



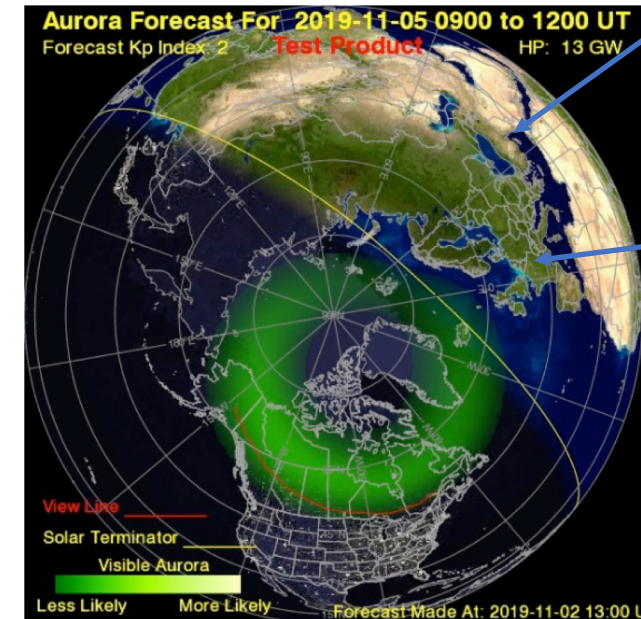
Lomonosov Moscow
State University



European Space Agency
Agence spatiale européenne

AMICal Sat, ATISE and WFAI: Three Space Instruments for Auroral Monitoring

Barthelemy et al.



You
are
here

I am
here

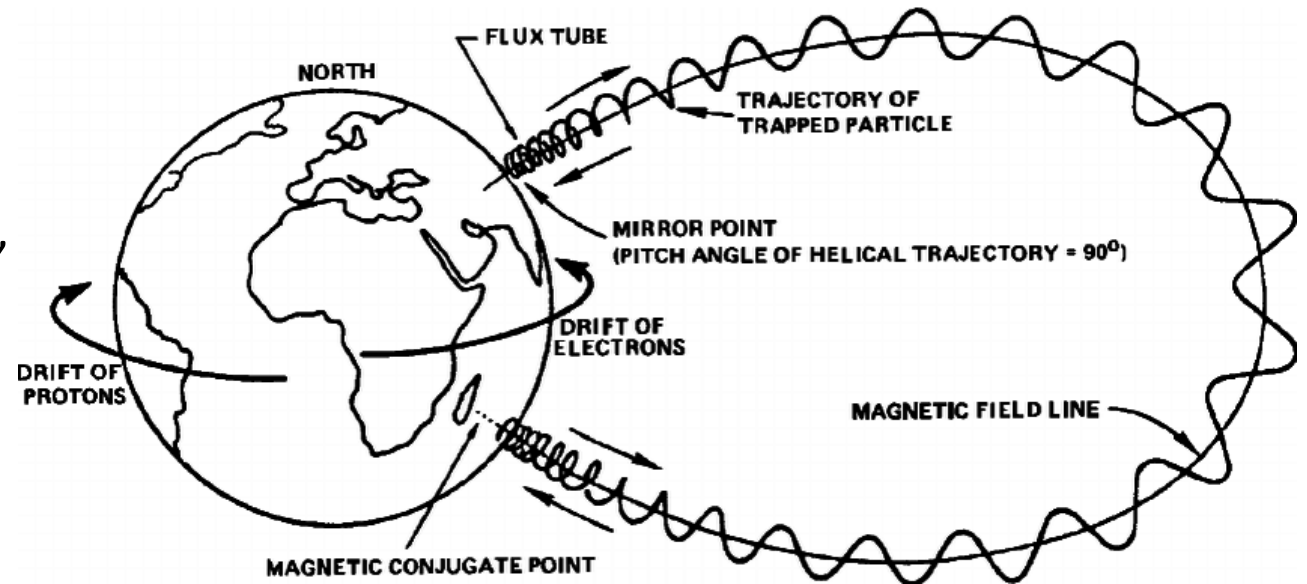
No aurora
where we
both are
but...





WFAI-ATISE-AMICal Scientific objectives

- Main questions:
 - Interface between upper atmosphere and magnetosphere
- Particle fluxes at the top of the atmosphere
 - Energy of individual particles, total flux, distribution shape
- Deposition into the atmosphere
 - Altitude of the emissions as a tracer...
 - Between 90 and 300 km

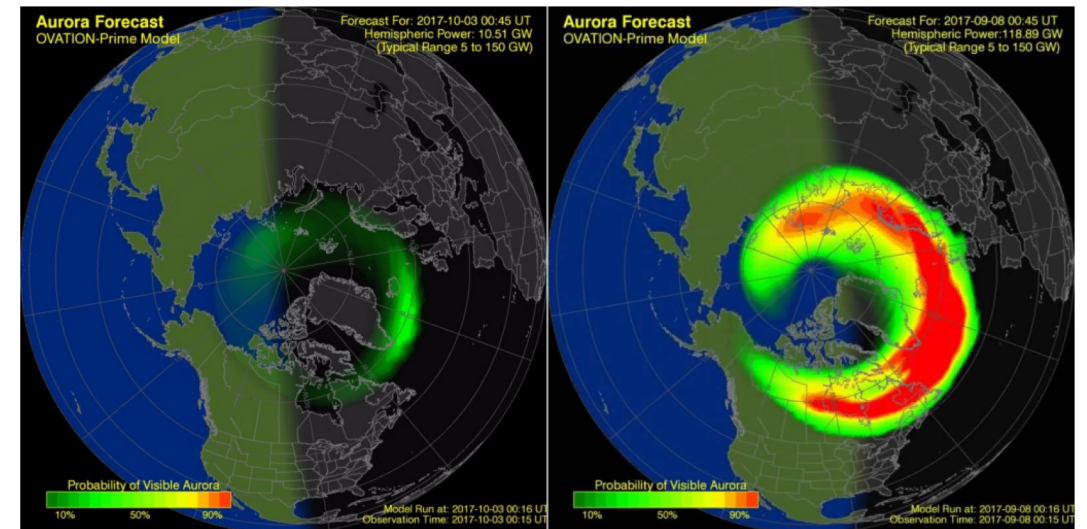




WFAI-ATISE-AMICal Scientific objectives

Auroras are a tracer of :

