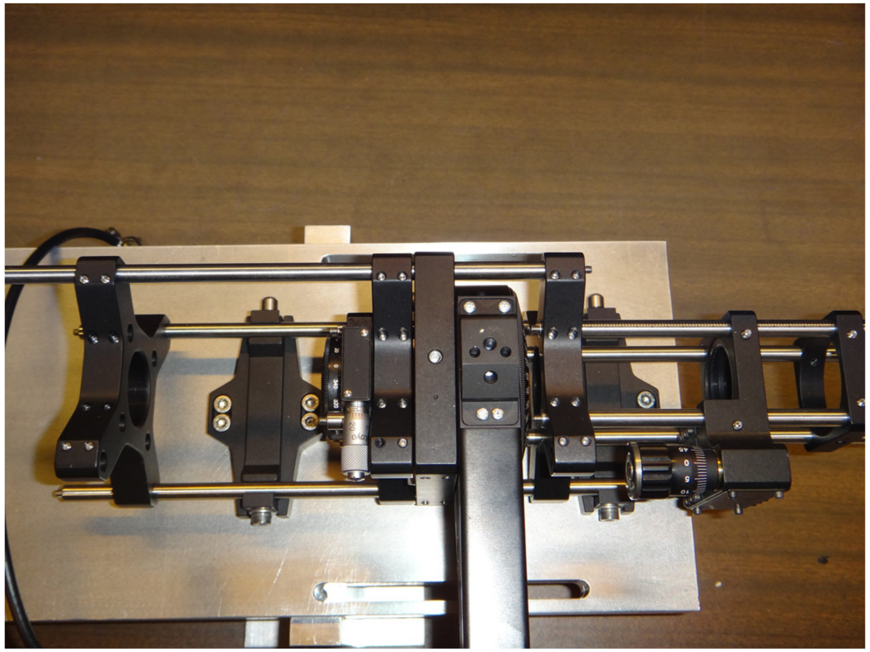
Premier cru : a new instrument to study the auroral lines polarisation

