The auroral polarisation: A new measurement technique for monitoring the upper atmosphere

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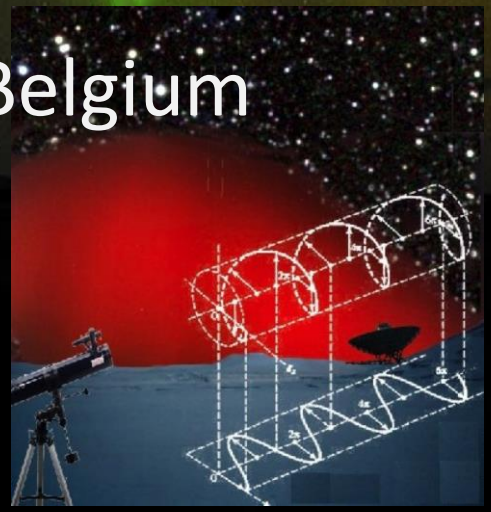

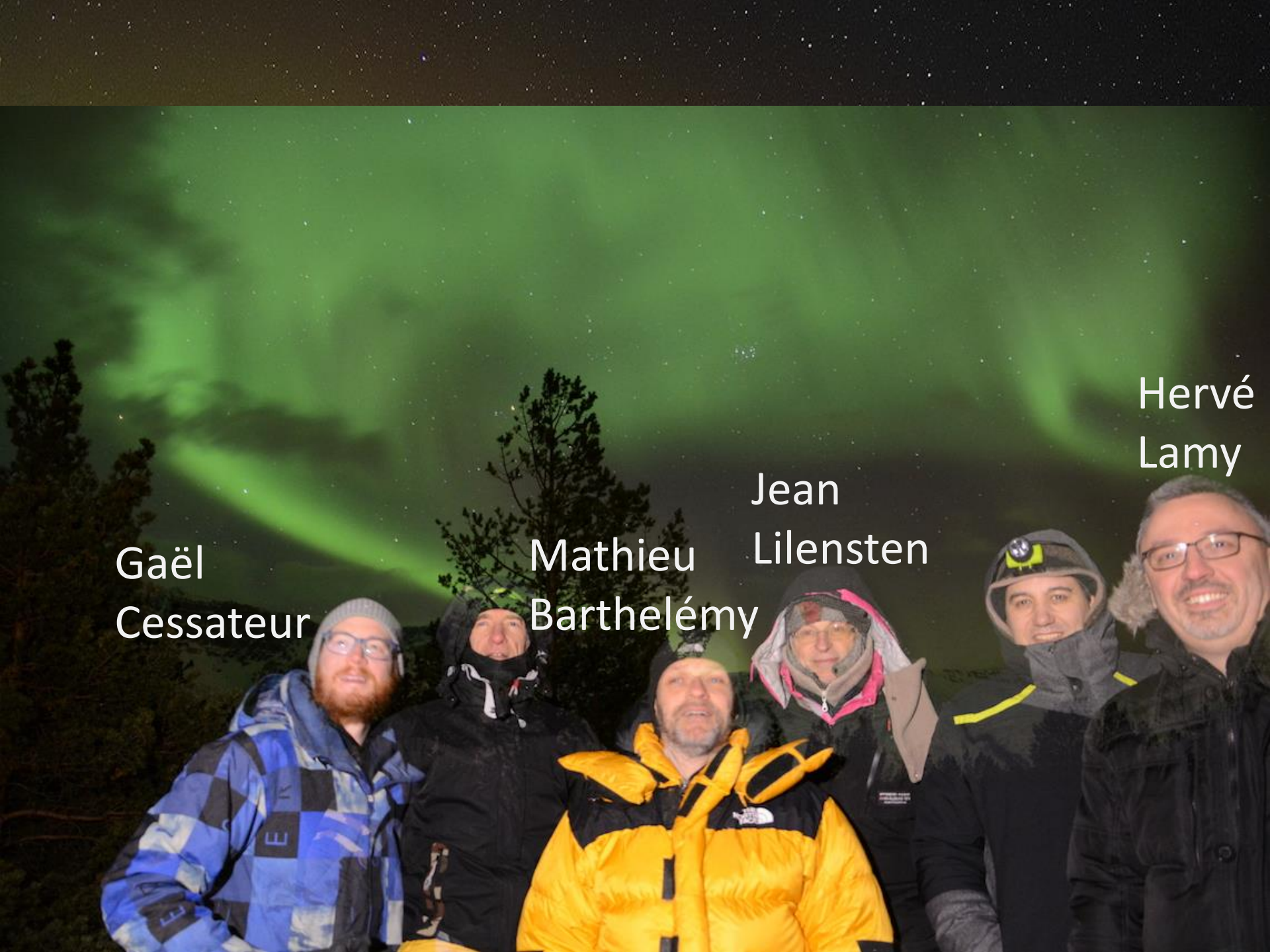
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Mathieu
Barthelémy
Jean
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Hervé
Lamy