- Particle precipitation from plasma sheet and boundary region (Suprathermal particles, eV and KeV ranges)
 - 2nd most important in term of energy
 - Need for overall coverage
- Observables:
 - Auroral oval location
 - Overall shape and small scale structures
 - Intensities in different lines and bands
- Goal of observations: Global reconstruction of particle precipitations
 - p^+ and e^-
 - Mean energy, total flux, distribution shape
- **No other way to get global large scale particle precipitation monitoring (quasi continuous)**





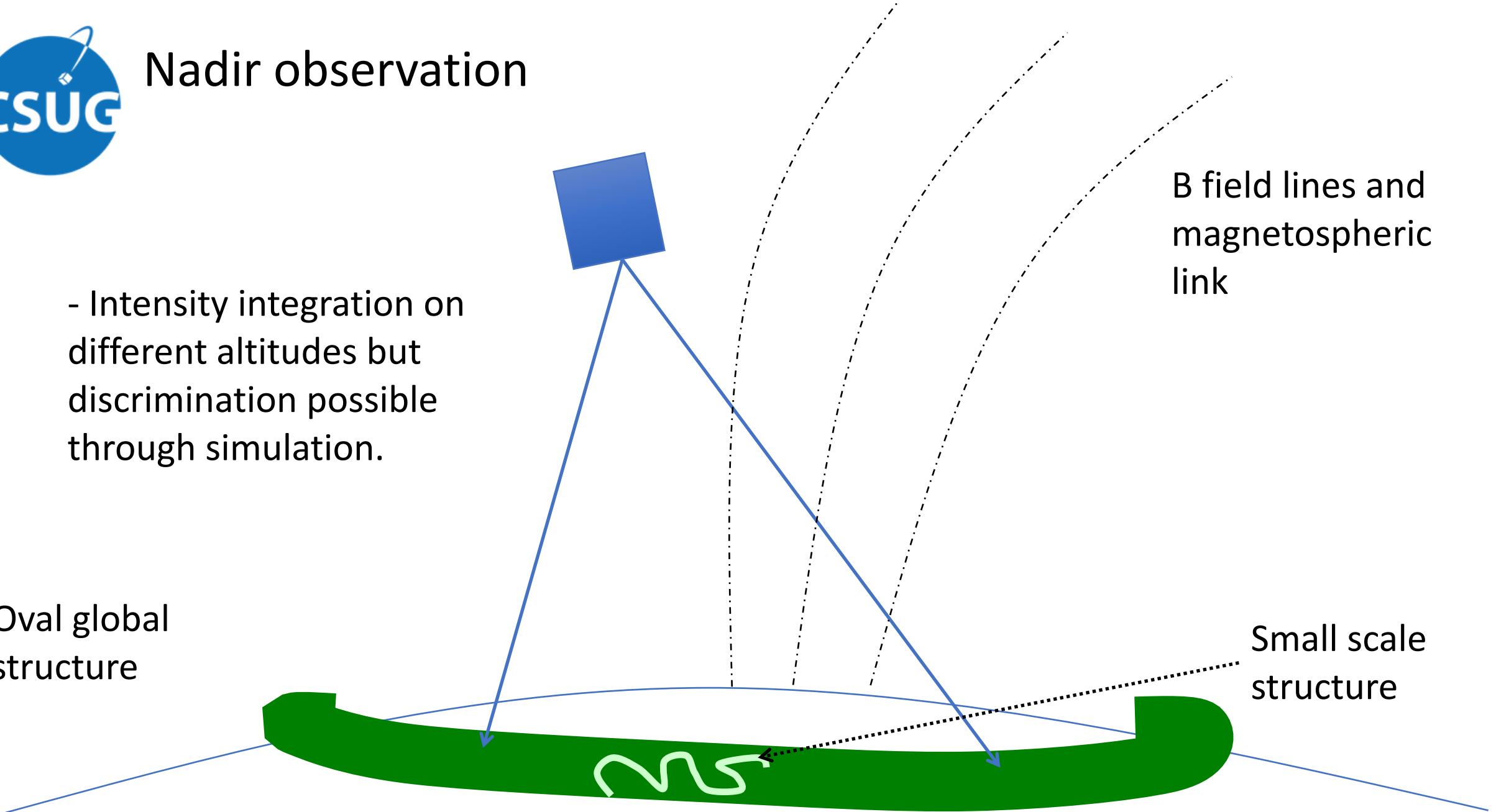
Nadir observation

- Intensity integration on different altitudes but discrimination possible through simulation.

