Triggered Lightning Spectrosopy

Thomas Daniel Walker

Special Thanks to Dr. Bill Beasley

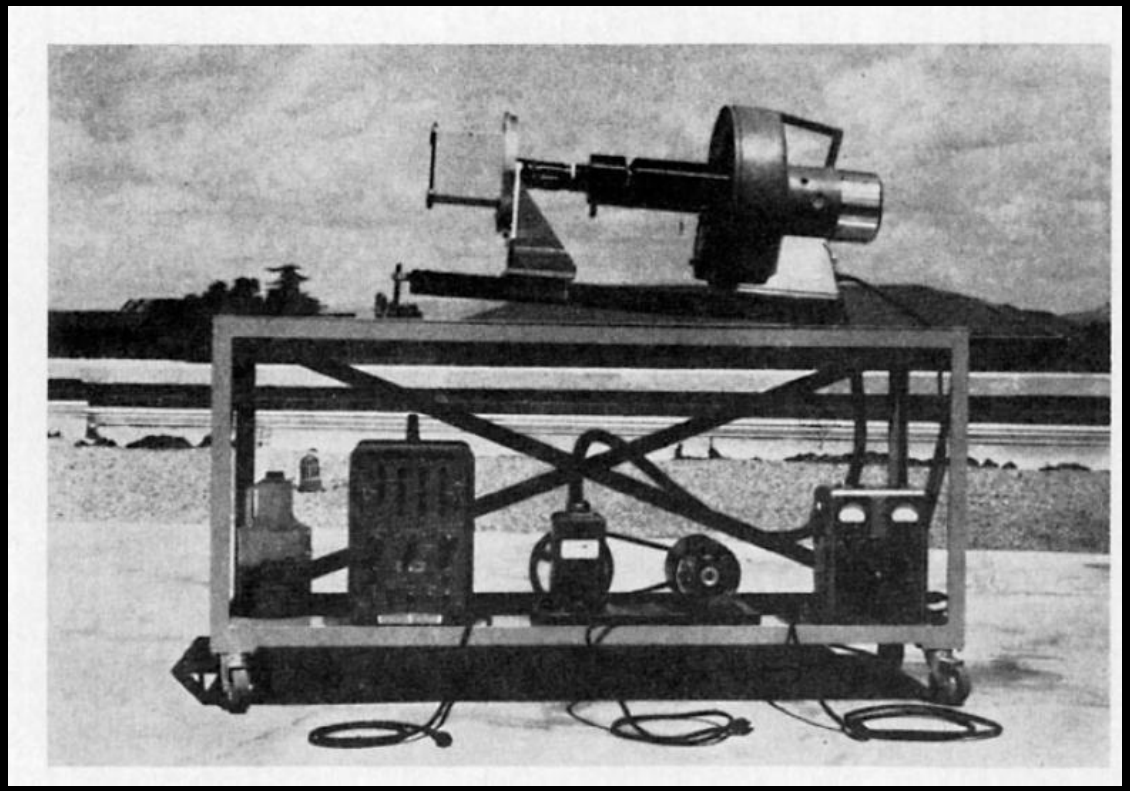
Purpose

Determine how the physical properties of the lightning channel, such as electron number density and temperature, change in time and height along the channel. Temperature and number density will also be investigated as a function of channel current and luminosity. Using these characteristic measurements of the lightning channel, the plasma dynamics of the channel will be explained.

History

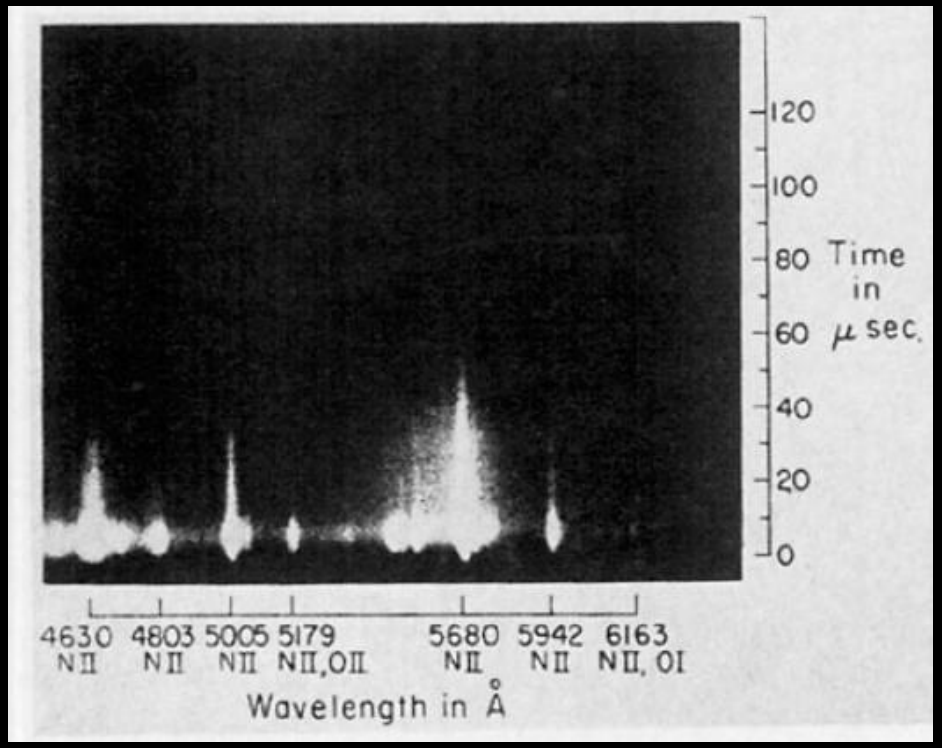
- Leon Salanave (1961)
  - History and overview in SCIENCE introduced the world to lightning spectroscopy
- Melvin Prueitt (1963)
  - First to use relative line intensities to determine the temperature
  - Time averaged over flash
- Richard Orville (1965)
  - First stroke resolved spectra
  - 5 microsecond time resolution

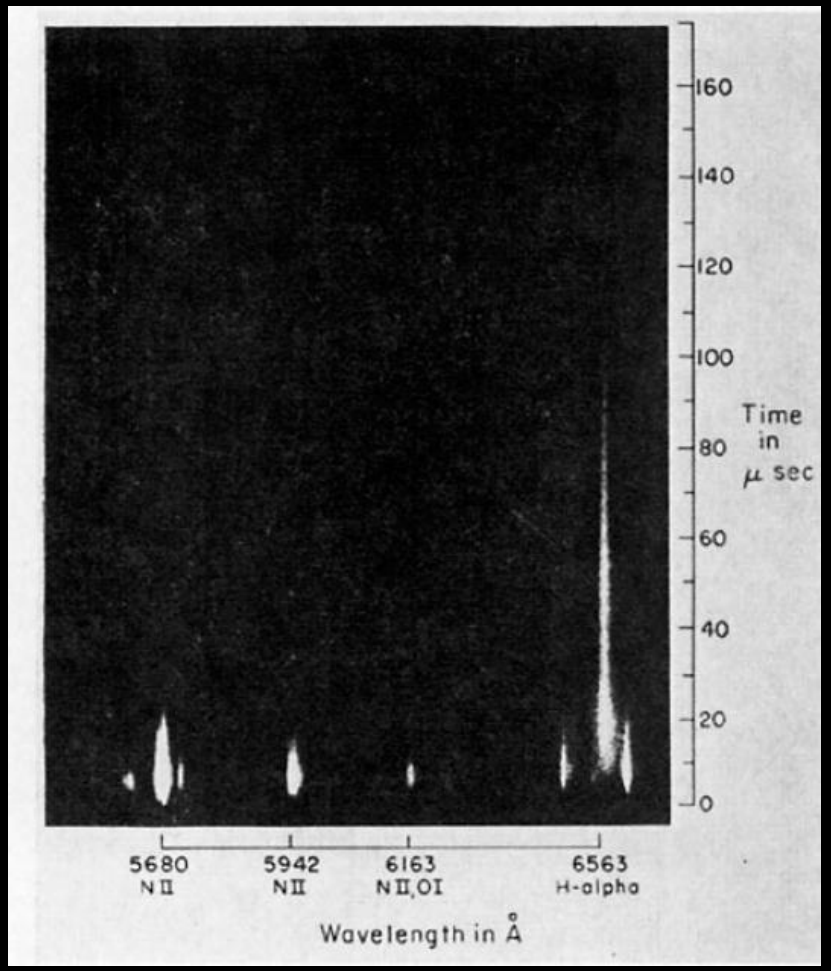
Equipment



R.E. Orville, J. Atmospheric Sci. **25**, 827-838, 1968.

Spectra





R.E. Orville, J. Atmospheric Sci. **25**, 827-838, 1968.

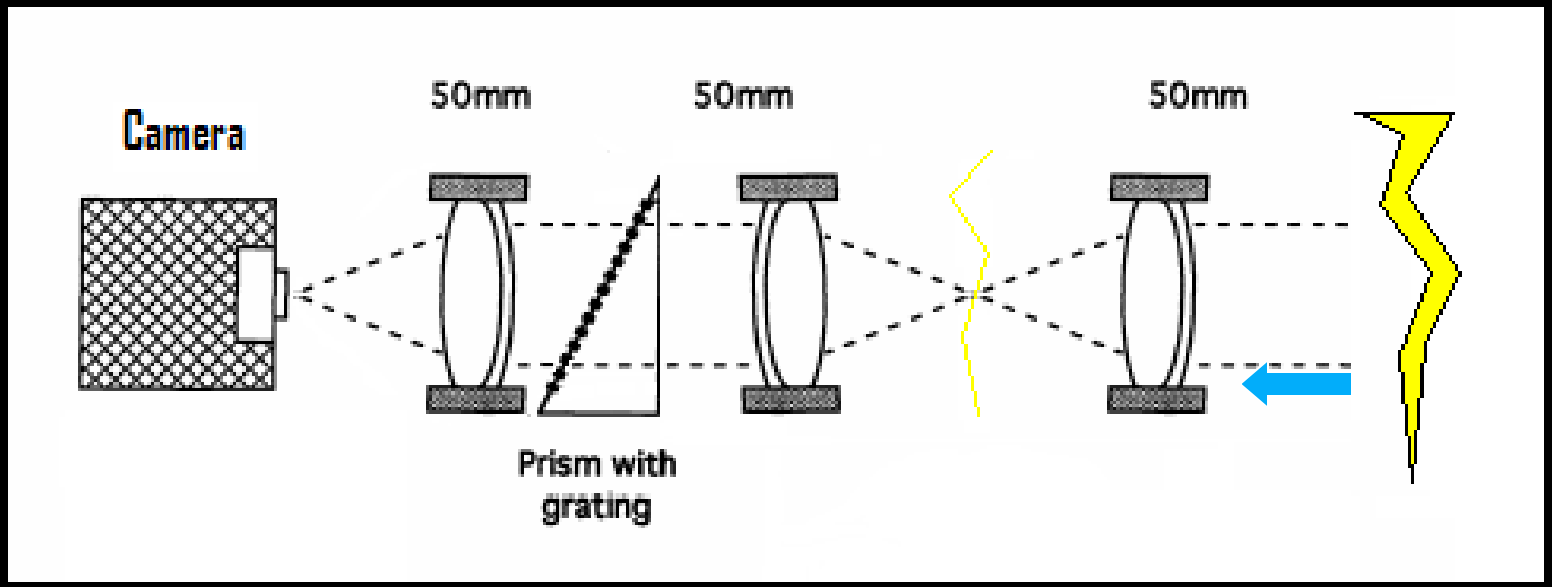
Previous Studies

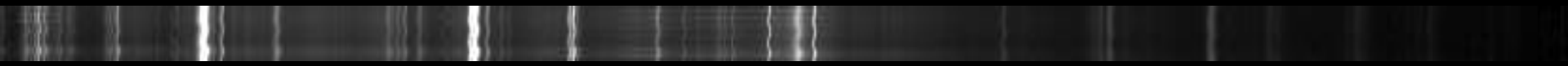
- Film
  - Nonlinear response to light
  - Sensitivity variations with wavelength
  - Exposure is sensitive to temperature/humidity
  - Processing
  - Dynamic range
- Photodensiometer tracings
- Relatively low number of spectra due to unpredictable nature of lightning flashes

