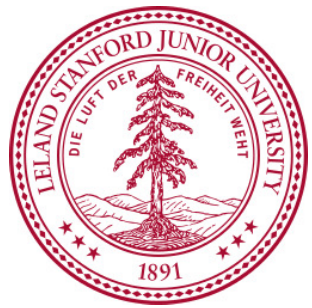
Elve Observations with the PIPER Photometer

Patrick Blaes Robert A. Marshall Umran S. Inan

Stanford University



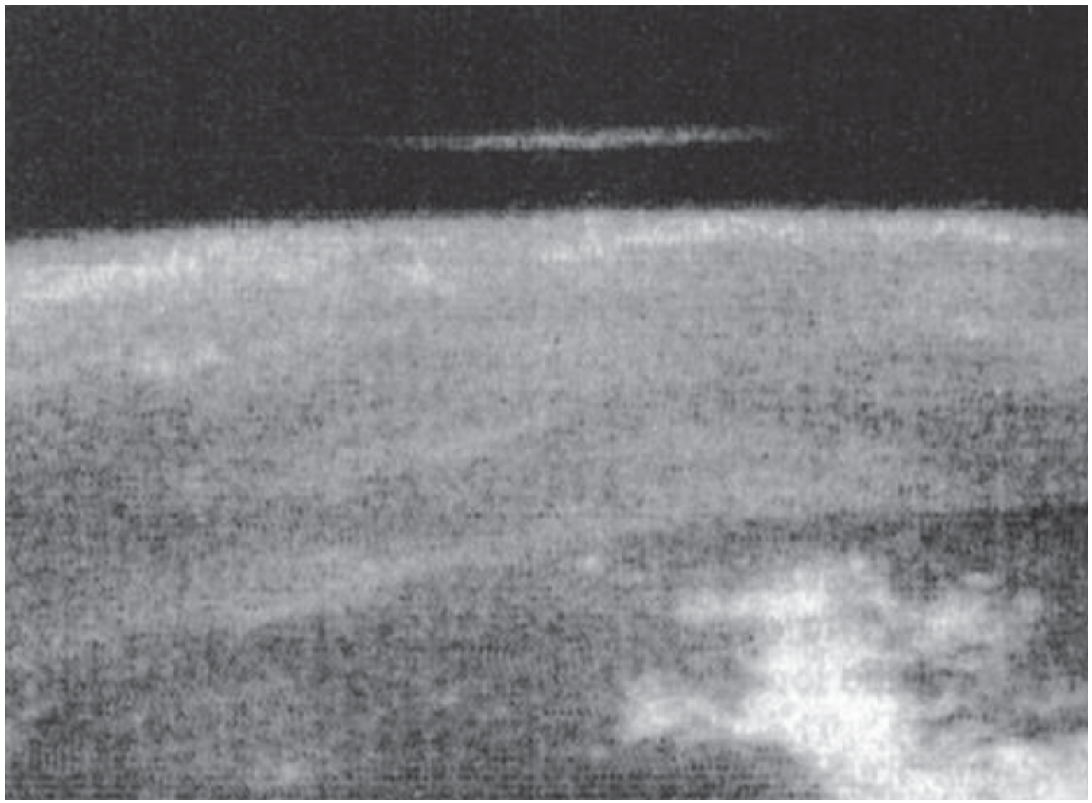
September 29, 2013

Outline

1. History of Elve Observations
2. The PIPER Photometer
3. Studies using PIPER Data

The First Elve Observation

- *Boeck et al. 1992*
- Captured onboard the Space Shuttle
- Used low-light television video camera
- Described the event as lightning-induced "airglow brightening"



Fukunishi et. al 1996

- Observed elves using three high-speed PMTs and a low-light CCD camera
- Was able to discriminate between sprites and elves

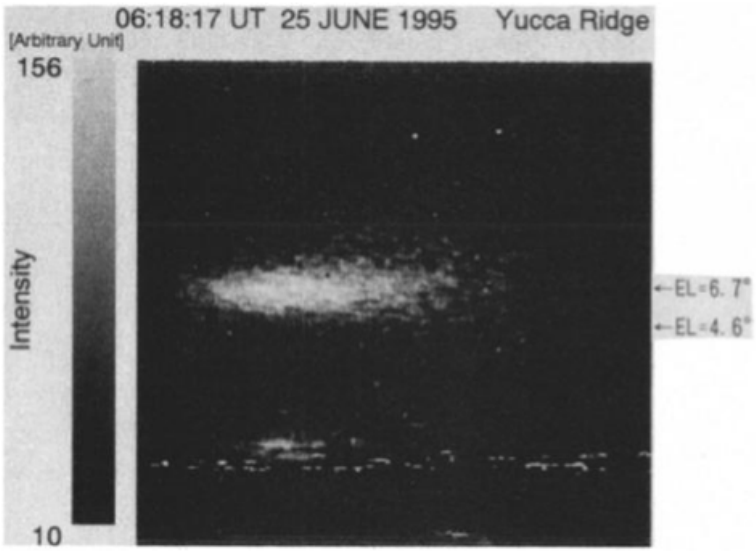


Figure 3. Example of lightning-induced diffuse flashes (tentatively called elves) in the lower ionosphere. This event occurred at a distance of 537 km from the observation point, Yucca Ridge Field Station.

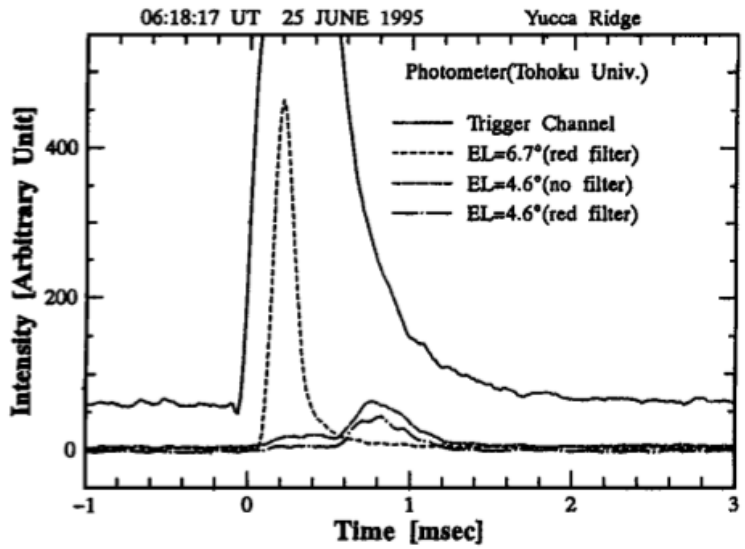
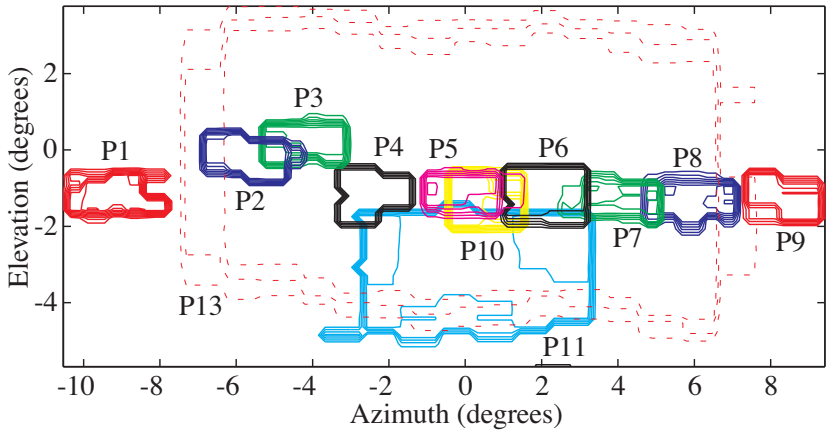
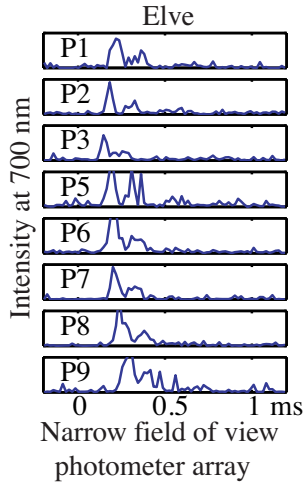


Figure 4. Traces of photometer signals for the June 25, 1995 event given in Figure 3. The photometer channels with elevation angles of 6.7° and 4.6° point the upper and bottom parts of the emission layer, respectively as shown by two arrows at the right side of Figure 3.

Fly's Eye

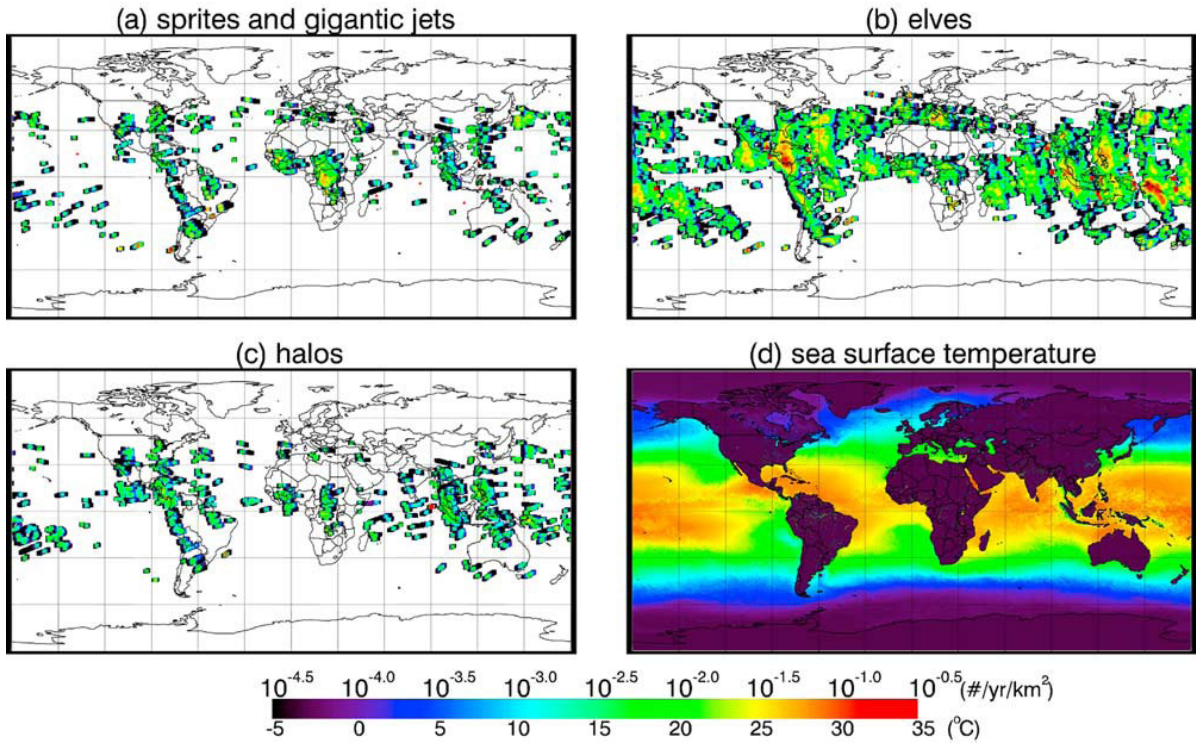
- 9 horizontally arrayed PMTs behind red filters, 4 PMTs with overlapping fields-of-view behind blue filters
- Triggered off of VLF radio emissions
- Confirmed radial expansion of elve and EMP as the driving mechanism *[Inan and Barrington-Lee, 1997]*