Oval global structure

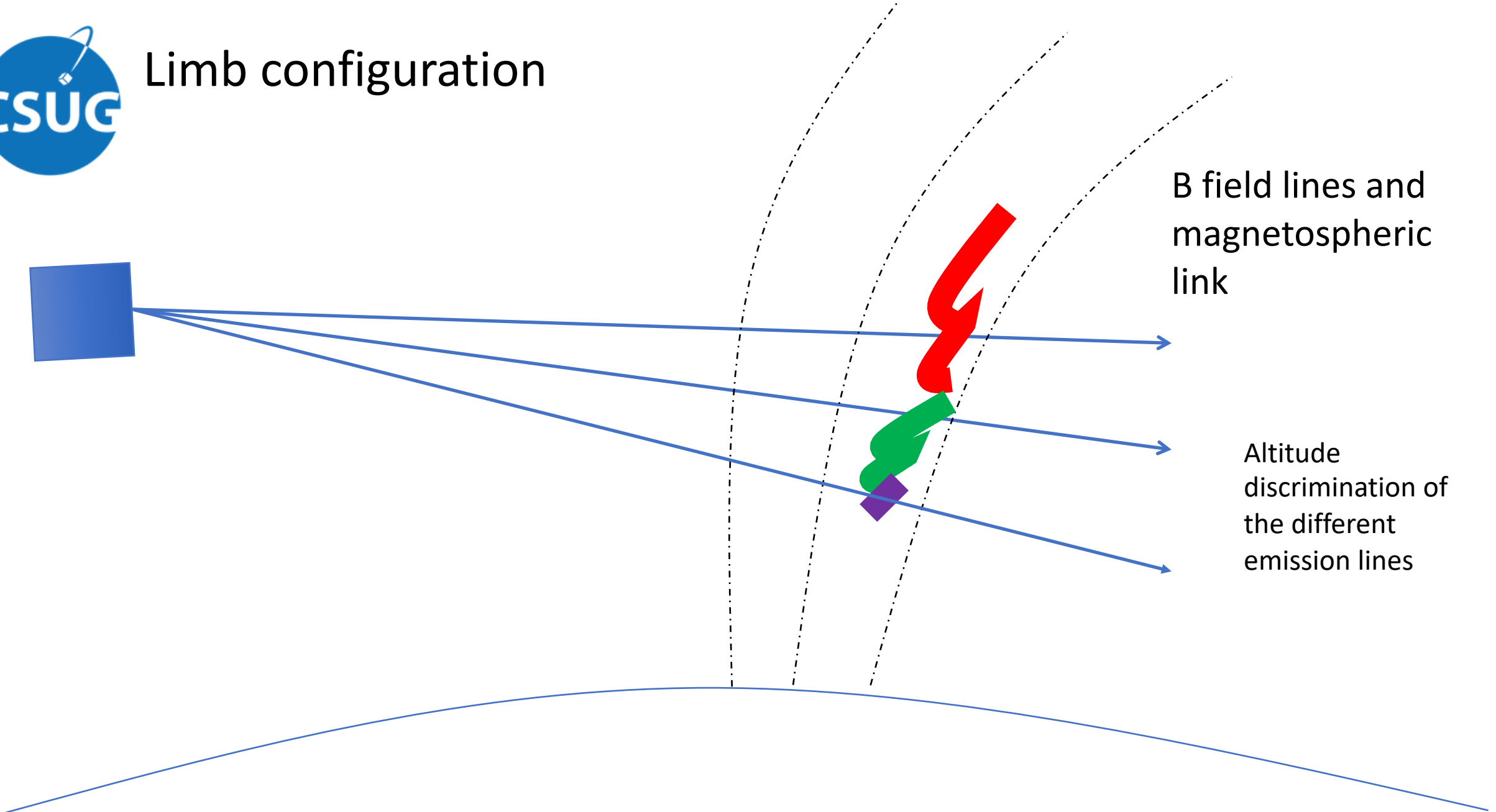
B field lines and magnetospheric link

Small scale structure





Limb configuration



B field lines and
magnetospheric
link

Altitude
discrimination of
the different
emission lines



Interpretation methods: the trans code

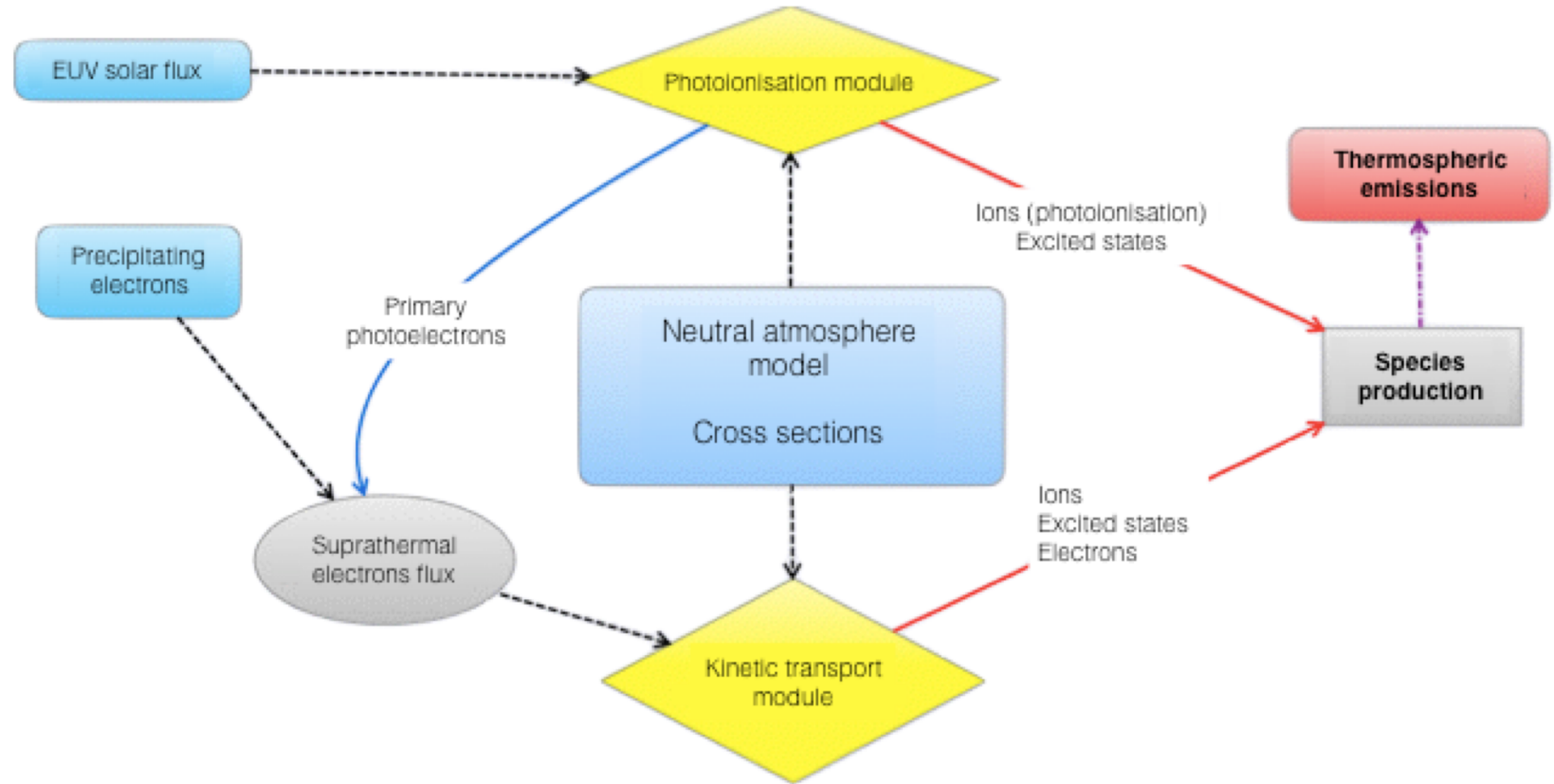
- Through the Transolo code

Fitted parameters

E_{tot}

E_{moy} for the distribution

