The Plasma Wave Experiment (PWE) aboard the ERG mission, just in the EM phase, will observe the electric field (from DC to 10 MHz) and magnetic field (from few to 100 kHz) for the clarification of global plasma dynamics, energetic processes, and wave-particle interactions in the radiation belt.

It is based on the Plasma Wave Investigation (PWI) aboard BepiColombo Mercury Magnetospheric Orbiter (MMO), which FM is now tested at ISAS. The key issues are:

(a) Examination of the high-energy particle acceleration by plasma waves,
(b) Diagnosis of plasma density and temperature, and
(c) Investigation of wave-particle interaction and mode conversion processes.

Some key development will also be the basis for the JUICE mission.

**Electric Field Sensors** (32m tip-to-tip dipoles)
- **WPT** (Wire-Probe anTenna) DC-10MHz [Tohoku U et al.]
- **EWO-EFD** (Electric Field Detector) [Toyama Pref. U et al.]
- **EWO-WFC/OFA** (WaveForm Capture/Onboard Frequency Analyzer) [Kyoto U et al.]
- **HFA** (High-Frequency) [Tohoku U et al.]

**Magnetic Field Sensors** (search-coils)
- **SC** (3-axis Search-Coils) 0.1 Hz – 100kHz [Kanazawa U et al.]
- **EWO-WFC/OFA** (WaveForm Capture/Onboard Frequency Analyzer) [Kyoto U et al.]

Plasma waves and E field in the inner magnetosphere during storm

**Spectrogram of plasma waves in the inner magnetosphere during geospace storm**, which suggests large scale variation of plasmasphere structures and injections of energetic electrons

Correspondence between relativistic electrons and intense whistler-mode chorus emissions during storm. [Miyoshi et al., 2003]

Unusual electric field structure during geospace storm [Rowland and Wygant, 1998]
Scientific Objectives of ERG/PWE

<table>
<thead>
<tr>
<th>Relativistic electron acceleration by plasma waves</th>
<th>E field in the inner magnetosphere</th>
<th>Plasma waves in the inner magnetosphere</th>
</tr>
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<tr>
<td>Verification of quasi-linear theory &amp; Development of non-linear model of acceleration process by waves</td>
<td>Evolution of E field structure in the inner magnetosphere during storms</td>
<td>Diagnosis of plasma density, temperature and composition in the plasmasphere by waves</td>
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<td>Direct detection of non-linear wave-particle interaction between whistler-mode chorus and medium energy electrons.</td>
<td>Generation mechanism of intense E field during storms.</td>
<td>Wave-particle interaction and mode conversion inside and outside of the plasmasphere</td>
</tr>
<tr>
<td>EWO-E/B, HFA + WPT/MSC</td>
<td>EFD + WPT-S</td>
<td>EWO-E/B, HFA + WPT/MSC</td>
</tr>
</tbody>
</table>

- Verification of quasi-linear theory & Development of non-linear model of acceleration process by waves
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- Generation mechanism of intense E field during storms.
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Miyoshi et al., 2003
Rowland and Wygant, 1998

ERG / PWE --- Plasma Wave Experiment

in ISAS-sympo. (Jan. 2013) -5-

Sensitivity & Dynamic range Issue

Wide coverage of both eggs of Non-linear processes ~ weak waves results of Non-linear processes ~ largest waves in the Radiation belt's!

OK!

1. \( dE > 100 \text{ mV/m} \) (largest observed \( > 300 \text{ mV/m} \))
2. \( dB > 1 \text{ nT} \) (largest observed \( > 8 \text{ nT} \))
3. Amplitudes correlated with AE

MSC saturation levels at several kHz
10 nT (for low gain)
1 nT (for high gain)

Strong waves found by Wind (Cattel et al. 2011)

Low frequency wave issue

Example: Magnetosonic Waves

Horne et al. [2007, GRL]

E: EFD (128Hz waveform in Bepi)  
“256Hz waveform” 
“Higher gain” by DPB \([-100mV/m, 16bit]\) 
“Lower gain” by SPBx2 \([-6V/m, 16bit]\)

B(&E): CPU reduction in order to get 256Hz waveform from 60kHz-sample data

Dawn side, with Chorus. Magnetosonic wave is around the equator.

EFD: EWO-E/B
ULF waves
Non-adiabatic Acceleration
Relativistic Electrons
Radial diffusion
Whistler-mode Chorus
Med. Energy Electrons
Ring Current Electrons
Plasma Sheet Electrons
Low Energy Electrons
Continuum waves
Plasmapause
Corotation/Convection
E: EFD (128Hz waveform in Bepi)  
“256Hz waveform” 
“Higher gain” by DPB \([-100mV/m, 16bit]\) 
“Lower gain” by SPBx2 \([-6V/m, 16bit]\)

B(&E): CPU reduction in order to get 256Hz waveform from 60kHz-sample data

This document is provided by jAXA.
### Electric field: Dipole wire antennas

~ First long wire antenna (32m tip-to-tip length) aboard a Planetary Orbiter ~

**WPT-S**  
[from Tohoku Univ. et al.]

- **Ti-alloy sphere** (mounting control)
- Stainless wire-polyamide-covered
- Conduction shield: Conduction line
- 10mm (TBC)
- 2 pairs. the same design with the MMO's.