M. Barthélemy (1); Hervé Lamy (2); J. Lilensten (1);
(1): IPAG, Grenoble, France.
(2): BIRA-IASB, Brussels, Belgium.

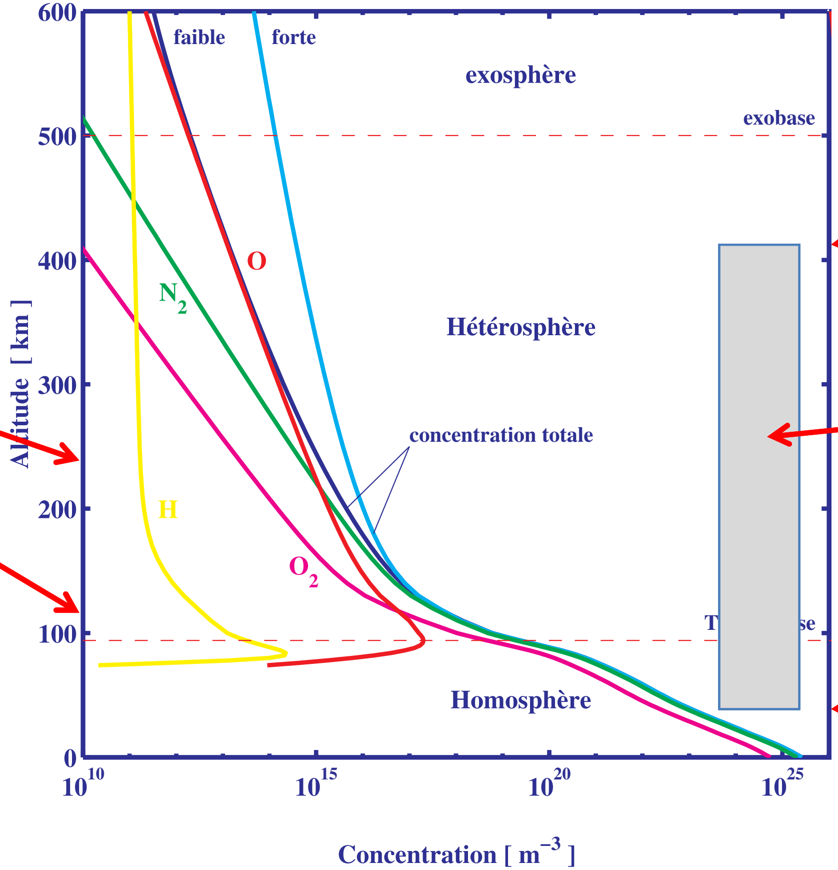


Context

Question: Ionospheric conditions at the altitudes of emissions are difficult to determine due to the **lack of observable quantities.** Especially intensities of red and green lines are not sufficent to constraint the ionosphere conditions.