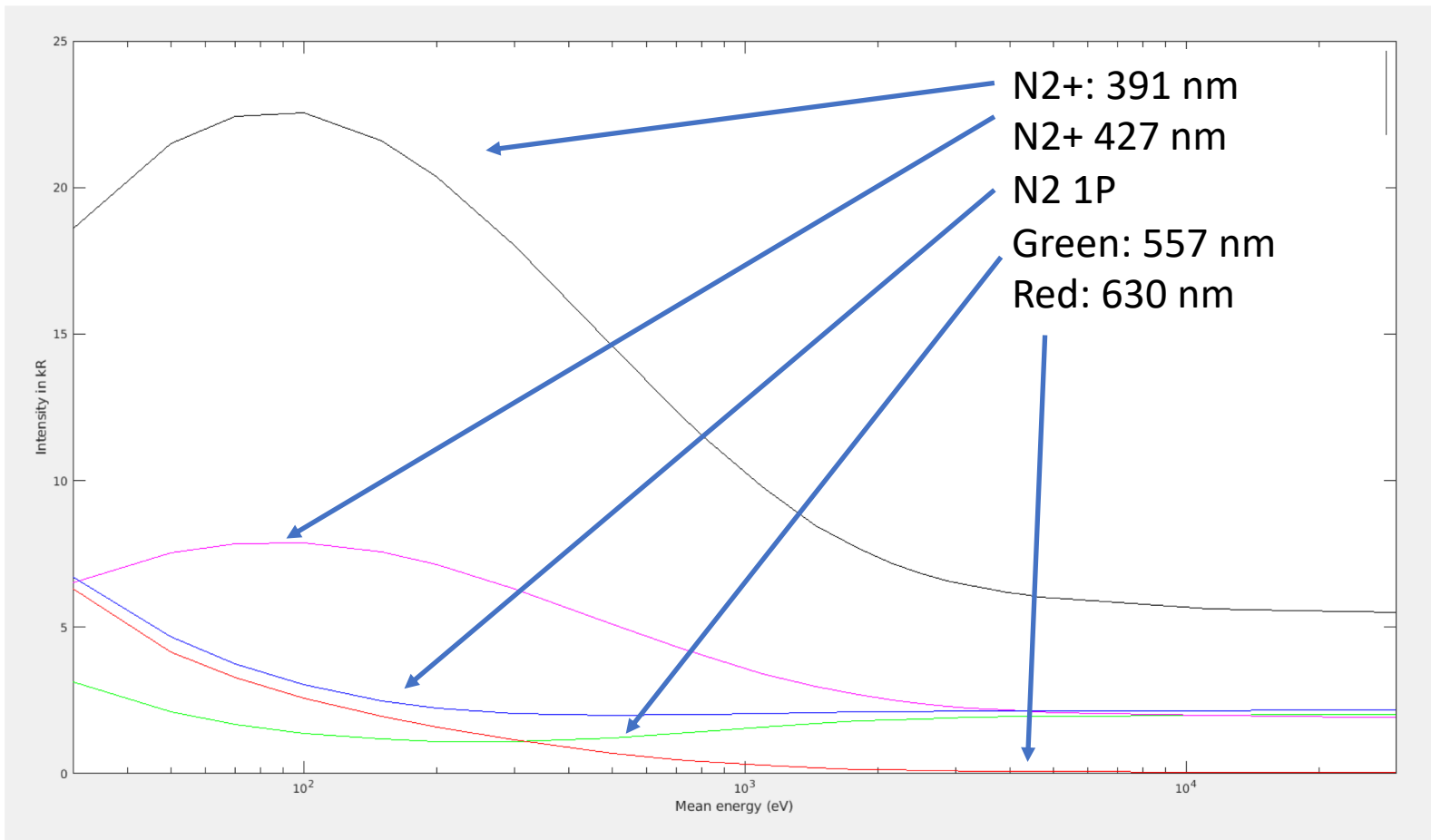
If possible: ΔE



Considering the possibilities of several distributions (Need for enough information ie enough emission lines)



Vertical integration of line intensities vs mean energy of the particles



Allow to reconstruct mean energy of the particle distribution quite well for particle with energies lower than 2 keV

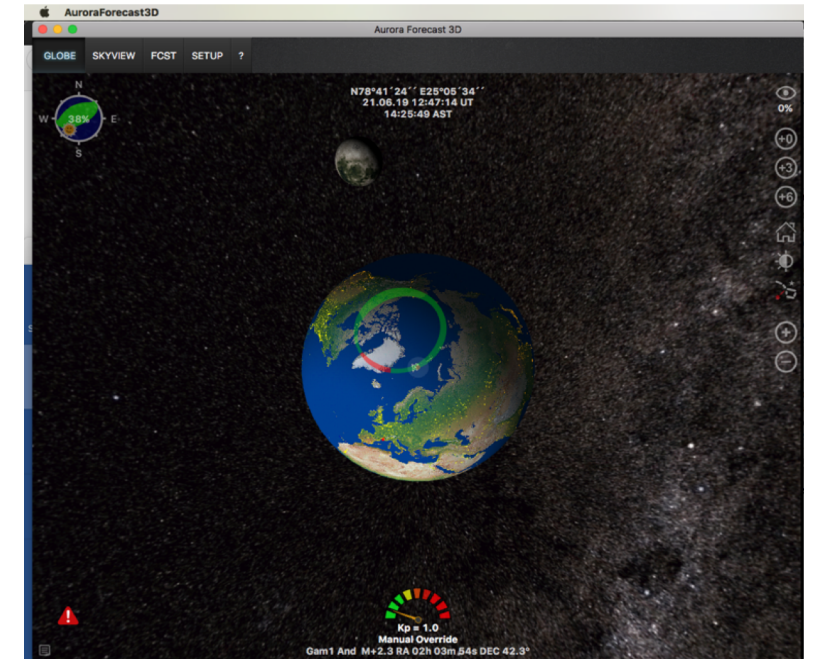
More difficult for 2 keV-30 keV particles

