Auroral Energy and Energy Flux Derivation using Simultaneous Multispectral Imaging

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Background

- Auroral electrons that precipitate into the atmosphere are stopped at different altitudes based on their energy [1]: simultaneous multi-spectral emission measurements have been used to derive energy and energy flux

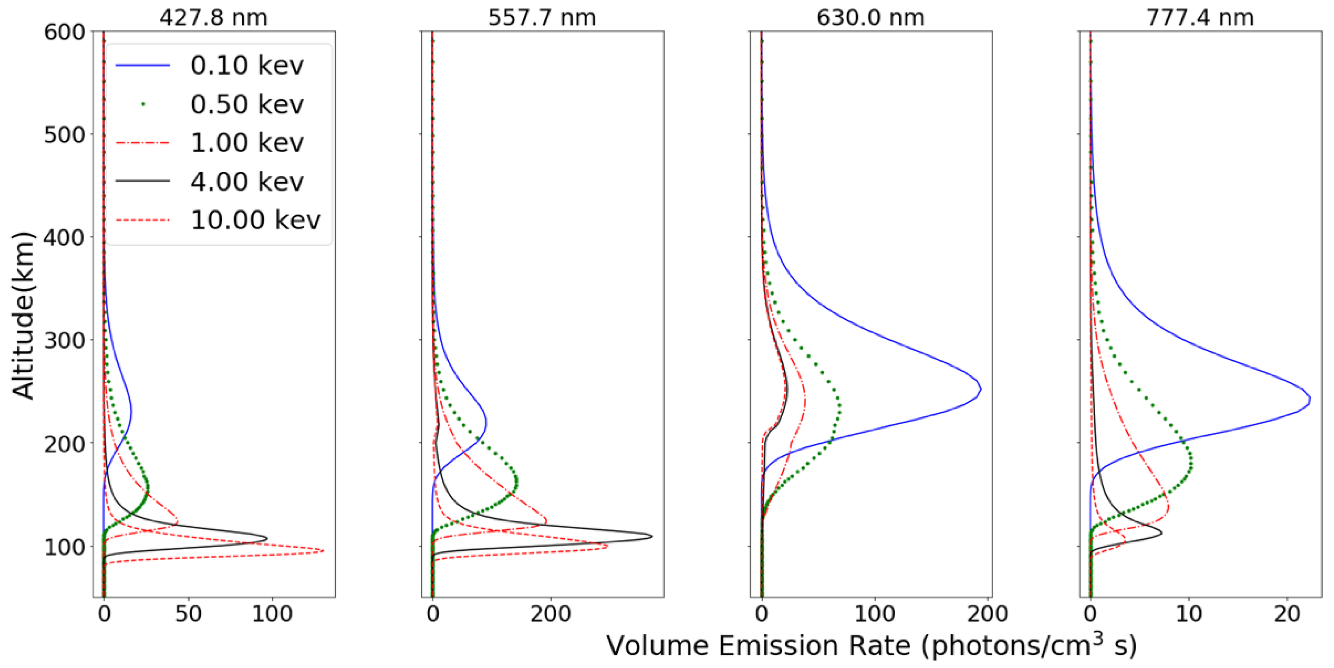


Fig I: Volume emission rates of various upper atmospheric emission features as a function of primary electron energy using GLobal airglOW (GLOW) model [2]. Note the peak height of emission shifts with energy.

Instrument and Data

- High Throughput and Multislit Imaging Spectrometer (HiT&MIS): ~ 0.01 nm resolution (at 630 nm) and FOV of 0.1 X 50° [3]
- We present June 22, 2015 G4 storm observed at Lowell, MA (42.6° N, 71.3° W) ~ 45° from zenith due northeast
- Simultaneous measurements OI: 630.0 nm, OI: 557.7 nm, OI: 777.4 nm and N_2^+: 427.8 nm and Ne I 630.5 nm (for cloud activity)