Red line

Green line



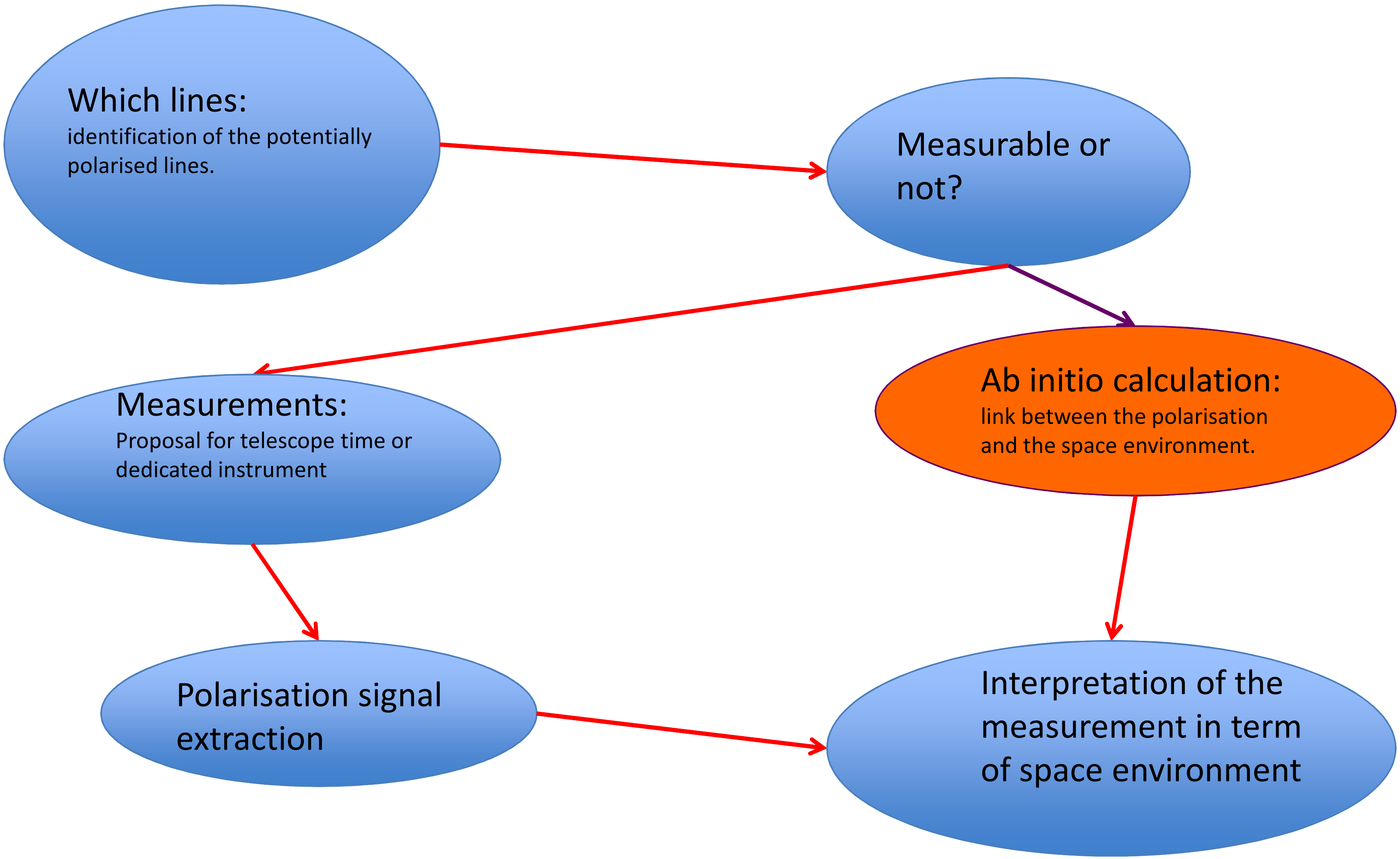
Z>400km

Need remote sensing.

Z<40km

Context:

Study of the polarisation of the auroral emission lines as an additional measurable quantity.



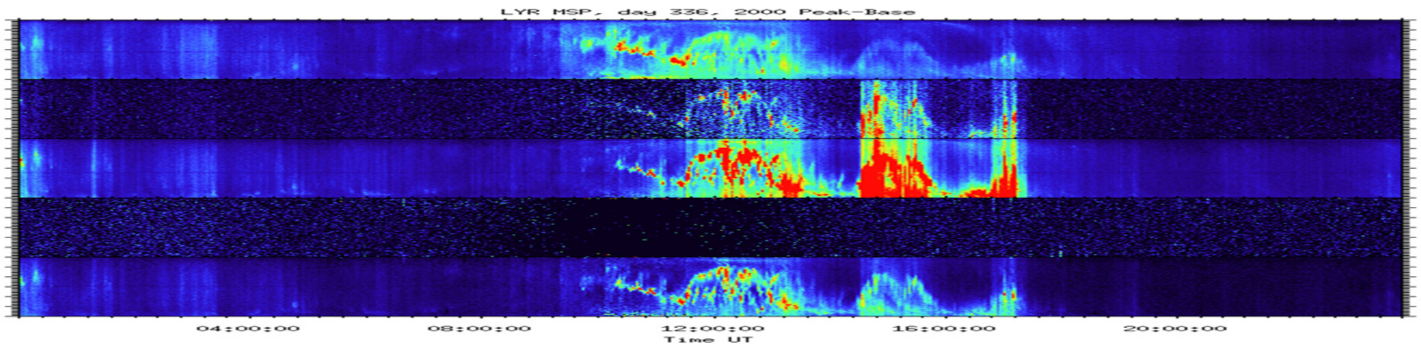
Context

- Measurement of the auroral red line line (O^1D-O^3P) polarisation through a photopolarimeter (Lilensten et al. 2008; Barthelemy et al; 2011, Lilensten et al. 2012; Lilensten et al 2014, submitted)
  - Polarisation degree: <2%
  - Direction parallel to B
  - Links between the polarisation and the ionospheric condition (Bommier et al. 2011 and Lilensten et al. 2015)

Context

- In the Earth case, need for measurement of other lines especially:
  - N2+ lines at 427 nm
  - N2, 1^{st} and 2^{nd} positive bands.
  - O I line at 844 nm

630 nm
427 nm
557 nm
486 nm
844 nm



MSP, UNIS-KHO. D. Lorentzen

➔Need for a new spectropolarimeter: "1^{er} Cru"

Fluxes

- Red line intensity ~ few kR (ie few 10^^{9} ph.cm^{-2}.s^{-1})
  - Other lines less intensive by a factor of :
    - 1 to 2 for the N_2^+ 427 nm line.
    - 2 or 3 for the O I 846nm
    - 10 for the H-Balmer lines
- Variations
    - Line dependant.
    - Different processes, different altitudes (ex: N2+ at low altitude around 100 km, red line at 220 km, green line at 120 km)

