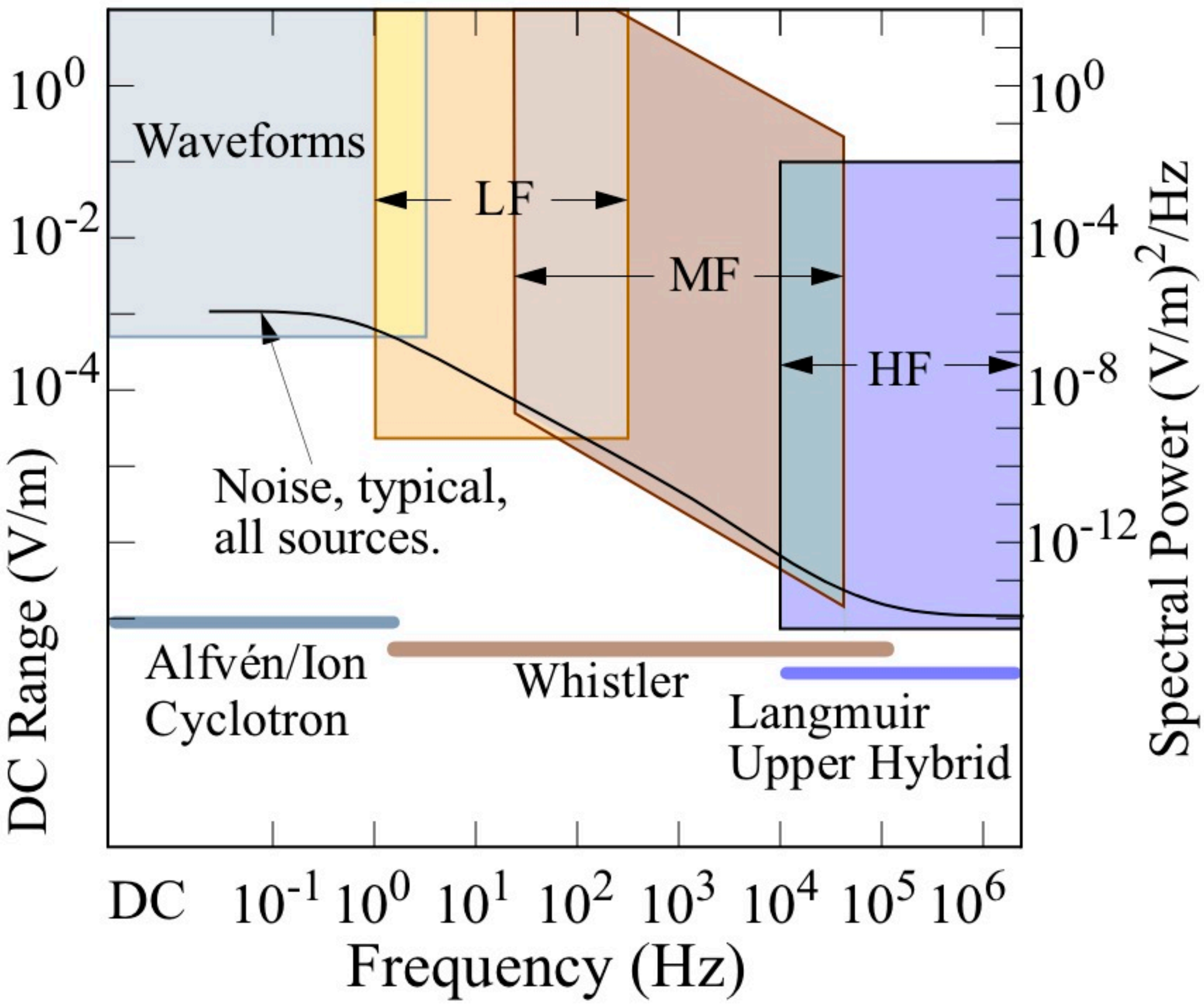


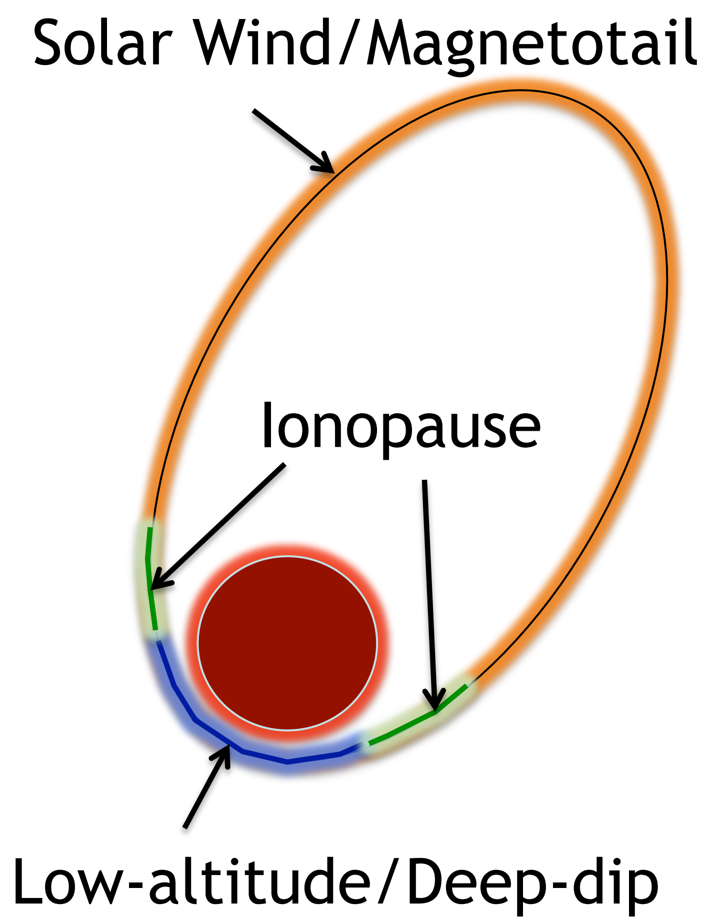
LPW Operation Strategy

Sensors and Booms

- Sensors will be in cleaning mode during cruise.
- Booms deployed MOI + 60.
- Sounding test scheduled after deploy.

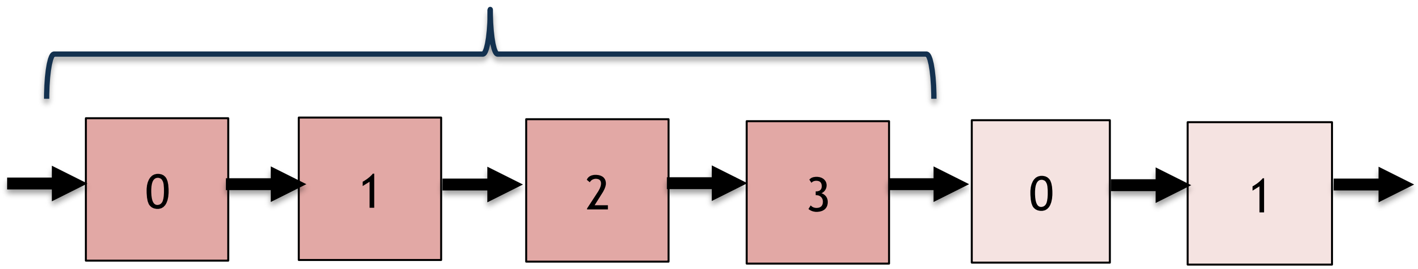
Operational configurations:

(0) Deep-dip in sun.
(1) Low-altitude in sun.
(2) Ionopause in sun.
(3) Solar Wind/Magnetotail in sun.
(4) Deep-dip no sun.
(5) Low-altitude no sun;
(6) Ionopause no sun
(7) Magnetotail no sun.
(8-15) Engineering / Spare



LPW Measurement Strategy

Each operational configuration uses a Master Cycle, which has four sub-cycles. The master cycle duration is 4s - 256s.



Types of Sub-cycles:

- Langmuir Probe Sweep
- Passive Electric Field
- Active Sounding

All sub-cycles have the same duration ($T_{SUBCYCLE}$): 1 s – 64s.

LPW Measurement Strategy

Configuration	00	01	02	03
Description	Deep-Dips	Low-Altitude (Prime Science)	Ionopause	High-Altitude
Nominal Orbit Location	< 400 km (TBD)	< 400 km (TBD)	>400 km <1000 km (TBD)	>1000 km (TBD)
Sub-configuration	Sun/No Sun	Sun/No Sun	Sun/No Sun	Sun/No Sun
Measurement	Ne, Te, E_{LF}, E_{HF}, EUV	Ne, Te, E_{LF}, E_{HF}, EUV	Ne, Te, E_{LF}, E_{HF}, EUV	Ne, Te, E_{LF}, E_{HF}, EUV