ISUAL

- Launched in 2004 as payload on the FORMOSAT-2 satellite
- CCD imager, six-channel spectrophotometer, and two array photometers
- Provided a global distribution of TLEs *[Chen et al, 2008]*



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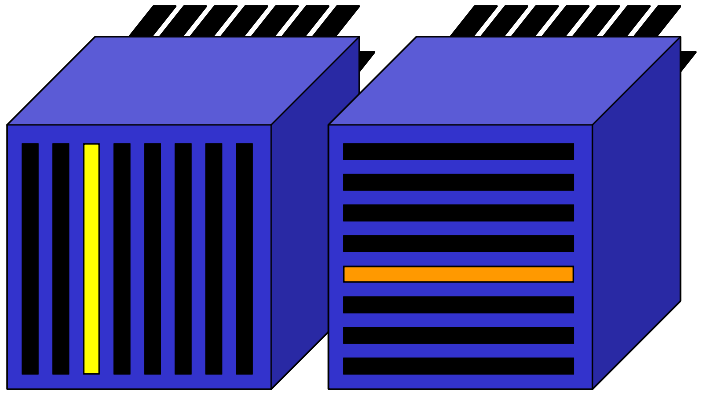
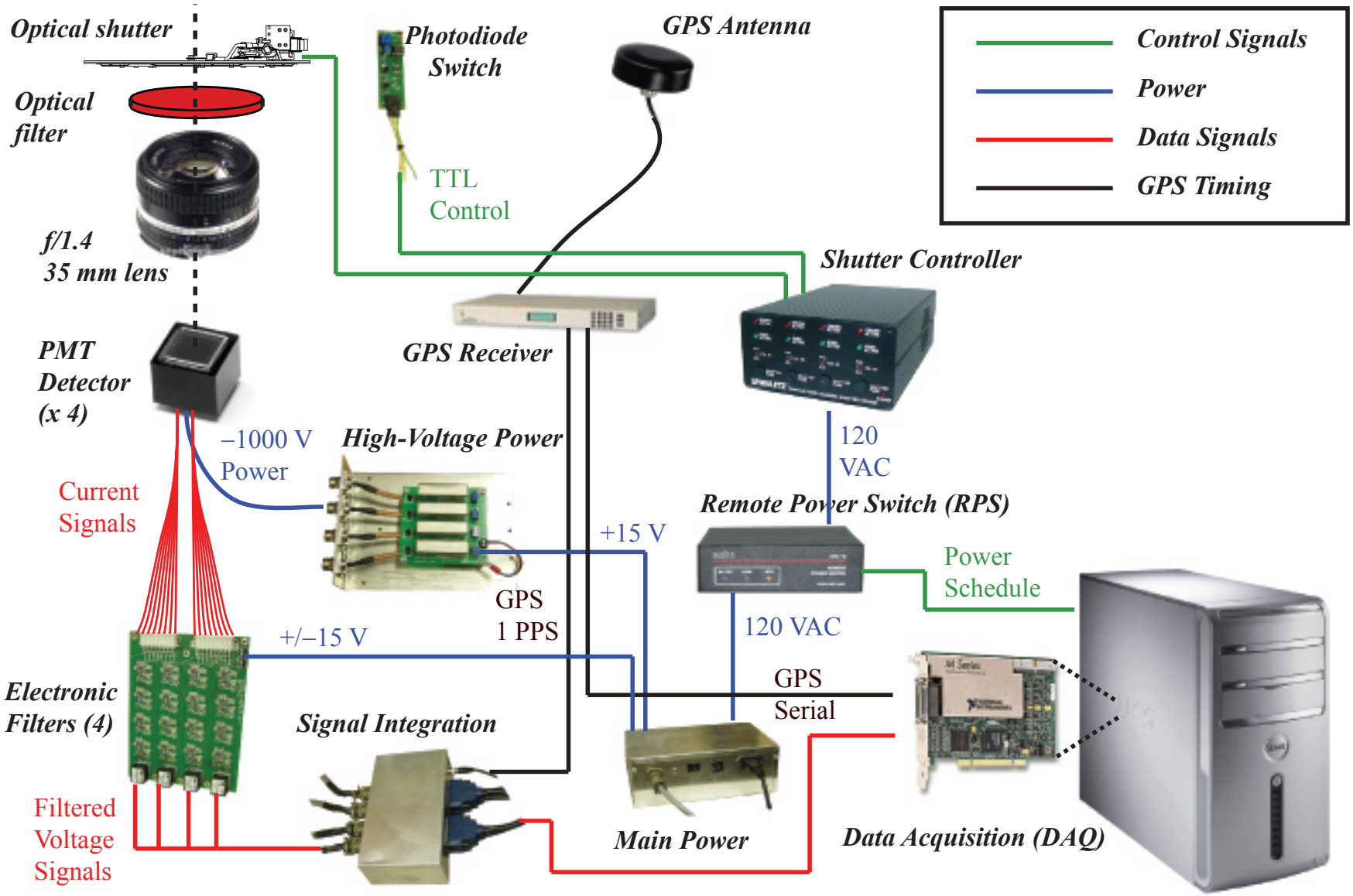
PIPER Imaging Photometer

Photometric Imager for Precipitation of Electron Radiation

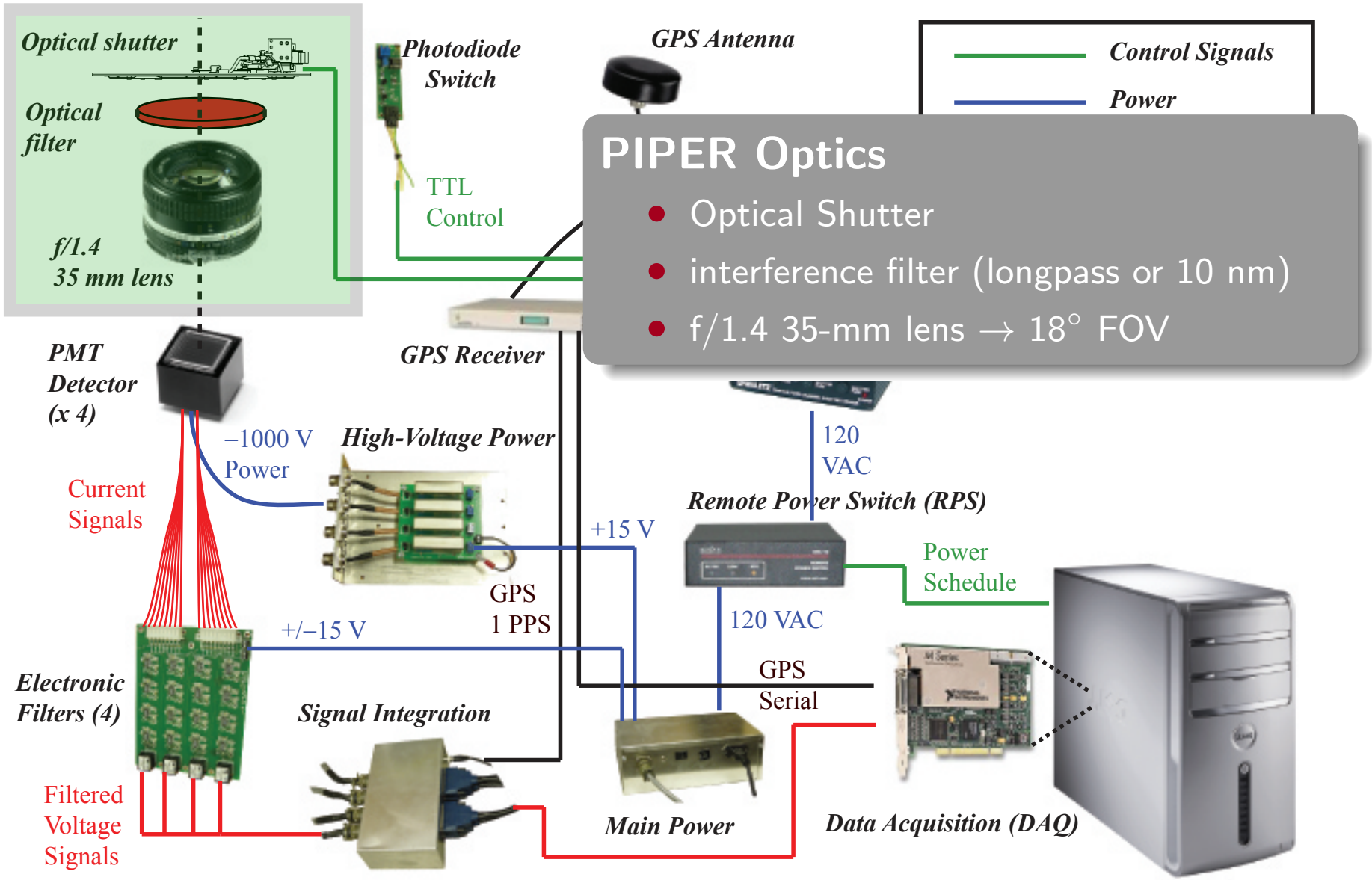
- 18 $\times$ 18 degree FOV
- Records at 25,000 samples per second per channel
- $\sim$0.1 R/nm noise level (elves are $\sim$MR)
- Two optical bands (red and blue)
- Free-running
- Ground based