Time resolution and field of view

- 4 exposures for a polarisation measurement
  - Need for high S/N

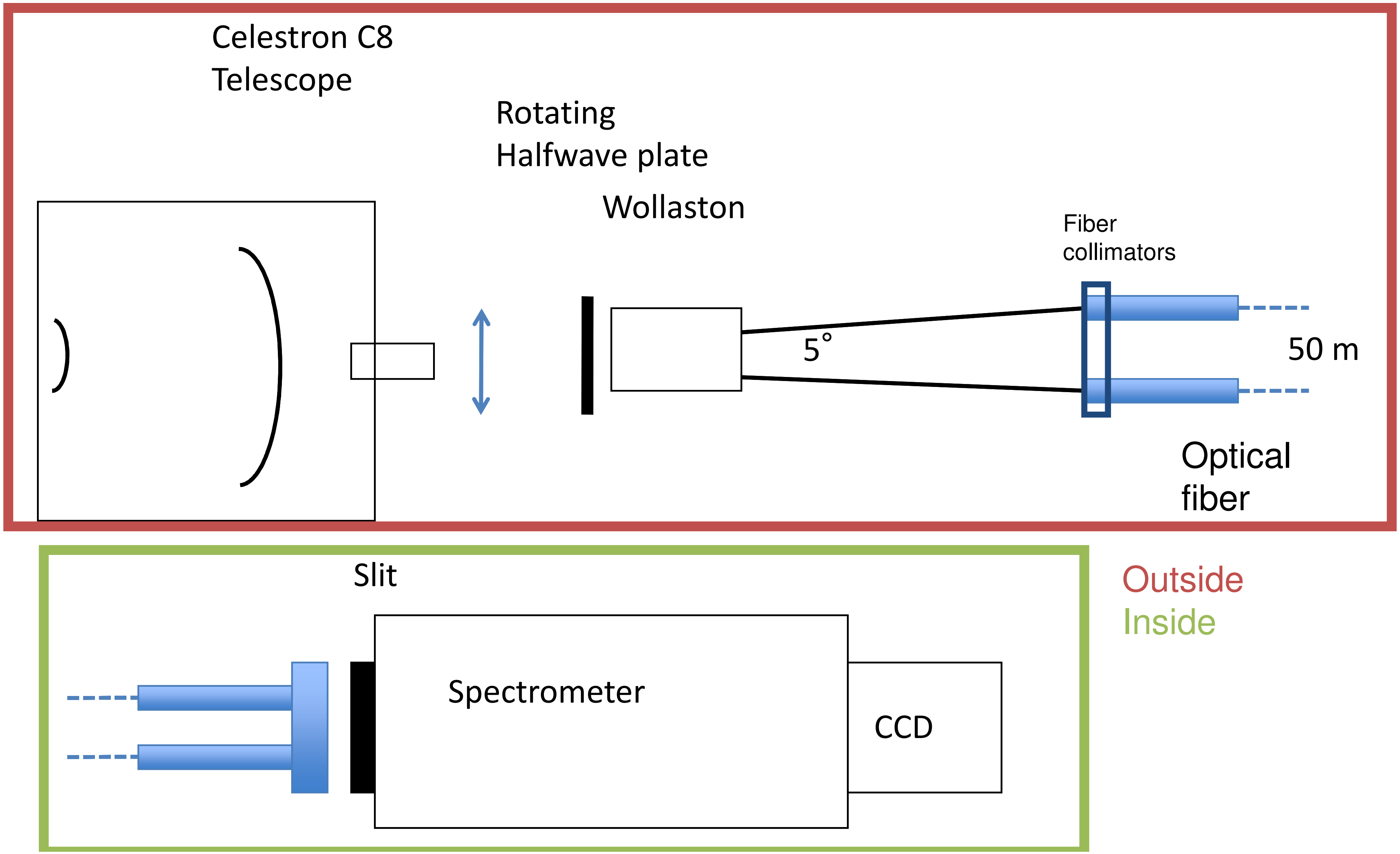
  But

  - Pb of the time variation of the aurora

  - Goal: Maximum of few seconds for each exposure
    - ~10s for a polarisation measurement
- Field of view (The source is extended): 0.6° or 1.2° depending on the eyepiece.

