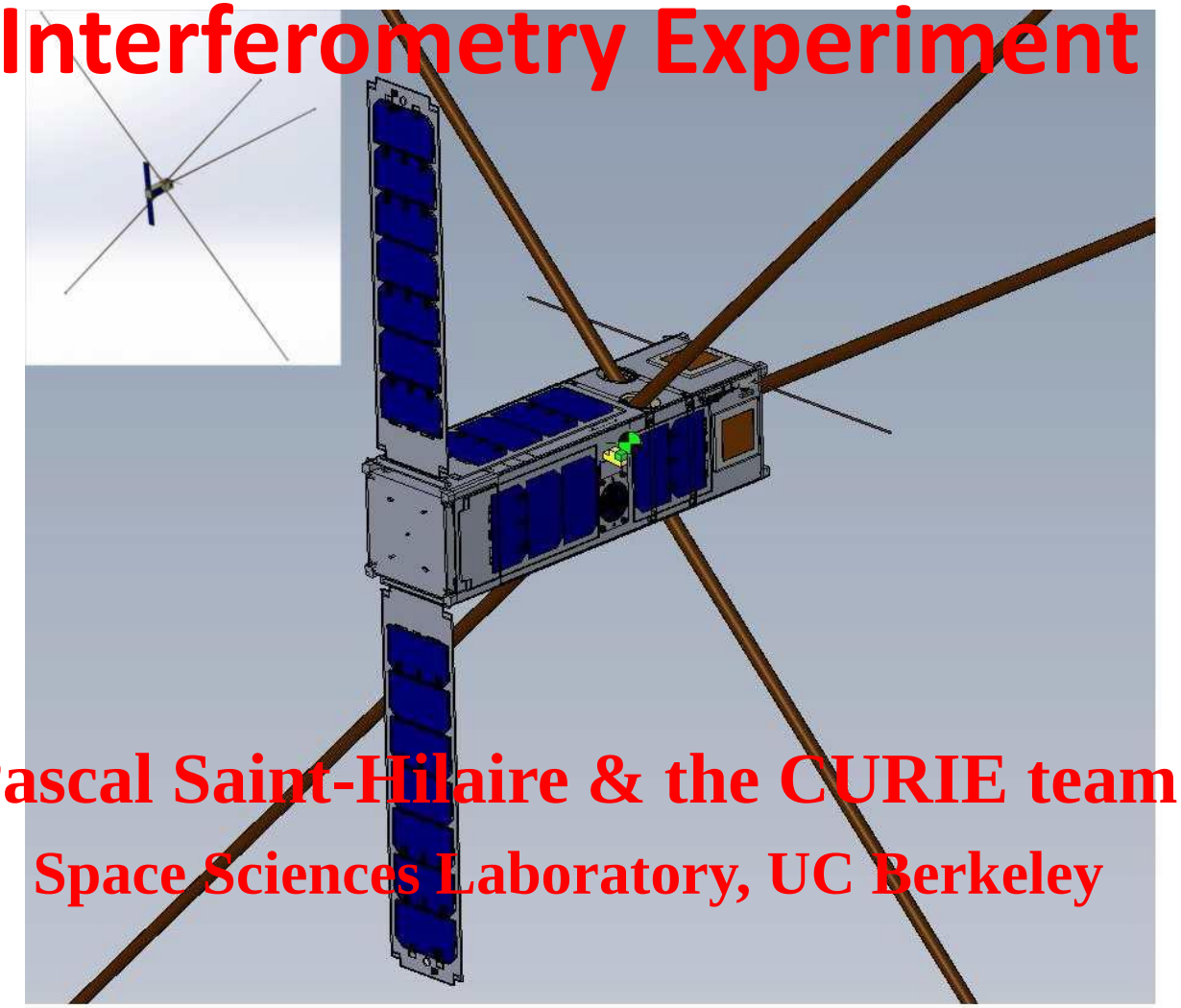
CURIE: CUbesat Radio Interferometry Experiment