Existence of multiple solution if considering both mean energy and total energy



FUV versus visible (or both)

- FUV visible on both night and day sides
 - However
 - O 130 nm optically thick and resonant with the sun
 - O 135 nm resonant with the sun
 - LBH of strong interest but concerns only N₂ excitations
- Visible
 - Not observable at the nadir on the dayside (Auroral mapping)
 - Observable at the limb
 - Perturbated by moonlight on night side (Nadir)
 - A larger panel of information (N₂⁺, N₂, O I, H alpha, faint lines ...)



Auroral oval can be entirely on the dayside at solstice . Simulation from Sigernes (UNIS, Norway)

Both FUV and Visible are needed for full auroral particle monitoring
But much less instrument in the visible



AMICal Sat: a 2U cubesat for SW on a short time schedule

- ATISE Imager tests
 - NADIR(Auroral Mapping)
 - LIMB Images (Vertical Profile)
 - Sensitivity: 500R
 - Exp time: 1s

- **Orbit**

SSO, Local times: 10h

Altitude : 510km

AMICal Sat Launch: Launch schedule.
Q1 2020
Vega, Kourou.

Lifespan: 1 year (extensible to 3 years)

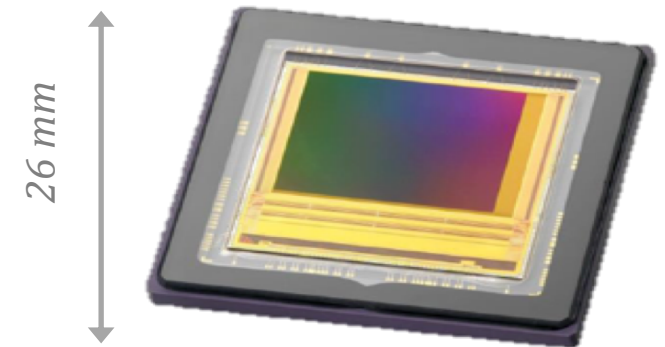
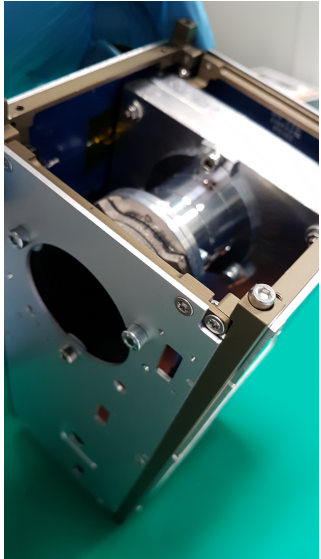
© Gabriel Dubreuil





AMICal Sat Payload– Imager

- **Commercial detector (ONYX Teledyne E2V)**
 - Large pixels : $10\mu\text{m}$
 - Sparse RGB matrix: high sensitivity
- Objective: Designed at IPAG. $f = 23\text{mm}$, $f/1.4$
- Wide FoV= 42° (Diag)
- Auroral shape
- Small scale structure
- Deposition reconstruction in RGB

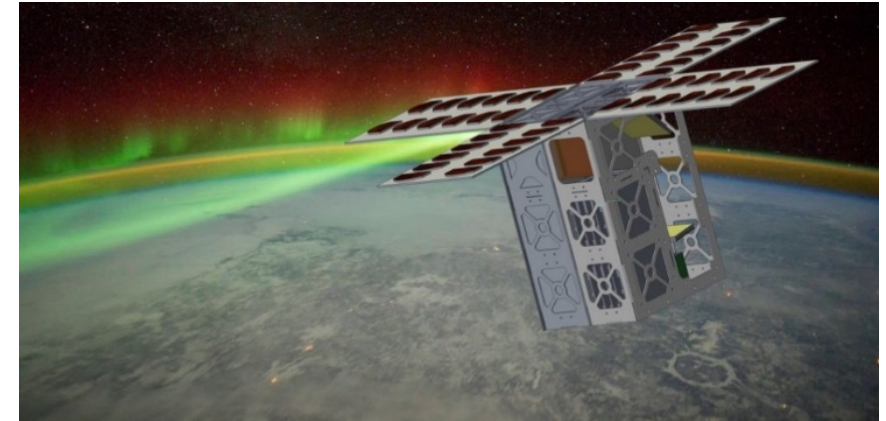


Onyx, 2Mpx, e2v



ATISE: A narrow FoV ultra-sensitive spectrometer

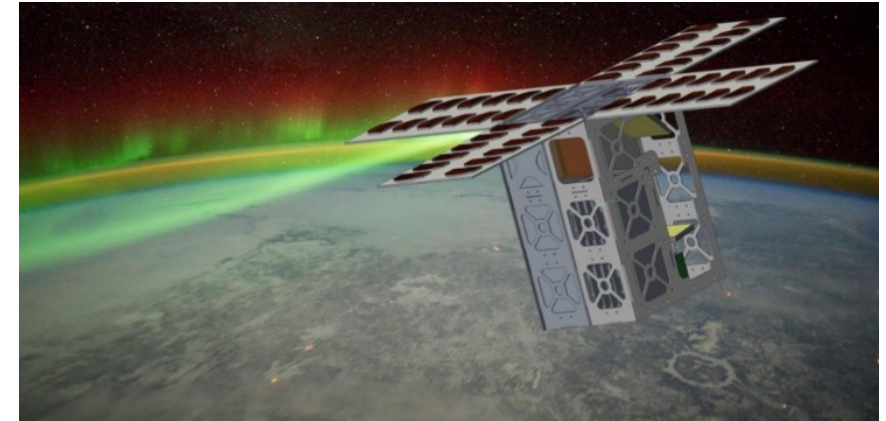
- **2 y mission nominal (ext 5y)**
- **Aurora (and Airglow)**
- **Orbital best choice : 70°-80°, 600km**
- **Shift in Local hours**
 - To scan the physics of different local hours.
- **Limb sighting for vertical profile reconstructions of the emissions**