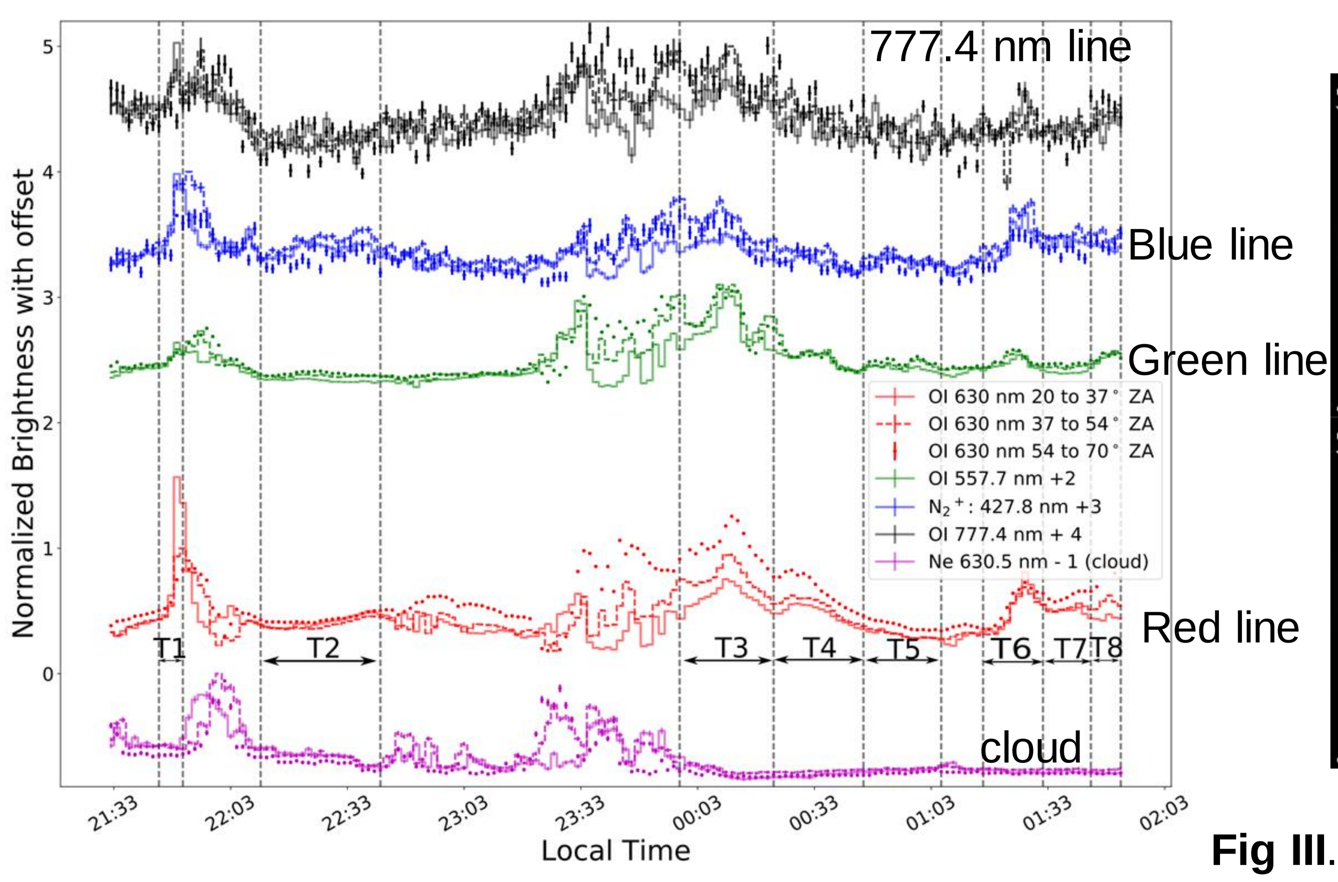


Fig II. Normalized average brightnesses as a function of local time (LT) for the four observed features at different Zenith Angle (ZA) bins. The Ne I: 630.5 nm feature (also present in HiT&MIS) is used as a tracer for cloud activity. The time periods T1 through T8 are picked for analysis based on the cloud activity.