Current Study

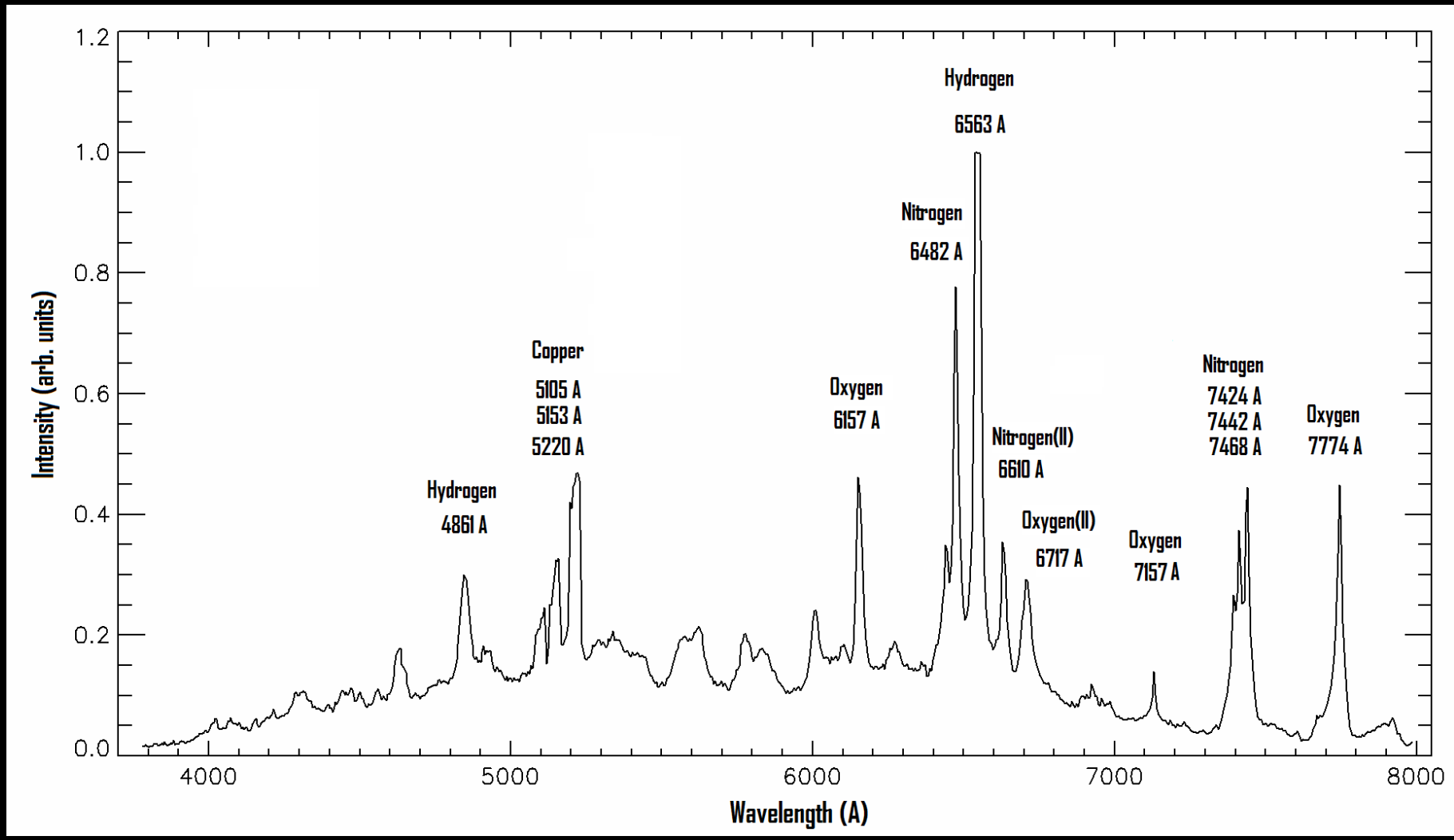
- CCD/CMOS cameras linear response to light and record intensity measurements
- Spectrometer is small and compact with no moving parts
- Simplified calibration, stable
- Using in-cloud and triggered lightning as sources of spectra should increase the number of flashes able to be observed