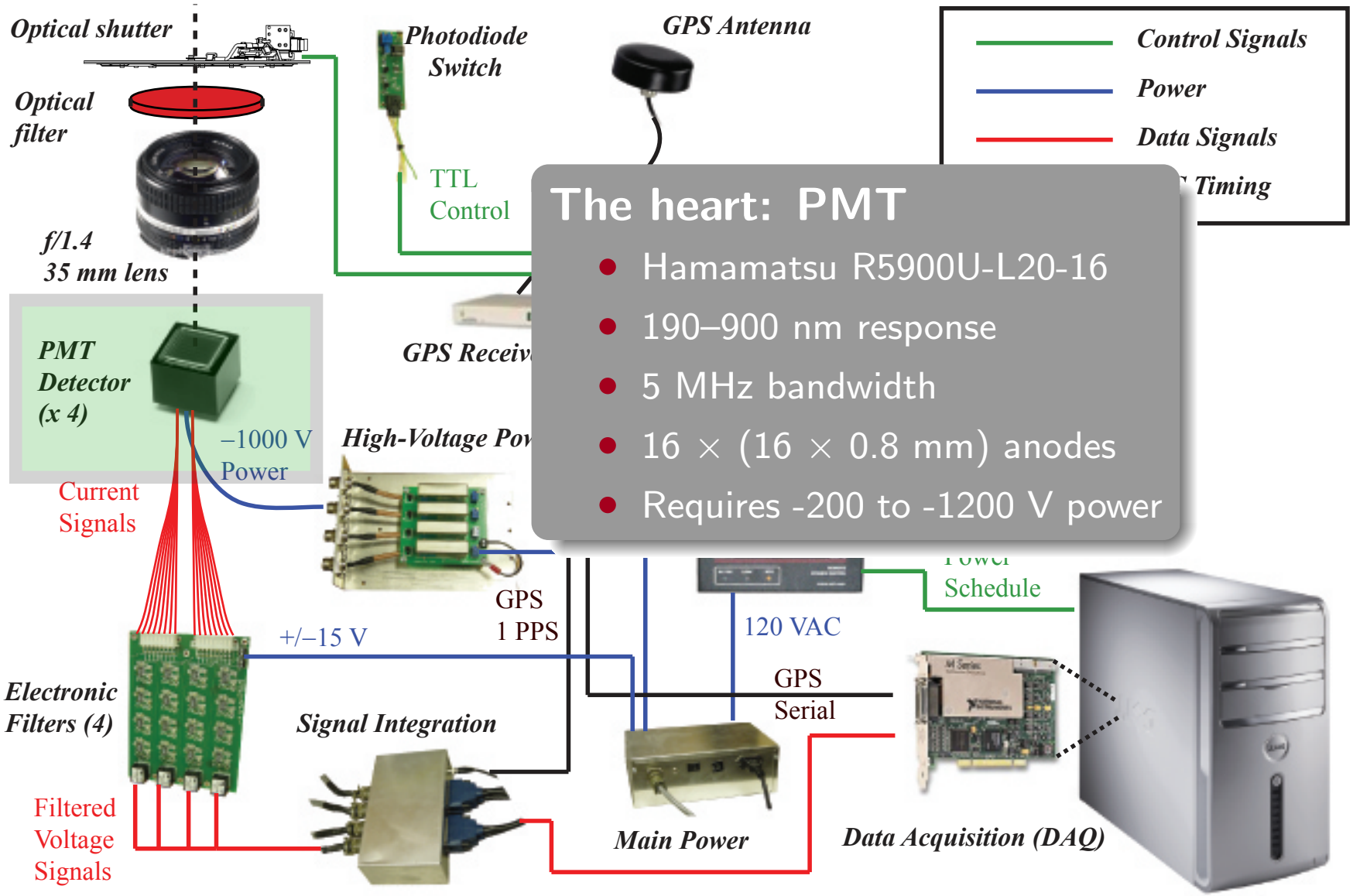
PIPER Block Diagram



PIPER Block Diagram



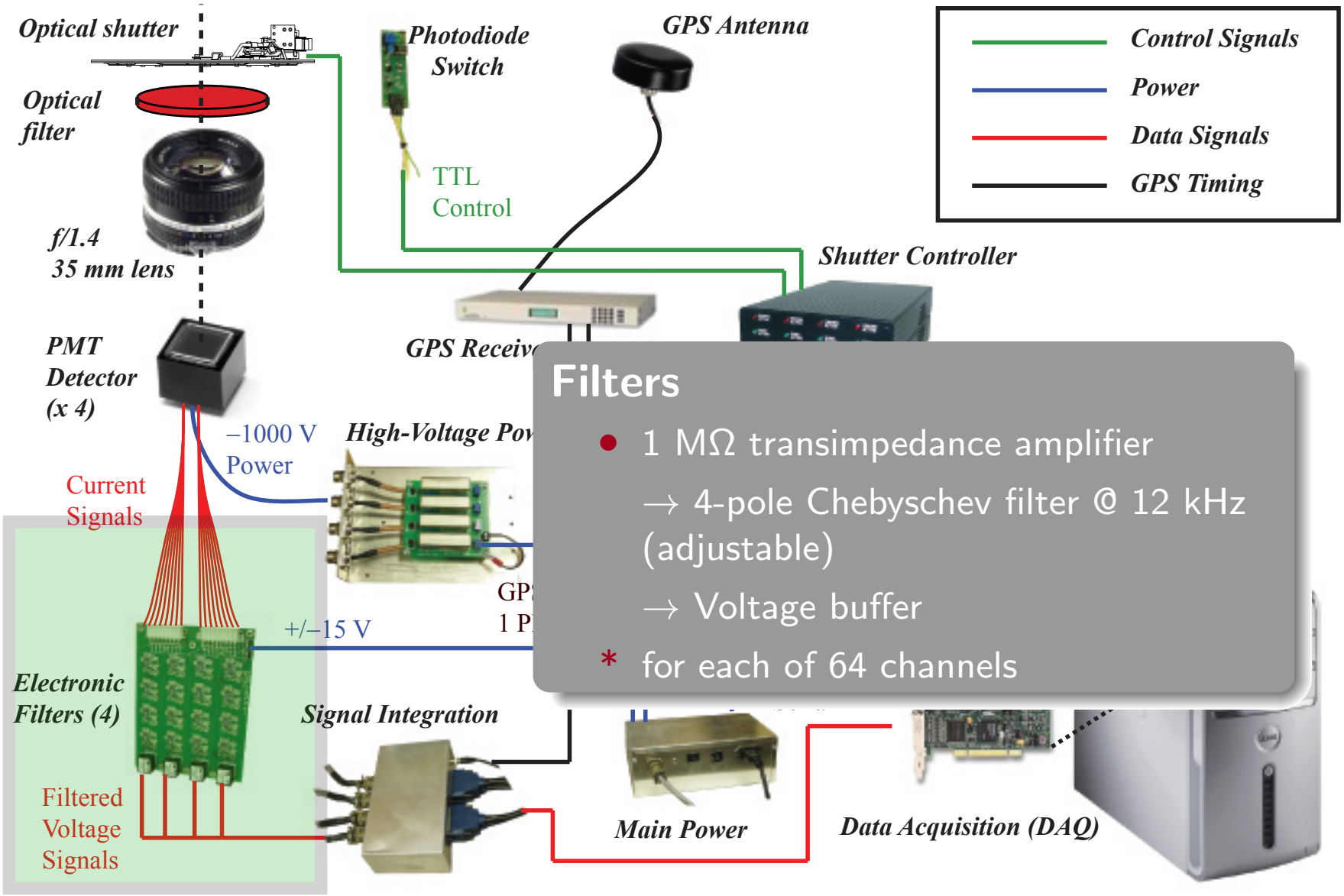
PIPER Block Diagram



The heart: PMT

- Hamamatsu R5900U-L20-16
- 190–900 nm response
- 5 MHz bandwidth
- 16 × (16 × 0.8 mm) anodes
- Requires -200 to -1200 V power