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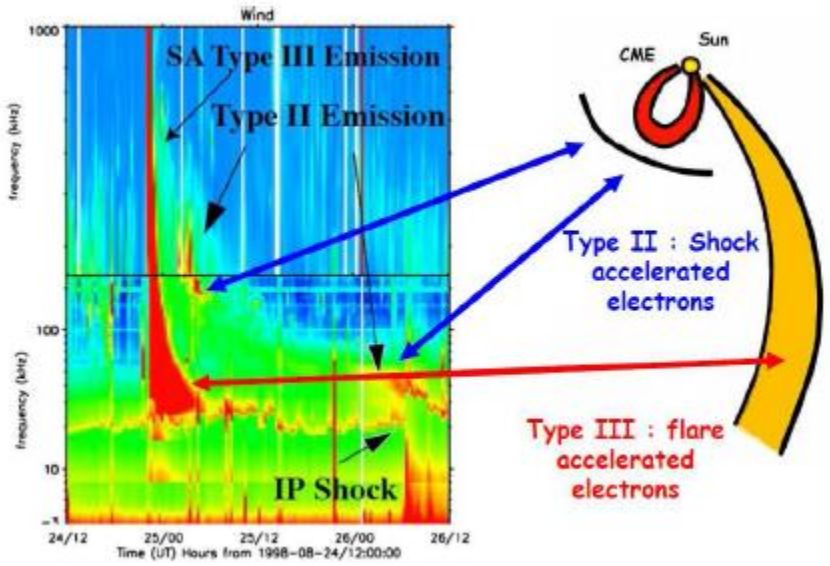
RHESSI 15, Graz, Austria, 2016/07/29

The highlights

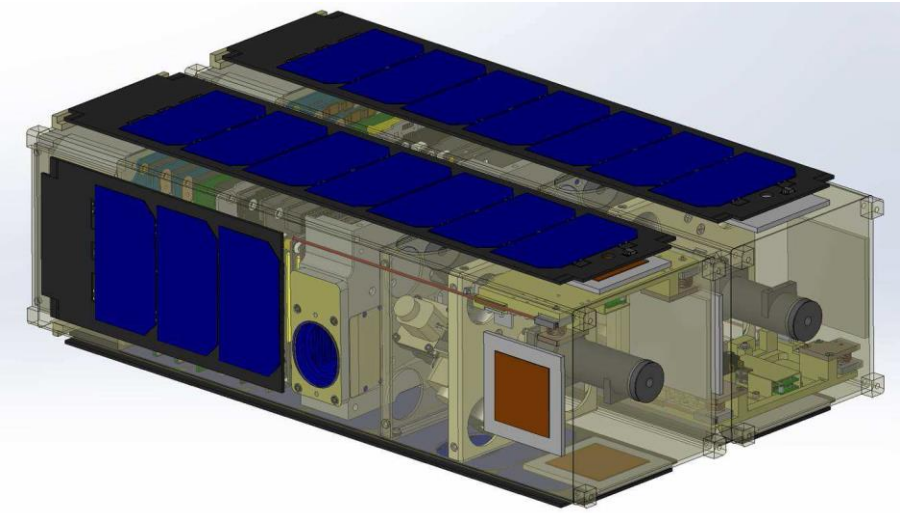
- Two-element radio interferometer in LEO/MEO
- Launched (piggyback) as 6U cubesat, separating into 2x3U
- Digital radio receiver inherited from Solar Probe Plus: 0.1-20 MHz range.
- Study (tracking & sizing + polarization) CMEs (Type II) and Type III bursts, at frequencies unreachable from the ground;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

Science

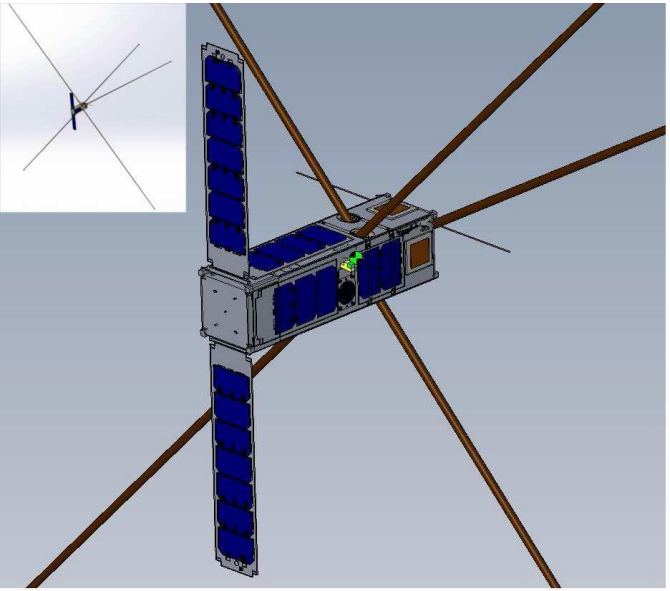


- CME tracking beyond ionospheric cutoff
- Type II/III source positions & sizes at various frequencies
  - Position of Type II along CME shock front
- Details of local plasma line (in-situ)
  - Density i& temperature gradients over few km
- Jupiter DAM brightness distribution (*)
- Mapping of radio sky

