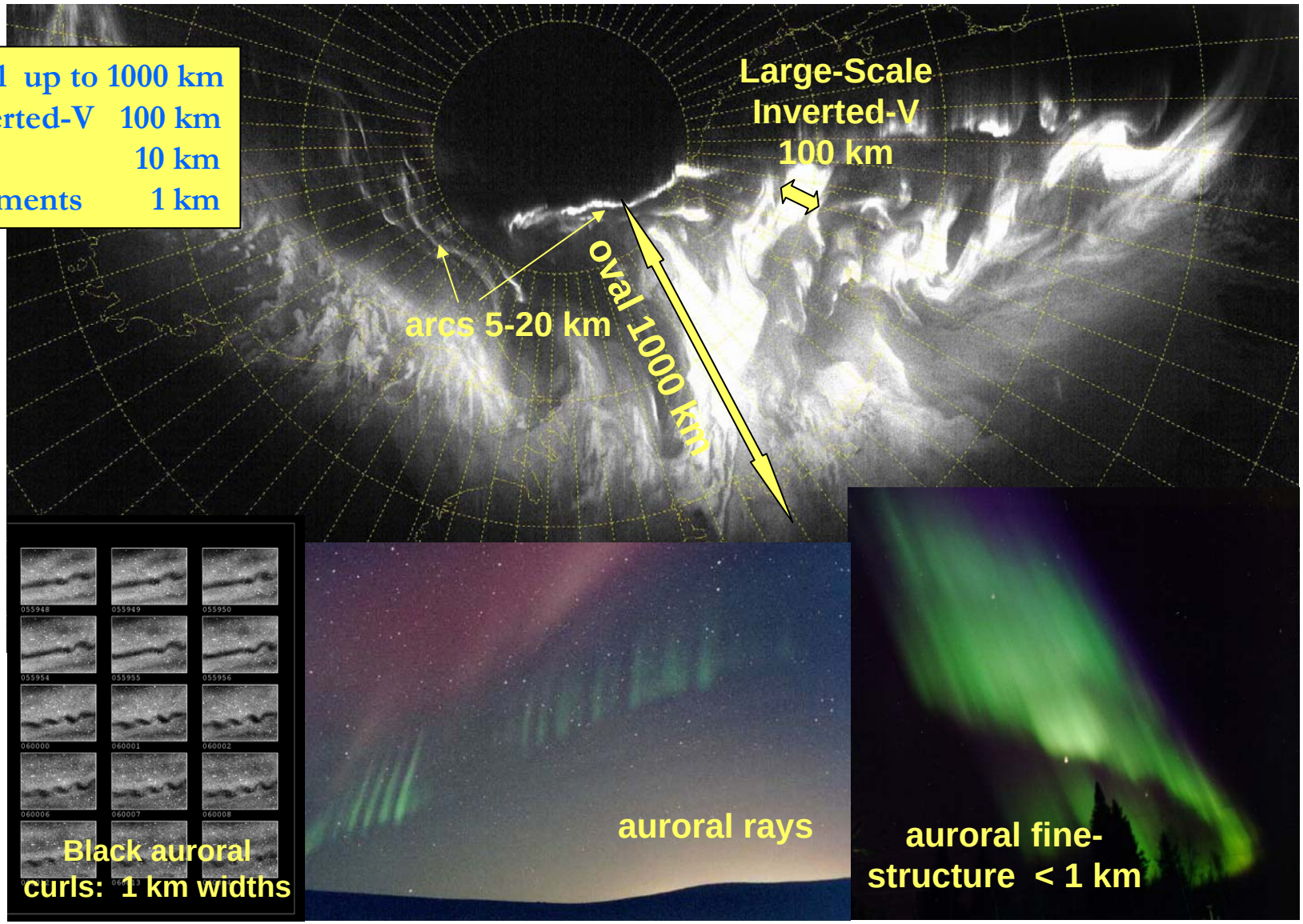
Motivating talk on exciting work with EISCAT:

Observing and analysing structures in active aurora with the ASK optical instrument and EISCAT radar.

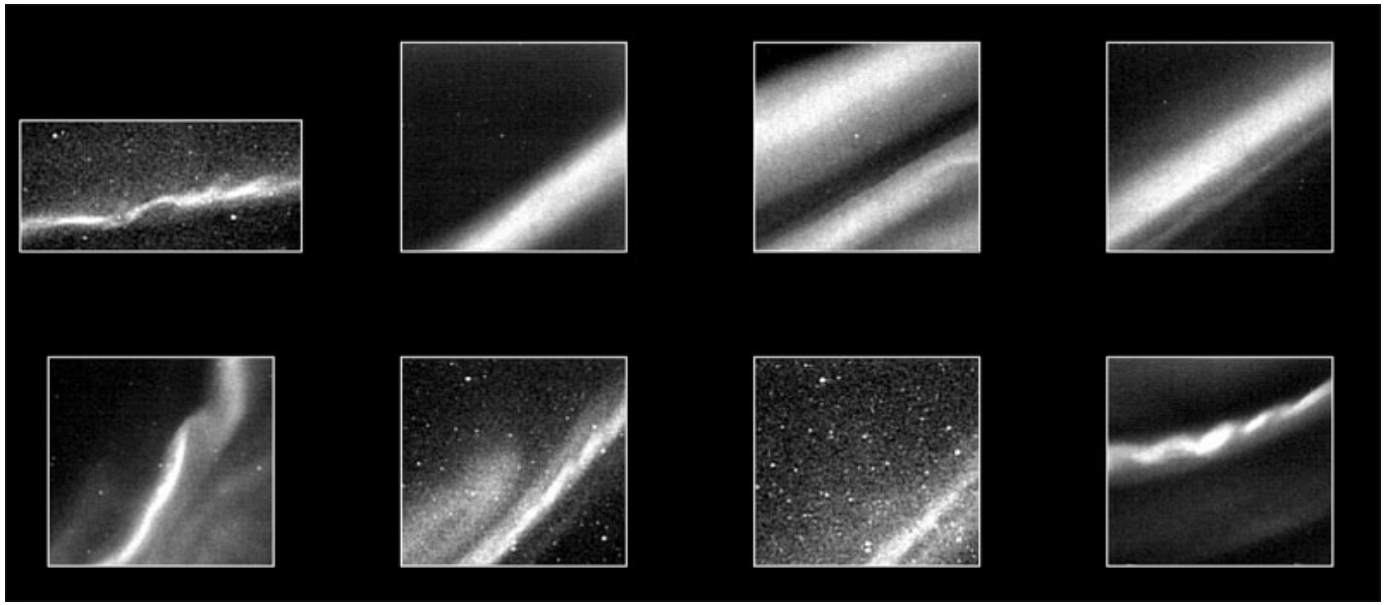
EISCAT Summer School part I - 31st July 2007
Hanna Dahlgren (KTH, Sweden) & Daniel Whiter (University of Southampton, UK)

Auroral Spatial Scales

Oval	up to 1000 km
Inverted-V	100 km
Arc	10 km
Filaments	1 km



Ground-based observations of the fine-scale aurora



Examples of discrete auroral structures 0.1 to 1 km wide
T.Trondsen (Univ of Calgary)

- Few instruments can measure it well
- Few theoretical models can account for it

Our Motivation

- Optical data provides information on morphology of the aurora.
- Simultaneous **radar measurements** give additional information on ionospheric properties.
- We focus on the smallest structures seen, by using high-resolution imagers, equipped with different filters to measure specific emissions.

  - The EISCAT radars give us information on the condition of the ionosphere at the time, electric fields and flows. This is used in our modelling of the ionosphere.

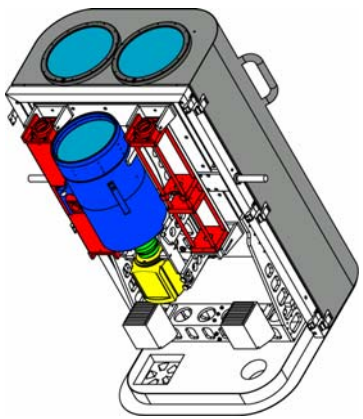
ASK Auroral Structure and Kinetics

Instrument to study small scale structure of the aurora, at high temporal and spatial resolution.