**MEFISTO-S**  
[from KTH, IRF-U, et al.]

- Stainless wire, 0.1-0.3 mm, 1-2 m
- Ti-Al probe 40 mm diameter
- Pre-amplifier
- Boom, 13-14 m, connected to solid ground

**Optimized for plasma waves & radio waves**

**Optimized for dc & low frequency electric field**

**Provision is not possible.**

### Magnetic Field: Magnetic Search Coils (MSC)

- **Kanazawa U., Japan**
- **Bx / By / Bz** [0.1 Hz - 100kHz]
- **MAST (~5 m)**
- **Preamp**
- (Inside spacecraft body for protection from high TID)

**MSC**  
[from Kanazawa Univ. et al.]

- **Search Coil (3-axis)**
- **20x20x20 cm**

### Receivers

**[Receivers]**

- **EWO-EFD**:  
  - DC – 80 Hz (512Hz waveform)
  - Double Probe: Dynamic range 110 dB
  - Single Probe: Spacecraft potential (128Hz) for Electron density

- **EWO-WFC/OFA**:  
  - 10Hz – 20kHz (60kHz sample) for E
  - Few Hz – 20kHz (60kHz sample) for B
  - Connected to WPT (E:2ch) & SC (B:3ch)

- **Waveform receiver with spectrum data (derived in DPU)**

- **HF receiver**:  
  - 10kHz – 10MHz for E
  - 10 – 100kHz for B
  - Connected to the WPT (E-2ch) [or E-1ch + MSC (B-1ch)]

### Raw data from PWE

#### Ring Buffer size in the DPU

- **320sec: WFCE/B, 1200sec: EFD, HFA**

<table>
<thead>
<tr>
<th>Receiver</th>
<th>Data</th>
<th>total (bps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWO-EFD</td>
<td>DPB [Sweep] 512Hz x 16bit x 2ch (sync)</td>
<td>16.4k</td>
</tr>
<tr>
<td></td>
<td>SPB 128Hz x 16bit x 4ch (non-sync)</td>
<td>8.2k</td>
</tr>
<tr>
<td>EWO-OFA/WFC(E)</td>
<td>Nominal 65.536kHz x 14(bit x 2ch)</td>
<td>2097.1k</td>
</tr>
<tr>
<td></td>
<td>[for SWPIA] 262.144kHz x 14(bit x 2ch)</td>
<td>or 8388.4k</td>
</tr>
<tr>
<td>EWO-OFA/WFC(B)</td>
<td>Nominal 65.536Hz x 14(bit x 3ch)</td>
<td>3145.7k</td>
</tr>
<tr>
<td></td>
<td>[LF mode] [16.384Hz x 14(bit x 3ch)]</td>
<td>or 786.4k</td>
</tr>
<tr>
<td>HFA E-2ch</td>
<td>1Hz x 8bit x 1024ch [10k-10M] x 2</td>
<td>16.4k</td>
</tr>
<tr>
<td>E/B</td>
<td>1Hz x 8bit x 1024ch [10k-10M]</td>
<td>&lt;16.4k</td>
</tr>
</tbody>
</table>

**Total of Raw Data: 3.0 – 11.6Mbps**
Keynotes of the PWE data strategy

- How to cover the wide frequency range?
  - PWE covers whole frequency range from DC to a few MHz
- Employment of Data compression
  - Would be necessary to obtain the mission data as much as possible
  - But should not lose the essence of the physics!
- Onboard data detection or selection
  - Should be carefully examined how to determine the index of important data
- Optimum design of onboard data processing
  - Optimization of CPU & Memory resources
  - Design of “special observation mode” is VERY important!
- Optimization of observation strategy in the operation plan
  - Optimized operation plan is needed binding with the other ground observatory & the other spacecraft
II. Apogee: DAWN, Magnetic equator: L~5
[for Chorus]

\[
\begin{align*}
L > 4, & \quad |\text{MLAT}| < 10^\circ \\
& \quad 440 \text{ min/day} \\
& \quad 5^\circ \quad 240 \text{ min/day} \\
& \quad 3^\circ \quad 150 \text{ min/day}
\end{align*}
\]

III. Apogee: DUSK, Magnetic equator: L~5 [for EMIC]

\[
\begin{align*}
L > 4, & \quad |\text{MLAT}| < 10^\circ \\
& \quad 430 \text{ min/day} \\
& \quad 5^\circ \quad 230 \text{ min/day} \\
& \quad 3^\circ \quad 140 \text{ min/day}
\end{align*}
\]

Team Structure

**PI / WPT-S**: Yasumasa Kasaba (Tohoku U.)
Eng. Manager / EWO: Hirotsugu Kojima (Kyoto U.)
EWO-EFD: Keigo Ishisaka (Toyama Pref. U.)
MSC: Satoshi Yagita (Kanazawa U.)
HFA: Atsushi Kumamoto (Tohoku U.)
Software: Yoshiya Kasahara (Kumamoto U.)
Outreach + SWPIA-I/F: Yuto Kato (Kumamoto U.)
Data: Yoshihumi Miyoshi (Nagoya U.)

**PWE & EWO**: HII

**WPT-S**: NIPPI
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**HFA**: Meisei
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Y. Kasaba
H. Misawa

**SWPIA**: Meisei
H. Kojima
Y. Kasaba
M. Hikishima

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A. Kumamoto (WPT)

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**<PWE>**
32 scientists in total

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Takahisa Kikuchi
Toshimi Okada
Isamu Nagano
Atsuki Shirahori
Yukitoshi Nishimura
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Masaki Okada
Takatoshi Miyake
Yoshii Haru Oomura
Hidesaki Usui
Yoshihumi Miyoshi

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