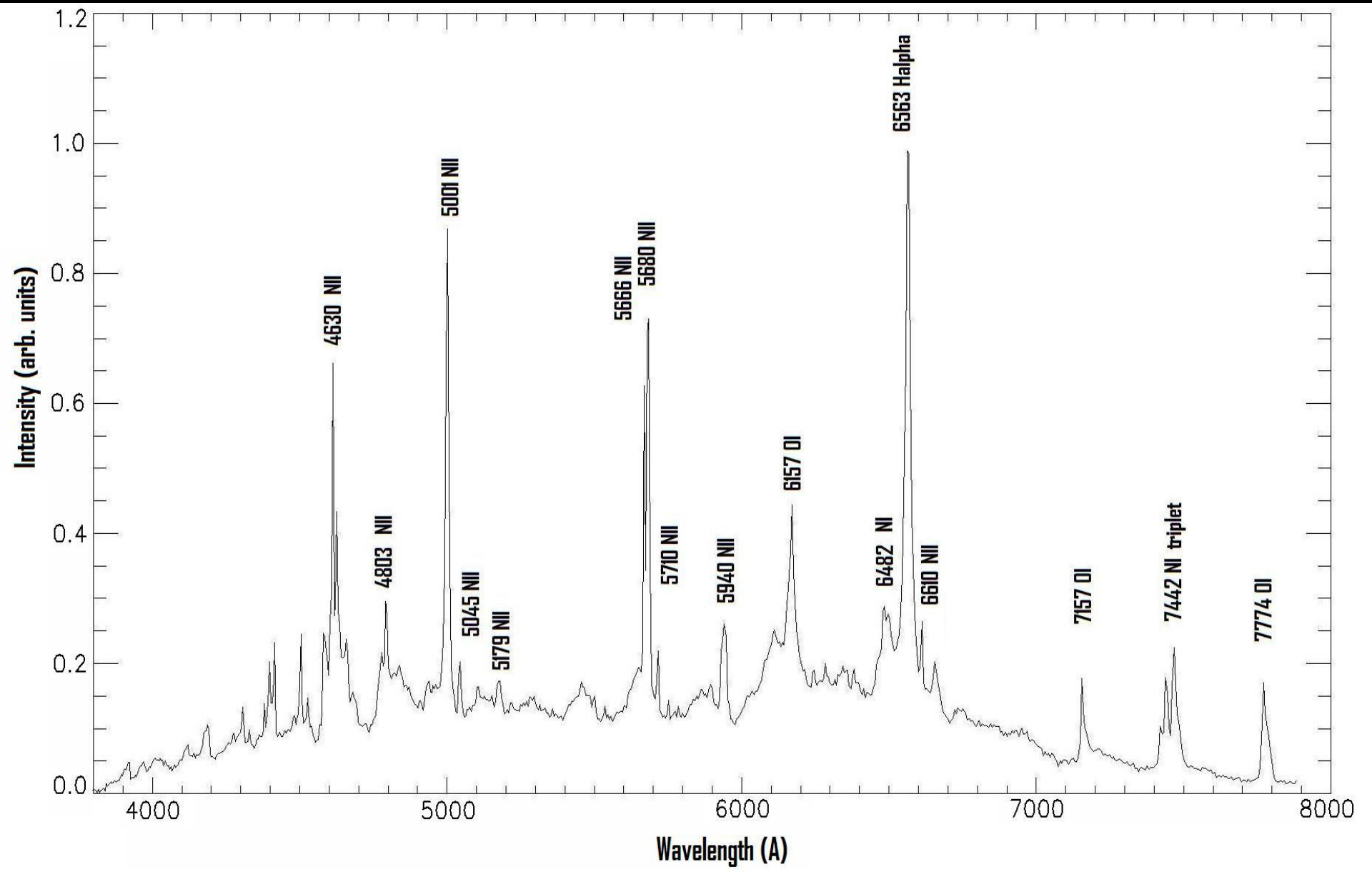
Spectrometer Design

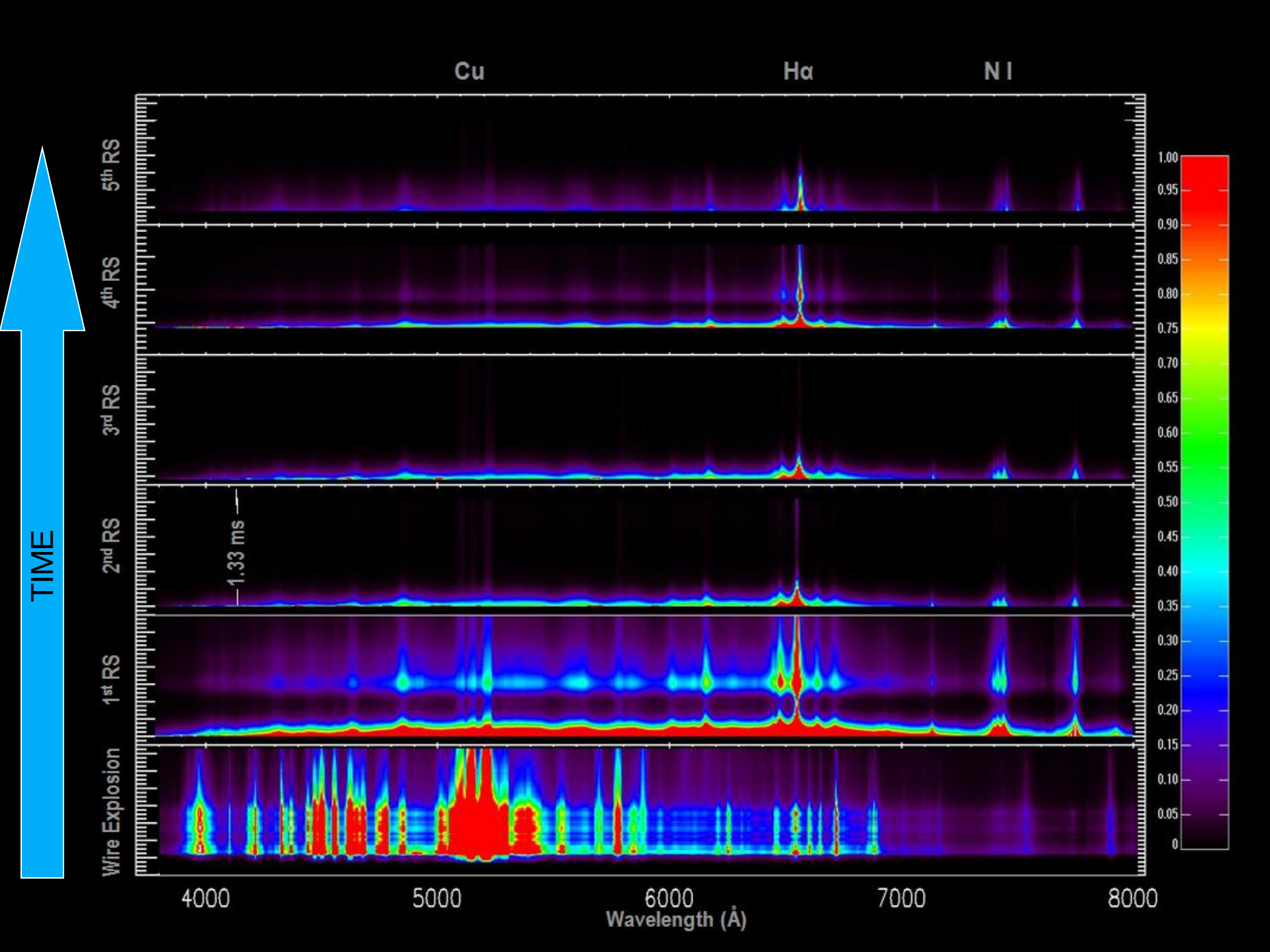




Sample Spectra

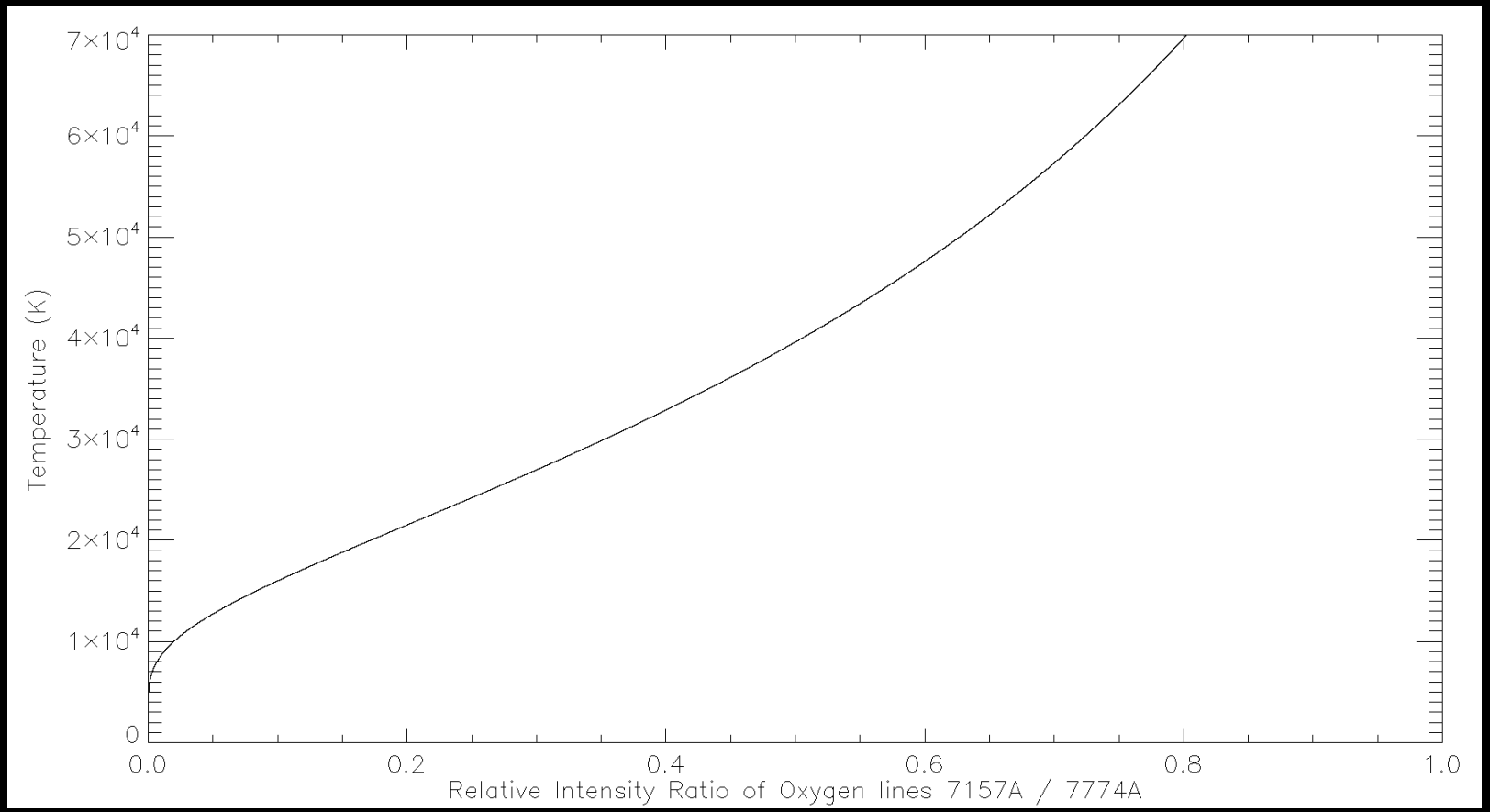



Intensity (arb. units)
Wavelength (A)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
4000
5000
6000
7000
8000
4630 NII
4803 NII
5001 NII
5045 NII
5179 NII
5666 NII
5680 NII
5710 NII
5940 NII
6157 OI
6482 NI
6563 Halpha
6610 NII
7157 OI
7442 NI triplet
7774 OI


Cu
Hα
N I
5th RS
4th RS
3rd RS
2nd RS
1st RS
Wire Explosion
1.33 ms
TIME
4000
5000
6000
7000
8000
Wavelength (Å)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0

Temperature Calculations

$$T = \frac{E_m - E_n}{k \ln \left[\frac{I_{nr} g_m A_{mp}}{I_{mp} g_n A_{nr}} \right]}$$



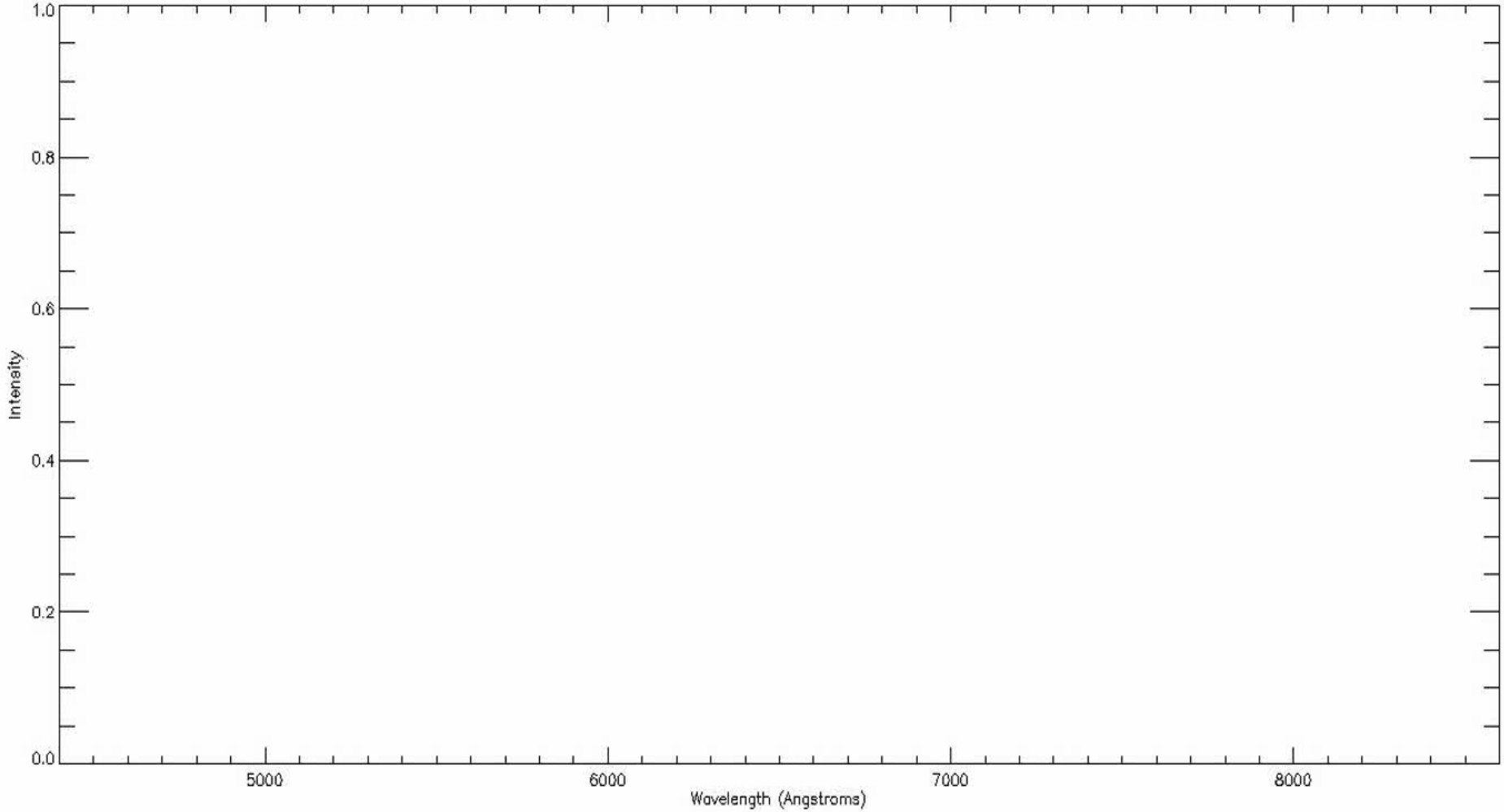
Electron Number Density

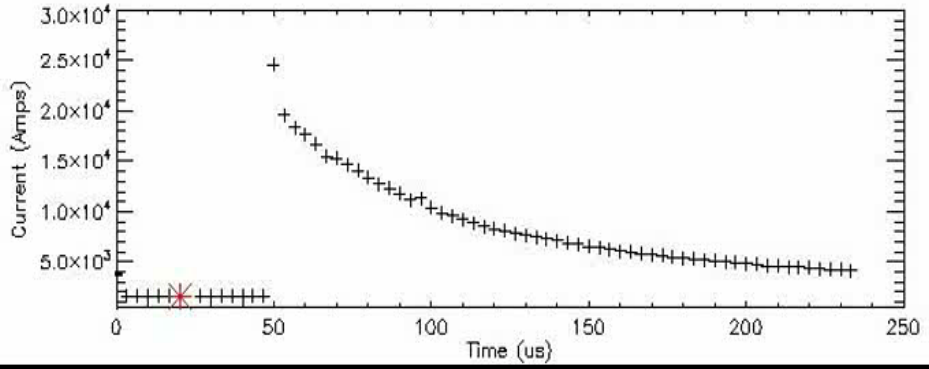
- Full-width half max of the H-alpha line

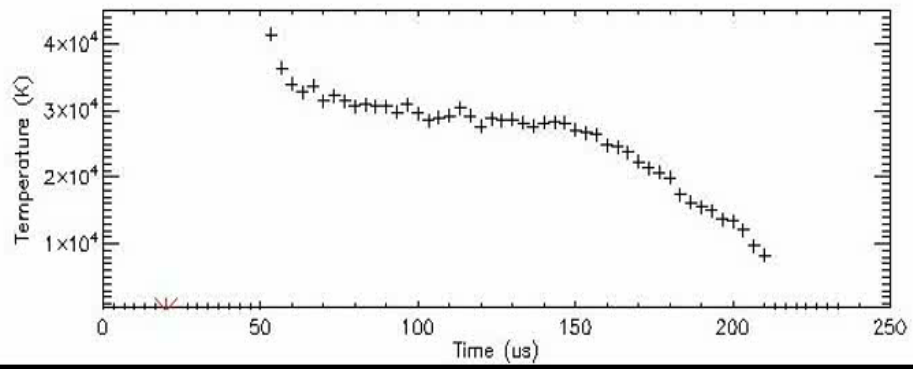
$$N_e = 8.02 * 10^{12} \left[\frac{\Delta\lambda}{\alpha} \right]^{\frac{3}{2}}$$

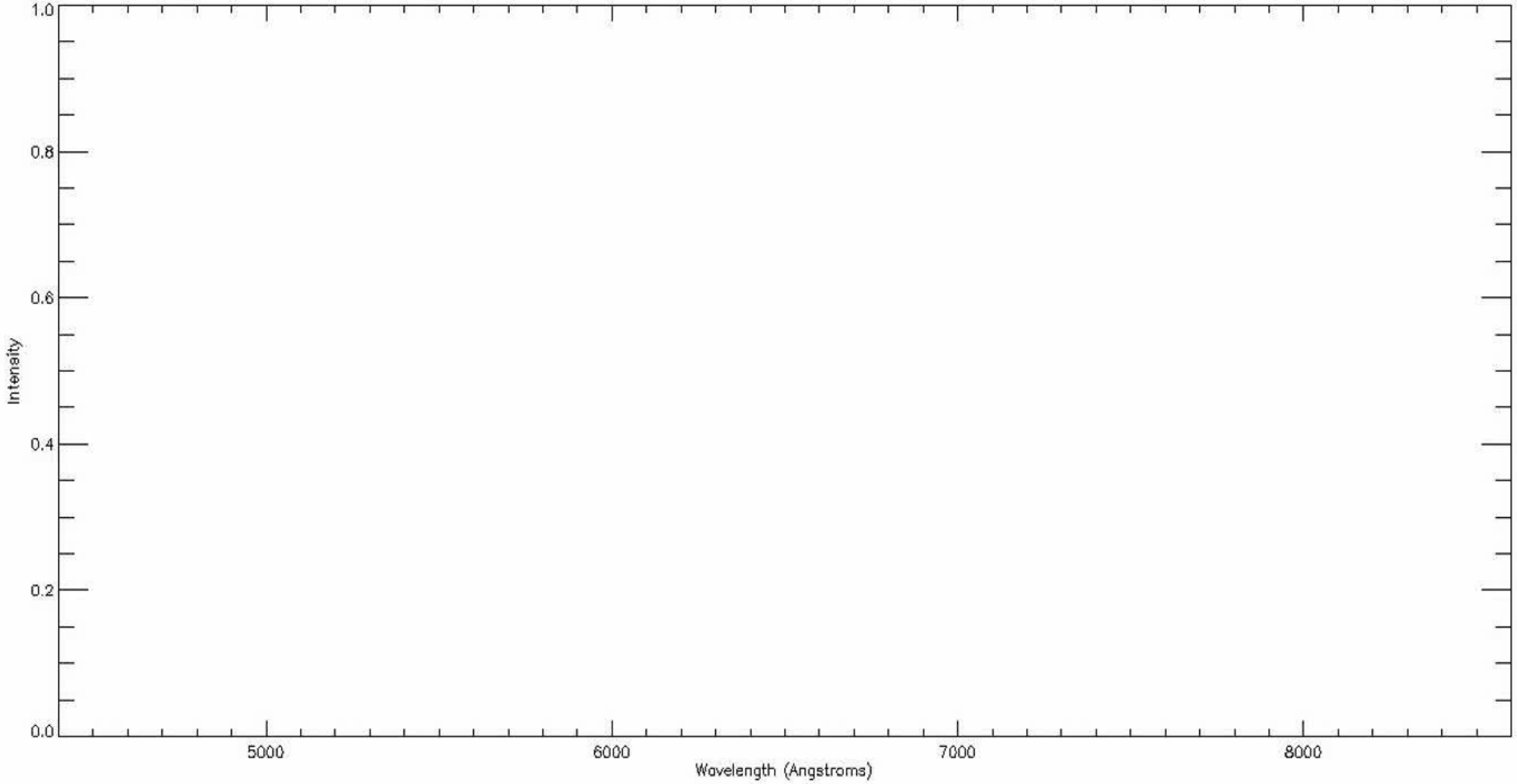
A. M. El Sherbini et al. *Spectrochimica Acta Part B*. **61** (2006) 532-539