Three narrow FOV cameras for simultaneous imaging in three spectral bands:

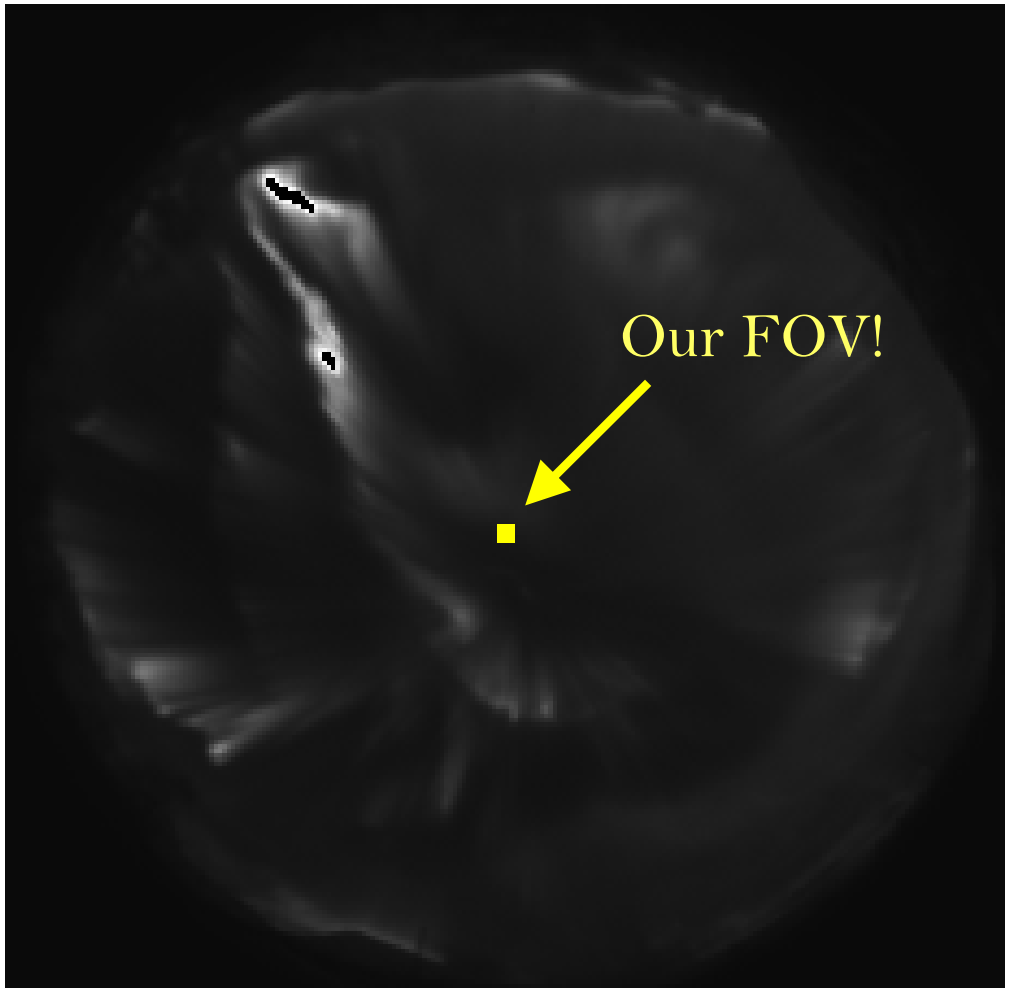
ASK1a: 5620 Å → O_2^+	**(E-region, high energy e^-)**
ASK1b: 6730 Å → N_2	**(E-region, high energy e^-)**
ASK2a: 7320 Å → O^+	**(F-region, low energy e^-)**
ASK2b: 4278 Å → N_2^+	**(E-region, high energy e^-)**
ASK3: 7774 Å → O	**(E- & F-region)**

Completed ASK instrument in Southampton workshop

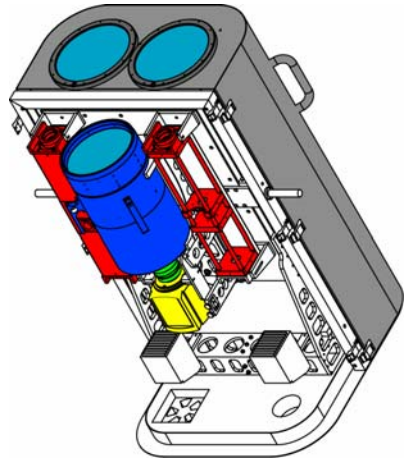


- FOV: 3° × 3° (5 × 5 km at 100 km)
- Frame rate: 10, 20 or 32 images/s
- Cameras equipped with telescopes

ASK Auroral Structure and Kinetics



180° (DASI2 All-Sky camera)



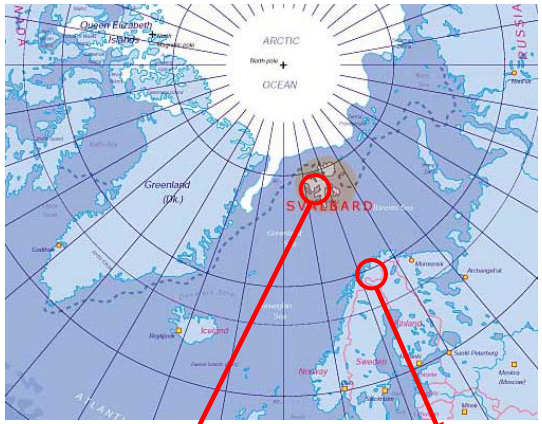
… and 2 photometers with 4 filters:

4709 – N_2^+

8446 – O

5620 – O_2^+

6300 – O

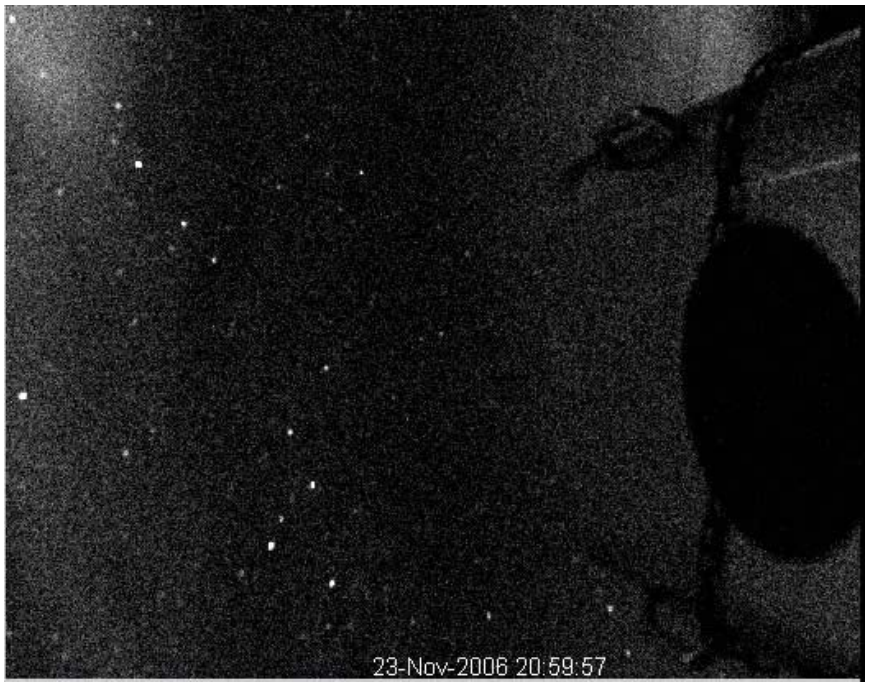


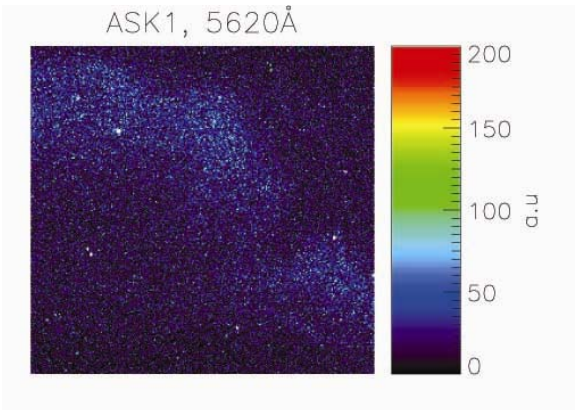
First campaign, on Svalbard 2005/2006

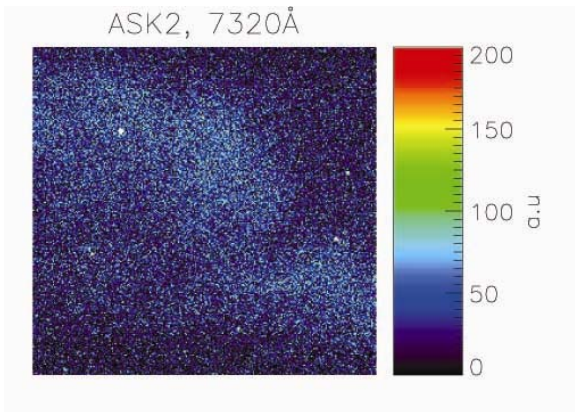
- Location: 78.15 N, 16.03 E
- Look direction: Magnetic zenith
- FOV: 6.1° × 6.1° (10 × 10 km at 100 km)
- Placed at EISCAT Svalbard Radar site