KHO. Longyearbyen Svalbard. Credit: O. Grundwald

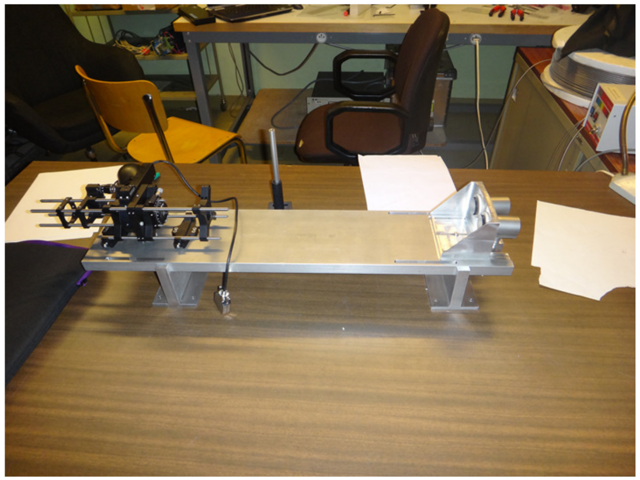
Concept of the instrument



Characteristics

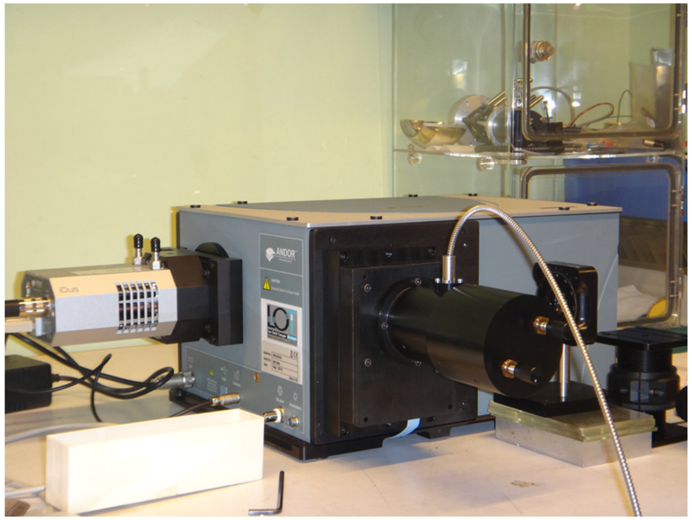
- ½ wave plate: diameter 12.5 mm; ½ wave at 530nm. Zeroth order plate. Coating 400-700nm.
- Wollaston prism: width 12.5 mm. Angle separation 5° . Same coating.
- Telescope C8 (~200mm, f/d ~10), Schmitt Cassegrain to avoid instrumental polarisation (cylindrical symmetry). Collecting surface: $2.76e^{-2}m^2$. Field of view: 0.64° .
- Optical fiber diameter: 600µm x2.

Length: 50m.



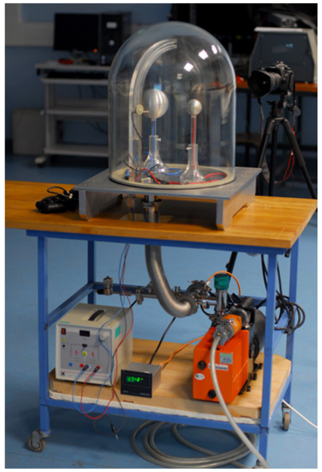
Characteristics

- Spectrometer:
  - Shamrock 303i.
    - Czerny-turner design
    - 3 gratings 300, 600, 1800 lines/mm
- Detector: Andor Idus 420 Camera
    - 2028x256