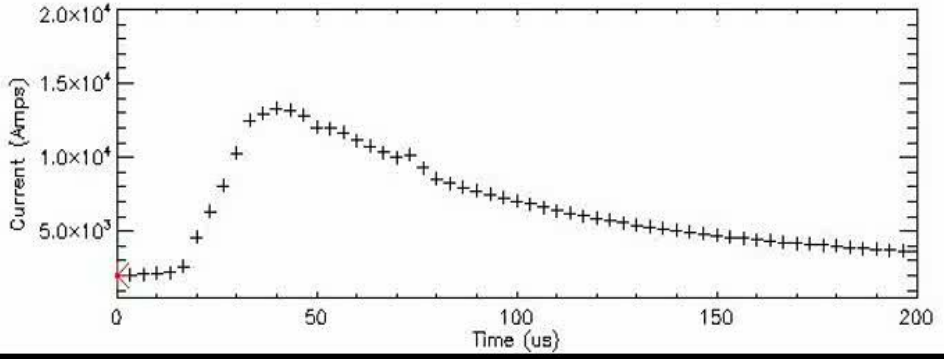
J. Ashkenazy et. al. *Phys. Rev. A*. **43** (1991) 5568-5574

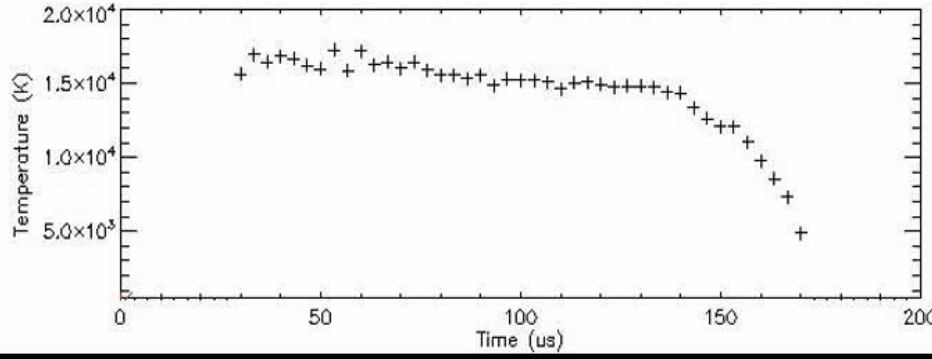

1.0
0.8
0.6
0.4
0.2
0.0
Intensity
5000
6000
7000
8000
Wavelength (Angstroms)

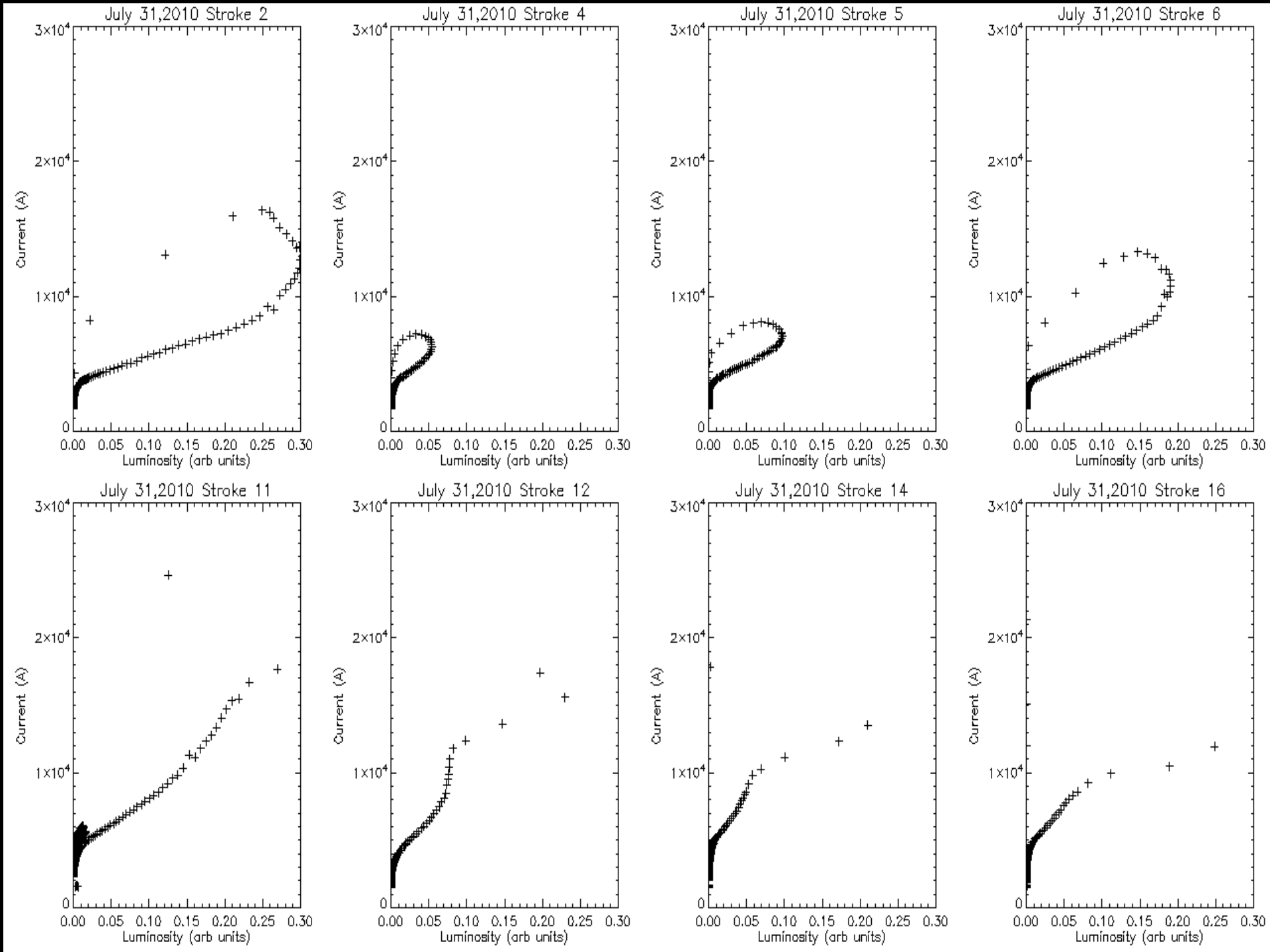

3.0×10⁴
2.5×10⁴
2.0×10⁴
1.5×10⁴
1.0×10⁴
5.0×10³
Current (Amps)
0
50
100
150
200
250
Time (us)

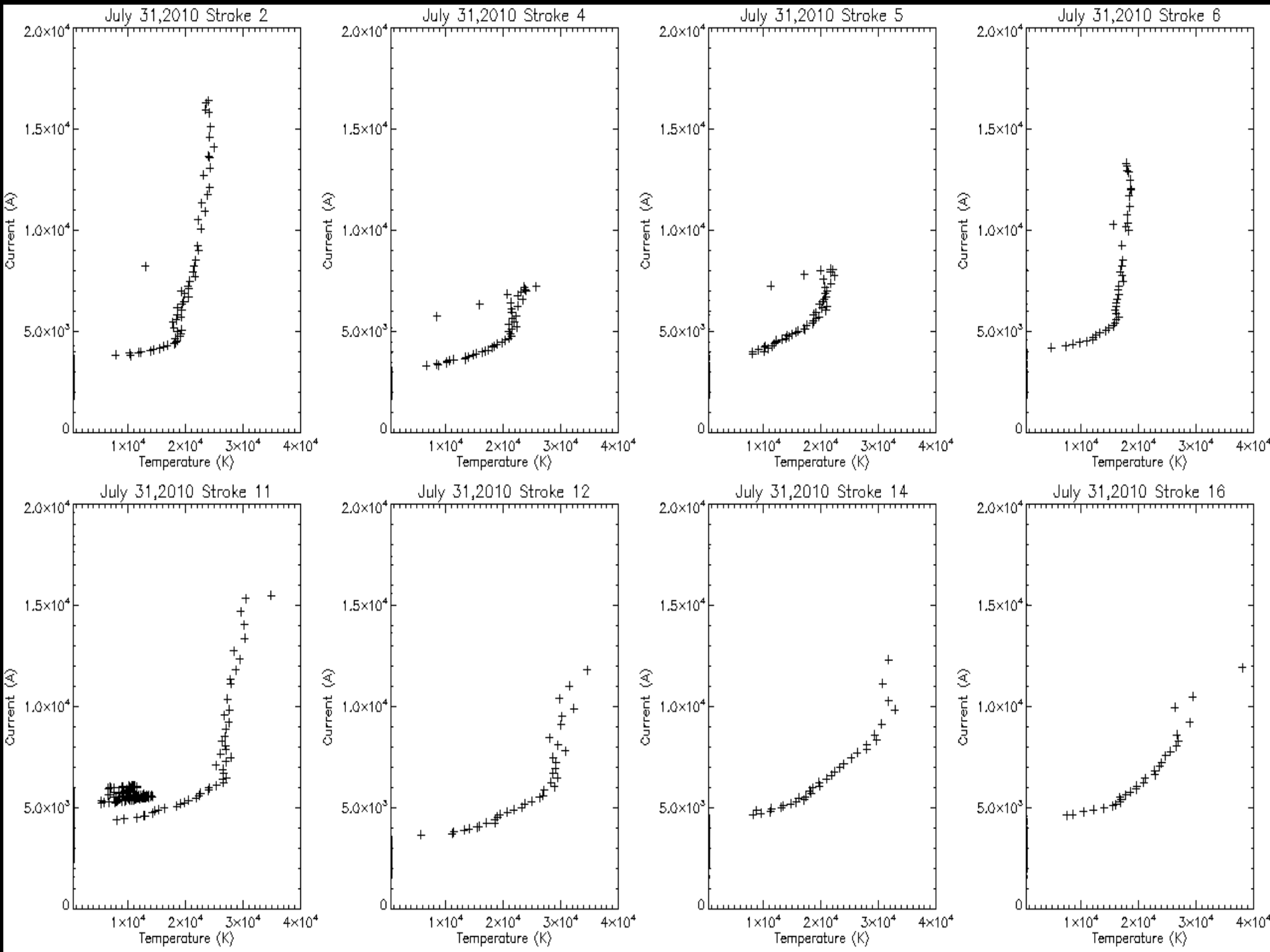

4×10⁴
3×10⁴
2×10⁴
1×10⁴
Temperature (K)
0
50
100
150
200
250
Time (us)

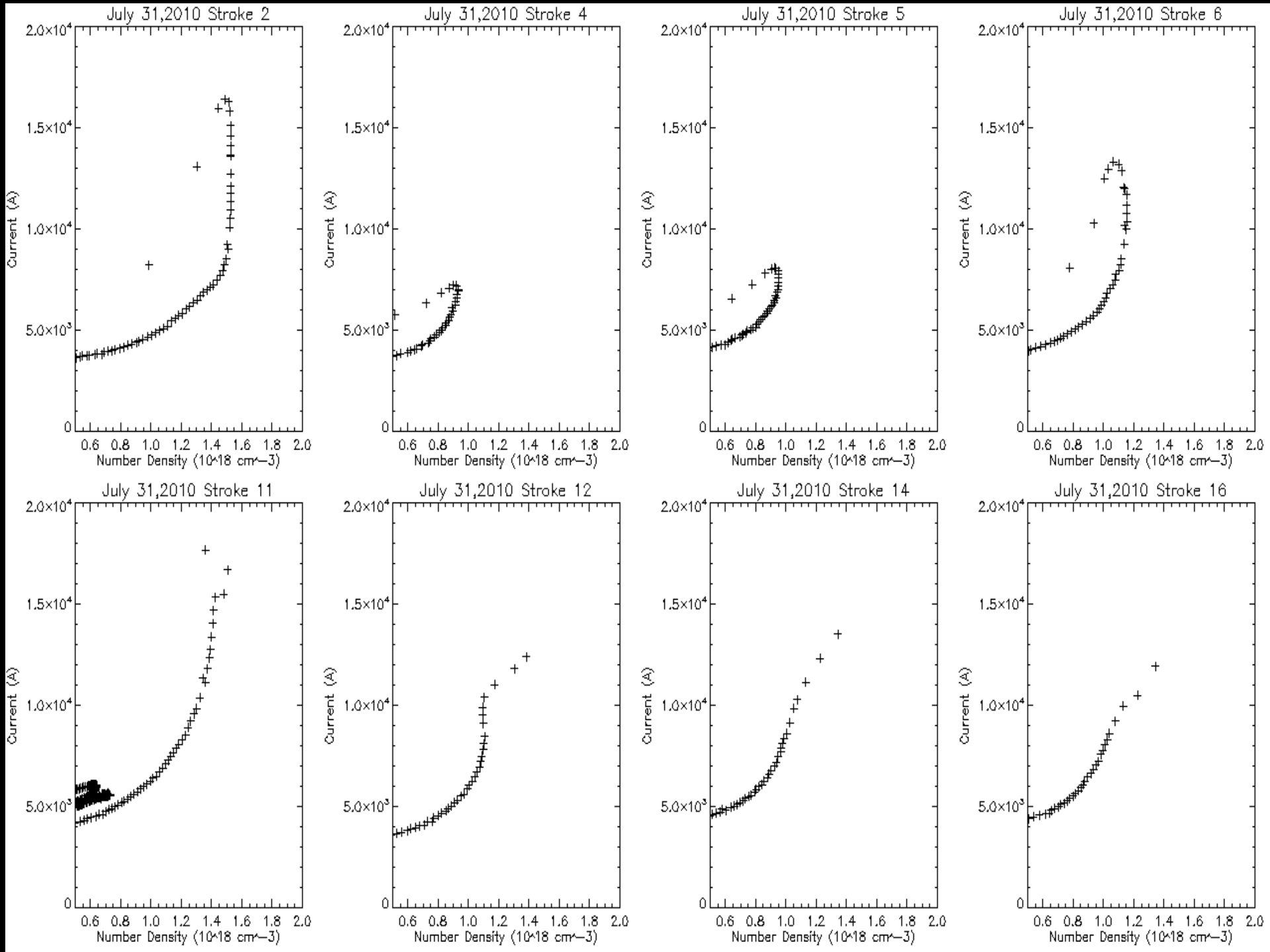

1.0
0.8
0.6
0.4
0.2
0.0
Intensity
5000
6000
7000
8000
Wavelength (Angstroms)