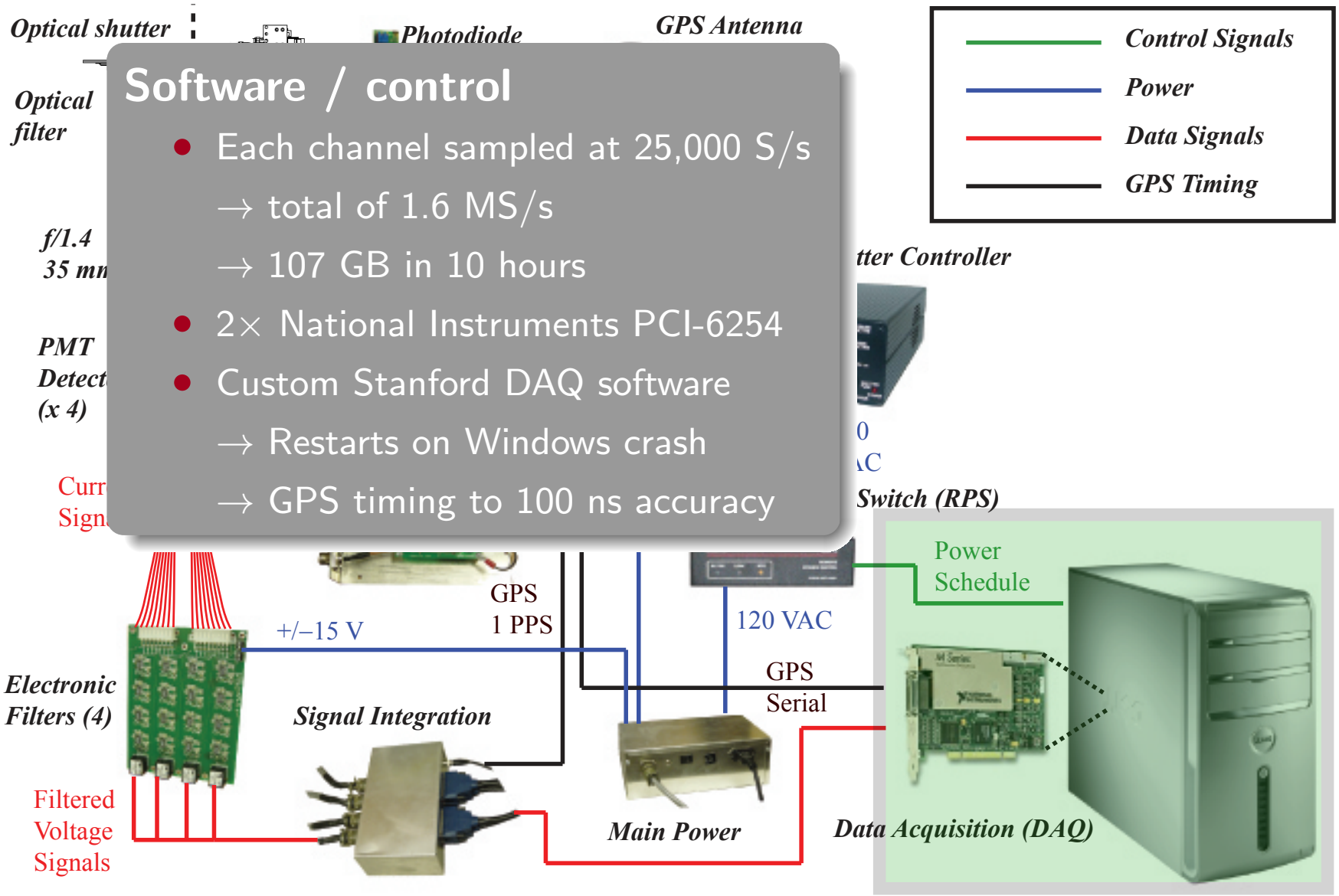
PIPER Block Diagram



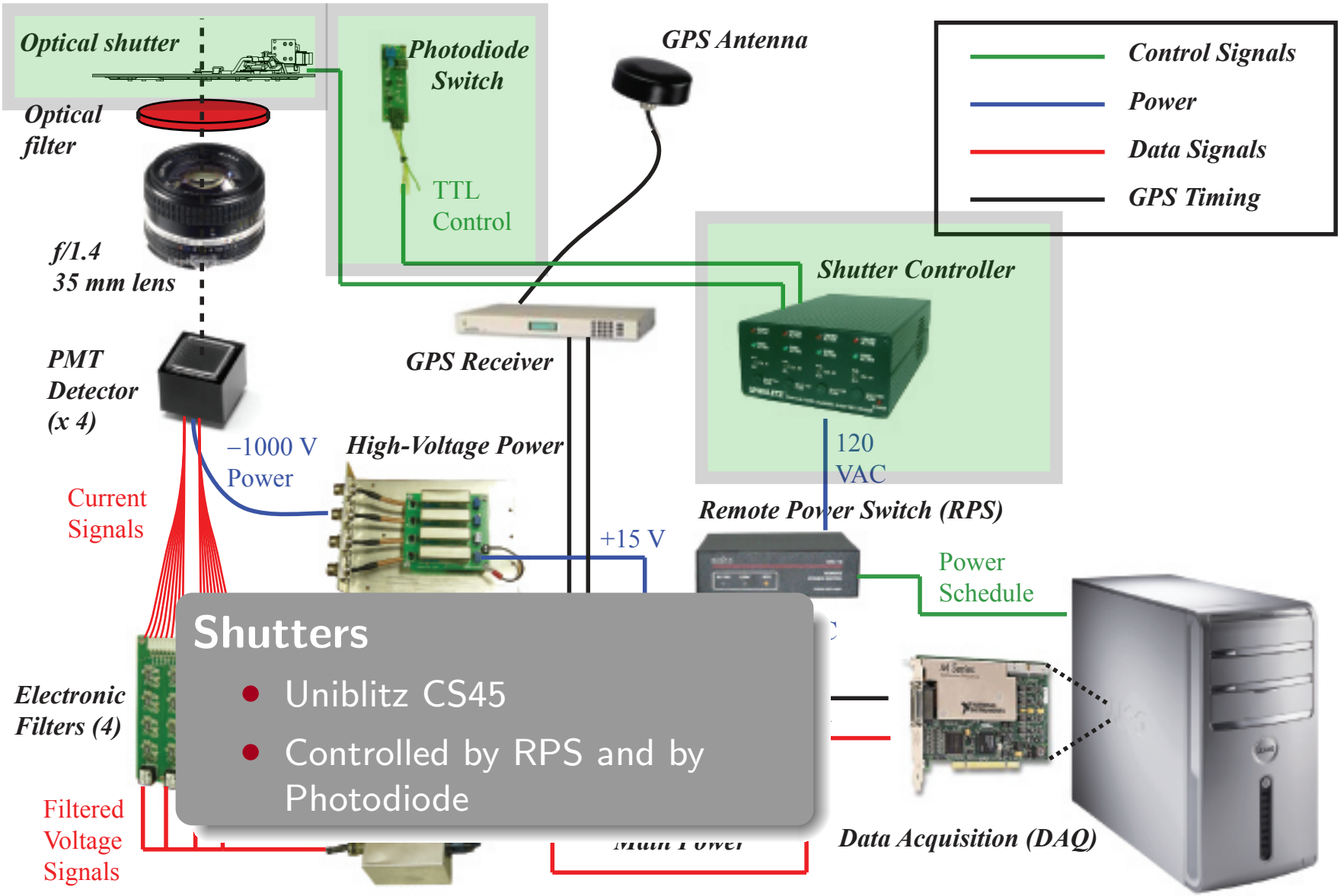
Filters

- 1 MΩ transimpedance amplifier
  → 4-pole Chebyschev filter @ 12 kHz (adjustable)
  → Voltage buffer
- * for each of 64 channels

