Observations of Decameter Small-Scale Structures in the Auroral Ionosphere: From Sounding Rockets to CASSIOPE Enhanced Polar Outflow Probe (e-POP)

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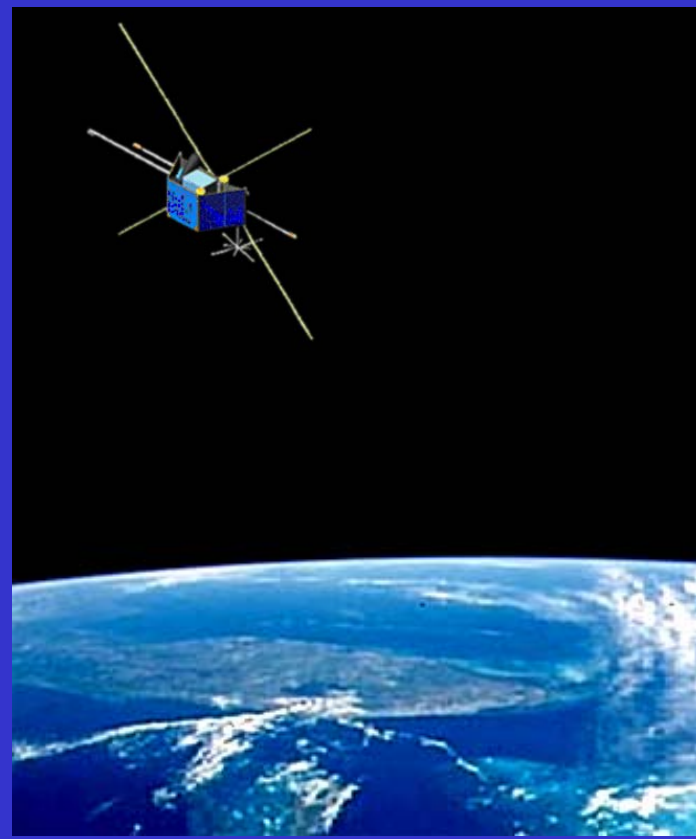