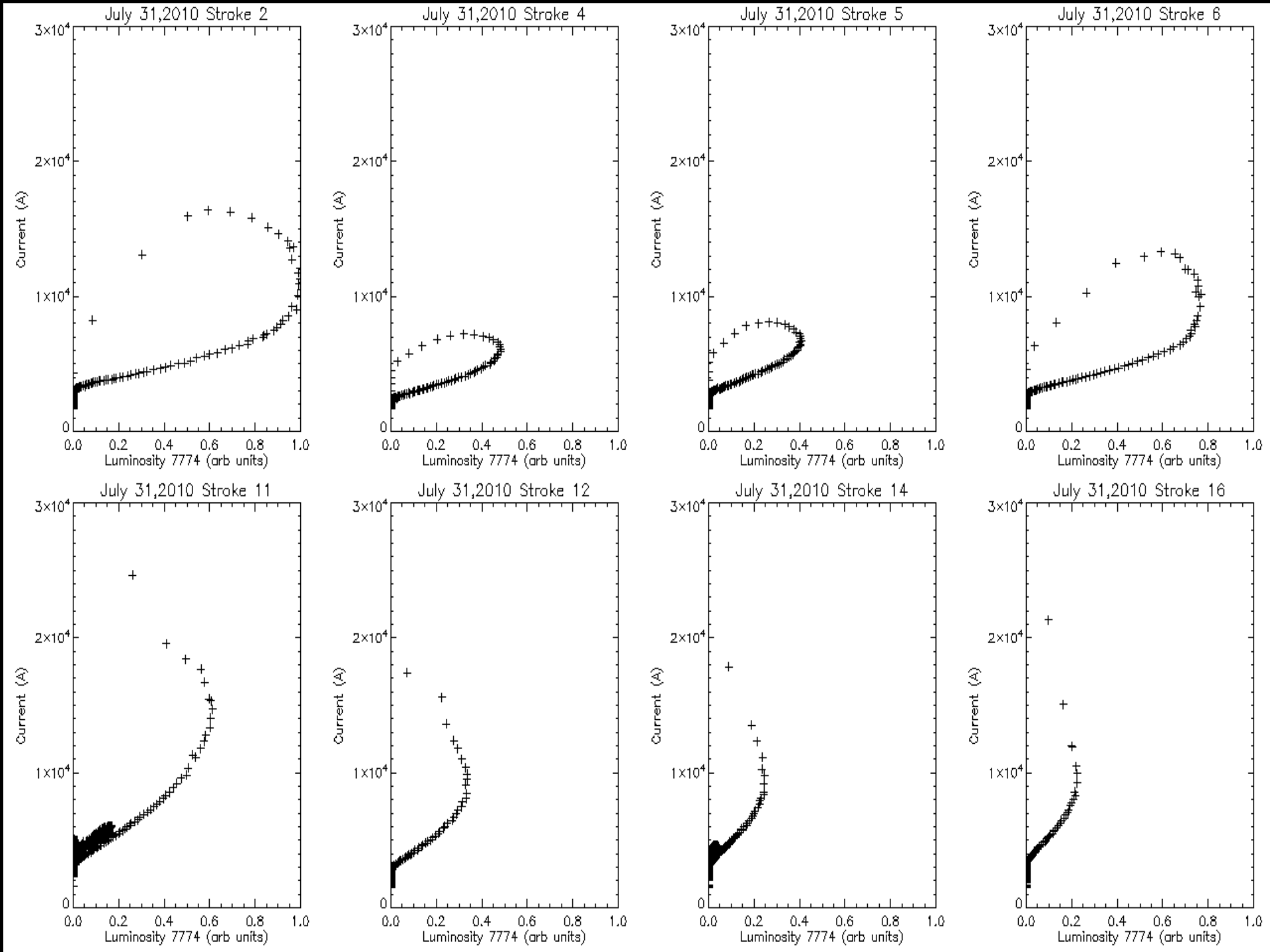

2.0×10⁴
1.5×10⁴
1.0×10⁴
5.0×10³
Current (Amps)
0
50
100
150
200
Time (us)

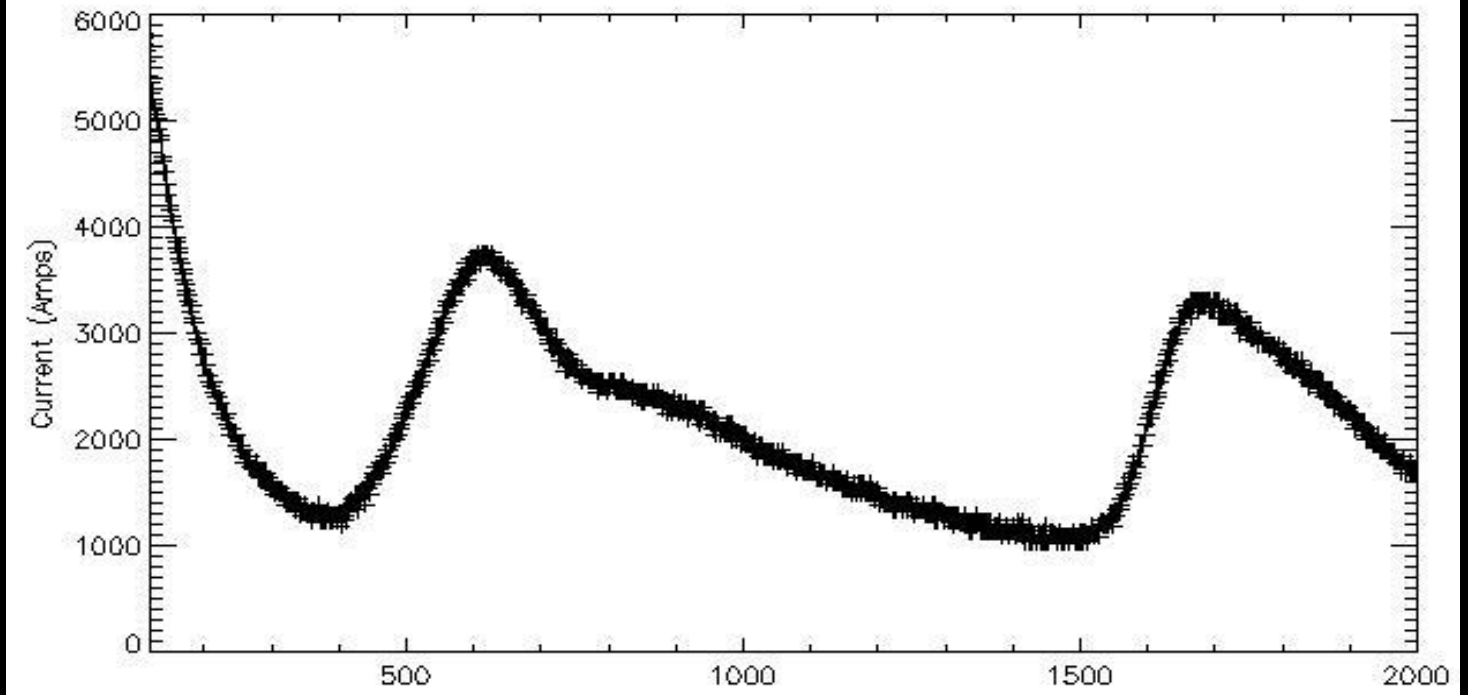

2.0×10⁴
1.5×10⁴
1.0×10⁴
5.0×10³
Temperature (K)
0
50
100
150
200
Time (us)

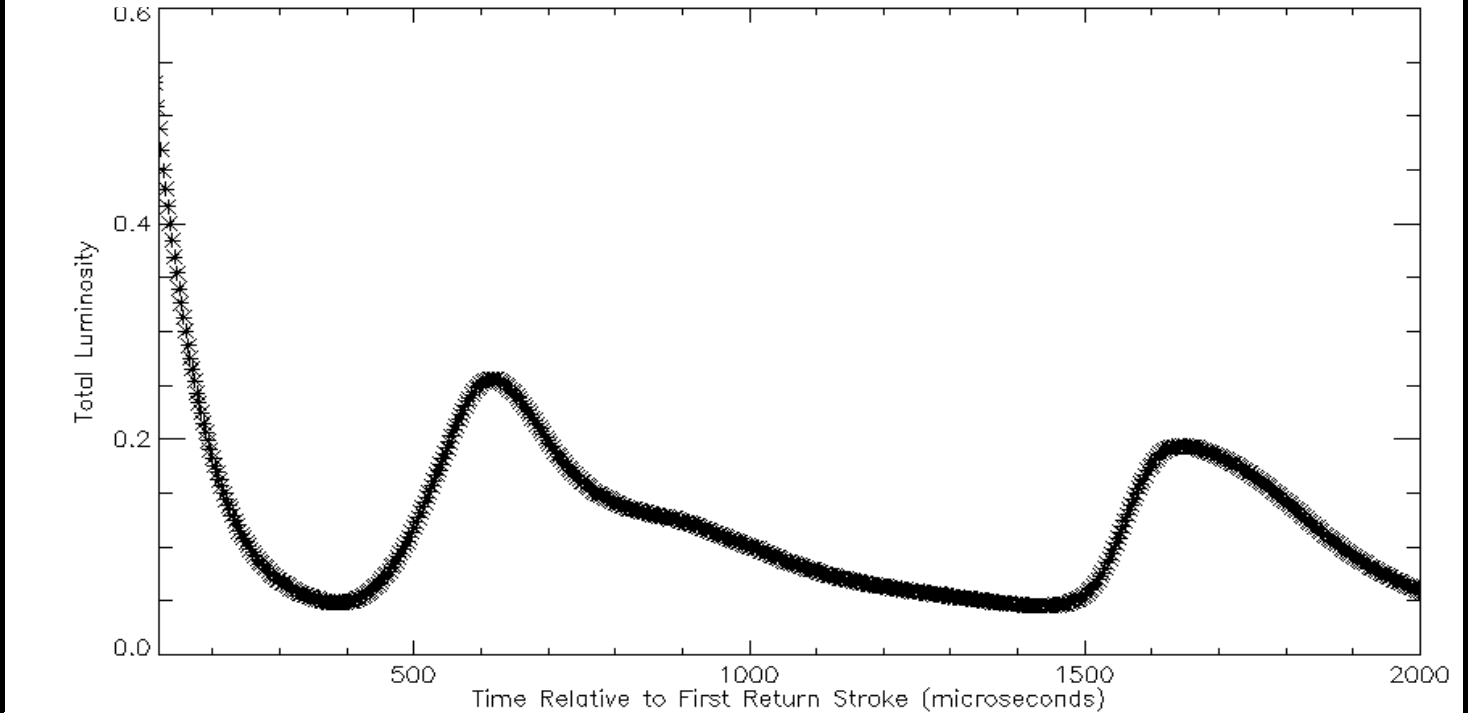

July 31,2010 Stroke 2
July 31,2010 Stroke 4
July 31,2010 Stroke 5
July 31,2010 Stroke 6
July 31,2010 Stroke 11
July 31,2010 Stroke 12
July 31,2010 Stroke 14
July 31,2010 Stroke 16
Current (A)
Luminosity (arb units)
0
1x10^4
2x10^4
3x10^4
0.00 0.05 0.10 0.15 0.20 0.25 0.30

