CURIE: CUbesat Radio Interferometry Experiment

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The highlights

- Two-element radio interferometer in LEO/MEO
- Launched (piggyback) as 6U cubesat, separating into 2x3U
- Digital radio receiver inherited from Solar Probe Plus: 0.1-20 MHz range.
- Study (tracking & sizing + polarization) CMEs (Type II) and Type III bursts, at frequencies unreachable from the ground; radio sky; study ionospheric $n_e$ & $T_e$ and their gradients over several km.
- Proposed to NASA Low-Cost Access to Space (LCAS)
Science

- CME tracking beyond ionospheric cutoff
- Type II/III source positions & sizes at various frequencies
  - Position of Type II along CME shock front
- Details of local plasma line (in-situ)
  - Density i& temperature gradients over few km
- Jupiter DAM brightness distribution (*)
- Mapping of radio sky
Deployment & Antennas

- launch as a 6U cubesat
- de-tumbling
- Separates into 2x 3U cubesats
- Deployment of science antennas & solar panels
- Thrusters keep the distance ~2 km
- Magnetic torquing to keep solar-pointed attitude
- 3-axis stabilizeds

- 5 monopoles, 4 of which in same plane
- Goniopolarimetry from each spacecraft
- Fourier components time-tagged and telemetred: Inter-SC baseline visibility computed on the ground
Digital radio receiver

- Solar Probe Plus’ FIELDS suite. Analog portion of RFS is circled.
- 2 channel input (combinations of monopoles or “dipoles”)
- FX, with Polyphase Filter Banks
- Output: 2048 channels (complex Fourier components)

- Timing provided by GPS augmented by on-board atomic clock
- Position provided by GPS (~1 m level)
Goniopolarimetry, interferometry

- For total SNR=100, at 10 MHz:
  - Goniopolarimetry (DF): ~0.5° (2-D)
  - Long baseline: ~0.1’ (1-D)
  - Source sizes accurate to ~2% (1-D)

- 1.5 km projected baseline optimal for heliophysical bursts (snapshot)
- Jupiter DAM imaging would require ~200 km (aperture synthesis possible)

- Top: uv-coverage and psf from 2 weeks of orbit (incl. station-keeping maneuvers)
- Bottom: same for 6 months of spacecraft drifting away at 1 mm/s
Calibration

- Galactic background
- Jupiter DAM
- Earth radio stations
Effects of the ionosphere

- Large-scale refraction: 
  \[ \Delta z/z \approx \frac{1}{2} \left( \frac{f_p}{f} \right)^2 \]
- Scattering (angular broadening): 2-3' at 10 MHz, prop to \( \lambda^2 \)
Telemetry & orbit

• 600 MB/day (both S/C), S-band
  – Heavily dependent on number of spectral bins, time accumulation, cadence, post-facto data selection, etc.
• Ideal orbit: ~450 x (1600-2000) km, 27-45° inclination
  – Meets torquing & orbital lifetime requirements
  – Long period with very low local plasma frequencies
  – Accessible by Berkeley Ground Station
• Station-keeping is loose (1-3 km range)
  – Very little fuel used
  – Maneuvers ~once a week
### Heritage

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<td><strong>Preamplifier</strong></td>
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<td><strong>Radio Receiver</strong></td>
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<td><strong>Data Controller Board</strong></td>
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<td><strong>Spacecraft</strong></td>
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<td><strong>Onboard Computer</strong></td>
<td>Solar Probe Plus, Van Allen Probes, MAVEN CINEMA, RHESSI, THEMIS, MAVEN, CINEMA, RHESSI, CINEMA, RHESSI, THEMIS, Van Allen Probes, THEMIS, Van Allen Probes, RHESSI</td>
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<td><strong>Power Management</strong></td>
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<td><strong>Mission Operations / orbit control</strong></td>
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Table 5: *CURIE* specific heritage at Space Sciences Laboratory.
More. More. More!!

- CURIE as presented here is a prototype-proof of concept for a larger constellation
- Easily expandable

- NASA Mission of Opportunity
  - Constellation of >= 4 S/C, beyond LEO
  - UCB/SSL vs. MIT/Haystack vs. NASA/JPL
  - Emphasis on heliophysical science