« Could these emissions be polarised? »

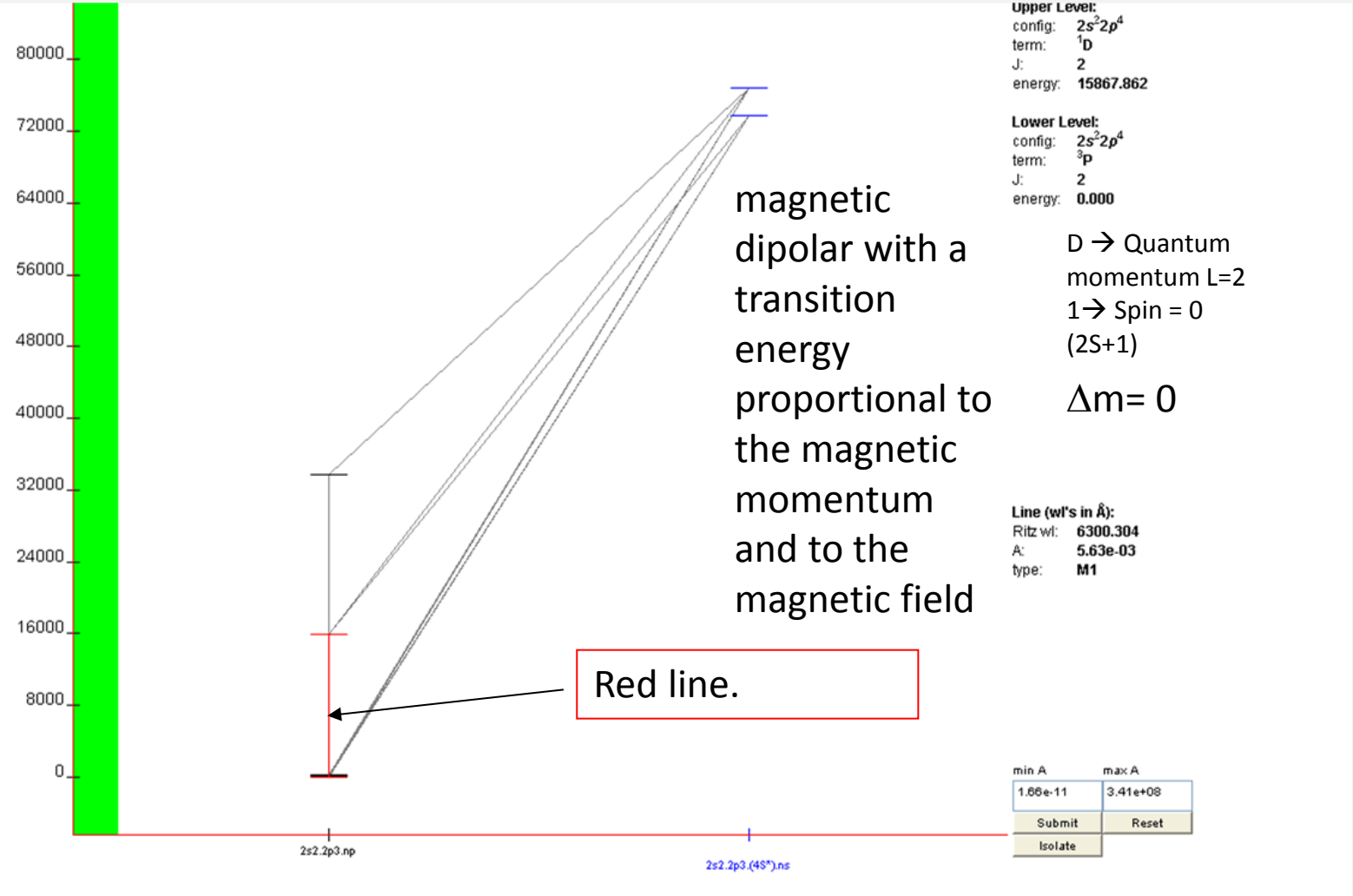
Polarized emissions.