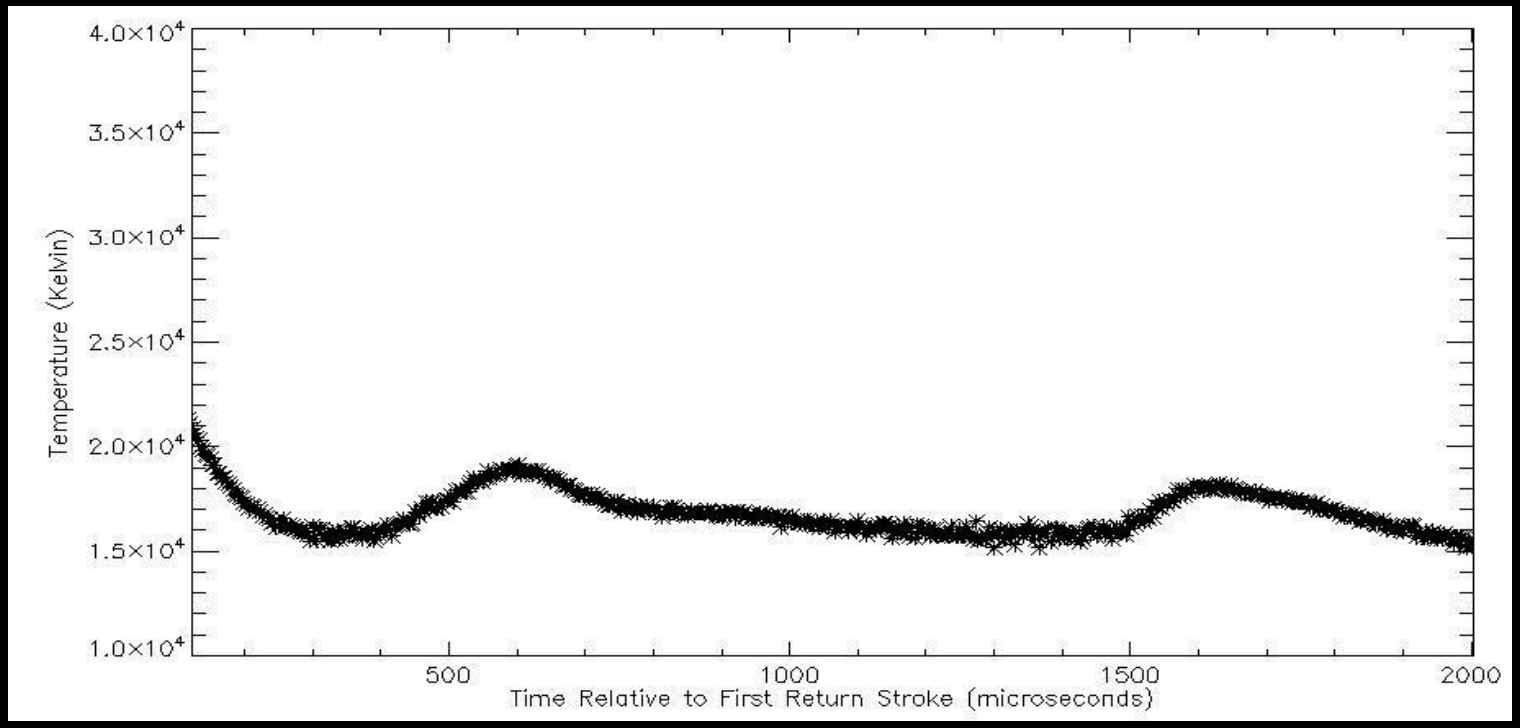

July 31,2010 Stroke 2
July 31,2010 Stroke 4
July 31,2010 Stroke 5
July 31,2010 Stroke 6
July 31,2010 Stroke 11
July 31,2010 Stroke 12
July 31,2010 Stroke 14
July 31,2010 Stroke 16
Current (A)
Temperature (K)
0
5.0×10³
1.0×10⁴
1.5×10⁴
2.0×10⁴
1×10⁴
2×10⁴
3×10⁴
4×10⁴

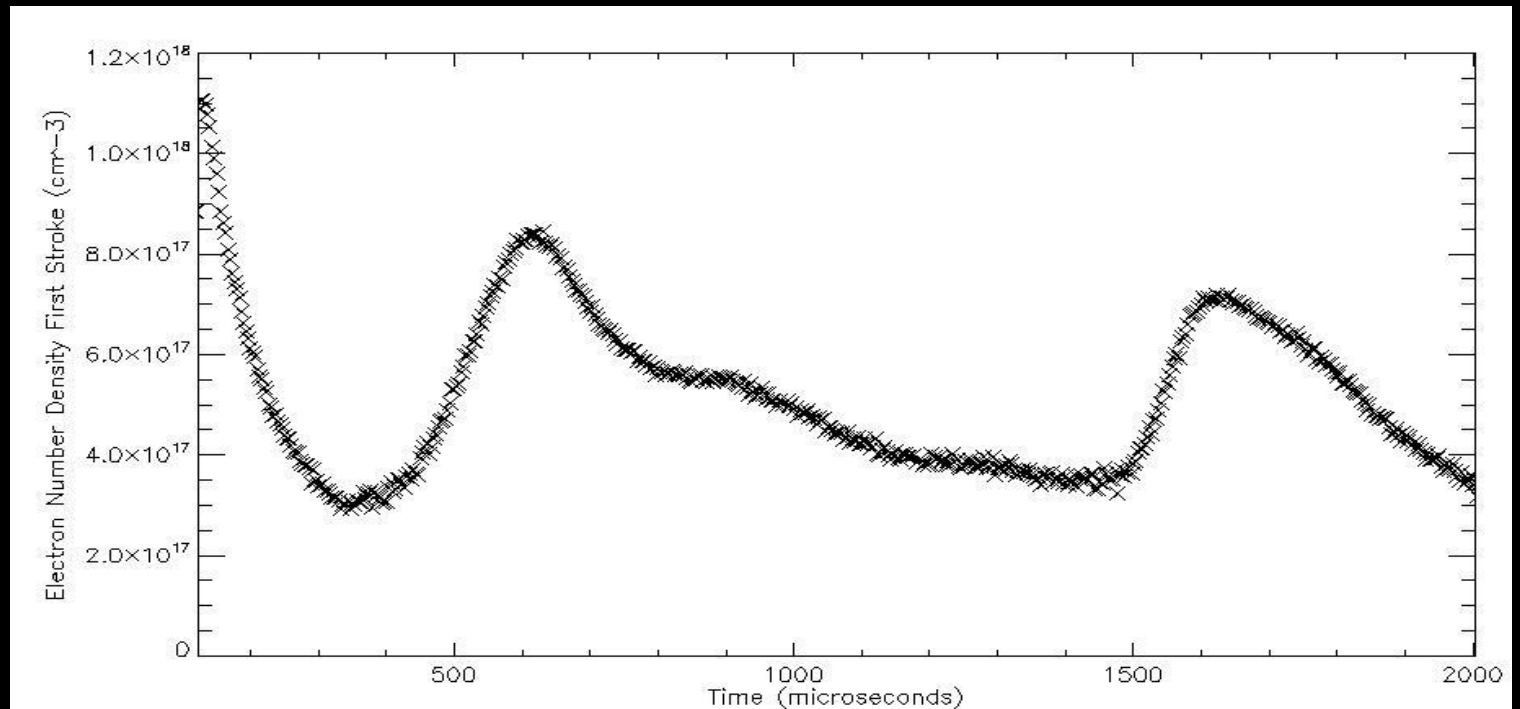

July 31,2010 Stroke 2
July 31,2010 Stroke 4
July 31,2010 Stroke 5
July 31,2010 Stroke 6
July 31,2010 Stroke 11
July 31,2010 Stroke 12
July 31,2010 Stroke 14
July 31,2010 Stroke 16
Current (A)
Number Density (10^18 cm^-3)
0
5.0×10^3
1.0×10^4
1.5×10^4
2.0×10^4
0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0


July 31,2010 Stroke 2
July 31,2010 Stroke 4
July 31,2010 Stroke 5
July 31,2010 Stroke 6
July 31,2010 Stroke 11
July 31,2010 Stroke 12
July 31,2010 Stroke 14
July 31,2010 Stroke 16
Current (A)
Luminosity 7774 (arb units)
0
1x10^4
2x10^4
3x10^4
0.0
0.2
0.4
0.6
0.8
1.0


Current (Amps)
6000
5000
4000
3000
2000
1000
0
500
1000
1500
2000


Total Luminosity
0.6
0.4
0.2
0.0
500
1000
1500
2000
Time Relative to First Return Stroke (microseconds)


4.0×10^4
3.5×10^4
3.0×10^4
2.5×10^4
2.0×10^4
1.5×10^4
1.0×10^4
Temperature (Kelvin)
500
1000
1500
2000
Time Relative to First Return Stroke (microseconds)

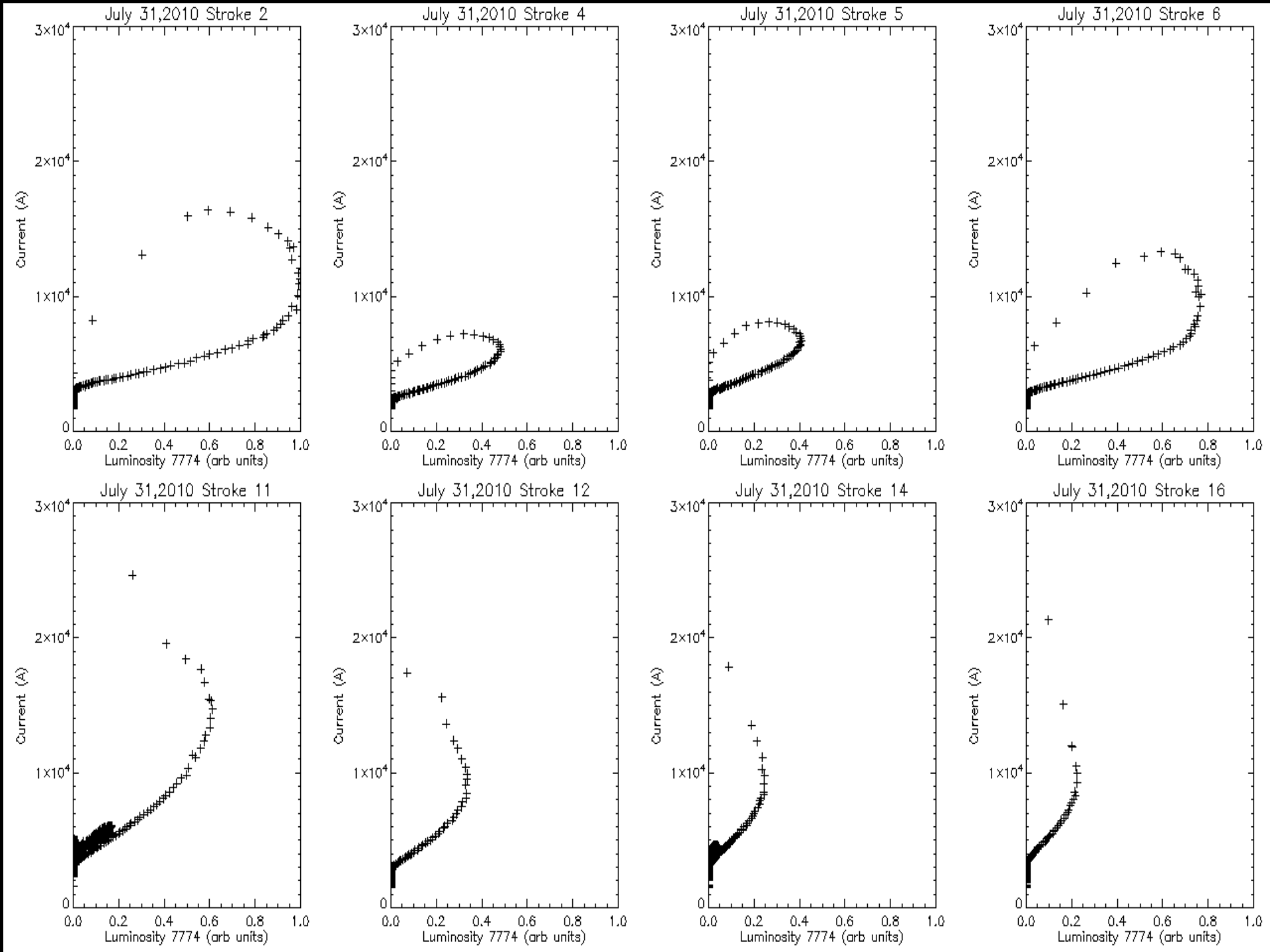

1.2×10^18
1.0×10^18
8.0×10^17
6.0×10^17
4.0×10^17
2.0×10^17
0
Electron Number Density First Stroke (cm^-3)
500
1000
1500
2000
Time (microseconds)