PIPER Block Diagram



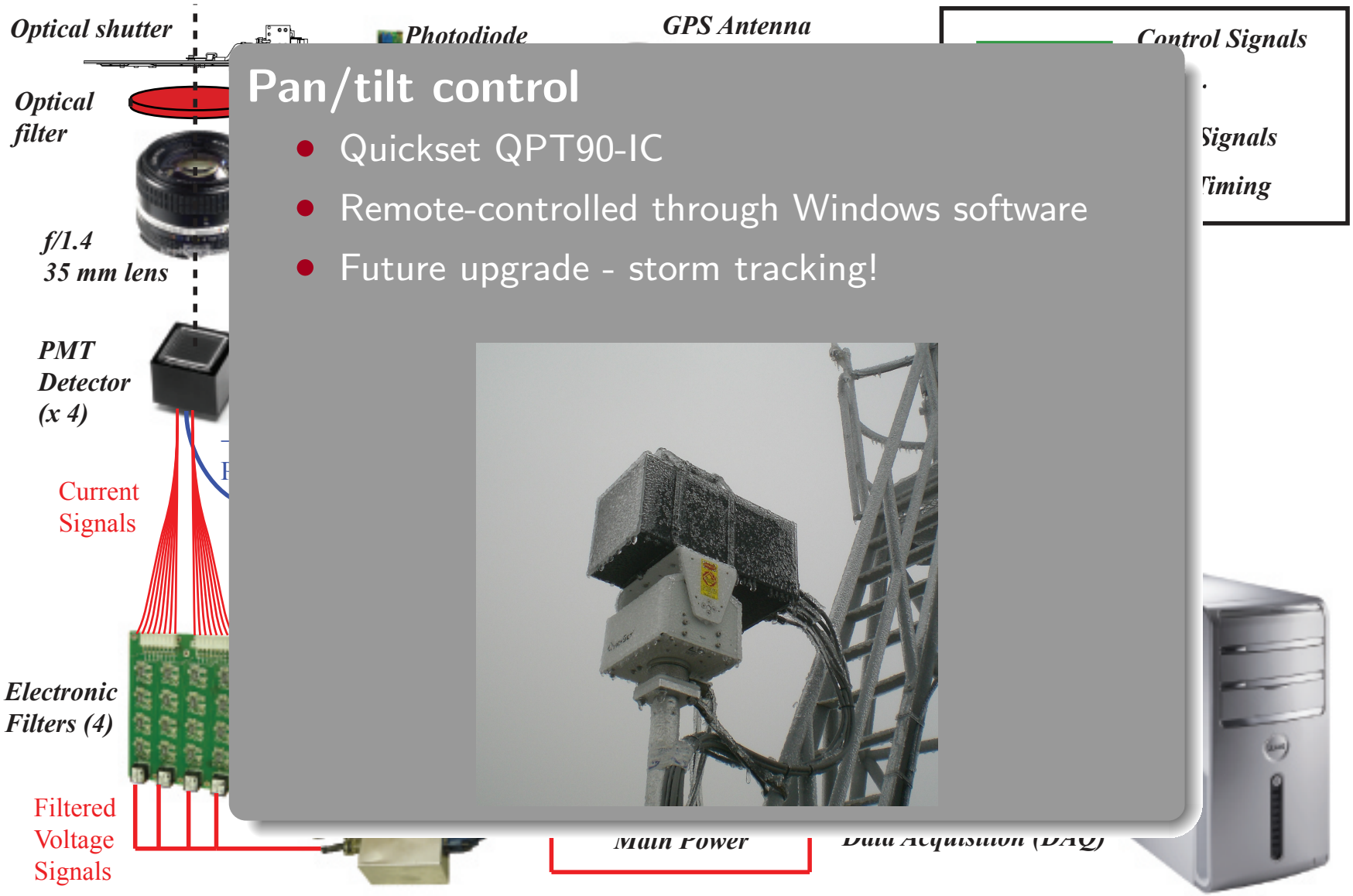
PIPER Block Diagram



Shutters

- Uniblitz CS45
- Controlled by RPS and by Photodiode

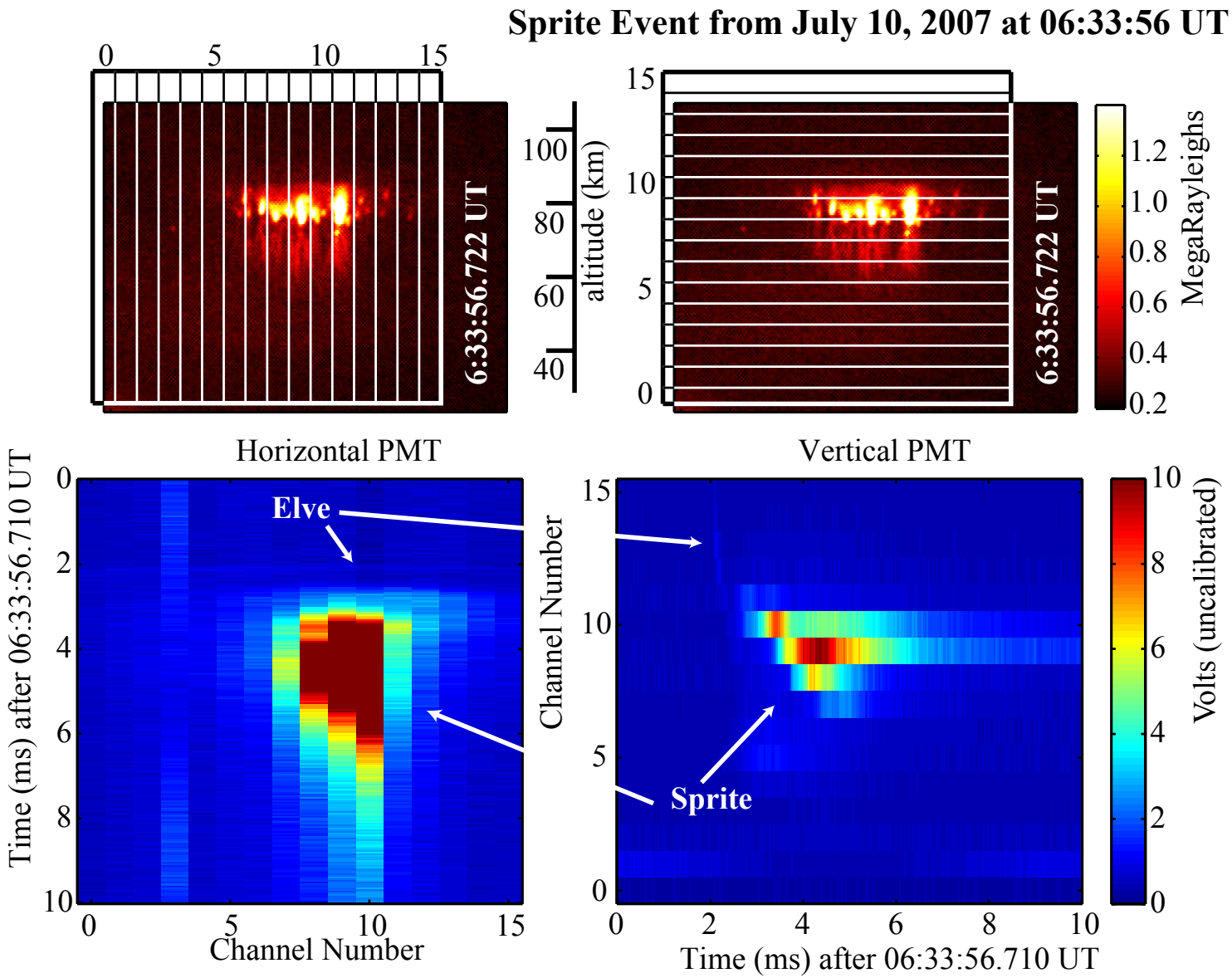
PIPER Block Diagram



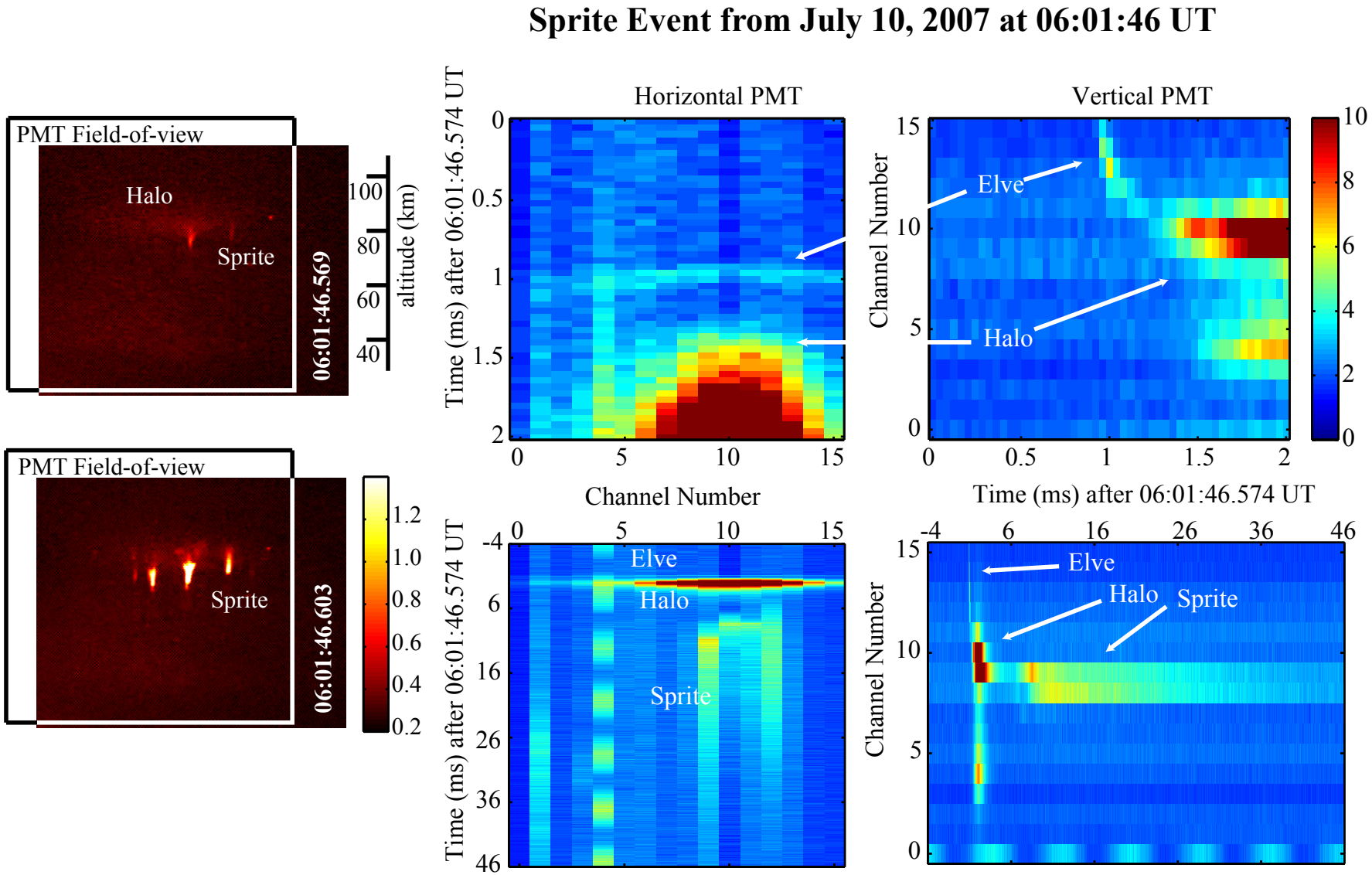
Pan/tilt control

- Quickset QPT90-IC
- Remote-controlled through Windows software
- Future upgrade - storm tracking!