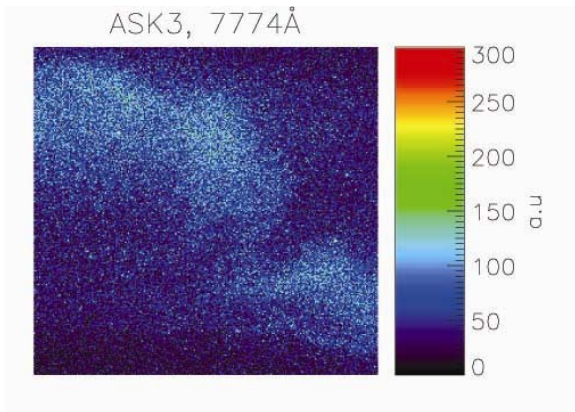
Second campaign, in Tromsø 2006/2007

- Location: 69.6 N, 19.2 E
- Look direction: Magnetic zenith
- Telescopes with 2 × angular magnification: FOV: 3° × 3° (5 × 5 km at 100 km)
- Placed at the EISCAT site in Ramfjordmoen









ASK1: 5620 Å → O_2^+
(E-region, high energy e^-)

ASK2: 7320 Å → O^+
(F-region, low energy e^-)

ASK3: 7774 Å → O
(E- & F-region)

Required radar characteristics

Optics: High spatial and temporal resolution.
→ We need a radar program with comparable temporal resolution.

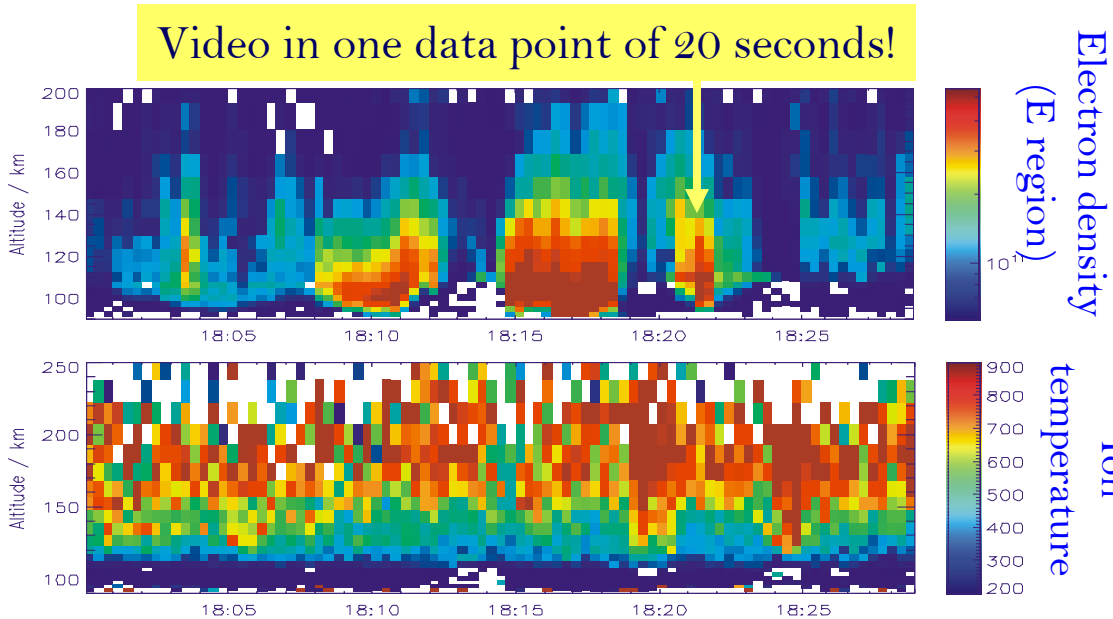
Other radar specifics: Range covered, and height resolution

Radar experiments used to support ASK

ESR:
Experiment: **steffe**: Multipurpose E- and F-layer experiment
Altitude range 105 – 216 km and 259 – 965 km.
Spatial resolution 1 km, time resolution 6.4 s

Mainland UHF:
Experiment: **arc1**:
Altitude range 96 – 402 km.
Spatial resolution 0.9 km, time resolution 0.44 s.