Cadence	Highest ~2 s Ne, Te ~1/64 s $E_{LF,}$ ~4 s Spectra	Highest ~2 s Ne, Te ~1/64 s $E_{LF,}$ ~4 s Spectra	Moderate ~16 s Ne, Te ~1/8 s $E_{LF,}$ ~8 s Spectra	Slow ~64 s Ne, Te ~1 s $E_{LF,}$ ~64 s Spectra

LPW Measurement Summary

Below 500 km

- T_e and n_e every 2 s through I-V sweep. Probes are alternated. One probe performs I-V sweep, the other probe will measure payload potential.
- Natural electric field wave spectra (10 Hz – 2 MHz) every 4s.
- Sounding wave spectra (50 kHz – 2 MHz) every 4 s.
- Electric Field waveforms, 64 points for 1 s, every other second.
- Burst Waveforms up to 4 Msamples/2.

LPW Measurement Summary

~500 – ~1000 km

- T_e and n_e every 8 s through I-V sweep. Probes are alternated. One probe performs I-V sweep, the other probe will measure payload potential.
- Natural electric field wave spectra (10 Hz – 2 MHz) every 16 s.
- Sounding wave spectra (50 kHz – 2 MHz) every 16 s.
- Electric Field waveforms, 64 points for 4 s, every other 4 second period.

LPW Measurement Summary

Above ~1000 km altitude

- T_e and n_e every 64 s through I-V sweep. Probes are alternated. One probe performs I-V sweep, the other probe will measure payload potential.
- Natural electric field wave spectra (10 Hz – 2 MHz) every 128 s.
- Sounding wave spectra (50 kHz – 2 MHz) every 128 s.
- Electric Field waveforms, 64 points for 32 s, every other 32 second period.