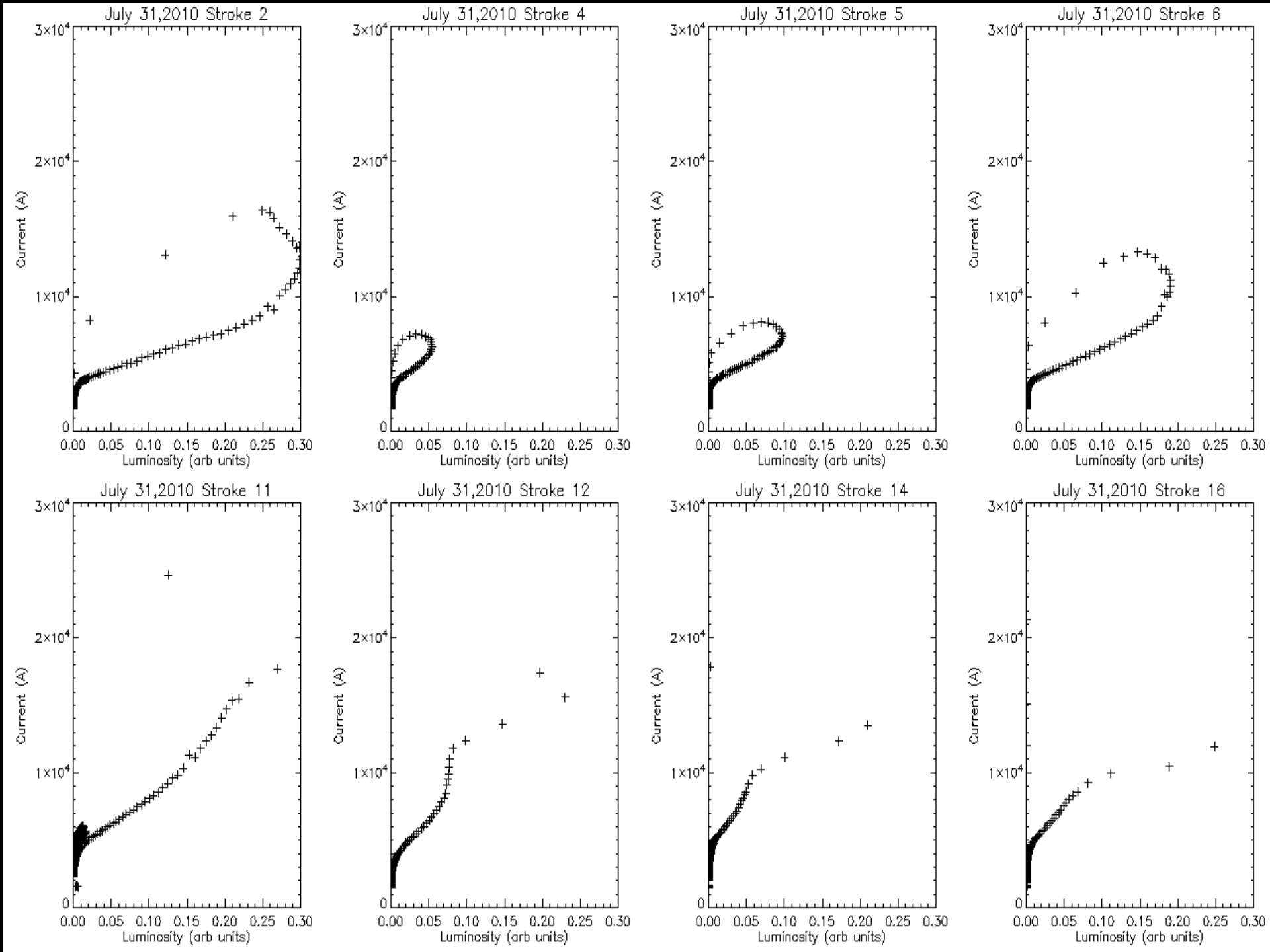
Future Studies

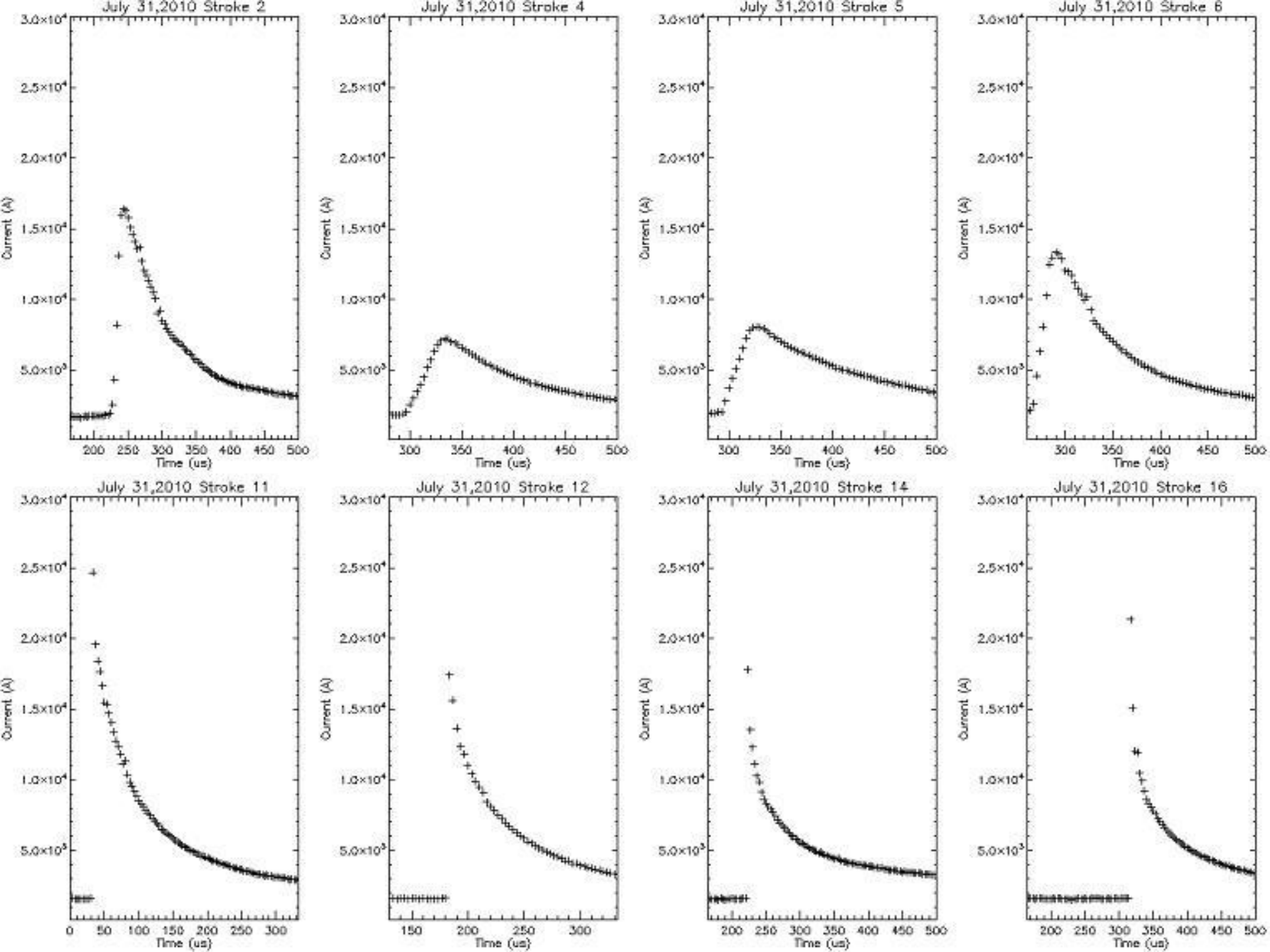
- More triggered lightning analysis
- Natural CG spectra
- IC Spectra
- Relationships of Physical Parameters
- Plasma Dynamics of the Channel
  - Conductivity
  - Ionization

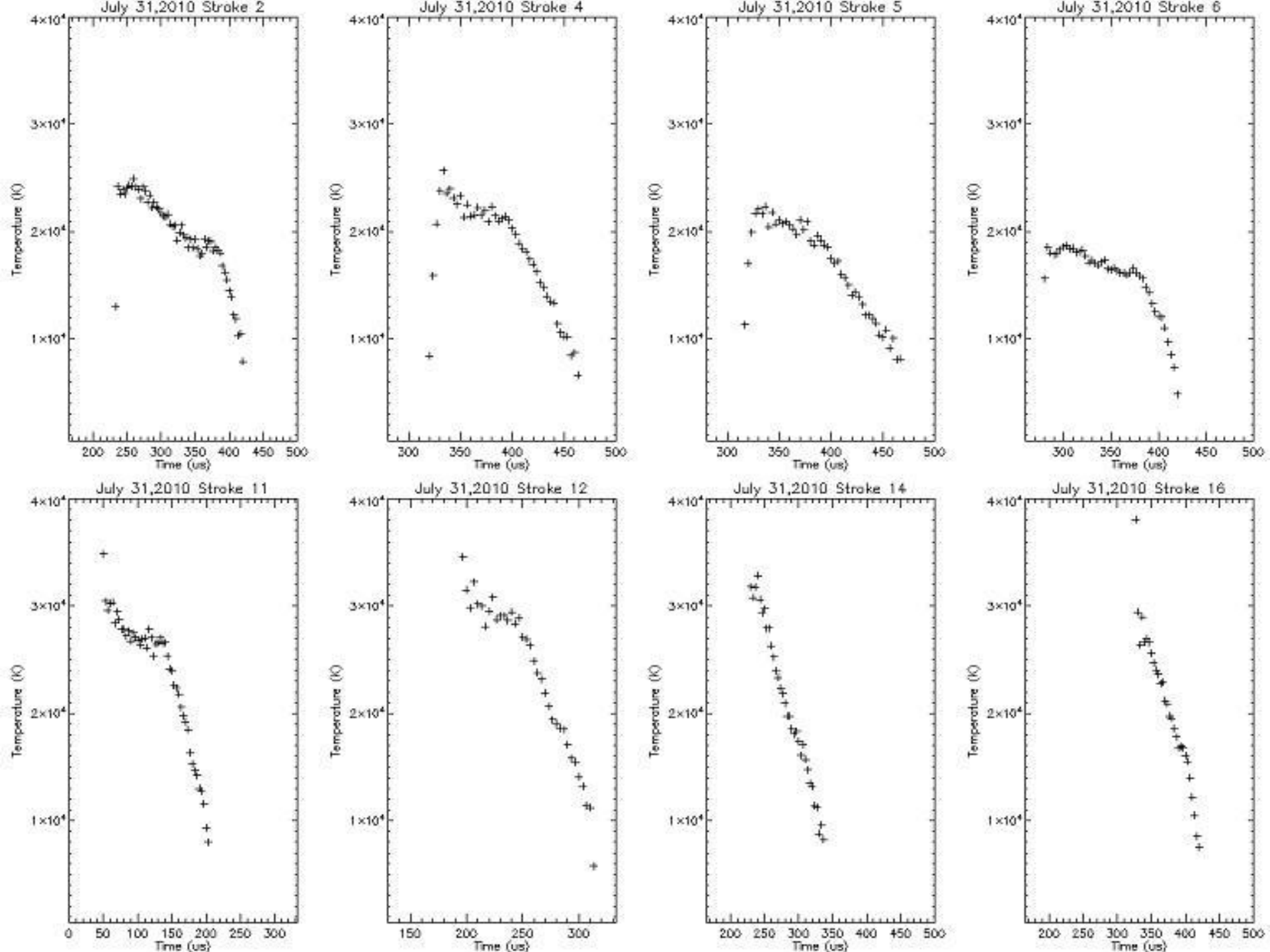
Summary

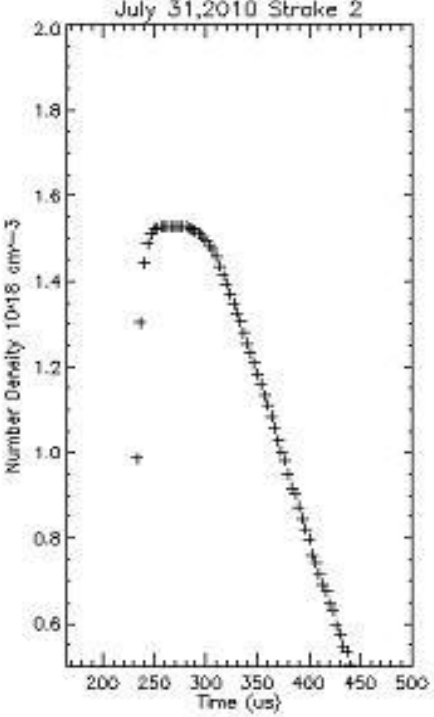
- Definite Relationship between the physical parameters of the lightning channel and current
- Physical parameters in line with previous studies
- With new technology closer look at the heating and cooling period
- Which will give us a better understanding of the physics within the channel