Deployment & Antennas



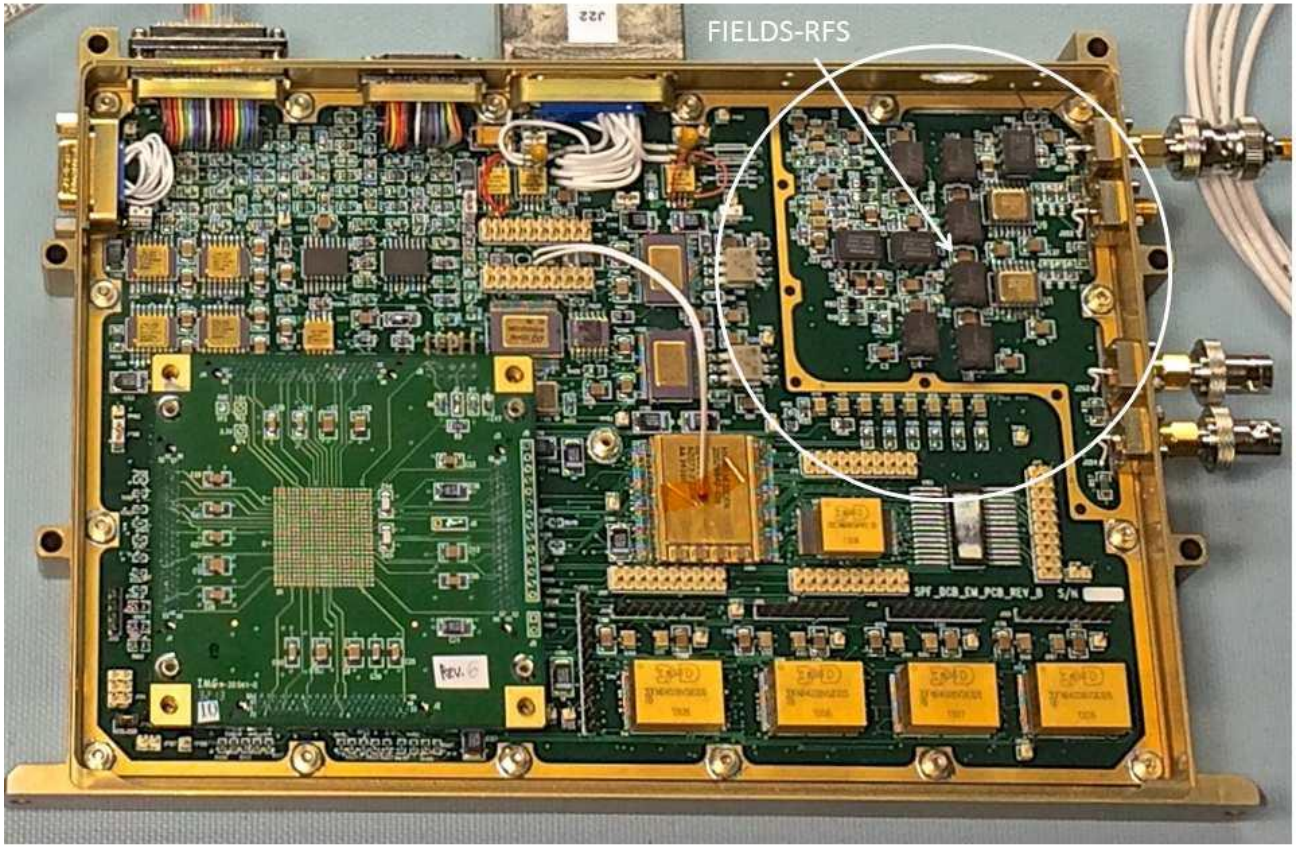
- launche as a 6U cubesat
- de-tumbling
- Separates into 2x 3U cubesats
- Deployment of science antennas & solar panels
- Thrusters keep the distance ~2 km
- Magnetic torquing to keep solar-pointed attitude
- 3-axis stabilizeds