22 October 2006

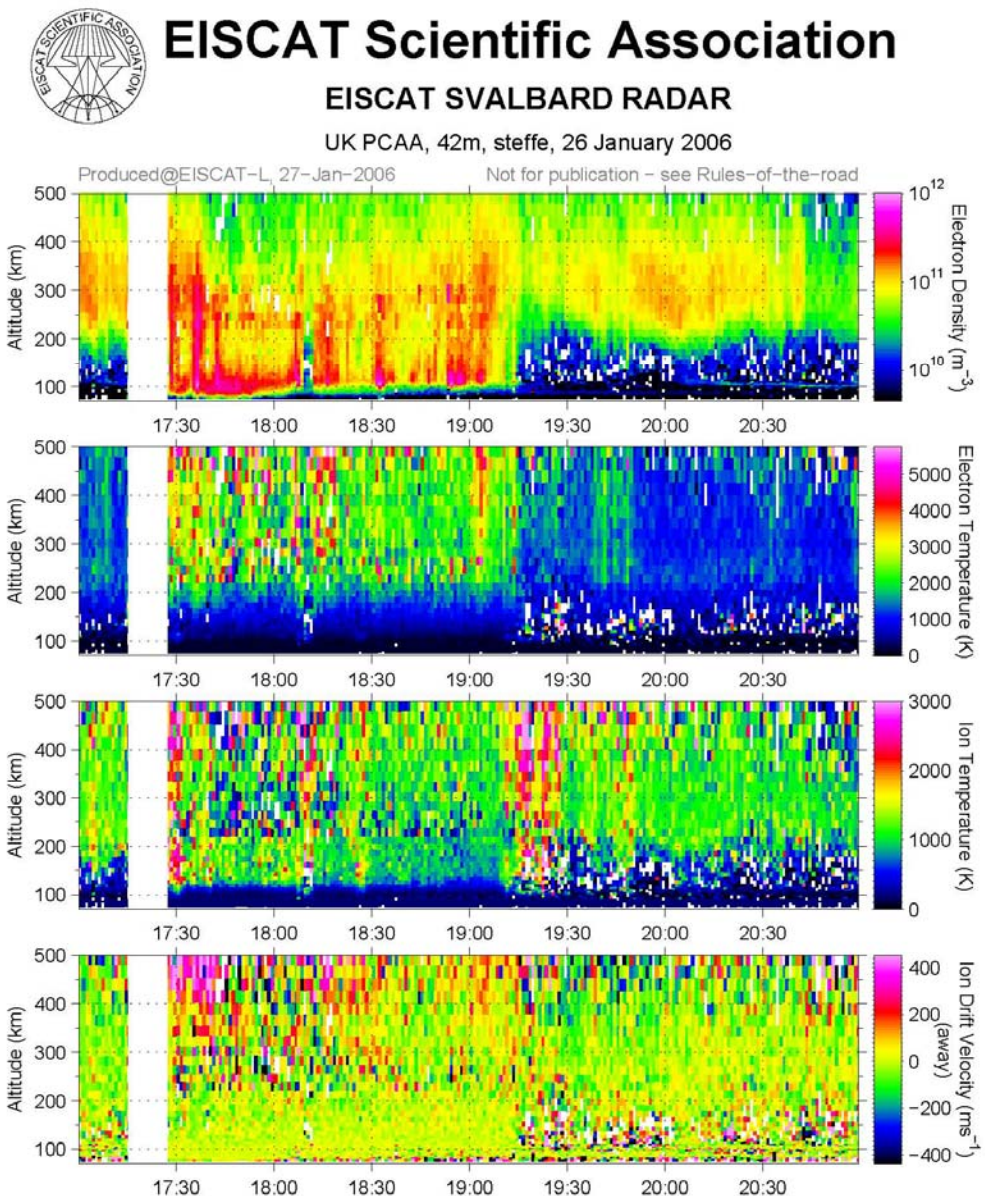


20 seconds of data at 32 fps

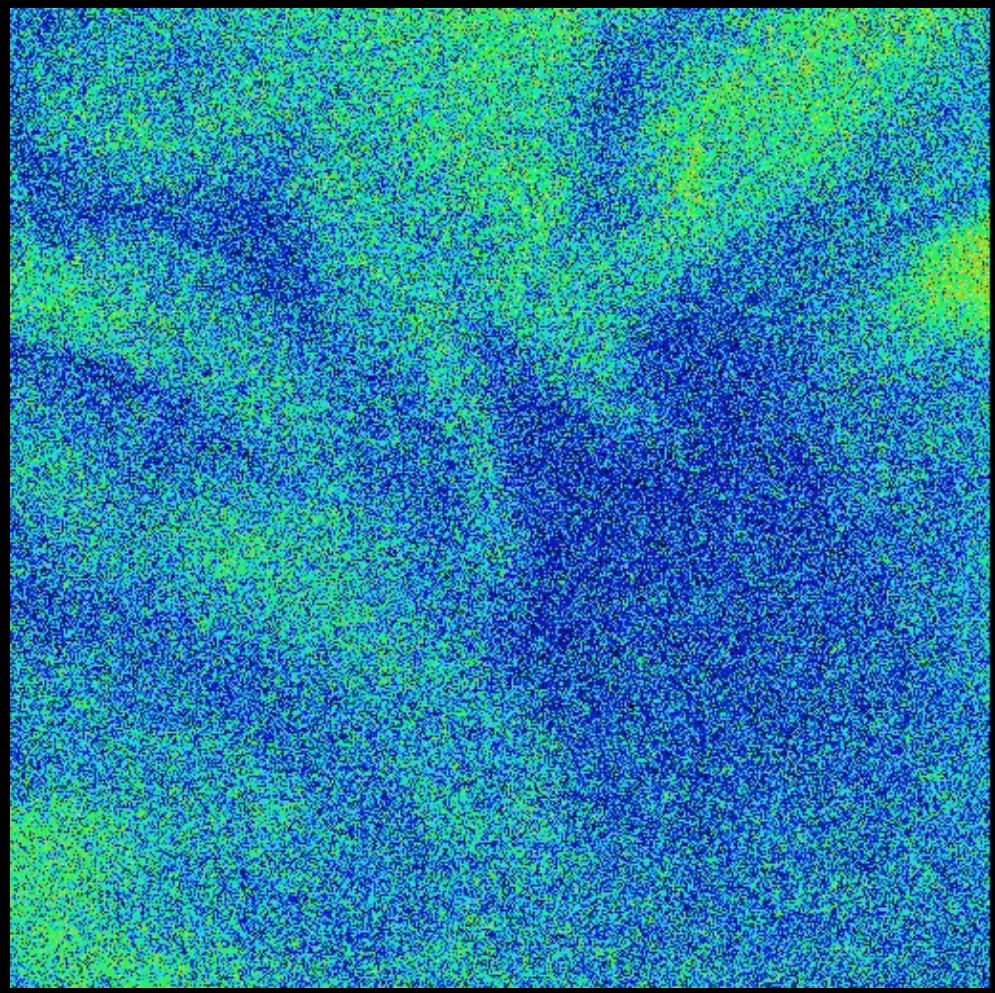
18:21:10 – 18:21:30 UT

Need as high temporal resolution as possible

Study of substorm on 26 January 2006, with ASK and ESR



Study of substorm on 26 January 2006, with ASK and ESR



14 s of data, from 17:36:18

Study of substorm on 26 January 2006, with ASK and ESR

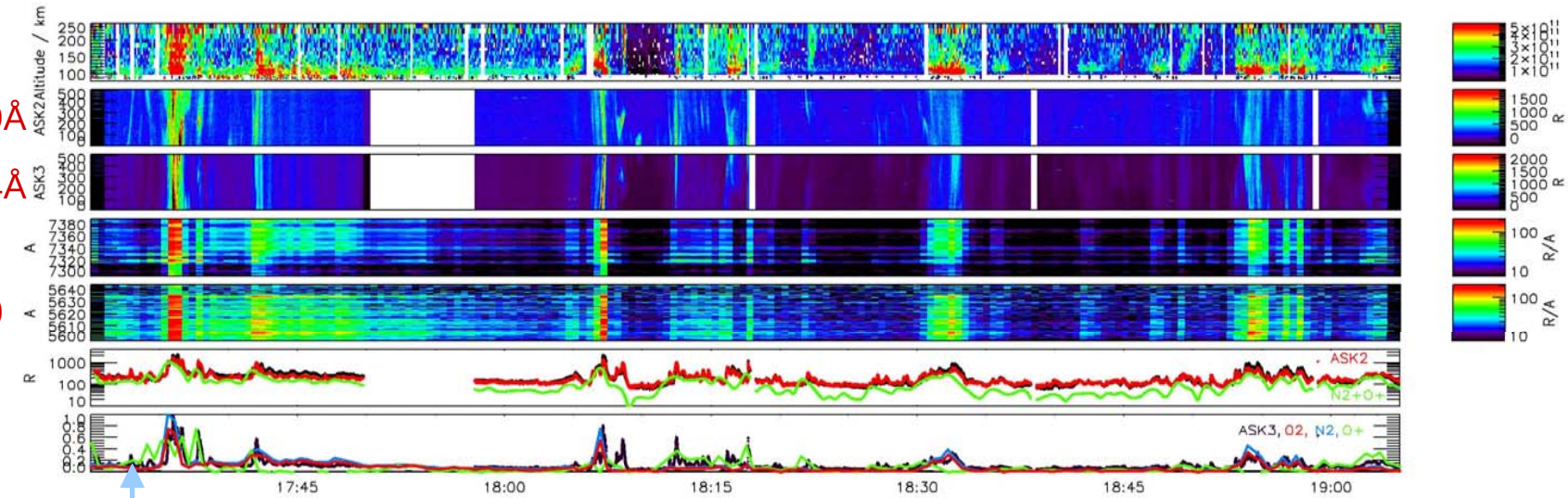
ESR n_e

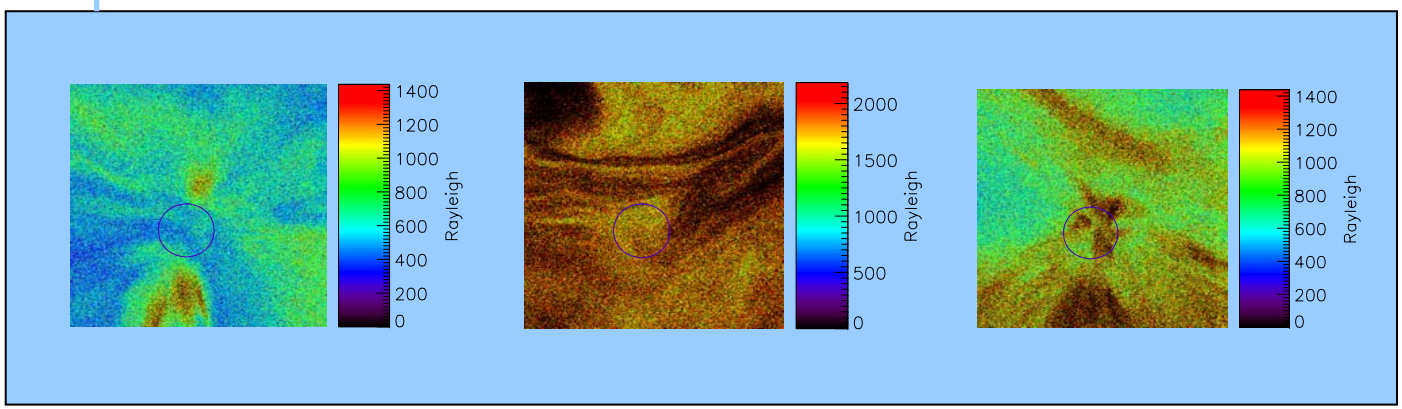
ASK2: 7319Å

ASK3: 7774Å

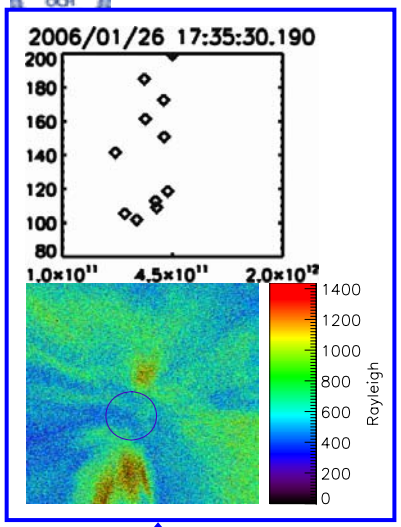
O^+(7319)

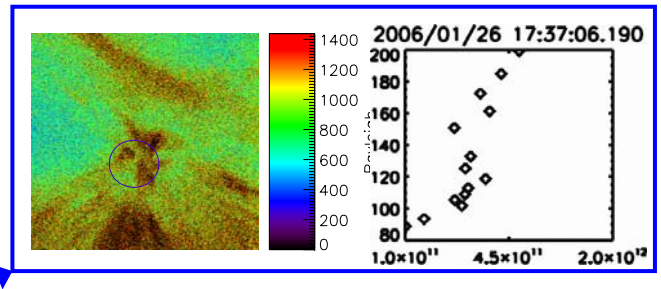
O_2^+(5620)