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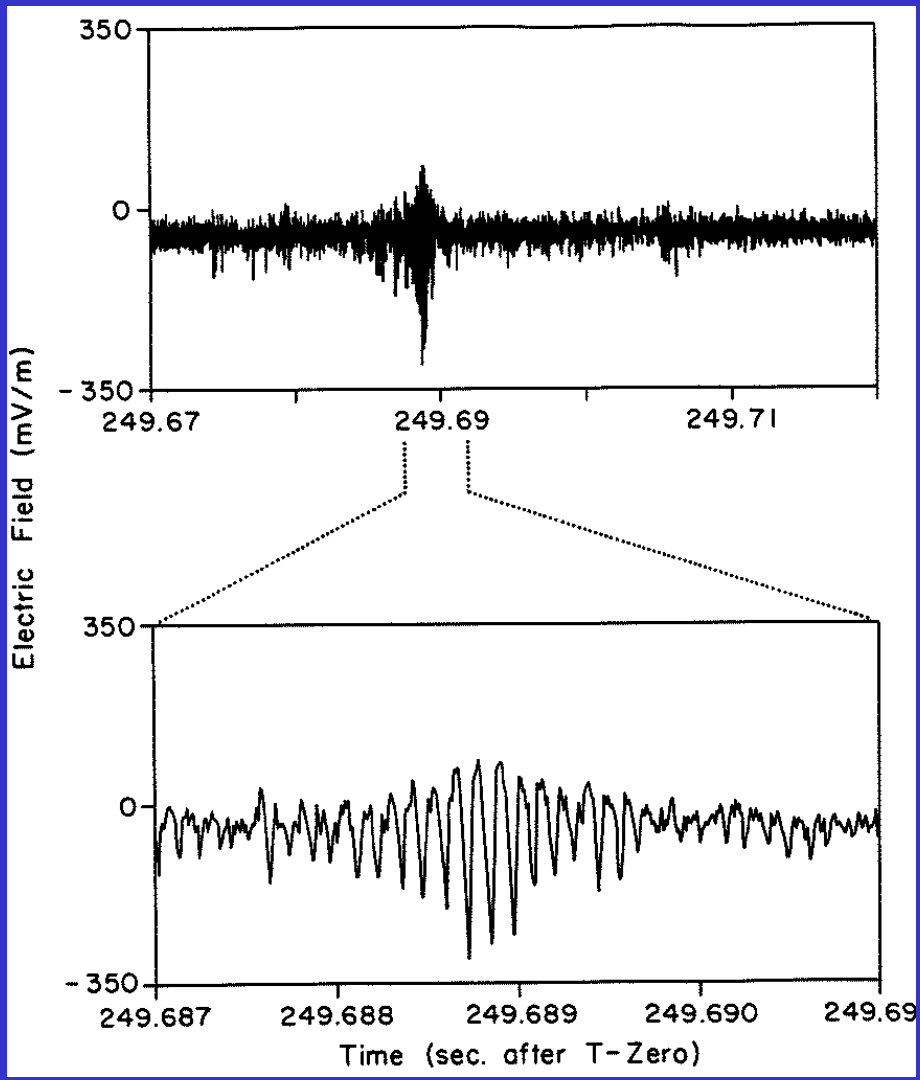
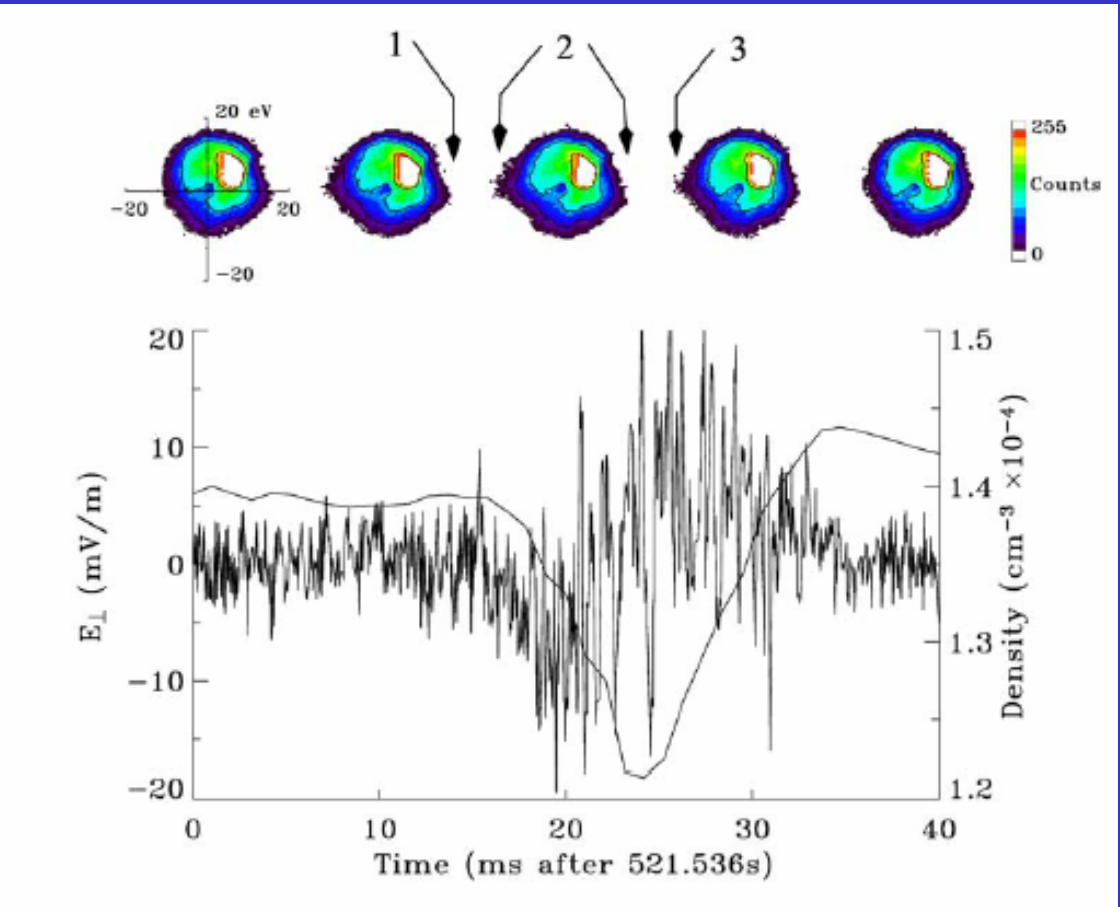
Sub-Decameter Scale Structures in Topside Ionosphere