- Atomic structure and selection rules
  - Polarization depends on the change of the m quantum number during the transition.
    - $\Delta m=+1$ circular right
    - $\Delta m=-1$ circular left
    - $\Delta m= 0$linear with electric field of the radiation // the magnetic local field.

- Green line: its upper state (1S) is not degenerated. This theoretical statement does not depend on the excitation mechanism

- But …

Atomic structure.



magnetic dipolar with a transition energy proportional to the magnetic momentum and to the magnetic field

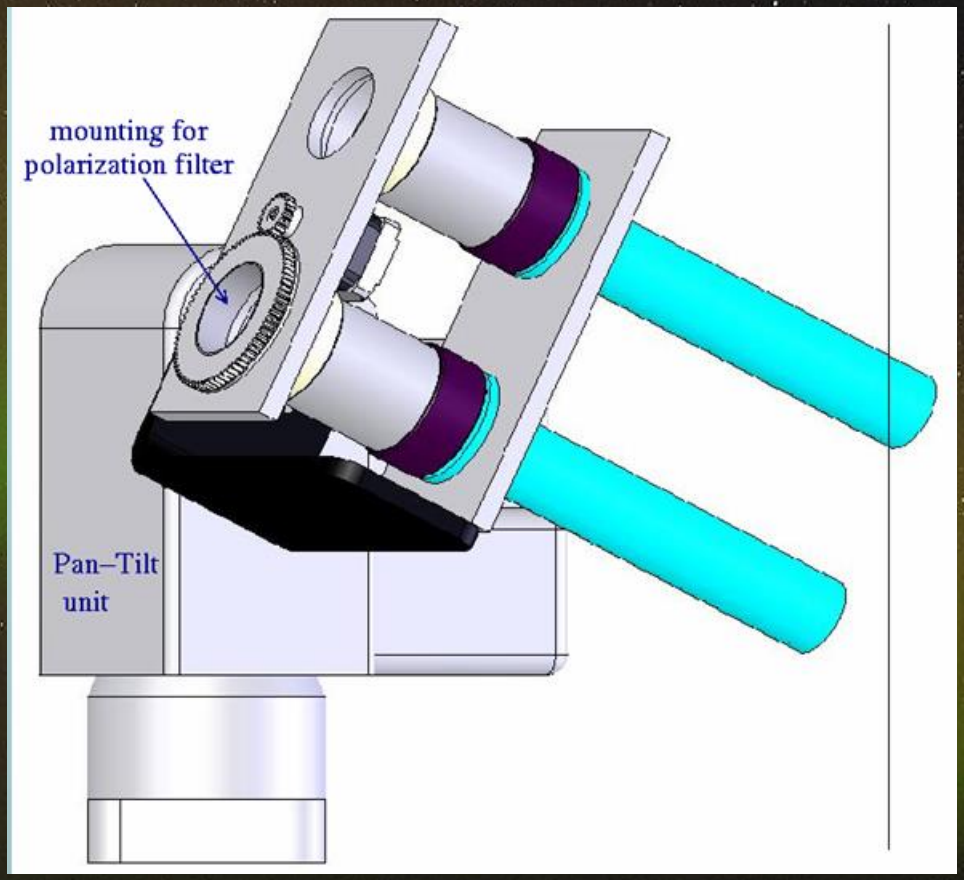
D → Quantum momentum L=2
1→ Spin = 0
(2S+1)

$\Delta m = 0$

Red line.