ATISE: A narrow FoV ultra-sensitive spectrometer

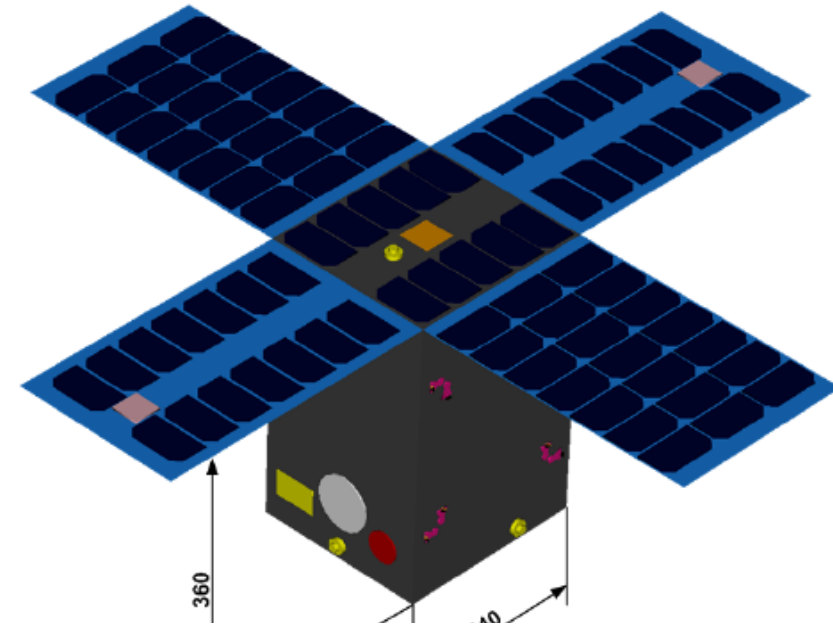
- **Visible (360-900nm). $R \sim 500$ to 1000; $\sim 1\text{nm}$**
- **Vertical profiles of the emissions (6 lines of sight)**
 - Limb sighting
 - between 100 and 350 km altitudes. $1^\circ \times 1.5^\circ$ for each LoS.
- **1s exposure time (20 s in Airglow)**
- **Detection threshold : 5R. Sensitivity: 1R.**
- **Absolute Photometric precision $\sim 5\%$ (In flight Calibration)**



Coupled with a particle detector in the same satellite (MSU)



ATISE: Platform: 12U from the CSUM



ADCS:

Stability: $0.05^\circ/\text{s}$

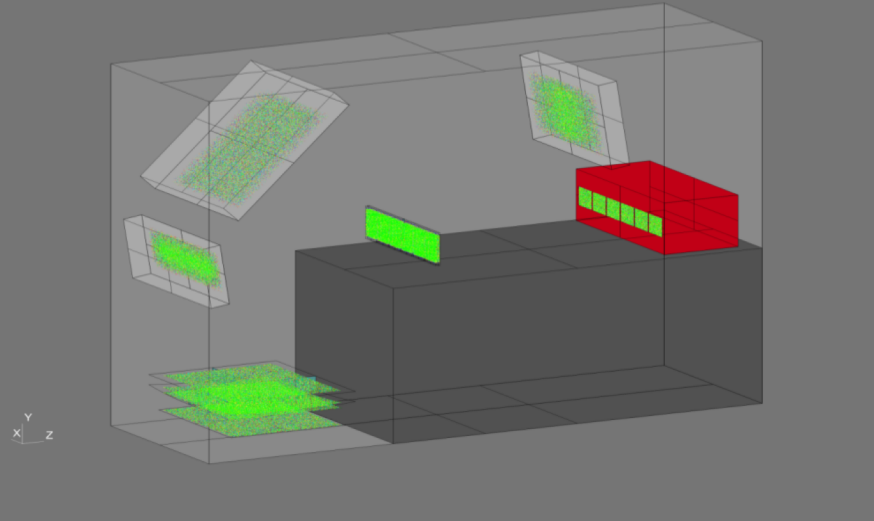
Accuracy: 0.2°

Power: ~ 20 W all included

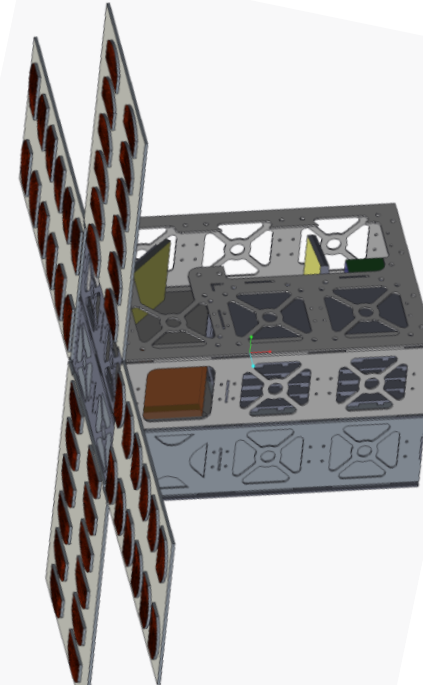
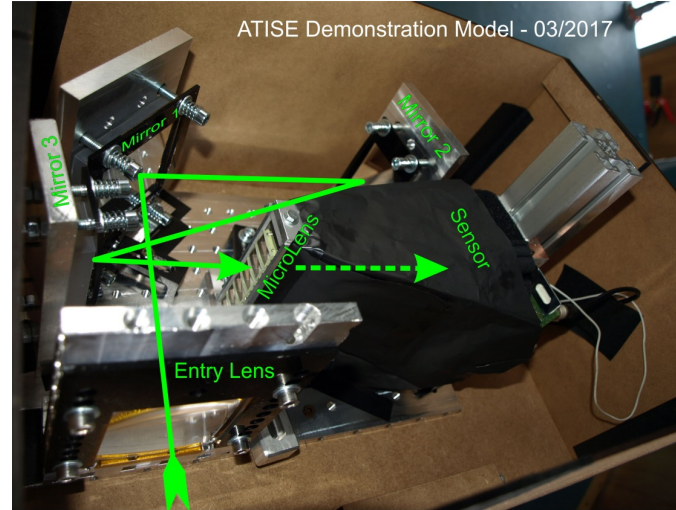