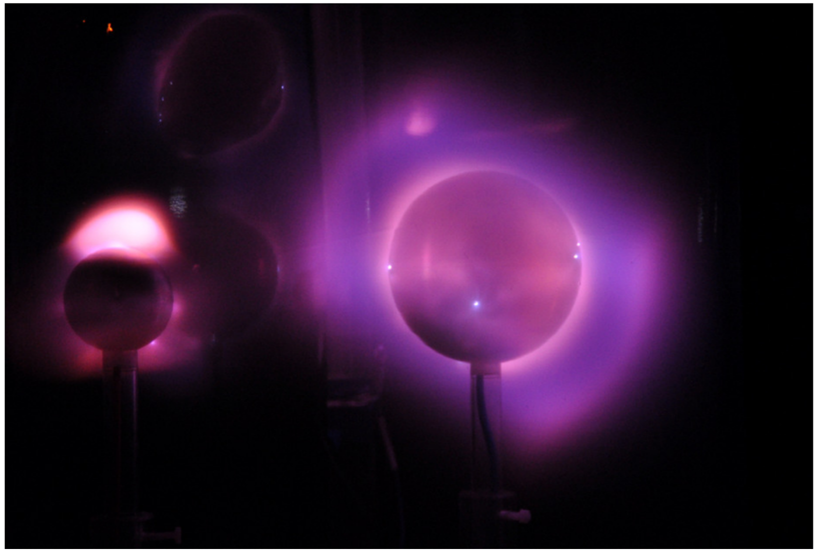


Calibration

- Several calibration procedure
  - In lab: on Hg-Cd lamp with polarizer. Fully polarised light. Lines from 400 to 650nm.
  - In lab: on the planeterrella auroral simulator with or without polarizer



http://planeterrella.obs.ujf-grenoble.fr/



Calibration

- During field operations: Adaptable, rotatable polariser film to produce full polarized light.
- During field operations: Green line at 557 nm is not polarised (Transition O1S➔O1D)
  - » Level of remaining polarisation due to Rayleigh scattering have to be determined but it should represent a reference with $p<10^{-3}$ (See Red line calculation in Barthelemy et al 2011a)

– Procedure still in development in order to minimize the uncertainties.

Data processing

- Ratio method possible for central wavelength half of the waveplate (532 nm)
- Pb of the retardance variation with wavelength.
  - Use of the method developped in Barthelemy et al (2011b) for Jupiter.
    - ie, least square inversion for each wavelength of the following

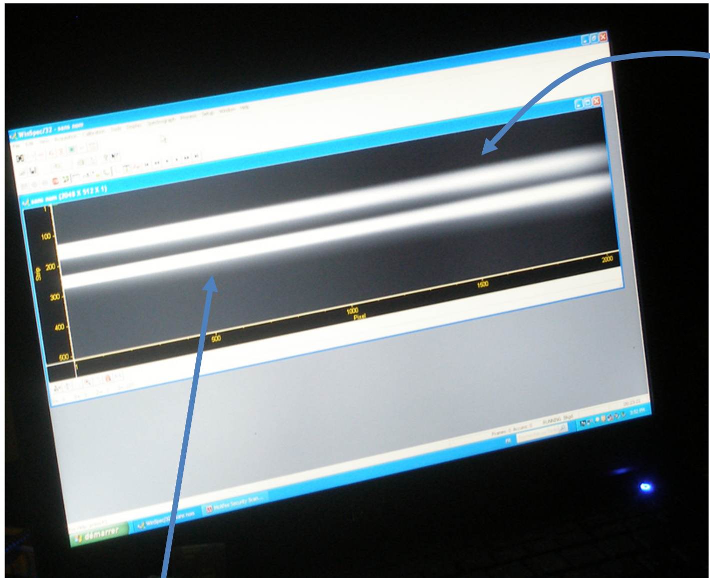
$$\begin{aligned} D(\alpha,\beta,\delta) \;=\; & \frac{1}{2}[I+(Q\times\cos(2\alpha)+U\times\sin(2\alpha))\times\cos(2(\beta-\alpha)) \\ & -(Q\times\sin(2\alpha)-U\times\cos(2\alpha))\sin(2(\beta-\alpha))\cos(\delta) \\ & +V\times\sin(2(\beta-\alpha))\sin(\delta)] \qquad (8) \end{aligned}$$

With α is the 4 waveplate positions (0°, 22.5°, 45°, 67.5°), β is 0° for ordinary beam and 90° for extraordinary, and δ is wavelength dependant.

Operations

- Conditions could be harsh in Svalbard
  - Cause some misalignement due to wind vibration.