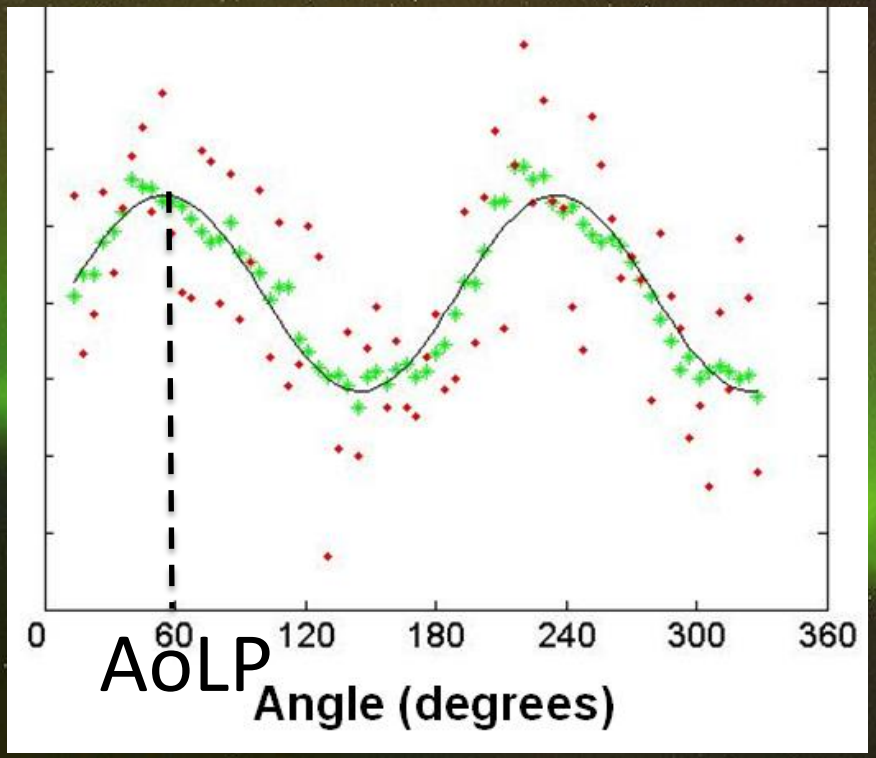
J. Lilensten, C. Simon, M. Barthélémy, J. Moen, R. Thissen and D. A. Lorentzen, Measurement of the polarization of the oxygen thermospheric red line: a review and a prospective in the frame of Space Weather studies, Space Weather, 4, S11002, doi:10.1029/2006SW000228, 2006

« What would be the source of the polarization ? »



Steerable Photo Polarimeter (SPP)

2008: discovery



DoLP

•Lilensten, J., J. Moen, M. Barthélemy, R. Thissen, C. Simon, D. A. Lorentzen, O. Dutuit, P. O. Amblard, and F. Sigernes (2008), Polarization in aurorae: A new dimension for space environments studies, *Geophys. Res. Lett.*, 35, L08804, doi:10.1029/2007GL033006, 2008

Hornsund, winter 2010-2011: The Degree of Linear Polarisation (DoLP) varies with the geomagnetic activity

M. Barthélémy, J. Lilensten , F. Pitout , C. Simon, J. Moen, D. Lorentzen, I.Mc. Crea, H. Rothkaehl, Polarization in auroral red line during coordinated ESR/optical experiment, **29**, 1101–1112, Annales Geoph., 2010, doi:10.5194/angeo-29-1101-2011

IPAG Institut de Planétologie et d'Astrophysique de Grenoble | Planet | OSUG Observatoire des sciences de l'Univers de Grenoble | BIRA-IASB | cnrs advancing the frontiers | UNIVERSITÉ Grenoble Alpes