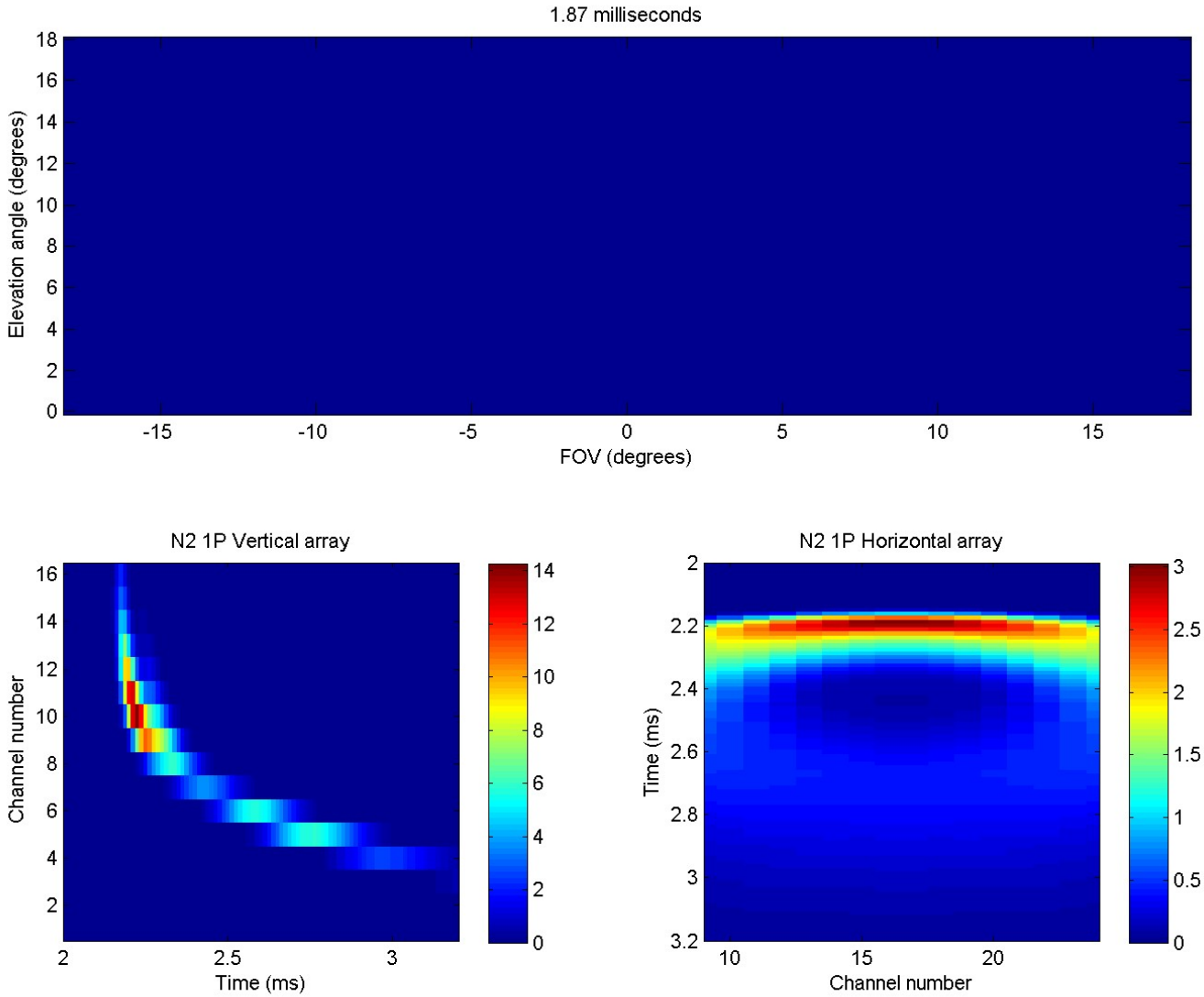
PIPER TLE Observations



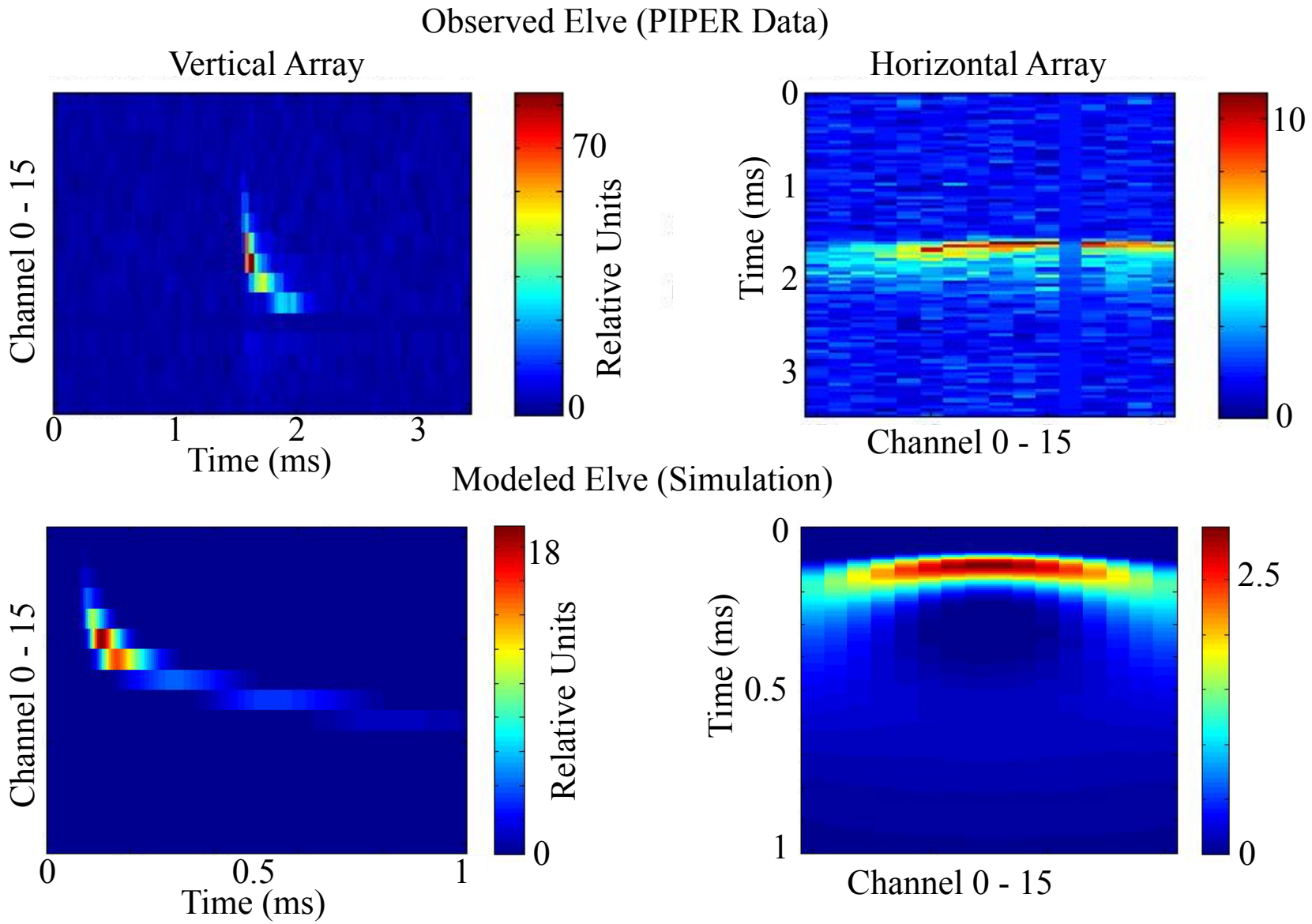
PIPER TLE Observations



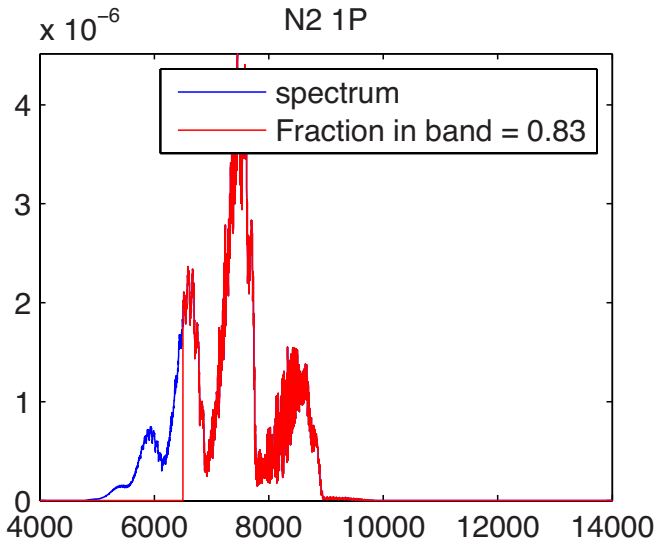
Simulated PIPER Elve

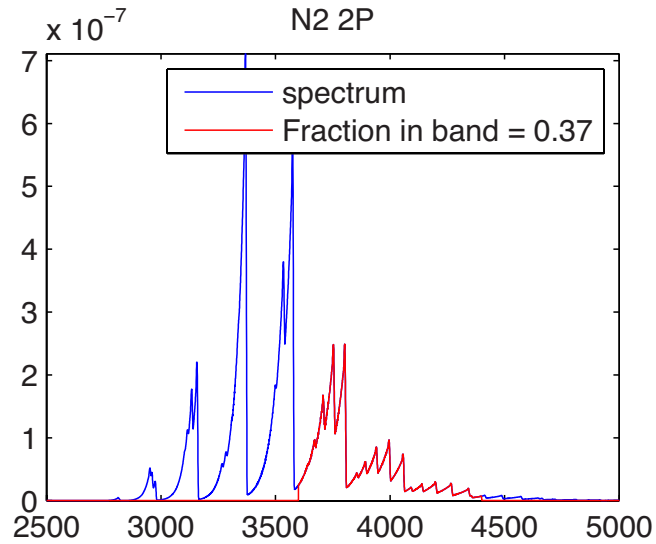


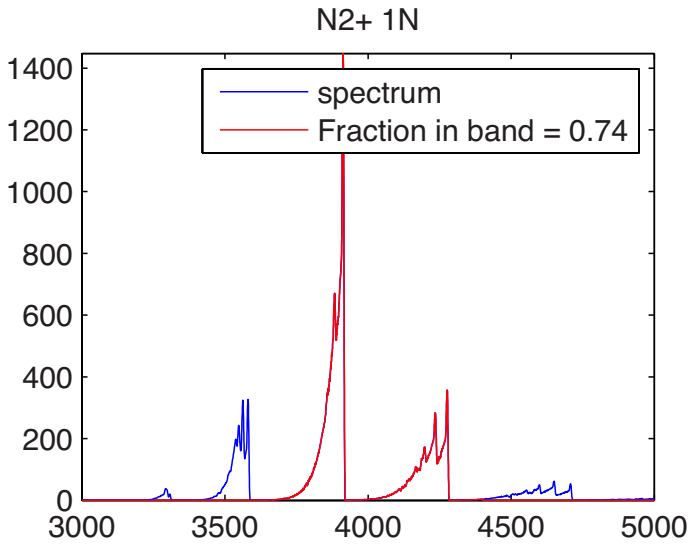
Simulation vs. Observation

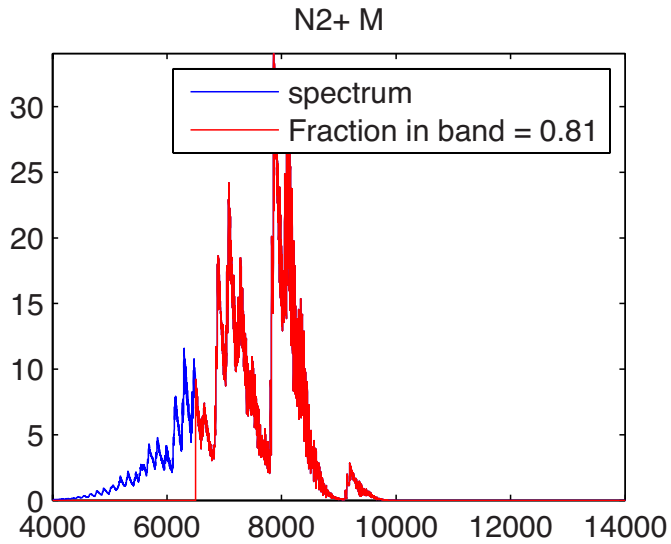


PIPER Filters and Elve Emission Spectra









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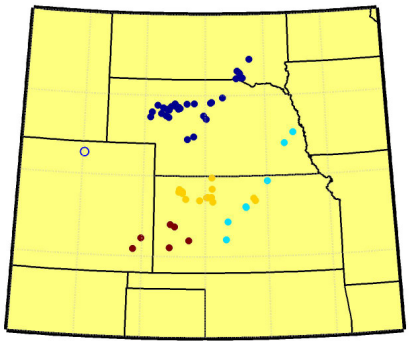
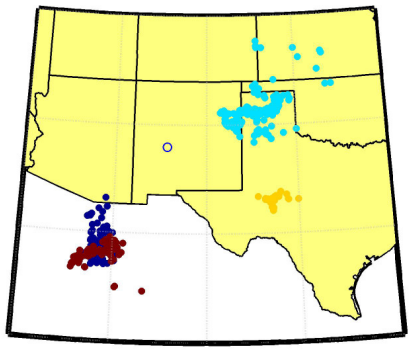
Aggregate Elve Studies

- *Newsome 2010* collected three years of elve observations
- Tracked 30 storms over their entire duration
- Observed 1644 total elves