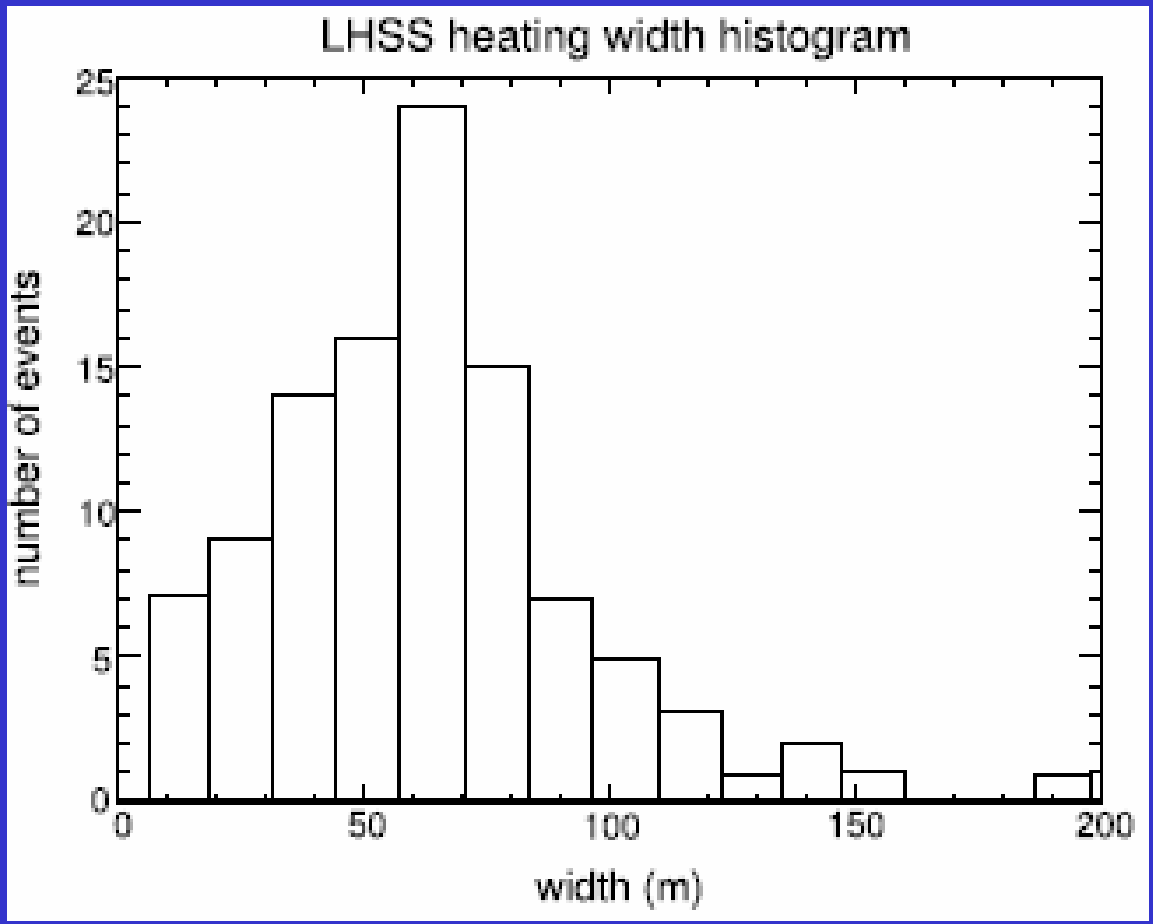
- MARIE rocket, 500-600 km altitude, large substorm (LaBelle 1986)
- "Spikelets"
  - Localized lower hybrid waves
  - Lower hybrid solitary structures
- Often coincided with localized regions of TAI ("perpendicular ion conics")
- ~1 ms time scale and/or ~1 m horizontal/vertical extent