2009 : discovery of the polarisation at Jupiter

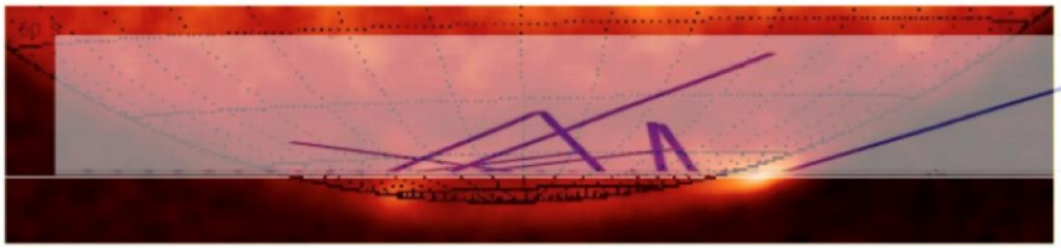


Fig. 8. Polarisation direction for data set 8, overlayed on the disk recorded at 7:49 UT. The length of the vector represents the polarisation degree.

M. Barthelemy, M. Lystrup, H. Ménager, S. Miller, J. Lilensten, First detection of polarization in jovian auroral H+3 emissions, Astronomy & Astrophysics, 530, A139 (2011), DOI: 10.1051/0004-6361/201014314

2013 and beyond: Modeling

$$\mathrm{DoLP} = \frac{Q}{I} = \frac{3\eta \sin^2 \Theta}{1 - \eta(1 - 3\cos^2 \Theta)}$$

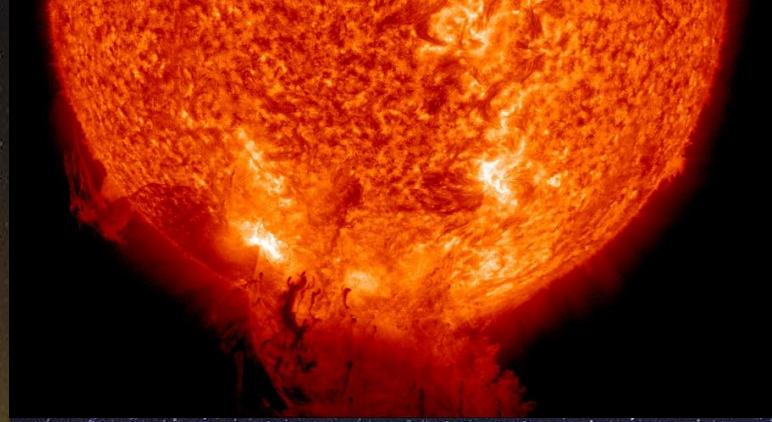
$$\eta(z) = C_\eta A(z) R_{\mathrm{coll}}(z), \qquad (1$$

where $A(z)$ is an anisotropy factor defined by:

$$A(z) = \frac{\int \int \mathrm{d}E\mathrm{d}\theta \, \sin\theta \, \Phi(z, E, \theta) \frac{1}{2}(3\cos^2 \theta - 1)\sigma(0 \rightarrow 2)}{\int \int \mathrm{d}E\mathrm{d}\theta \, \sin\theta \, \Phi(z, E, \theta)\sigma(0 \rightarrow 0)}$$

J. Lilensten, M. Barthelémy, P.O. Amblard, J. Moen, H. Rothkaehl, C. Simon Wedlund, H. Lamy, J. Eymard, and J. Ribot, Calibrated polarization of the thermospheric auroral red line, J. Space Weather Space Clim., **3**, A01, 12 pages, http://dx.doi.org/10.1051/swsc/2012023, 2013