Instrumentation ATISE: Spectrometer

05/07/2016 11:10:49 ATISE 5 ATISE 6c F650 N11 N-BK7 435-852 nm - A' - tol - lambda - Copie Configuration 0
échelle 1.99379, 49005 rayons

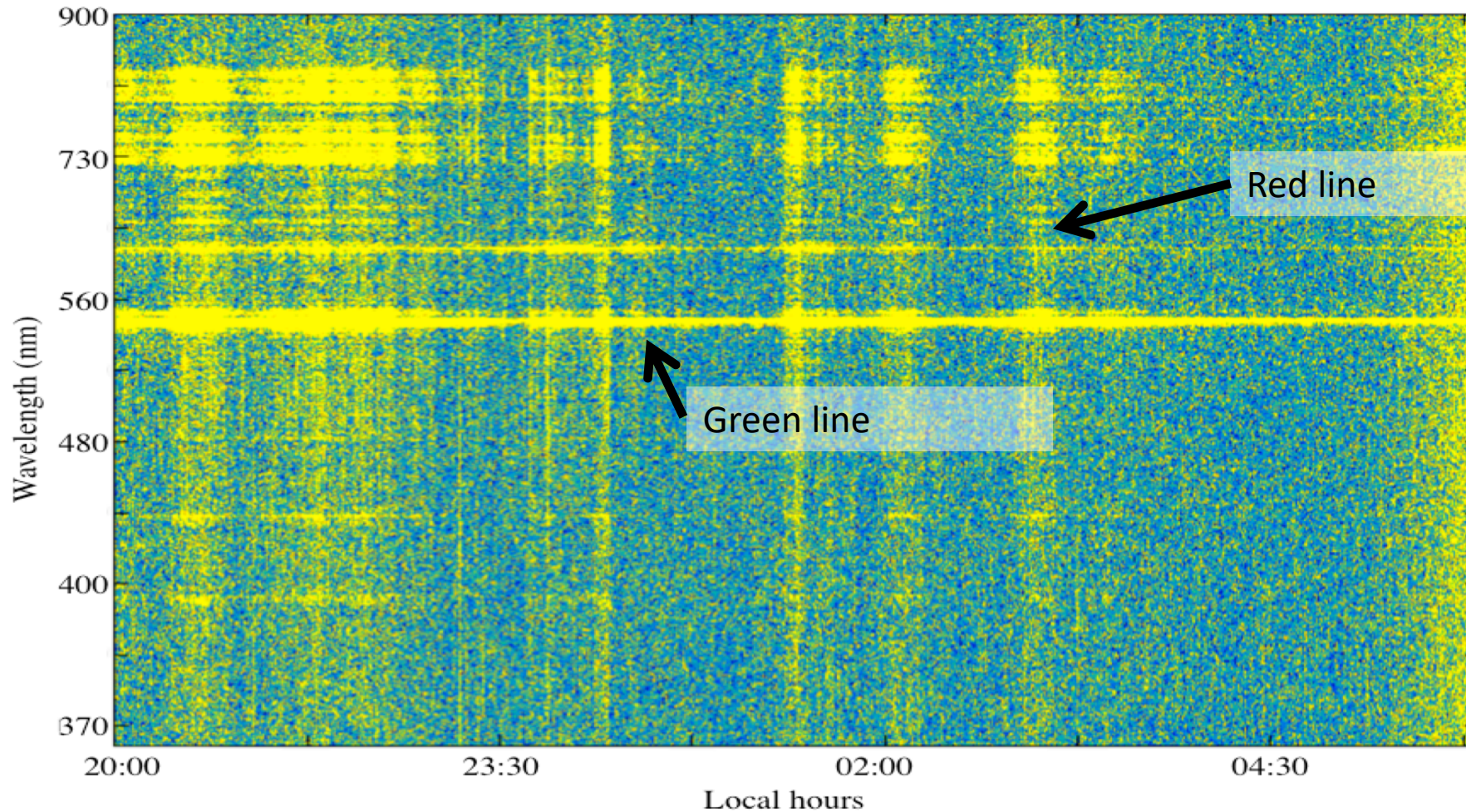


Based on the μ SPOC concept:
Fizeau interferometer directly glued
on the detector





Ground based demonstration (March 2017, Skibotn, Norway)



Around 18000
spectra

Exp time 2s for
each

Barthelemy et al. 2018



Imager (ATISE)

- Same as AMICal Imager
- Wide field of view
 - 42°
- Important to Interpret the data.
- Need to know which structure is aimed.
- Cross check of total intensity.