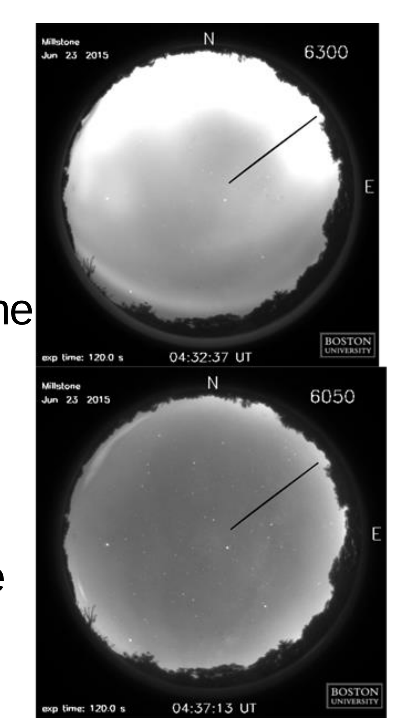


Fig III. Boston University all sky images around the time period T4 in 630.0 nm (top) and 605.0 nm (for cloud) taken at Millstone Hill observatory in Westford, MA (~10 miles southeast of Lowell, MA). Approximate slit position of HiT&MIS is shown as a solid black line

Model

- GLOW model [2]: Electron transport and chemical reaction model applied to the IRI-90 ionosphere [4] and MSIS-2K neutral atmosphere [5]
- Brightness values are modeled assuming Maxwellian energy distribution of electrons for different characteristic energies and characteristic energy fluxes .

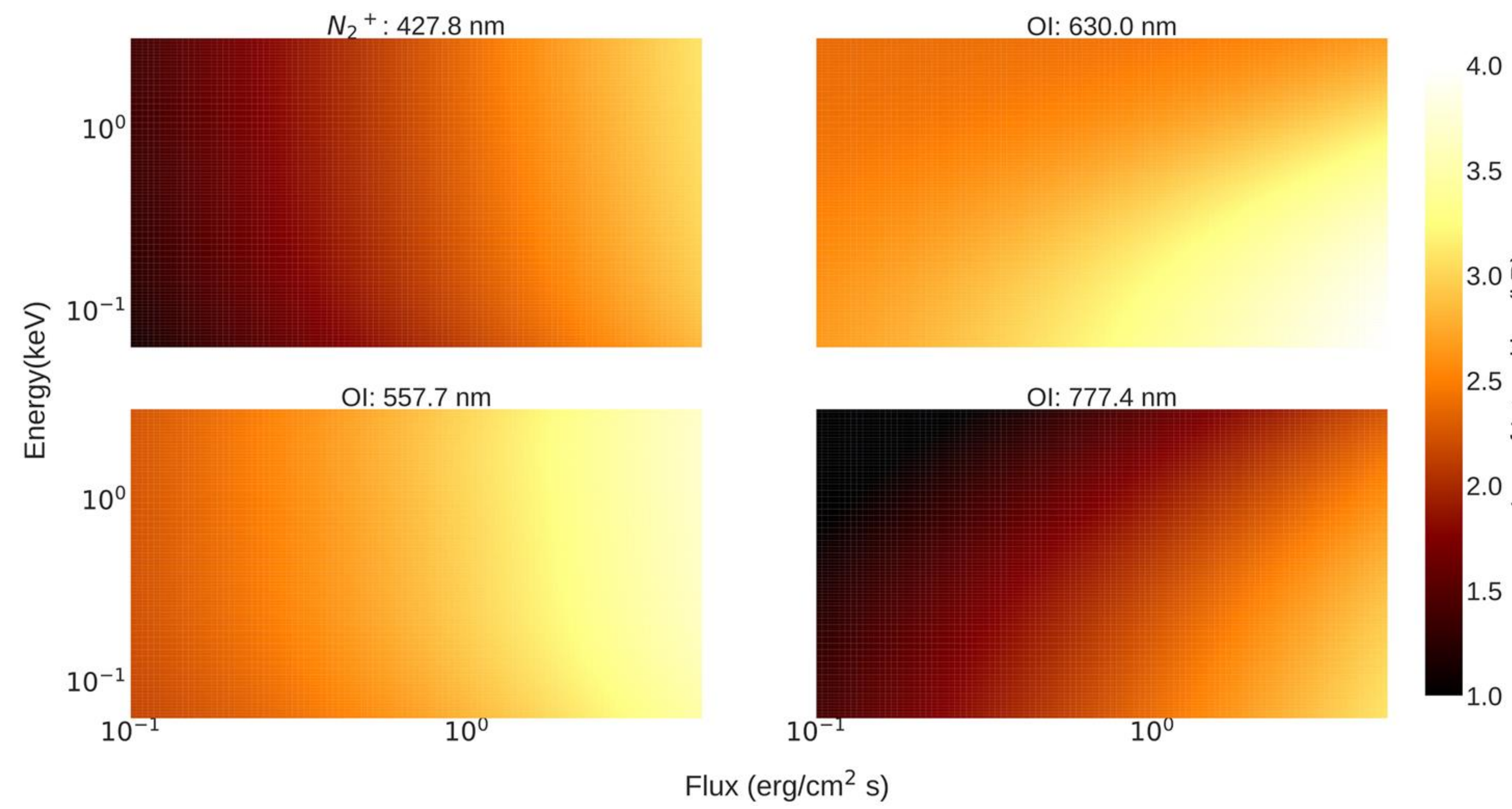
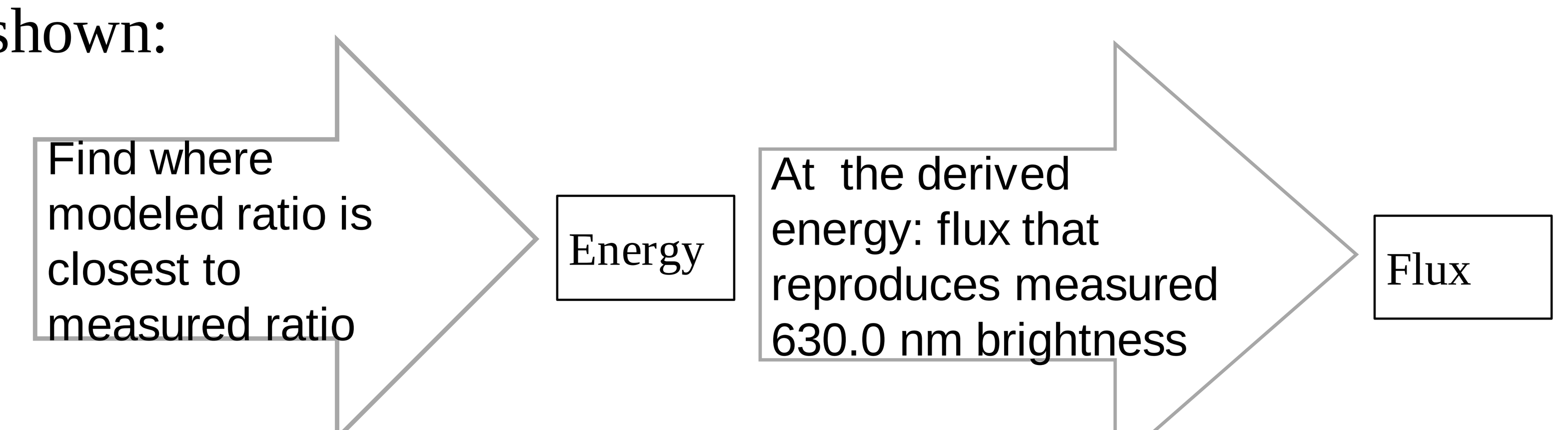