Solution: Using optical fiber collimating systems (With mirrors for achromaticity problems).

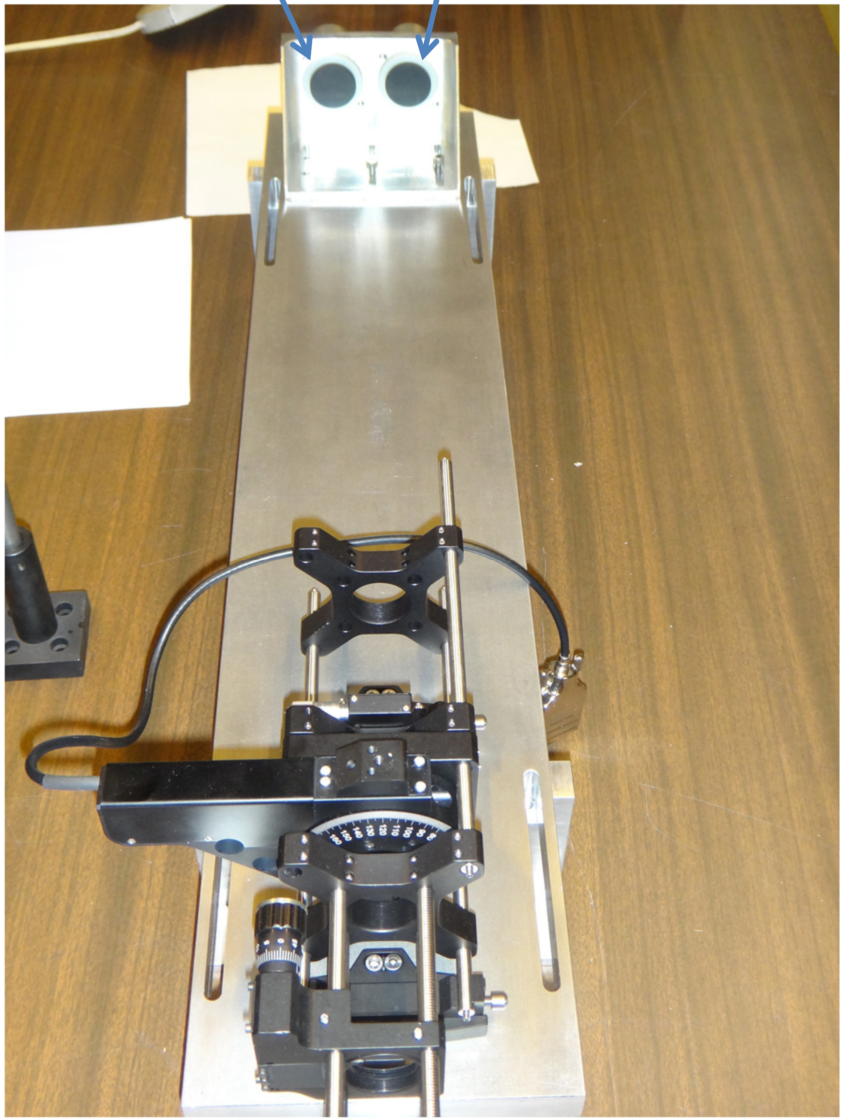


Extraordinary beam

Ordinary beam

With a white lamp.

Large fiber collimator to avoid defocalisation pb to to wind vibration



Operations

- 2015 January, Skibotn mainland Norway
- Winter first light and coordinated campaign, EISCAT/SPP/1er Cru in Svalbard.