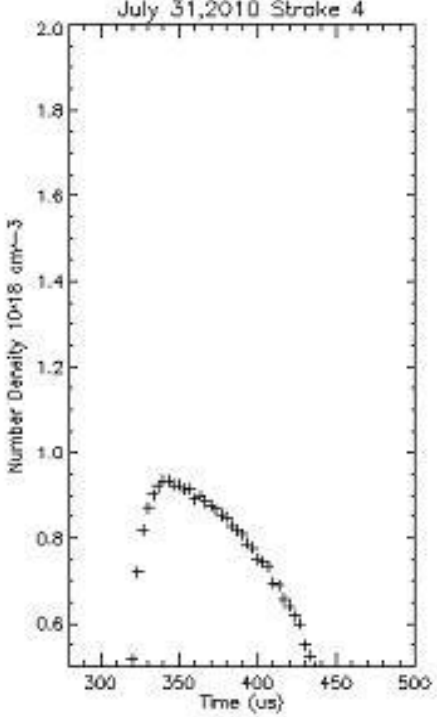

July 31,2010 Stroke 2
July 31,2010 Stroke 4
July 31,2010 Stroke 5
July 31,2010 Stroke 6
July 31,2010 Stroke 11
July 31,2010 Stroke 12
July 31,2010 Stroke 14
July 31,2010 Stroke 16
Current (A)
Luminosity 7774 (arb units)
0
1x10^4
2x10^4
3x10^4
0.0
0.2
0.4
0.6
0.8
1.0

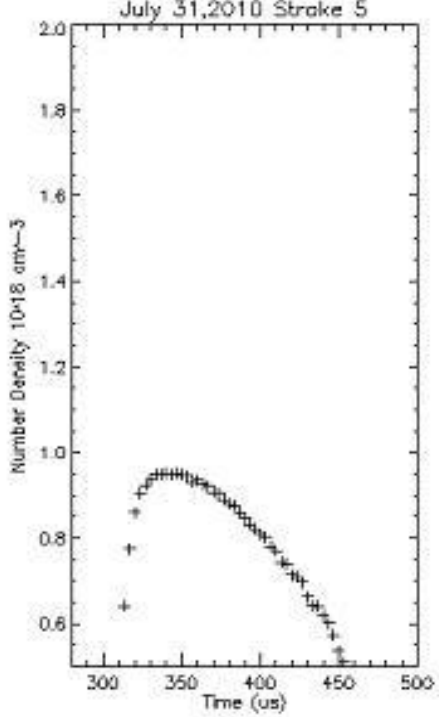

July 31,2010 Stroke 2
July 31,2010 Stroke 4
July 31,2010 Stroke 5
July 31,2010 Stroke 6
July 31,2010 Stroke 11
July 31,2010 Stroke 12
July 31,2010 Stroke 14
July 31,2010 Stroke 16
Current (A)
Luminosity (arb units)
0
1x10^4
2x10^4
3x10^4
0.00 0.05 0.10 0.15 0.20 0.25 0.30

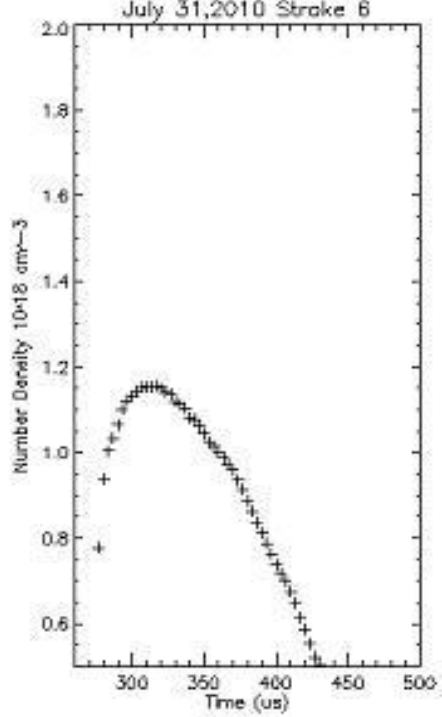

July 31,2010 Stroke 2
July 31,2010 Stroke 4
July 31,2010 Stroke 5
July 31,2010 Stroke 6
July 31,2010 Stroke 11
July 31,2010 Stroke 12
July 31,2010 Stroke 14
July 31,2010 Stroke 16
Current (A)
Time (us)

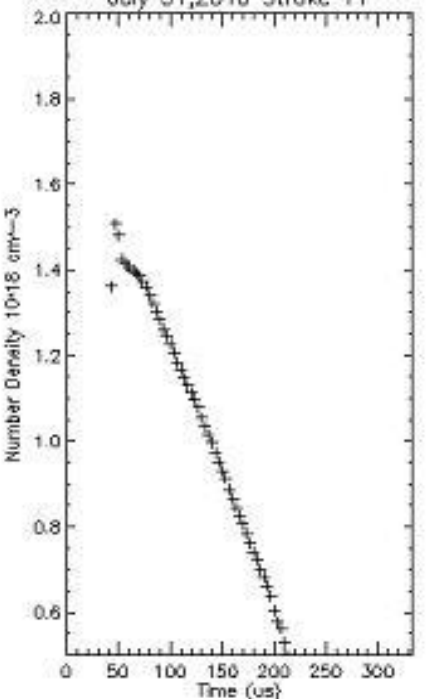

July 31,2010 Stroke 2
July 31,2010 Stroke 4
July 31,2010 Stroke 5
July 31,2010 Stroke 6
July 31,2010 Stroke 11
July 31,2010 Stroke 12
July 31,2010 Stroke 14
July 31,2010 Stroke 16
Temperature (K)
Time (us)

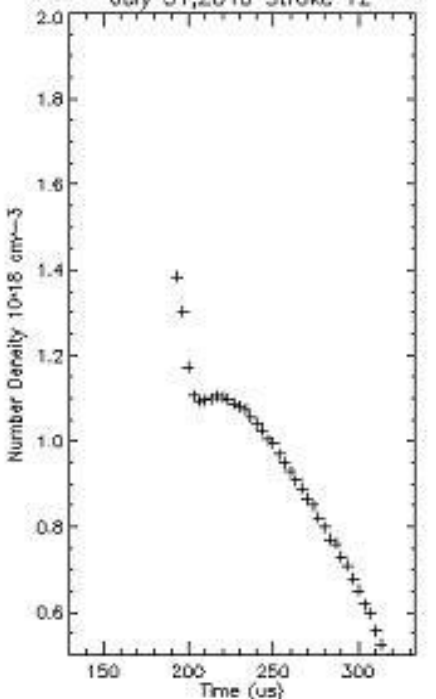

July 31,2010 Stroke 2
Number Density 10^18 cm^-3
Time (us)

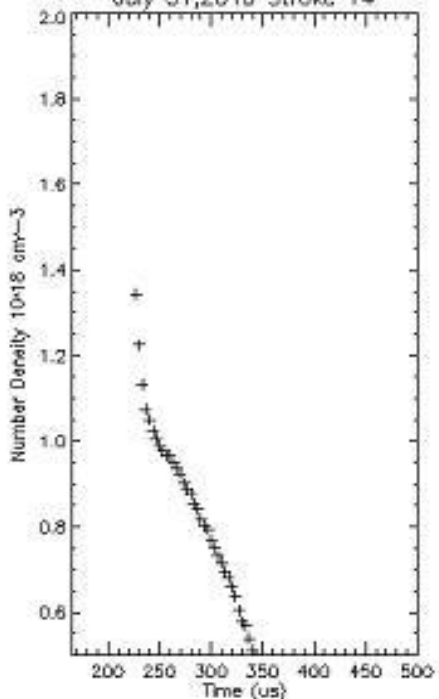

July 31,2010 Stroke 4
Number Density 10^18 cm^-3
Time (us)

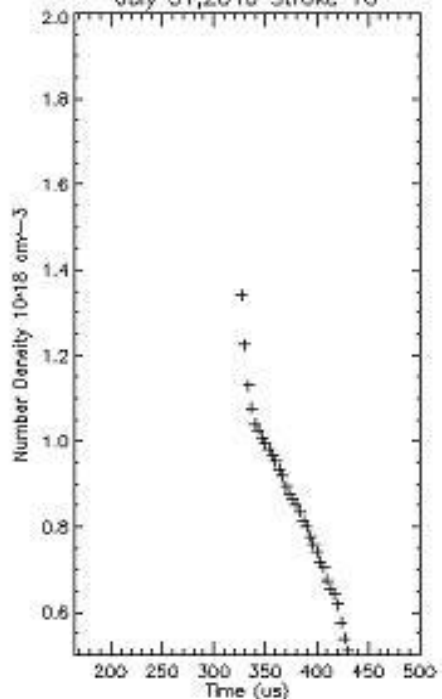

July 31,2010 Stroke 5
Number Density 10^18 cm^-3
Time (us)

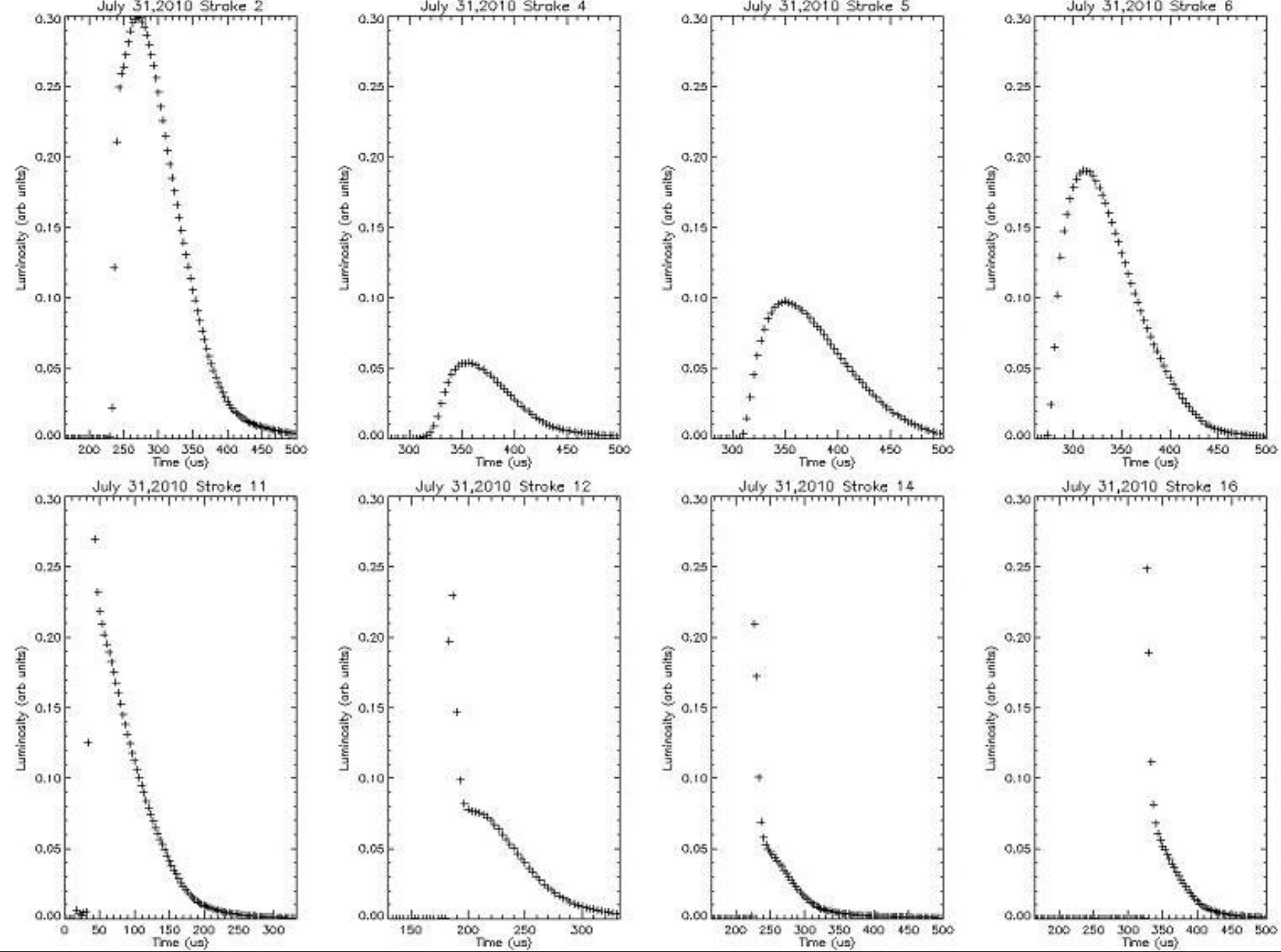

July 31,2010 Stroke 6
Number Density 10^18 cm^-3
Time (us)


July 31,2010 Stroke 11
Number Density 10^18 cm^-3
Time (us)


July 31,2010 Stroke 12
Number Density 10^18 cm^-3
Time (us)


July 31,2010 Stroke 14
Number Density 10^18 cm^-3
Time (us)


July 31,2010 Stroke 16
Number Density 10^18 cm^-3
Time (us)


July 31,2010 Stroke 2
July 31,2010 Stroke 4
July 31,2010 Stroke 5
July 31,2010 Stroke 6
July 31,2010 Stroke 11
July 31,2010 Stroke 12
July 31,2010 Stroke 14
July 31,2010 Stroke 16
Luminosity (arb units)
Time (us)