Lower Hybrid Solitary Structures in Topside Ionosphere



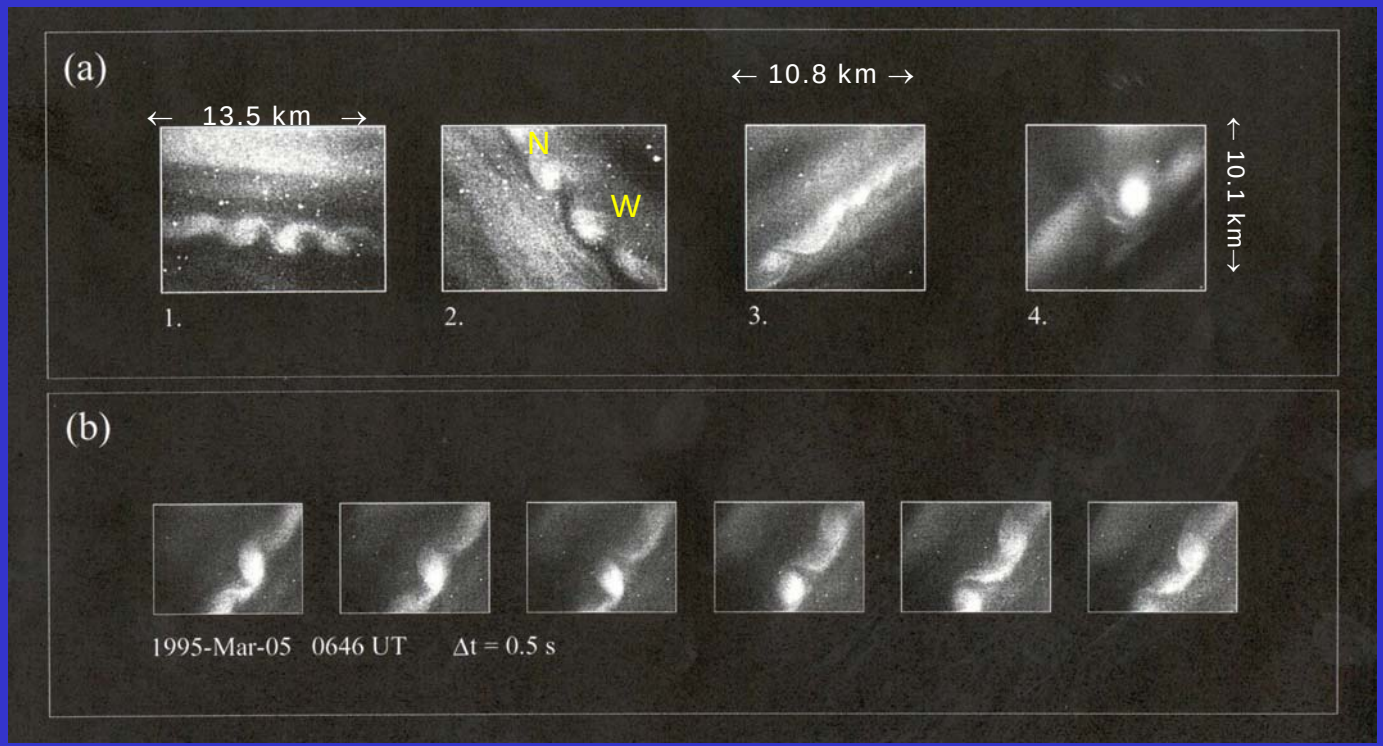
- LHSS signatures
  - Density depletion
  - TAI and/or BB VLF noise
- GEODESIC rocket, 980 km (Burchill 2004)
- Low-energy ion distributions
  - 11 ms/13 m resolution
  - T ~ 0.2 eV (rammed O^+ ions)
  - Heated ions at several eV
- Observed density cavity
  - ~15% depletion
  - Temporal extent: ~10 ms

LHSS "Heating" Width



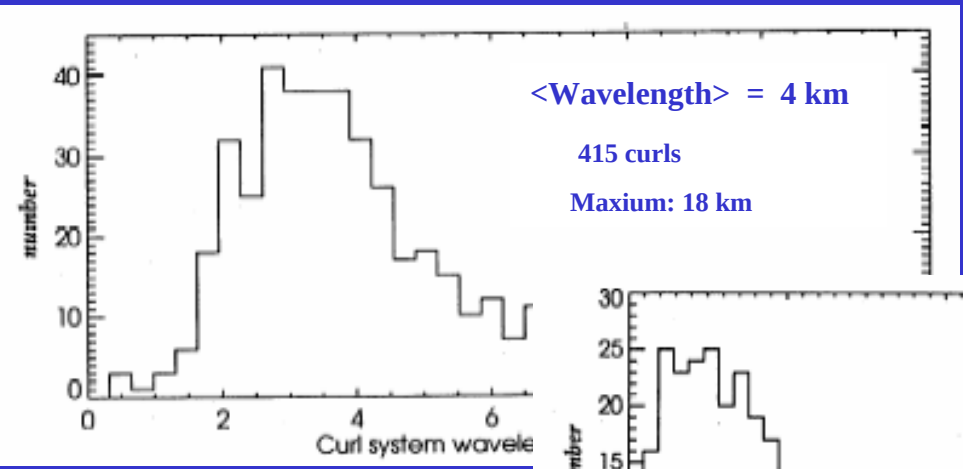
- "Heating" width of LHSS on GEODESIC
  - from velocity images
- Average width: 63 m
- Standard dev.: 25 m
- Range: 13 – 190 m
- "Density depletion" width ~ 20 m