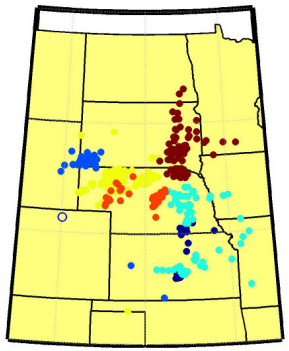
YR2007 Manned Campaign



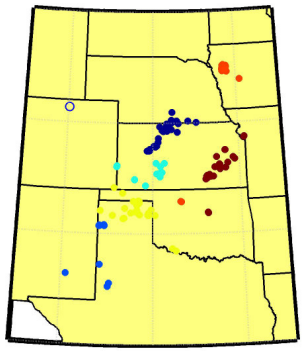
LL2008 Manned Campaign



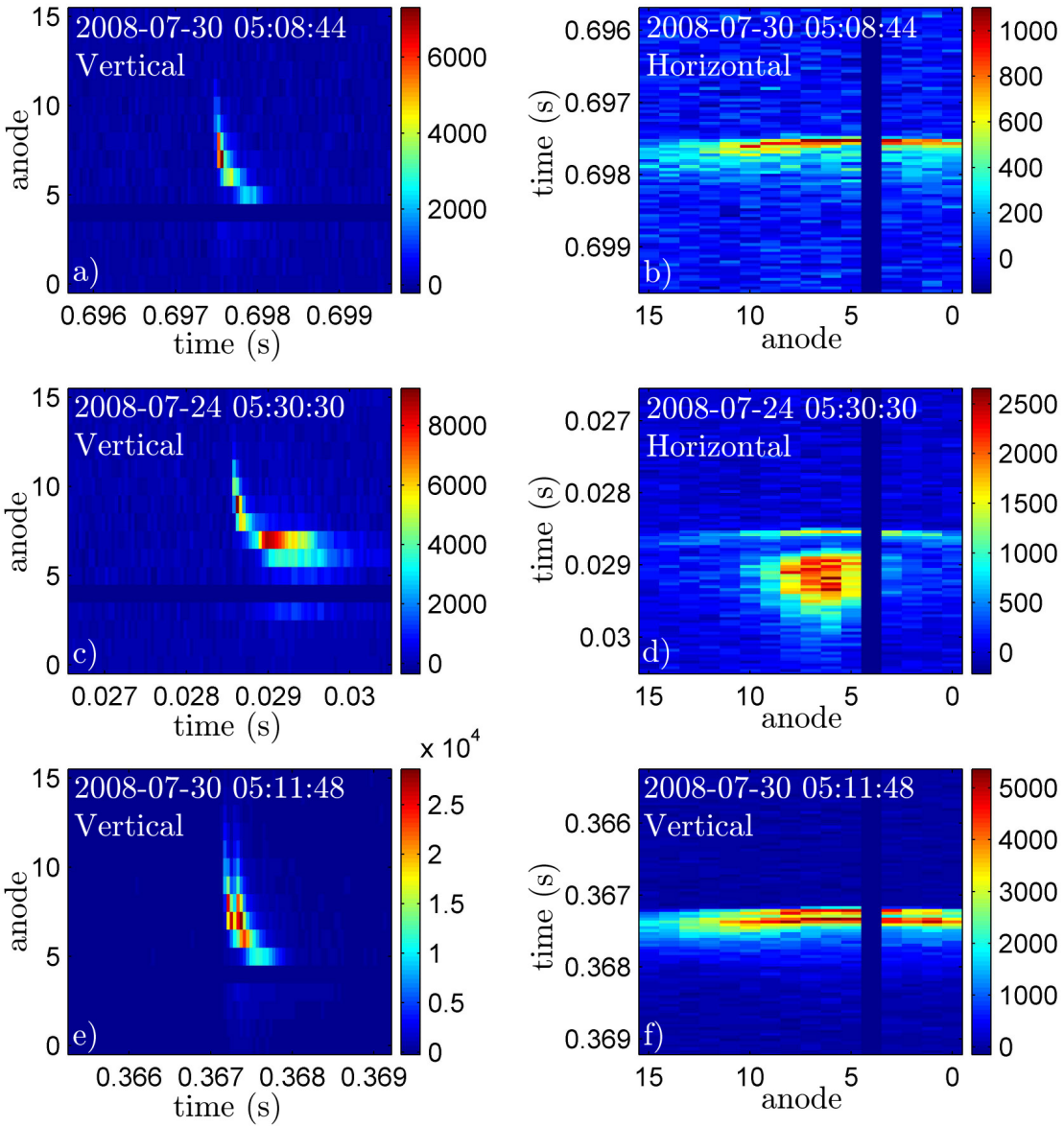
YR2009 Manned Campaign



YR2009 Remote Campaign

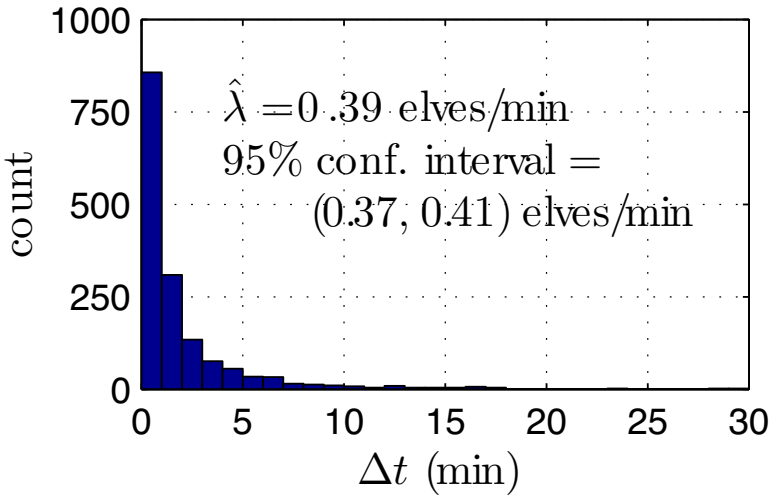


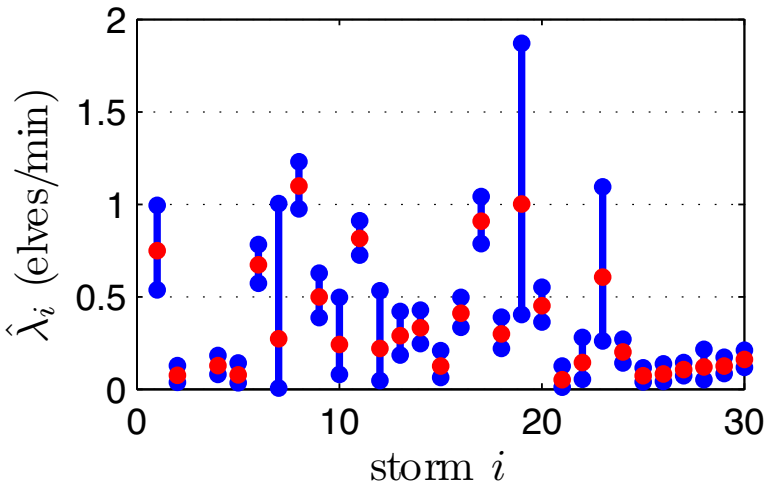
Example Data



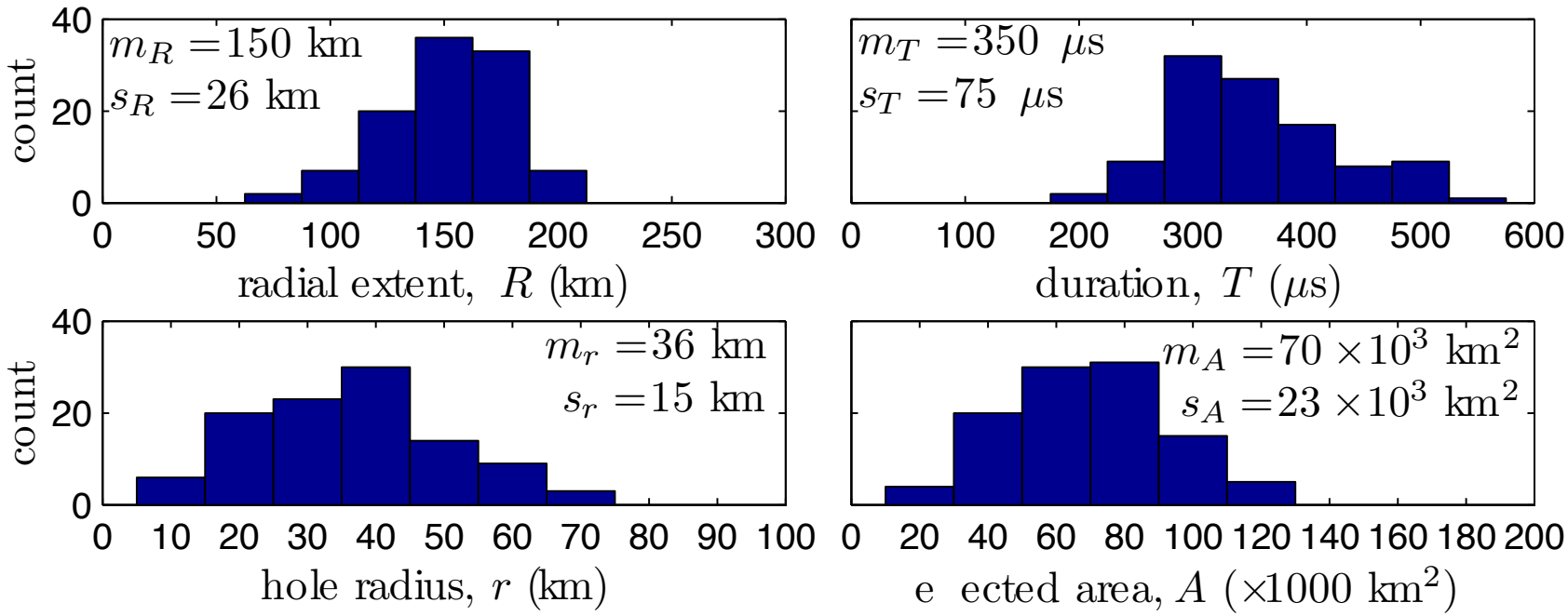
Elve Occurrence Rates

- Elve interarrival time is nearly exponential, with rate of $\lambda = 0.39$elves/min