- 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

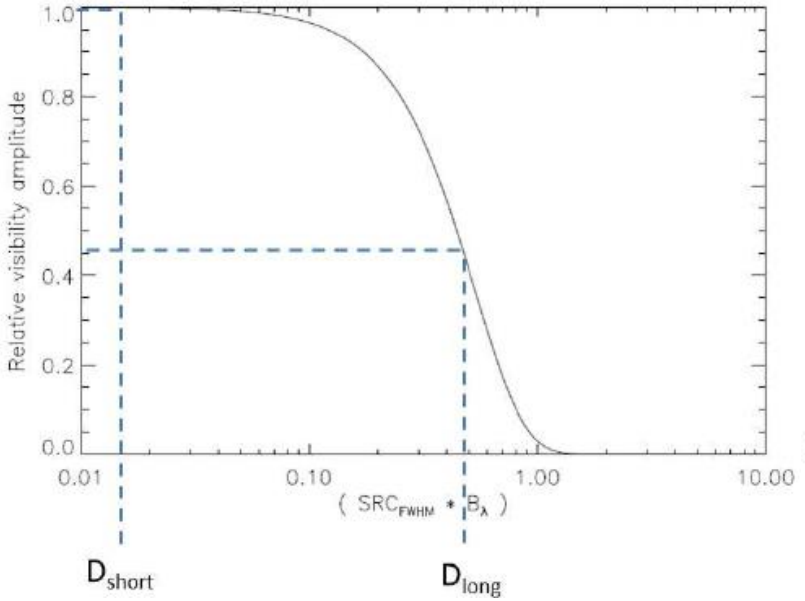
Digital radio receiver



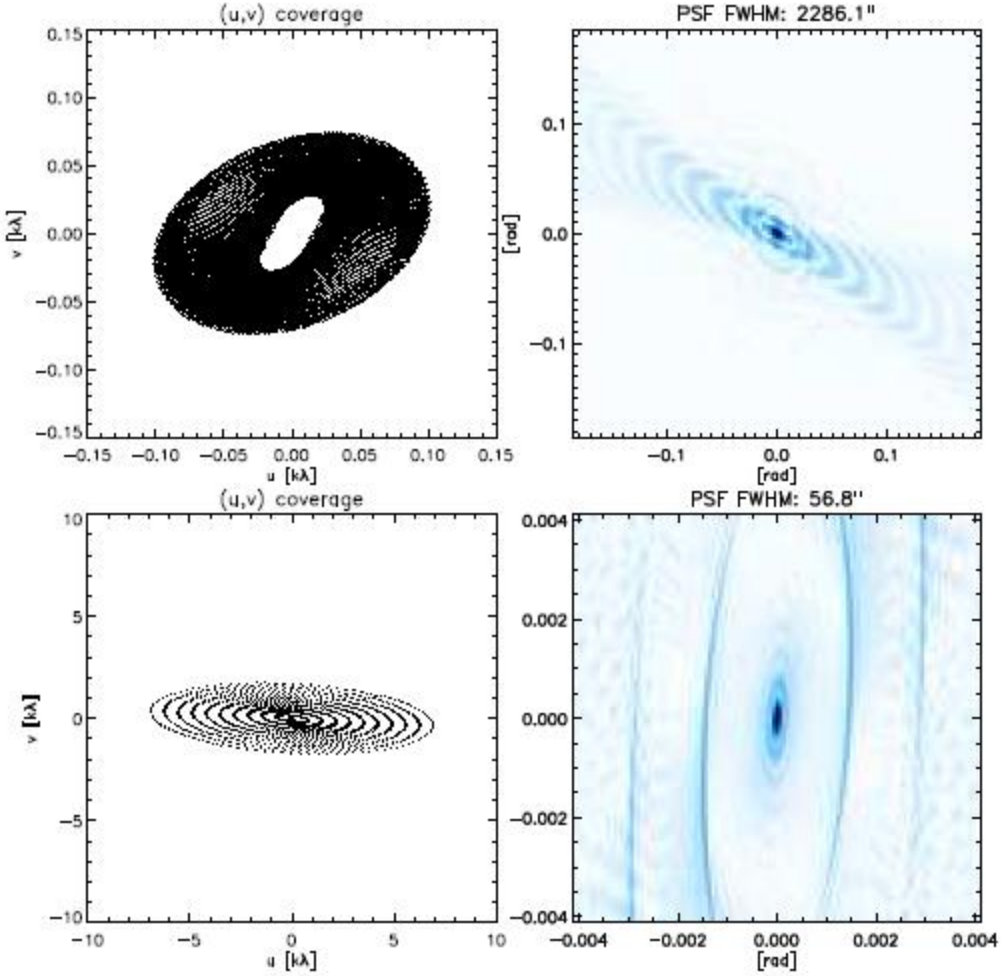
- Solar Probe Plus' FIELDS suite. Analog portion of RFS is circled.
- 2 channel input (combinations of monopoles or "dipoles")
- FX, with Polyphase Filter Banks
- Ouput: 2048 channels (complex Fourier components)