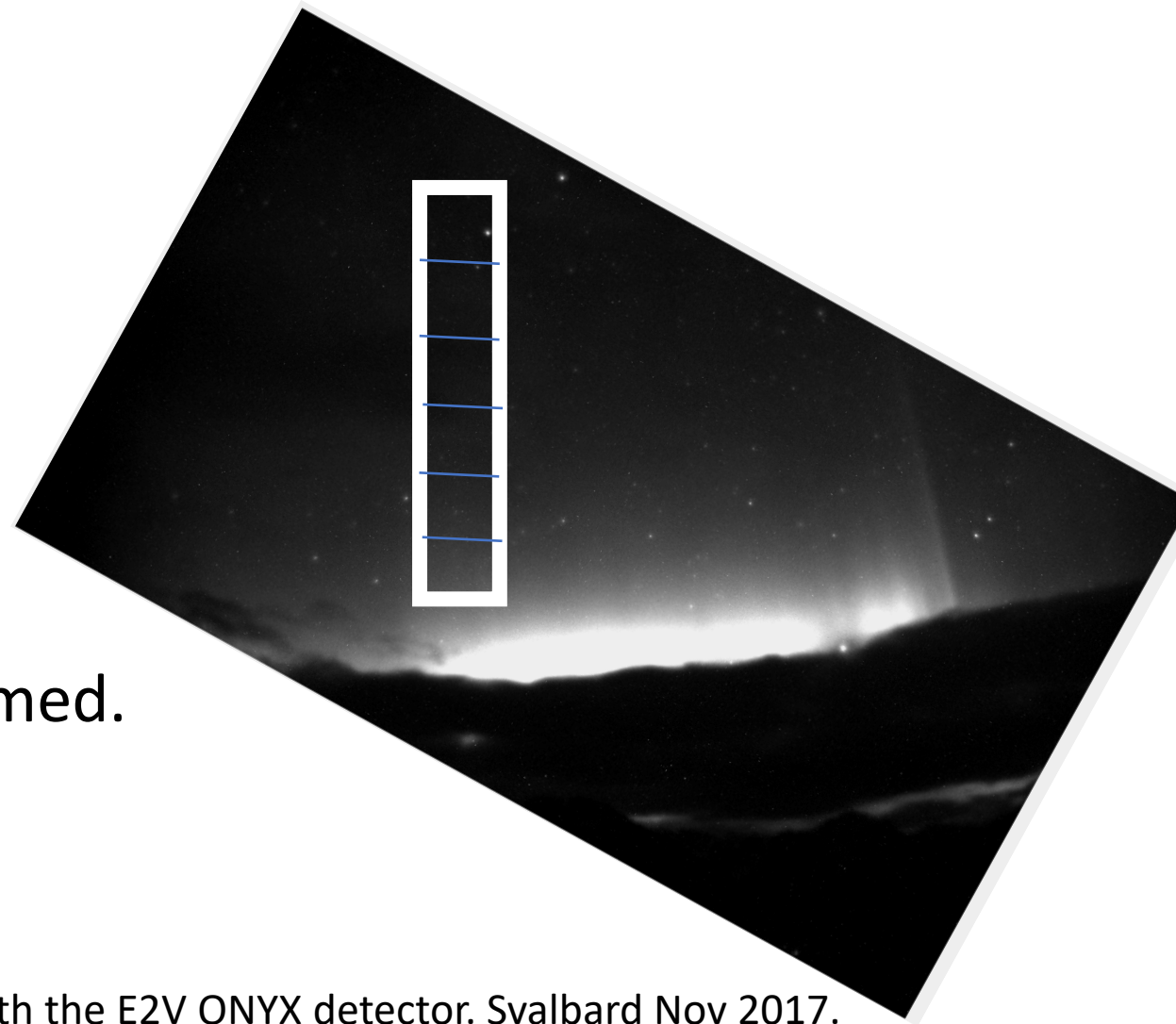
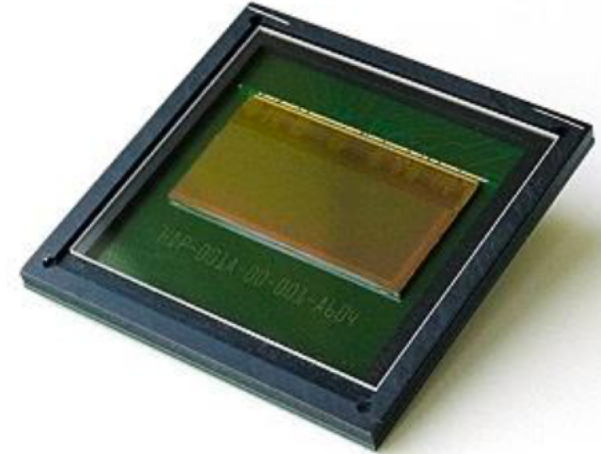


Image taken with the E2V ONYX detector. Svalbard Nov 2017.
The potential FoV of the 6 spectral LoS is added



D3S-WFAI

- Imagery + Spectrometry: spectro-in
 - Joined with an FUV imager.
- A set of Fabry interferometer
- Detector (HDPYX, CMOS, 10 μm)
- To get both night and day sides
- Wide field: 60°x60°
- Spectral resolution: 1 to 10 nm depending of the wavelength
- Spatial resolution 10 to 20 km (@2500 km alt)





WFAI Budgets and requirements

Requirements	Visible	FUV
Spectral resolution	nm range (1-12 nm depending of the wavelength)	
FoV	60° (Possible in one frame with 40 km resolution @2500km)	60°
Wavelengths	350 nm – 750 nm	130, 135 & 138nm
Spatial resolution	10 km@ 2500 km altitude (TBC) 20 to 40 km @2500 km depending of chosen options	25 km@ 2500 km altitude
Mass	≤ 3 Kg	≤ 2 Kg
Power Consumption	≤ 20 W (goal 10W)	≤ 10 W
Data rate	≤ 230 kbps/image	≤ 30 kbps/image
Dimensions	Instrument 100 x 100 x 200 mm ³ TBC Electronic Box 150 x 70 x 200 mm ³ TBC	Instrument 100 x 250 x 250 mm ³ TBC Electronic Box 100 x 100 x 200 mm ³ TBC

Trade off in yellow





Conclusion and take home message

- Auroral monitoring is the only way to get a full coverage of auroral particle precipitation
 - Need both UV and Visible (Day and night sides)
 - Need imagery and spectrometry (and thus Spectro-imagers)
 - Space instrument are necessary for quasi continuous monitoring
- We are developing 3 instruments
 - 1 imager (Wide FoV), 1 spectrometer (Narrow FoV), 1 spectro-imager (Wide FoV).

Imager: AMICal Sat (Q1 2020).

Spectrometer: ATISE (2022)

Spectro-imager: WFAI (2023-...)

- WFAI is under pre-study with ESA for the D3S mission
- AMICal Sat and ATISE has been partially funded by the CSUG partners and the Grenoble IDEX