Dynamic Small-scale Structures in Visual Aurora



- Auroral spatial scales: 10-100 km (bands), to 0.1-1 km (curtains)
- Auroral curls (Trondsen 1998):
  - 1-2 km spatial scale
  - Anti-clockwise rotation and motion (when viewed anti-parallel to B)

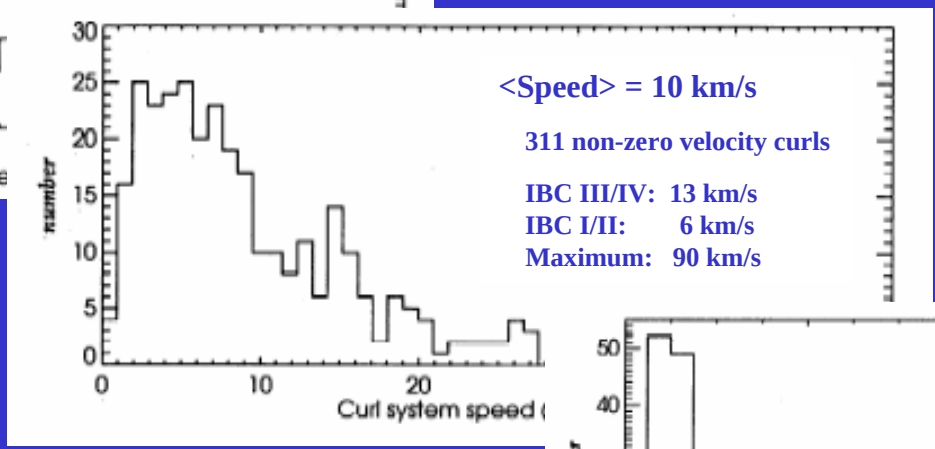
Auroral Curl Wavelength, Speed, and Lifetime