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

Goniopolarimetry, interferometry



- *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

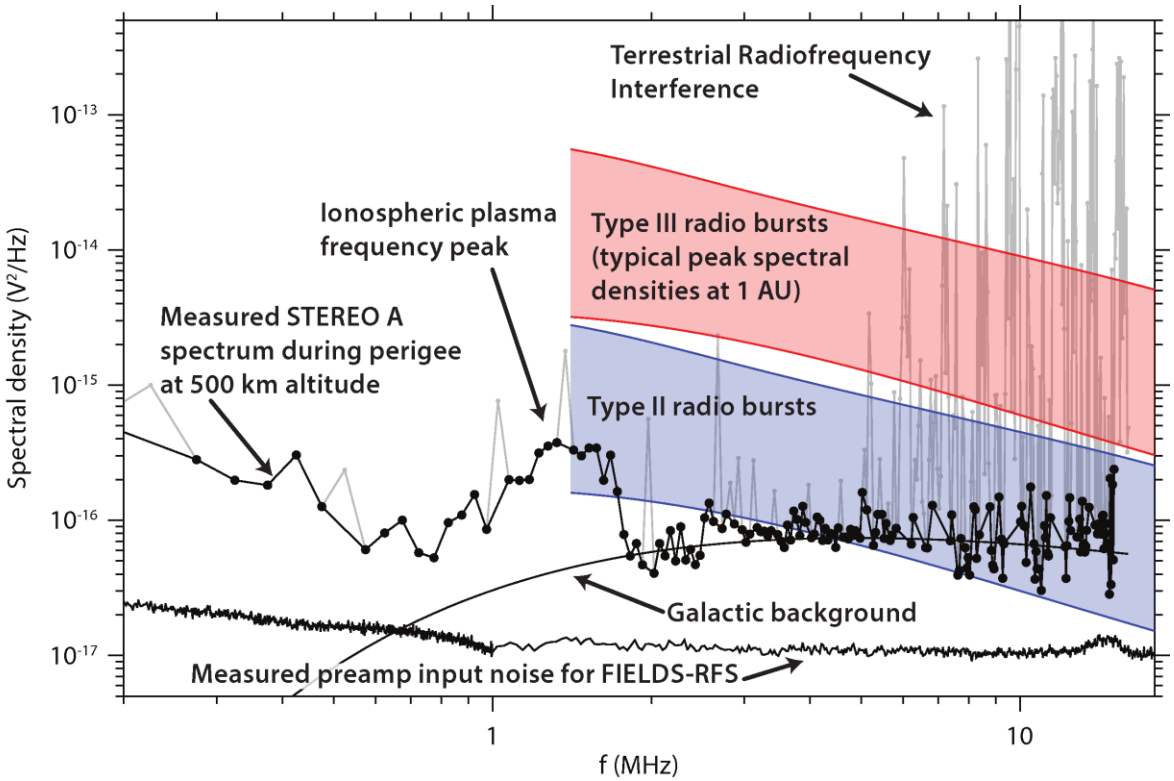


- For total SNR=100, at 10 MHz:
  - Goniopolarimetry (DF): ~0.5° (2-D)
  - Long baseline: ~0.1’ (1-D)
  - Source sizes accurate to ~2% (1-D)

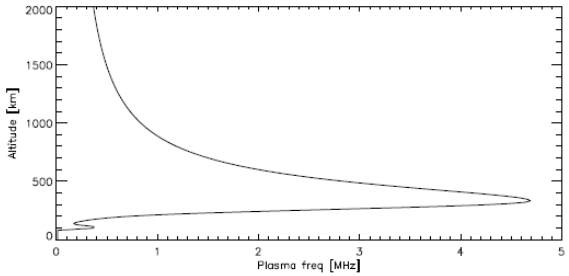
- 1.5 km projected baseline optimal for heliophysical bursts (snapshot)
- Jupiter DAM imaging would require ~200 km (aperture synthesis possible)