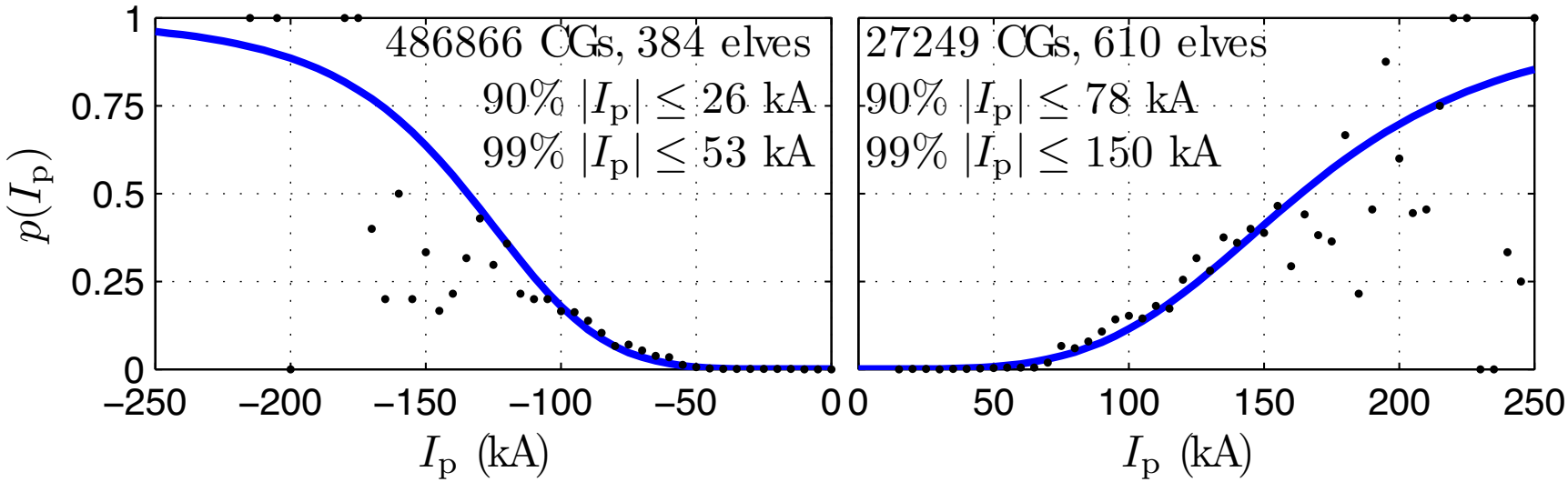


Distribution of Elve Geometric Parameters



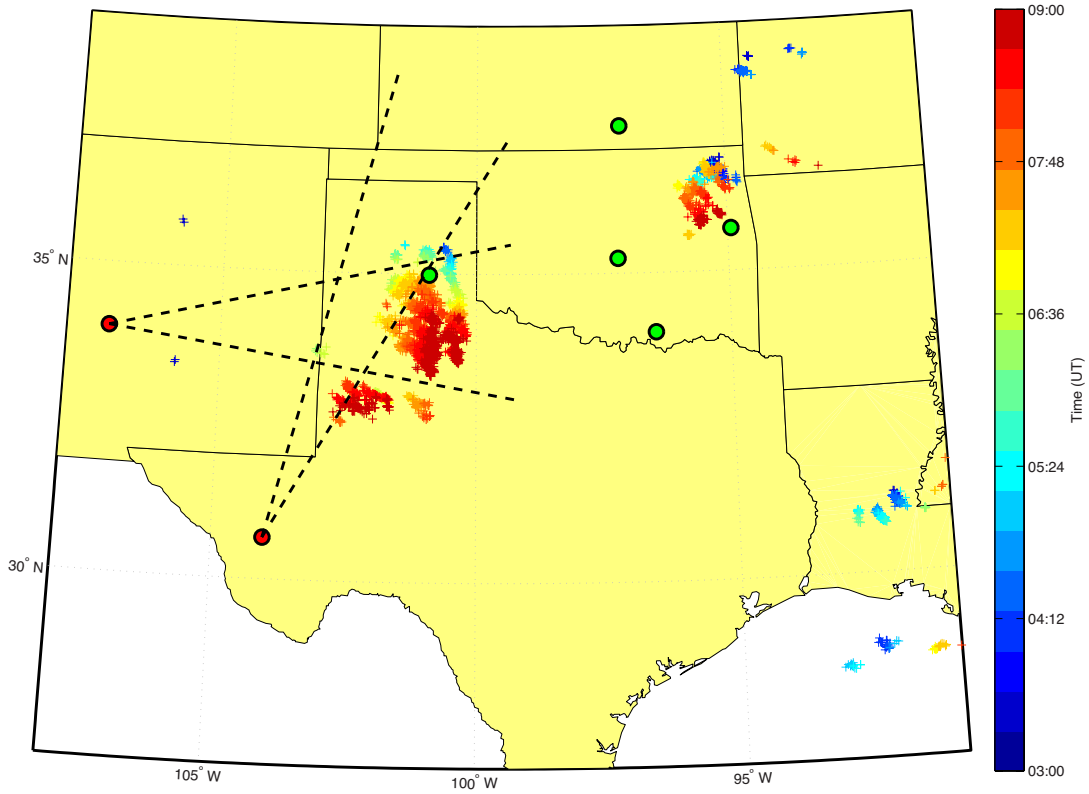
Elve Production Probability vs. Peak Current

- Earlier studies (e.g. *Chen et al. 2008*) have used the rule of thumb that all CGs with $I_p \geq 60$ kA produce elves
- This data shows that only about 10% of 60 kA CGs produce elves



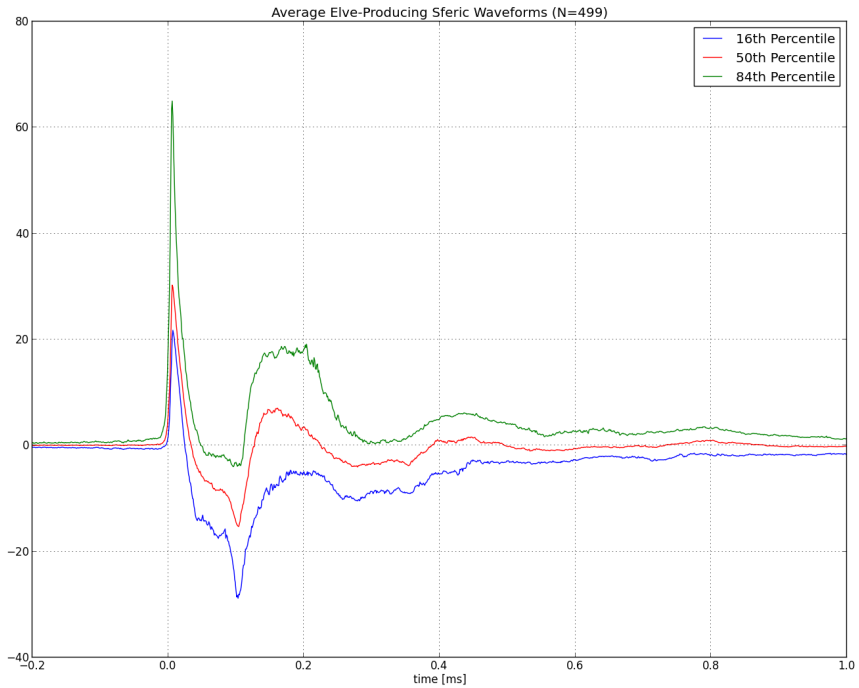
2013 Summer Campaign

- Two PIPER photometers have been installed since June
  - Langmuir Laboratory, New Mexico
  - McDonald Observatory, Texas
- Both photometers are pointed remotely
- Fields-of-view above the Stanford Oklahoma LF receiver array



Goals

- Extract geometric parameters from elves for lightning return stroke study
- Use simultaneous elve and lightning RF observations (Stanford LF receivers, LMA, etc.) to learn about the features of lightning important for elve production



Langmuir Laboratory

- Installed June 18

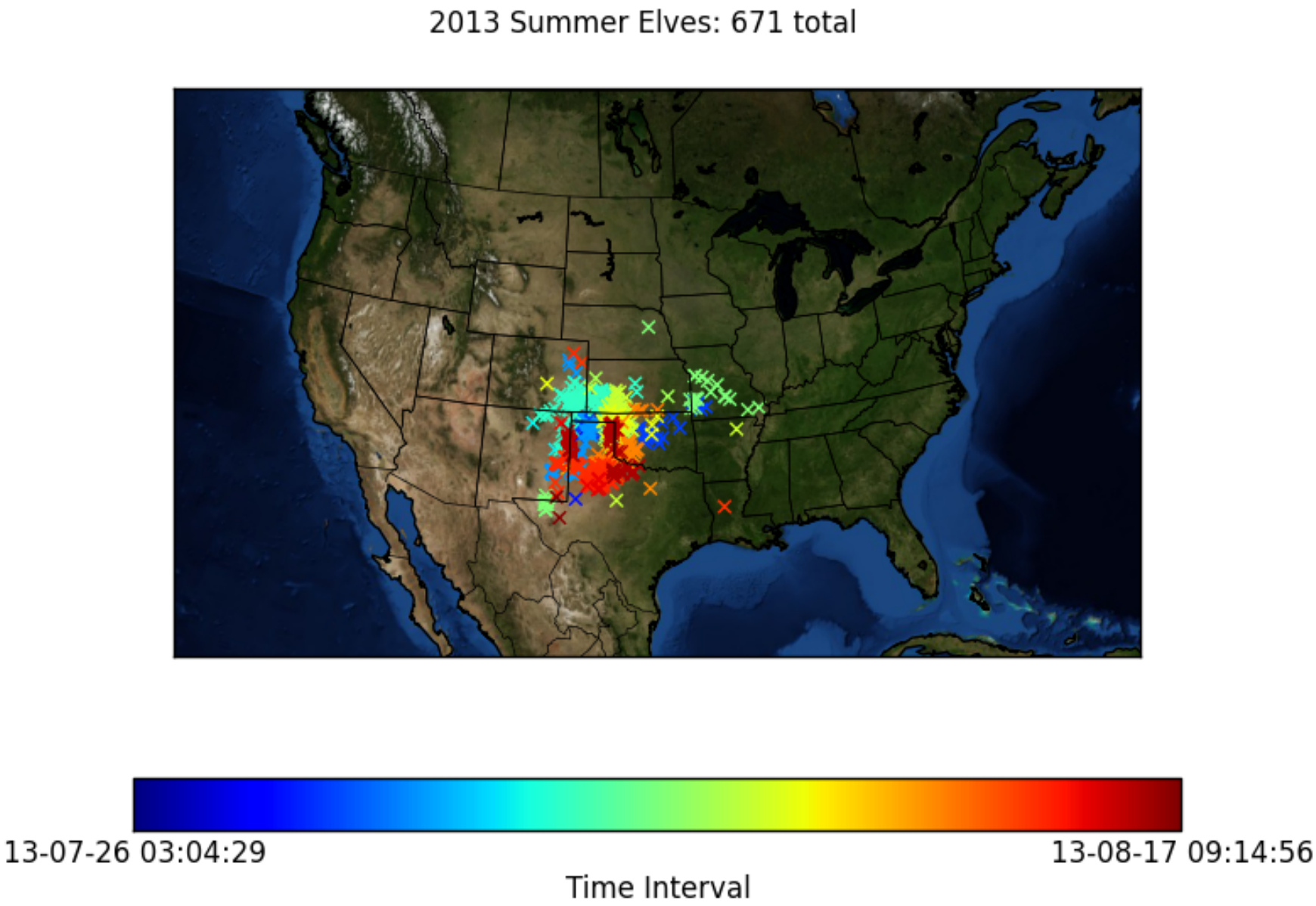
McDonald Observatory

- Installed June 16

LF Receivers

- 2-channel broadband LF receiver
- Two orthogonal B-field loop antennas
- 1 MHz samplerate

Elve Count


2013 Summer Elves: 671 total
13-07-26 03:04:29
13-08-17 09:14:56
Time Interval

Thank you!

Questions?