Results 2015 campaign

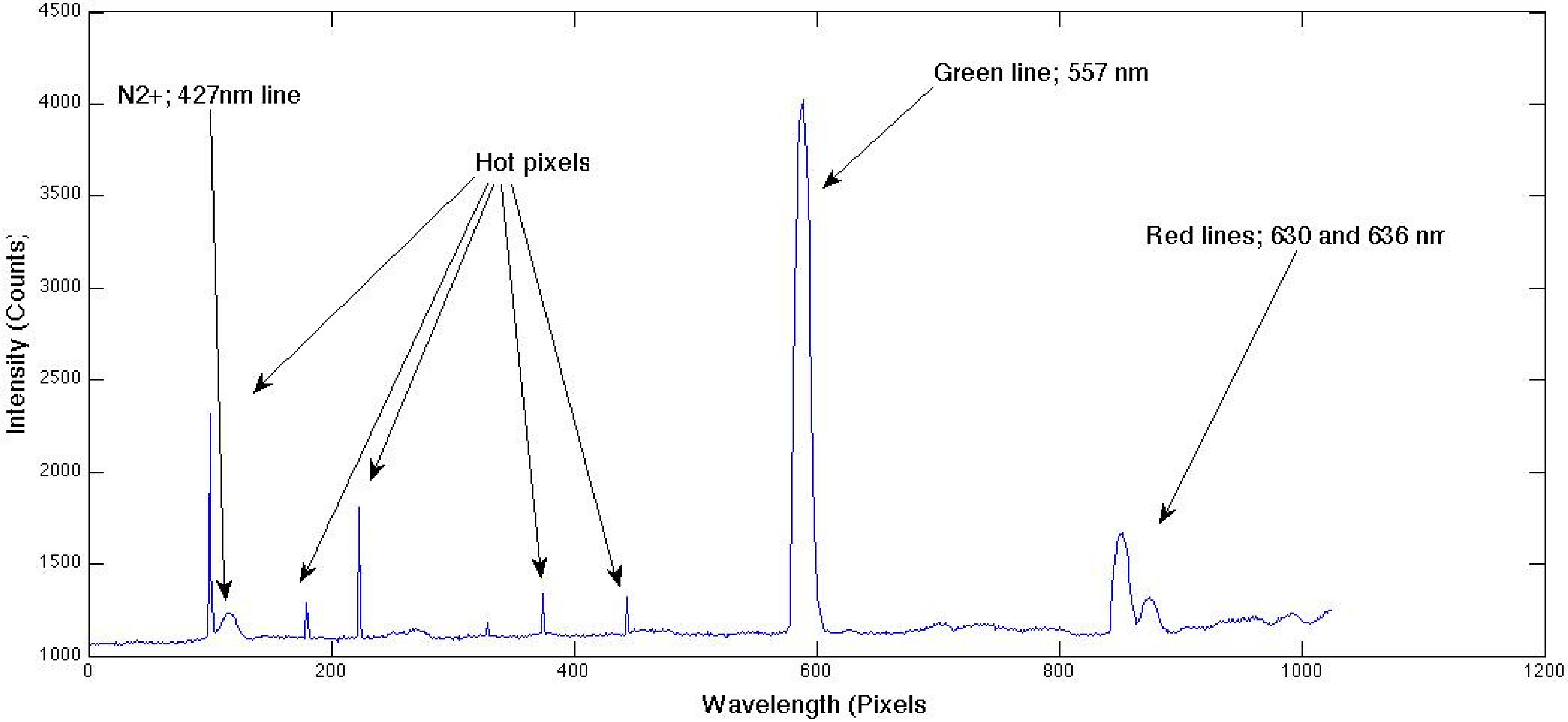
- Misalignement problem on one channel
    - e channel get less light
    - Exposure time are still too long
    - Poor spectral resolution (slit openning)
  - Due to a small mechanical problem
  - But

- Red line is confirmed to be polarised (DOLP between 3 and 4% during an auroral event)
    - First confirmation with an independent instrument

Overview of the data processing procedure

- Based on a non polarised green line
  - Identification of the lines
  - Hot pixels correction
  - Calculation of the intensities of both green and red lines (e and o beams).
  - And least square reduction (or ratio method).

Example of a spectrum



To summarise

- 2 STSM (and many more visits in Brussels) on this project
  - Confirmation of red line polarisation with an independent instrument.
    - Misalignment will be fixed…next Thursday (I stay in Brussels to work on the problem)
    - Next campaign 1 to 10 March 2016 in Skibotn with a fully operational instrument.
      - And hopefully polarisation of new auroral lines.