<Wavelength> = 4 km

415 curls

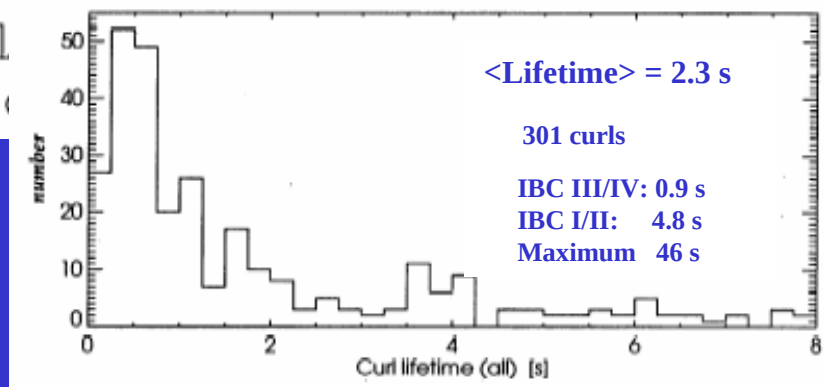
Maxium: 18 km



<Speed> = 10 km/s

311 non-zero velocity curls

IBC III/IV: 13 km/s
IBC I/II: 6 km/s
Maximum: 90 km/s



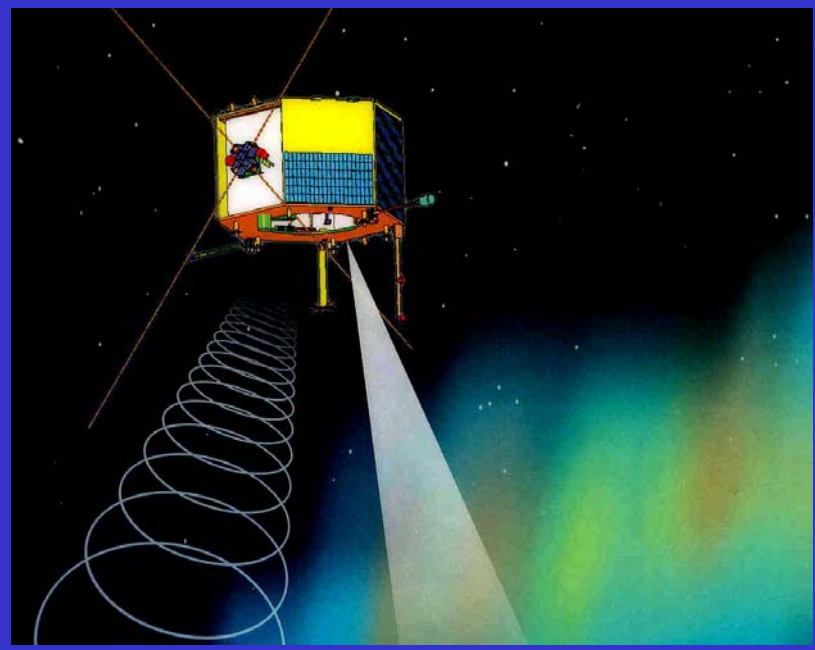
<Lifetime> = 2.3 s

301 curls

IBC III/IV: 0.9 s
IBC I/II: 4.8 s
Maximum 46 s

CASSIOPE

ENHANCED POLAR OUTFLOW PROBE (e-POP)



Science

Plasma outflow: Micro-scale ion acceleration; wave particle interaction; auroral connection

Wave propagation: 3D structure of ionospheric irregularities; GPS radio occultation

Neutral escape: Temperature enhancement, non-thermal atmospheric escape

Mission Concept

Highest-resolution in-situ measurements

Radio wave propagation 3D studies

Fast imaging of meso-scale aurora

Satellite Design

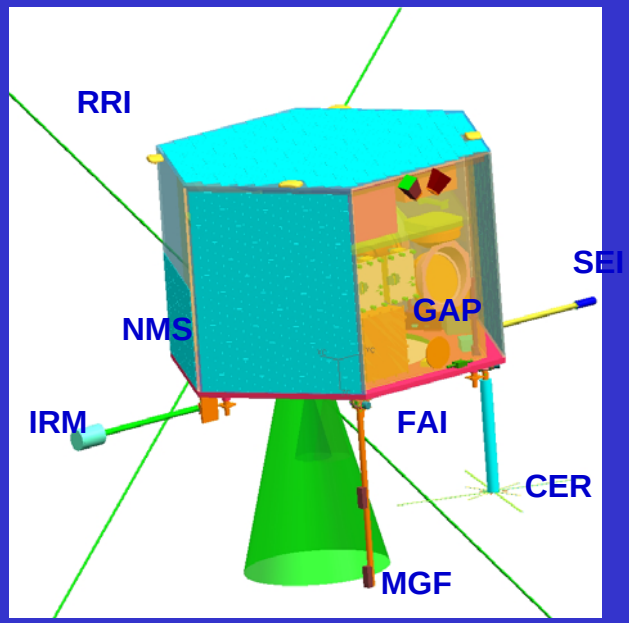
Polar orbit: 325 × 1500 km; 80°

3-axis stabilized (for fast imaging)

Large (terabyte) data storage

Fast (>300 Mbps) TM downlink

e-POP Instruments and Measurements



Instruments and Measurements		Max Resolution
IRM	Imaging ion mass spectrometer	0.01 s; ~70 m
f ($v_\perp$, $v_{//}$)	0.5-70 eV ions	
SEI	Suprathermal electron imager	0.01 s; ~70 m
f (E, α)	1-200 eV electrons	
NMS	Neutral mass/velocity spectrometer	0.1 s; ~0.7 km
n, T, v	0.1-2 km/s neutrals, O, N_2	
FAI	Fast auroral imager	0.1-s (exposure);
I (x, y)	630 nm, NIR	0.4 km (pixel size)
RRI	Radio receiver instrument	60,000 samples/s
E(ω), k(ω)	HF/VLF	
MGF	Magnetic field instrument	0.006 s; ~40 m
$j_{//}$	3-axis perturbation magnetic field ΔB	
GAP	GPS attitude/profiling experiment	
L1, L2	Radio occultation	
CER	Coherent EM radio tomography	
TEC	Ionospheric irregularity	

Summary: Decameter Small-Scale Structures

- Spikelets and lower hybrid solitary structures (LHSS) are observed in-situ
  - LHSS: ~20 m depletion width, 60 m heating width
  - In association with TAI and/or broadband VLF noise
- Auroral structures down to 0.1 km observed by ground TV
  - Curls: wavelength ~ 4 km, speed ~ 10 km/s, lifetime ~ 2.3 s
- Such sub-decameter/sub-km structures suggest auroral acceleration processes on ion gyro-radius or electron or ion inertial length scale
- CASSIOPE/e-POP to measure particle, field, and wave in-situ at sub-decameter (70 m) resolution, and image the aurora at sub-km (400-m) pixel resolution