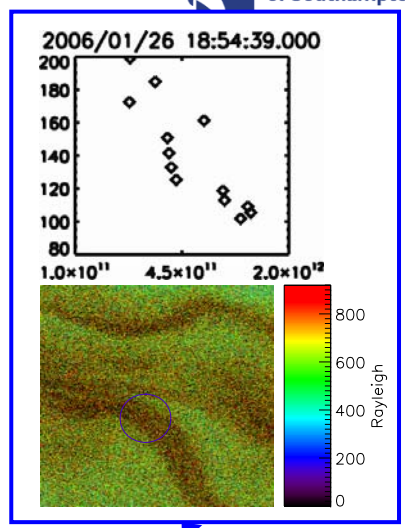


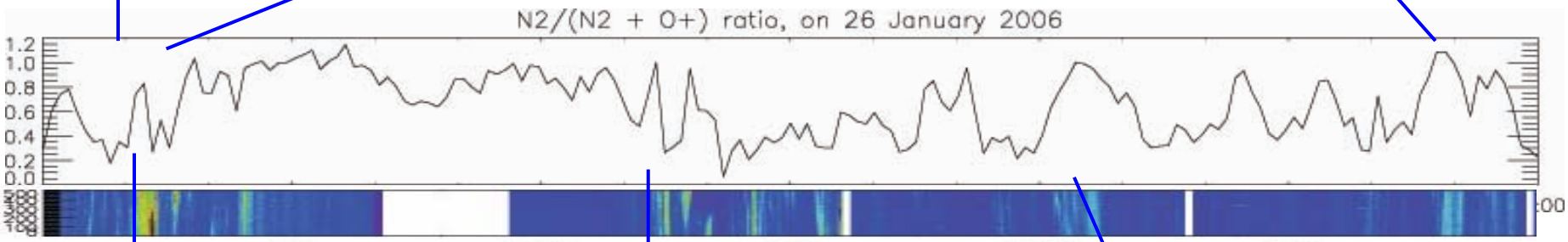


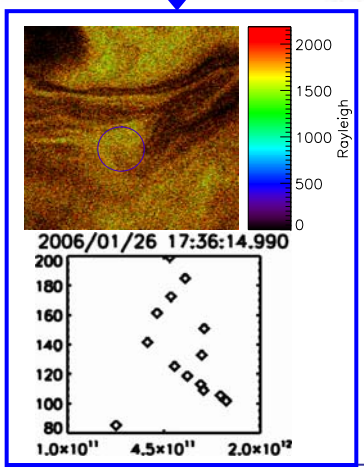
$N_2/(N_2 + O^+)$ ratio

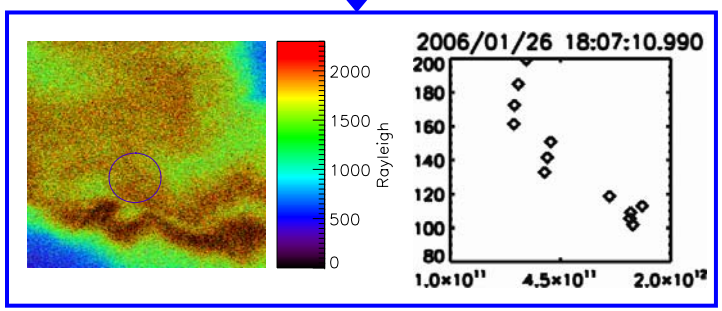

2006/01/26 17:35:30.190
Rayleigh


2006/01/26 17:37:06.190
Rayleigh


2006/01/26 18:54:39.000
Rayleigh


N2/(N2 + O+) ratio, on 26 January 2006
17:45
18:00
18:15
18:30
18:45


2006/01/26 17:36:14.990
Rayleigh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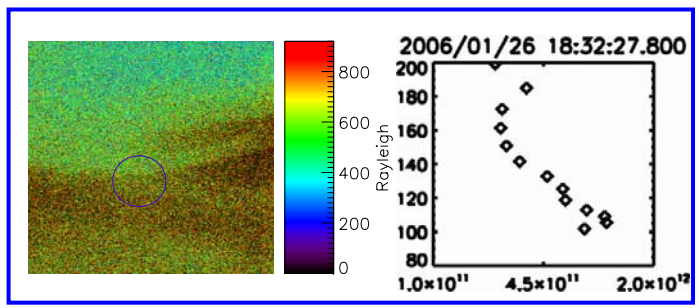
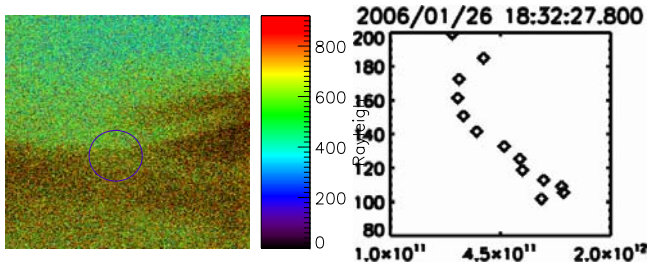
Rayleigh


2006/01/26 18:32:27.800
Rayleigh

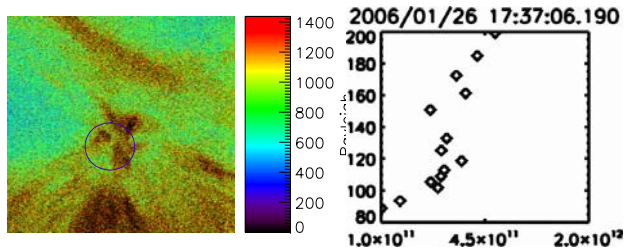
Results from the study:

Peak in electron density in the E-layer at times when the N_2 emission is dominating over oxygen emission. However when the oxygen emission is dominating, there is no peak.

Nitrogen dominating

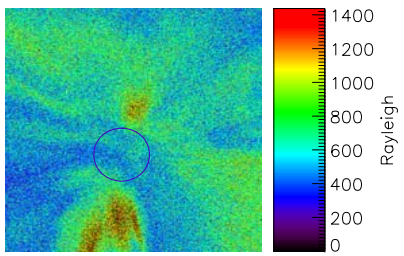


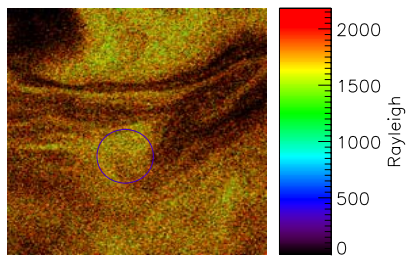
Oxygen dominating



The small-scale structures are coherent, and dynamic at times when we have a peak in the E-layer, but more ray-like structures with pointy edges are seen at times when the electron density profile is more flat.