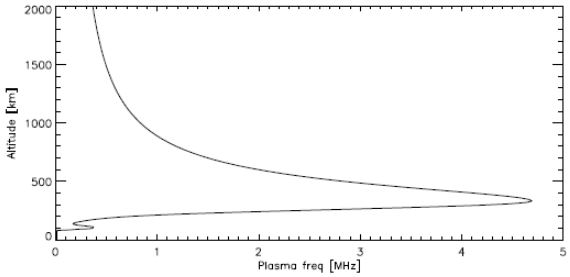
Calibration

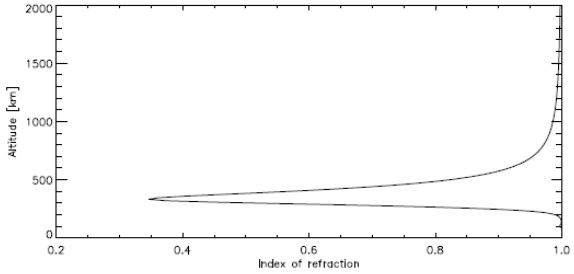
- Galactic background
- Jupiter DAM
- Earth radio stations

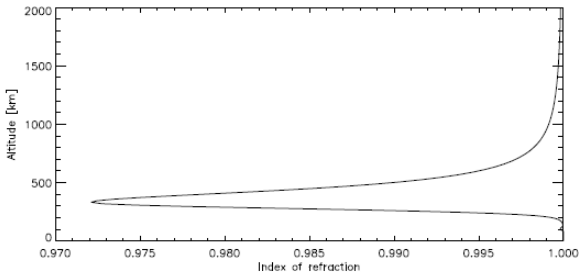


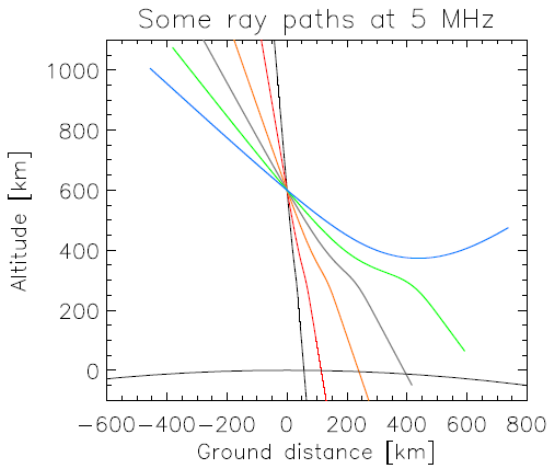
Effects of the ionosphere

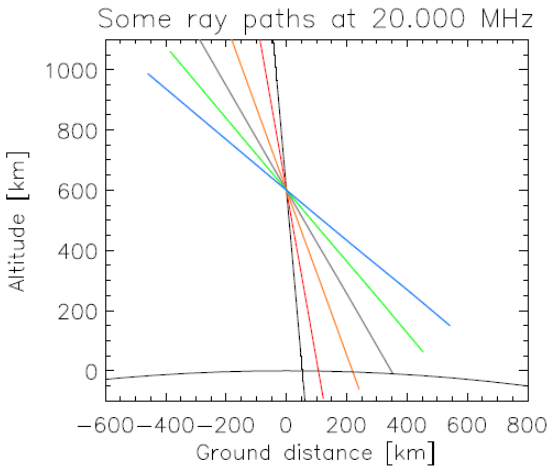












- Large-scale refraction:

$$\Delta z/z \approx 1/2\,(f_p/f)^2$$

- Scattering (angular broadening): 2-3' at 10 MHz, prop to λ^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

Instrument	
Antenna system	THEMIS, STEREO, POLAR, Van Allen Probes
Preamplifier	Solar Probe Plus, STEREO
Radio Receiver	Solar Probe Plus,
Data Controller Board	Solar Probe Plus, THEMIS, MAVEN,Van Allen Probes
Spacecraft	
Onboard Computer	Solar Probe Plus, Van Allen Probes, MAVEN
Power Management	CINEMA
Flight Software	RHESSI, THEMIS, MAVEN, CINEMA
ACS System	CINEMA, RHESSI
Communications	CINEMA, RHESSI, THEMIS, Van Allen Probes
Mission Operations / orbit control	THEMIS, Van Allen Probes, RHESSI

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