Fig IV. Modeled brightness in the four spectral features as a function of energy and energy flux using the GLOW model for the input geophysical parameters (e.g. F10.7 solar flux) at 1:50 AM June 23 LT . These parameters are assumed to be constant during our observation period.

Derivation of Energy and Flux

- Energies and fluxes for the time periods chosen (T1 through T8) in Fig. II are then derived using two methods
- Method I: Compare modeled and measured ratios to derive the energy and energy flux, only 630.0 nm/ 427.8 nm (red/blue) shown:



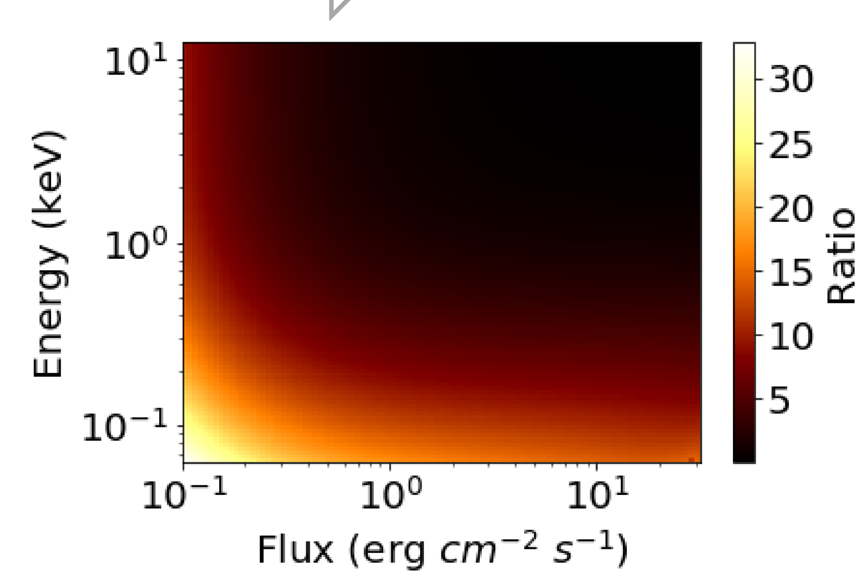


Fig V. The OI:630.0 nm/ N_2^+: 427.8 nm (red to blue) ratio as a function of characteristic energy (E_0) and flux (Q_0)

- Method II: Minimize the χ^2 value defined as:

$$\chi^2 = \sum_{\text{All measurements}} \frac{(Measured - Modeled)^2}{\sigma^2_{measured}}$$

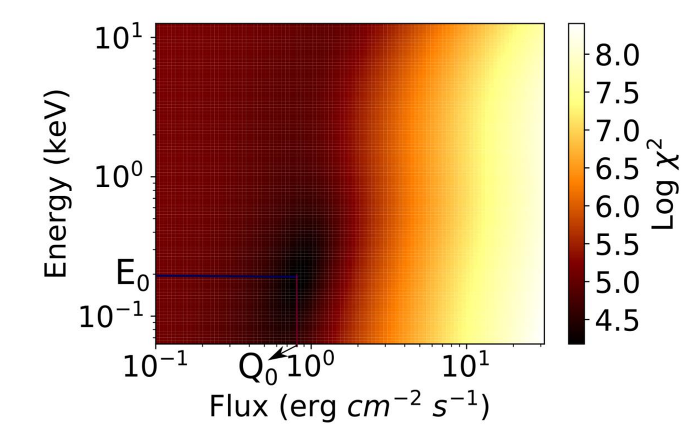


Fig VI. The location of the minimum χ^2 gives the location of the characteristic energy (E_0) and the characteristic (Q_0) simultaneously

Results

	Energy (eV)						Flux (ergs cm^{-2}s^{-1})					
	20-37 ZA		37-54 ZA		54-70 ZA		20-37 ZA		37-54 ZA		54-70 ZA	
Time	red/blue	χ^2	red/blue	χ^2	red/blue	χ^2	red/blue	χ^2	red/blue	χ^2	red/blue	χ^2
T1	70	120	600	170	200	150	1.45	1.45	1.90	1.29	1.63	1.22
T2	90	140	120	180	70	150	0.72	0.76	0.60	0.81	0.72	0.86
T3	90	260	70	250	100	160	1.10	1.72	0.48	2.05	2.18	2.2
T4	70	200	150	200	60	130	0.81	1.08	0.81	1.21	1.21	1.29
T5	430	290	800	330	170	250	1.40	0.85	3.30	0.96	0.91	1.02
T6	100	180	100	210	110	180	0.90	1.08	0.70	1.14	1.08	1.22
T7	100	140	110	170	60	130	0.97	0.96	0.81	1.08	1.08	1.15
T8	80	250	100	190	100	120	0.80	1.14	0.80	1.21	1.54	1.37

Table I: Table showing the derived energies and fluxes using the ratio method (only red/blue shown) and the χ^2 method for the time periods and look directions shown in Fig. I

Summary

- We derived energy and energy flux of an auroral event at mid-latitude during a G4 storm by (a) comparing measured brightness ratios to modeled ratios and (b) χ^2 minimization of multispectral emission brightnesses with modeled emission brightnesses
- The χ^2 minimization method derives energy and flux simultaneously unlike the ratio method
- The energy is derived to be ~ 100-300 eV and flux of ~ 1-3 ergs cm^{-2}s^{-1} and there are spatial and temporal variations.

References:

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