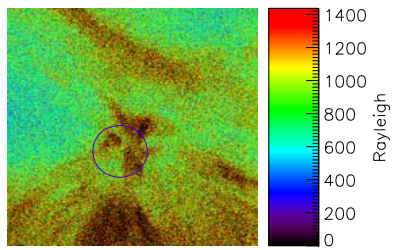
Pointy

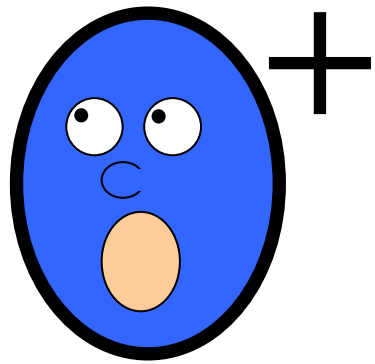




Coherent

Pointy





Reality

Model

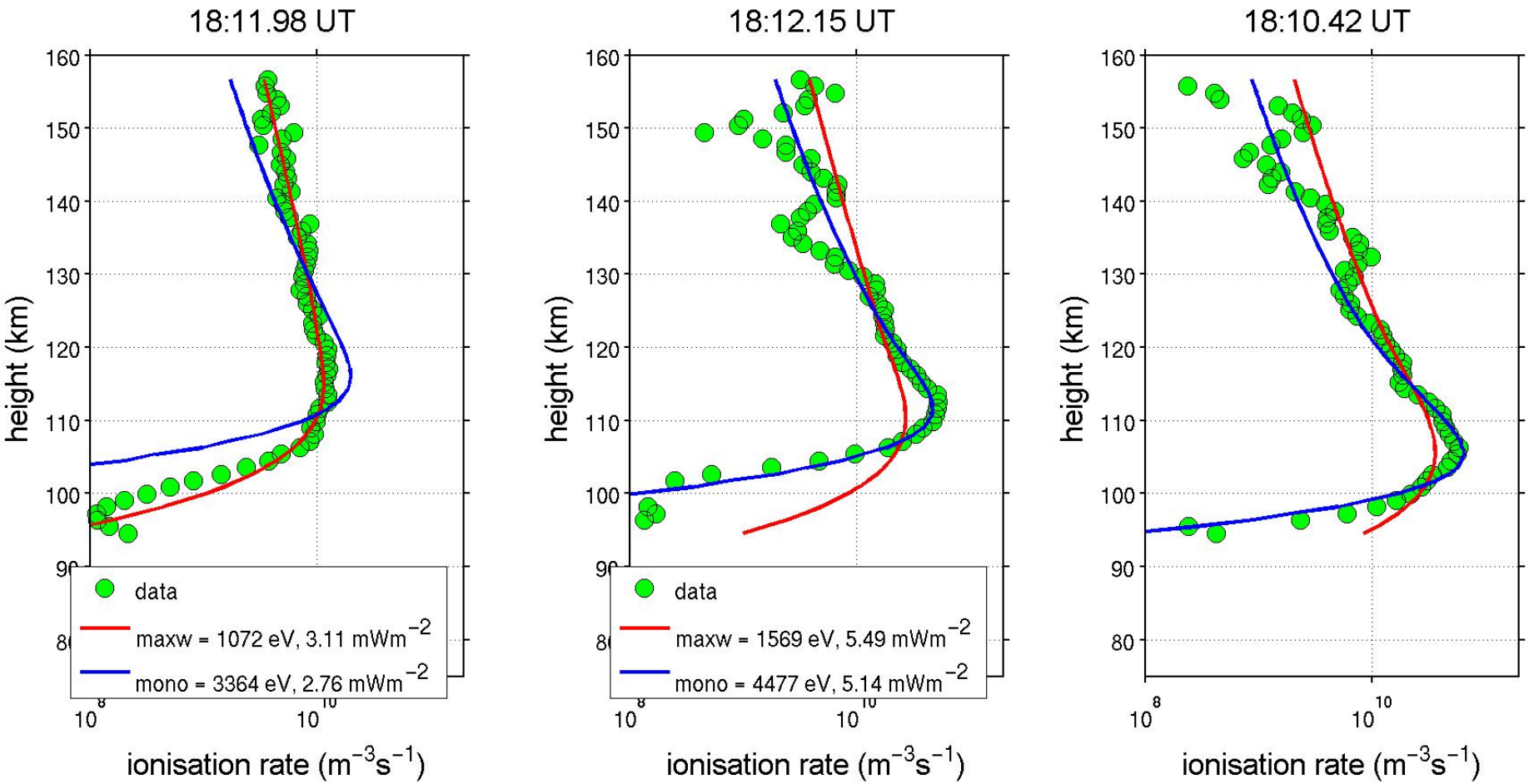
Ion Chemistry and Electron Transport Modelling

Can model ionosphere to produce data matching EISCAT electon densities and emission and ionisation rates for the species observed by ASK.

Can then use the model to give information about other ion species and the precipitating electrons causing the auroral emissions.

Ion Chemistry and Electron Transport Modelling

Generate input spectra from EISCAT data…



Ion Chemistry and Electron Transport Modelling

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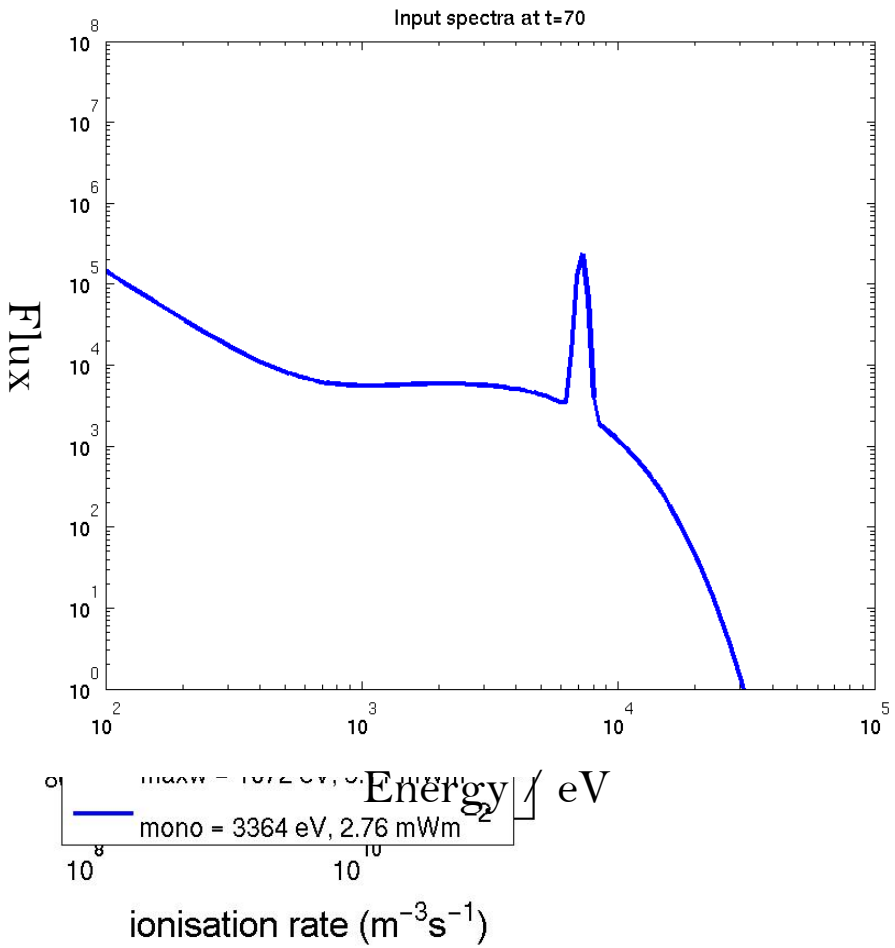
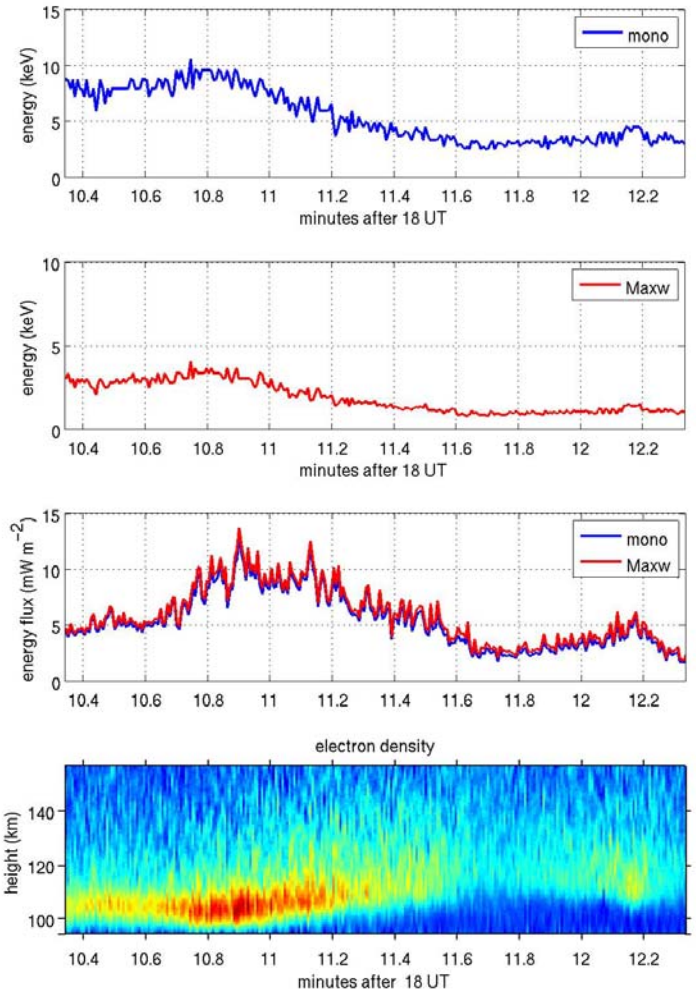
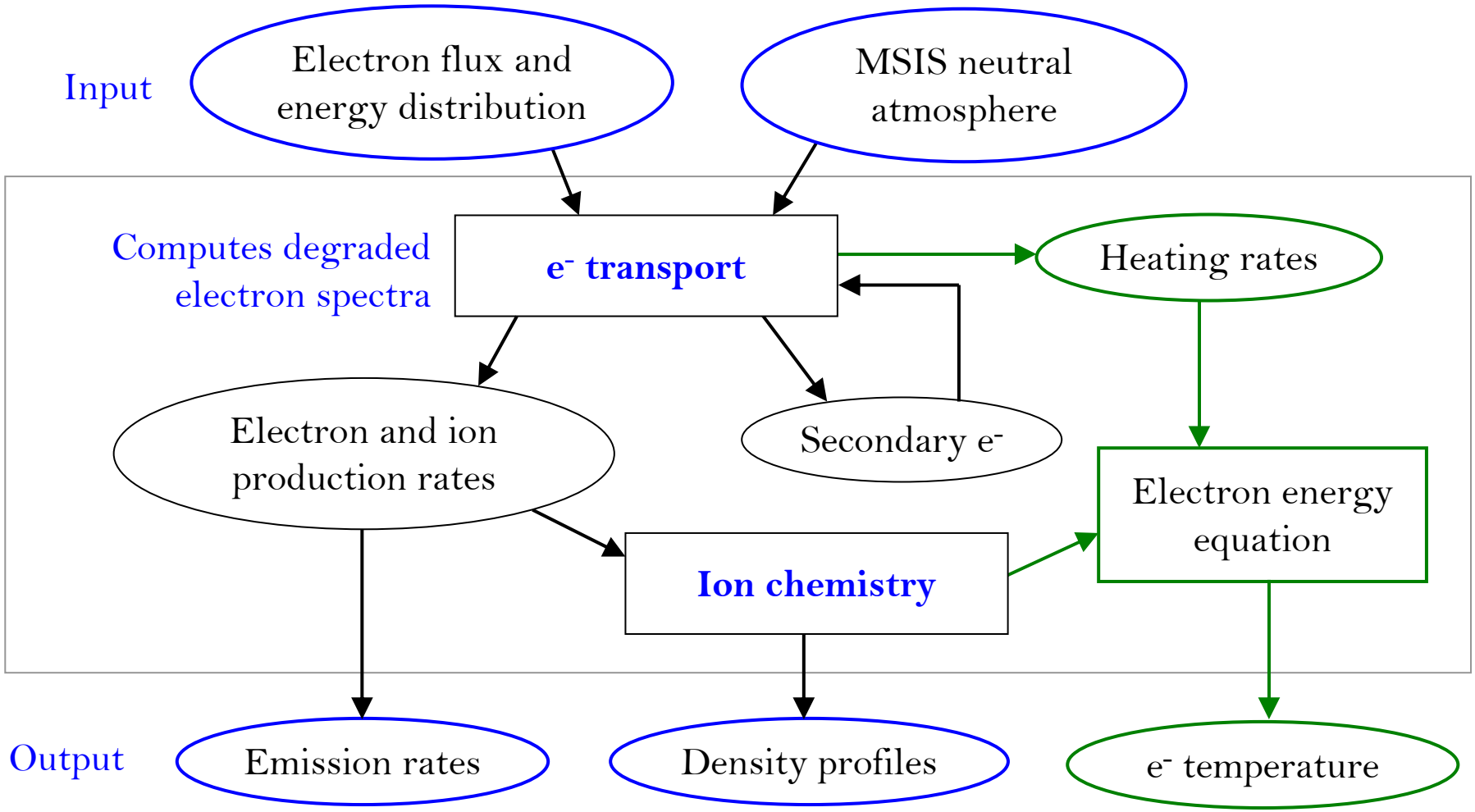




