SYNERGISTIC RADIO AND PLASMA WAVE SCIENCE FOR EJSM

B. Cecconi, N. André and the EJSM-EM sensor Study Team
Electrodynamic portrait of the Jovian System

**Io**
- Io-Jupiter Circuit
- Plasma Torus
- Alfvén Wings
- Auroral Footprint
- Source of plasma
- Dust streams

**Europa**
- Exosphere
- Internal conductive layer
- Auroral footprint
- Io torus interaction

**Ganymede**
- Intrinsic Mag. Field
- Internal conductive layer
- Mini-Magnetosphere
- Local Waves
- Ganymede aurorae
- Auroral Footprint

**Callisto**
- Exosphere
- Internal conductive layer
- Induced Mag. Field

**Jupiter**
- Radio Emissions
- UV Aurora
- Magnetic Field
- Polar Cap
- Ionospheric Currents

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## History of Jovian exploration

<table>
<thead>
<tr>
<th>Spacecraft</th>
<th>Orbits</th>
<th>Radio Instrumentation</th>
<th>Maximum frequency</th>
<th>Plasma Wave Instrumentation</th>
<th>Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voyager</td>
<td>flyby</td>
<td>total flux, sign of circular polarization</td>
<td>40.5Mhz</td>
<td>E only</td>
<td>Electrical: 2 monopoles (10m)</td>
</tr>
<tr>
<td>Ulysses</td>
<td>flyby (outbound was polar)</td>
<td>flux, polarization, direction finding</td>
<td>940kHz</td>
<td>E+B</td>
<td>Electrical: 1 dipole (72.5m) 1 axial monopole (7.5m)</td>
</tr>
<tr>
<td>Galileo</td>
<td>misc orbits</td>
<td>total flux only</td>
<td>5.6MHz</td>
<td>E+B</td>
<td>Electrical: 1 dipole (6.6m)</td>
</tr>
<tr>
<td>Cassini</td>
<td>distant flyby &gt;135Rj</td>
<td>flux, polarization, direction finding</td>
<td>16MHz (GP up to 2Mhz)</td>
<td>E+B</td>
<td>Electrical: 3 monopoles (10m)</td>
</tr>
<tr>
<td>New Horizons</td>
<td>distant flyby</td>
<td>— no Radio &amp; Plasma Waves instrumentation —</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juno</td>
<td>polar orbits</td>
<td>total flux only</td>
<td>40MHz</td>
<td>E+B</td>
<td>Electrical: 1 dipole (~2m)</td>
</tr>
<tr>
<td>EJSM (JGO, JEO?)</td>
<td>Tour + Satellites</td>
<td>flux, polarization, direction finding</td>
<td>45Mhz</td>
<td>E+B</td>
<td>TBD (This study!)</td>
</tr>
</tbody>
</table>
Electromagnetic Sensors for EJSM

[See also the EJSM ElectroMagnetic Sensor Study Poster]

Possible sensor types:
- [a] Electric antenna boom (E-HF + E-BF)
  - long dipole (~6 to 10 m)
  - triad of short antennas (~1 m)
- [b] Langmuir Probe (plasma + E-BF + E-DC)
- [c] Search Coil (B-BF)
- [d] High Frequency Magnetic Loop (B-HF)
- [e] Rogovski Coil (current)
- [f] Association with MAG instrument (B-DC)
- [g] Mutual Impedance Probe (plasma)

Science optimized sensor selection criteria:
- Size, mass of sensors
- Sensitivity (overall gain, preamplifier sensitivity)
- Interference with other instruments FoV
- Accommodation, risks (momentum, oscillations, planetary protection)
- Radiation tolerance (shielding, instrument design)
- Electromagnetic cleanliness (e.g. prefer passive instrumentation)
- ...
Unique Science Aspects

- **Goniopolarimetry**: [a] or [d], monopole or dipole, (depending on EM-Sensor Study outcome)
- **Thermal Noise Spectrometry**: [a] with long antennas
- **Dust, nano-dust**: [a] with long monopole
- **Plasma waves / waveform**: [a] [b] [c] with long dipole
- **Local plasma parameters**: density [a] [b], temperature [a] [b], speed [e], S/C potential [b], magnetic field [a] [f], core/halo electron distribution [a]
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SYNERGISTIC SCIENCE JGO/JEO
(Cross-Instrument or Cross-Spacecraft)

Galilean Satellite Science
- flyby science (local electrodynamic content, induced magnetic response)
- magnetospheric interaction (alfven wings, current, magnetosphere, exosphere, footprints)
- Ganymede magnetosphere (stereo observations)
- magnetospheric context (ENA, UV, IR, Radio, Io torus)

**Radio & Plasma Wave Instrumentation provides:**
- Unique and continuous radio remote sensing
- Unique and reliable local plasma diagnostic

- Stereo *(radio-in situ)*: correlation radio footprint + local electrodynamic content
- Stereo *(radio-radio)*: Io radio footprint + Ganymede ? + Europe ? ➞ radio emission microphysics (radio beaming, electron energy and distribution function)
SYNERGISTIC SCIENCE JGO/JEO
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Magnetosphere Science
- Stereo (radio-radio):
  both inside magnetosphere;
  Solar Wind Spaceweather;
  Io torus Spaceweather
- Latitudinal coupling (radio & in situ)
- Plasma wave interactions
- dust $\rightarrow$ sputtering $\rightarrow$ surfaces
- radio monitoring $\rightarrow$ Radar intruments
- calibration reference (plasma density + S/C potential)
- event triggering: burst mode observation, onboard boundary crossings detection, instrument mode change (cf STEREO, THEMIS)
- current detection $\rightarrow$ magnetometer data $\rightarrow$ interior magnetic field (cf ESA/SWARM)
- diagnostic of onboard S/C activity/interference
- radio/UV $\rightarrow$ auroral emission
- Ganymede/Io local aurora

**DIAGRAM:** Dust detection with STEREO/Waves
“Radio Bode’s Law”
astrophysical interest: radio signature of exoplanet

![Diagram showing the relationship between incident kinetic power and radio power](image_url)

[Zarka, PSS, 07]
RPW instrumentation added value

• Unique jovian system space weather (Solar Wind, Io torus...) via remote sensing and in situ measurements.

• Unique stereoscopic mission concept opportunity.

• Pluri-disciplinary science.

• Passive and reliable local plasma parameters diagnostics necessary for other instruments.

• Strong collaboration/enhanced science return between instrument teams (see MAPS group on Cassini)

• Strong heritage in the community (Cassini, STEREO, Bepi-Colombo/MMO, JUNO, RBSP... )