Ion Chemistry and Electron Transport Modelling

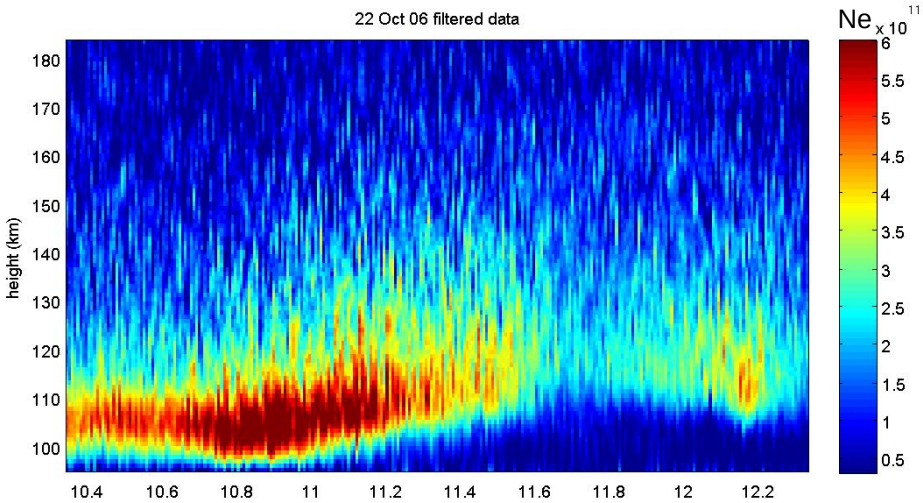
Run the model with this input…



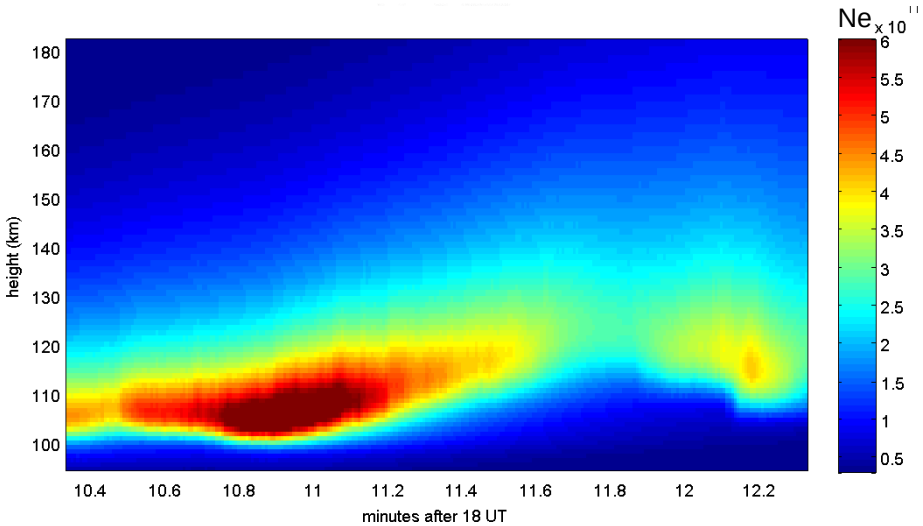
Ion Chemistry and Electron Transport Modelling

Compare model electron densities to EISCAT data…

EISCAT data



Model data

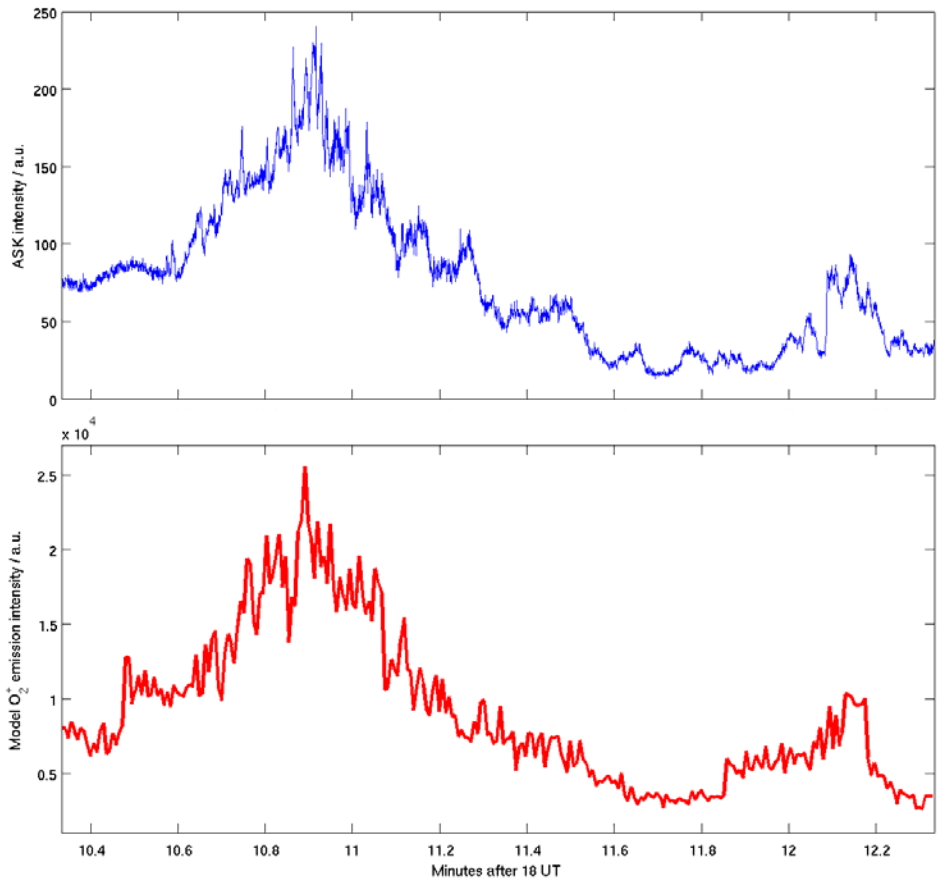


Ion Chemistry and Electron Transport Modelling

Compare emissions with ASK data, and obtain density profiles for many ion species…

ASK intensity

Model O_2^+ emission



Ion Chemistry and Electron Transport Modelling

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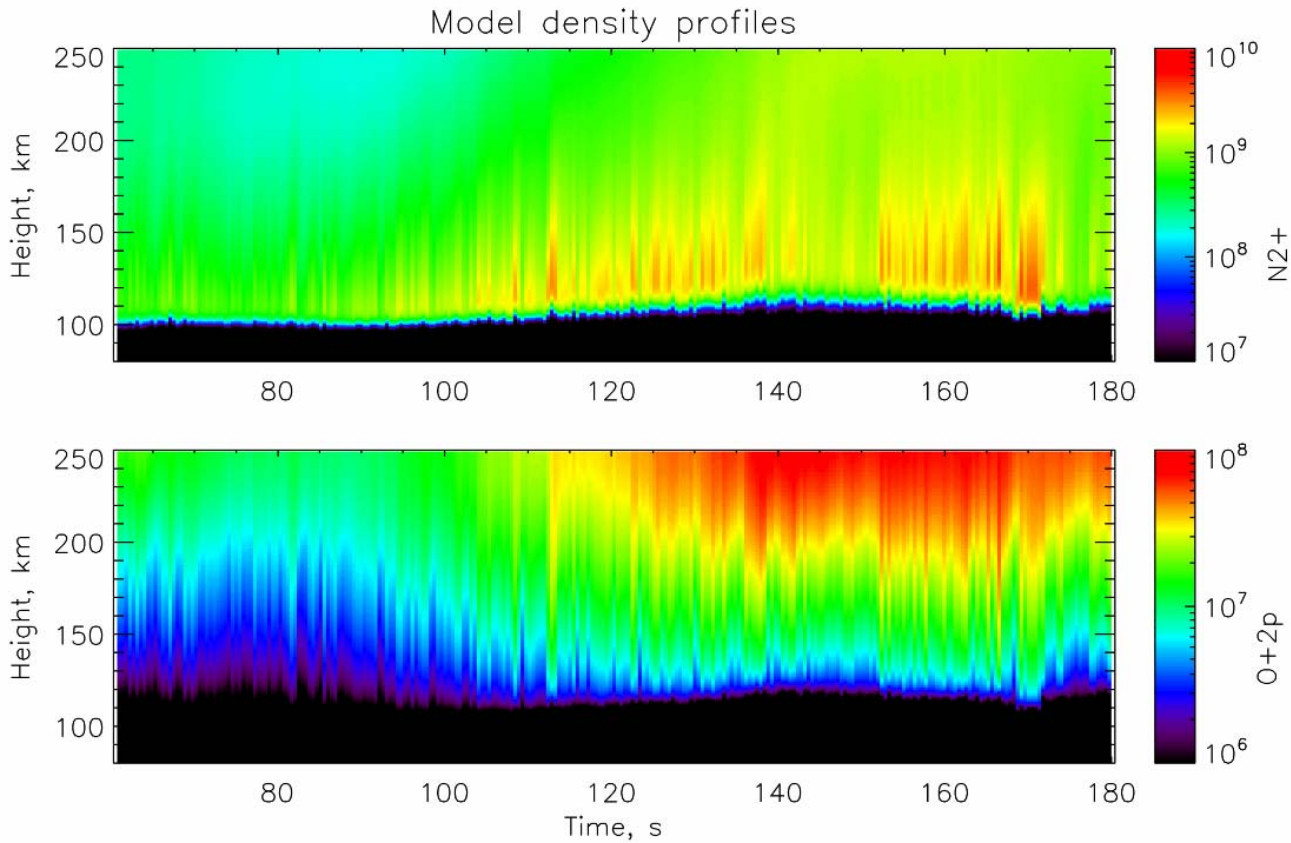
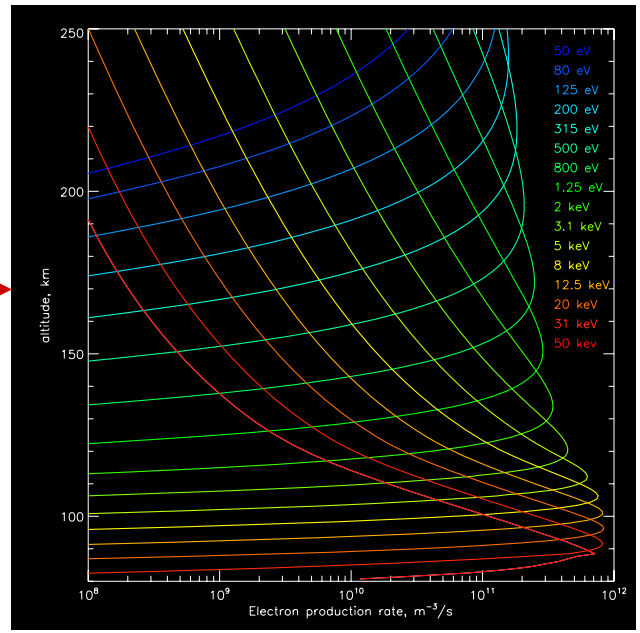


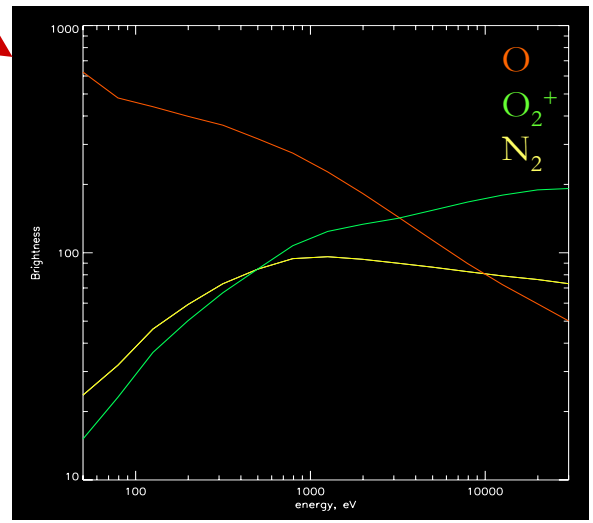
Ion Chemistry and Electron Transport Modelling

Find energies of precipitating electrons causing features in ASK.

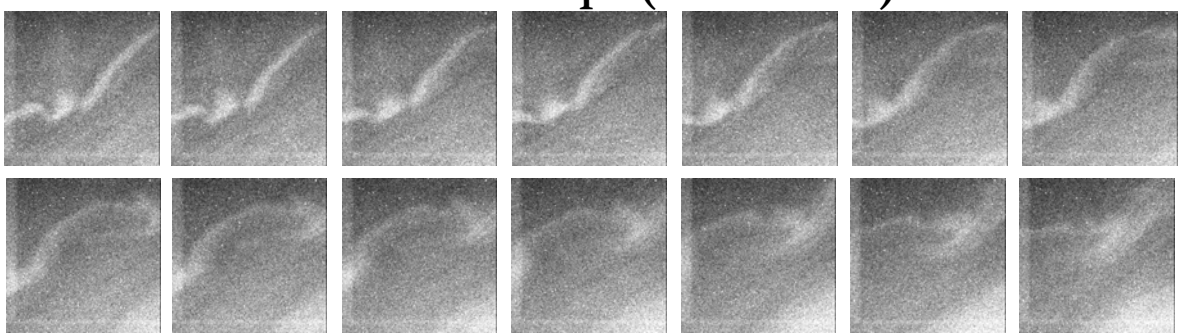
Altitude profiles of **ionisation rates** for narrow gaussian energy distribution with energy flux of 1 mW/m^2.



Corresponding **emission brightnesses** of O (7774Å), O_2^+ and N_2 emissions are shown below to the right. This data can be compared to the EISCAT ionisation data.



22 October: Data at 32 fps (½ s of data) from ASK1



Other studies with ASK and EISCAT in progress

- Naturally Enhanced Ion Acoustic Lines (NEIALS)
- Combined electric field and optical flow studies
- “Heating” and radar/optical signatures
- Optical signatures due to the energy dispersion of precipitating electrons
- And much more…!