2013 / 2014



From the modeling, we could deduce the scatering phase function in atomic oxygen

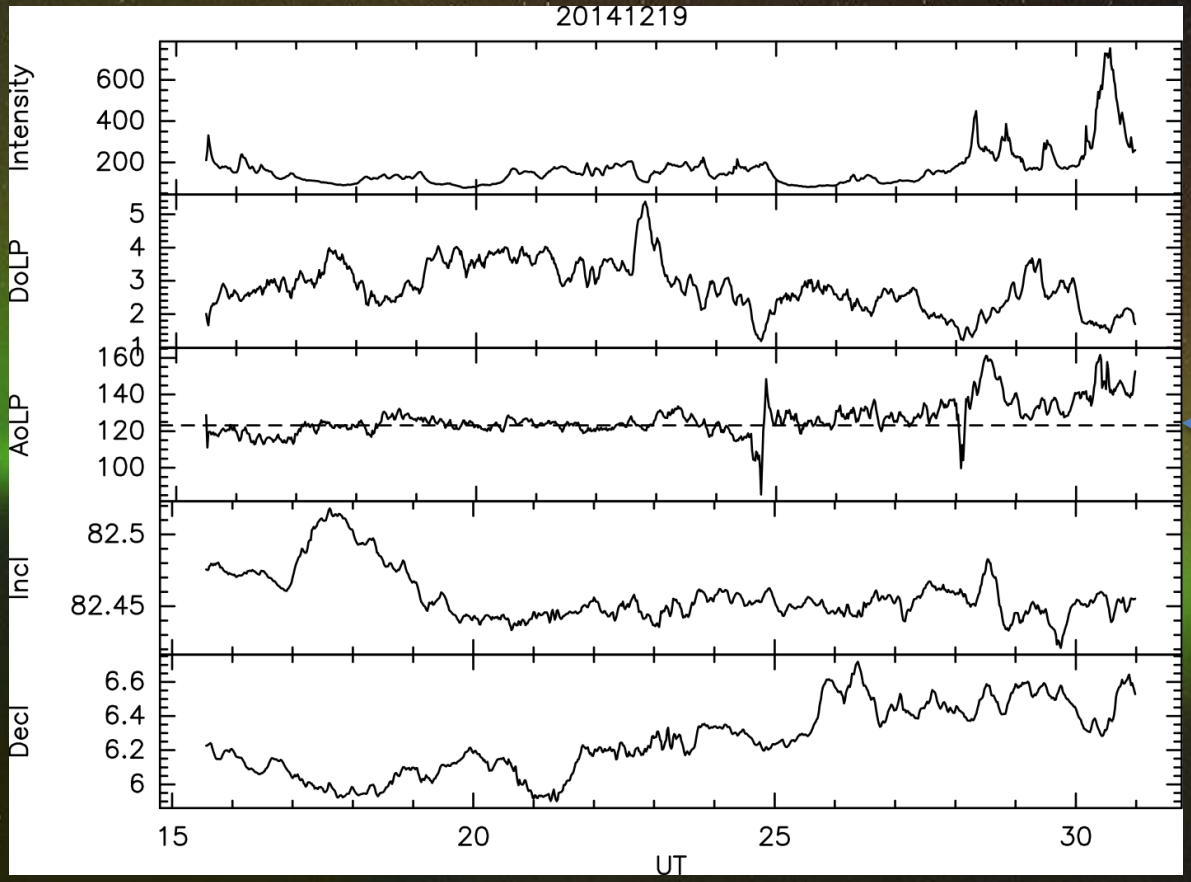
J. Lilensten, V. Bommier, M. Barthélémy, D. Bernard, H. Lamy, J. Moen, M. G. Johnsen, U. P. Løvhaug, and F. Pitout, The thermospheric auroral red line polarisation: comparison between theory and observations, J. Space Weather Space Clim., 5, A26, DOI: 10.1051/swsc/2015027, 2015

2014 / 2019: Wintering at a polar scientific base, Ny Alesund, 79° N

2014 / 2019: Goal: to cover a large span of solar activity

Crédit: E. Martin, Ciel et Espace

Maybe one of the most exciting result :



The AoLP is parallel to the theoretical magnetic field line during quiet periods and deviates during perturbed ones

Lilensten, M. Barthélemy, G. Besson, H. Lamy, M.G. Johnsen, J. Moen, The thermospheric auroral red line Angle of Linear Polarisation, J. Geophys. Res. Space Physics, **121**, 7125 – 7134, doi:10.1002/2016JA022941, 2016

IPAG Planet OSUG BIRA-IASB cnrs UNIVERSITÉ Grenoble Alpes

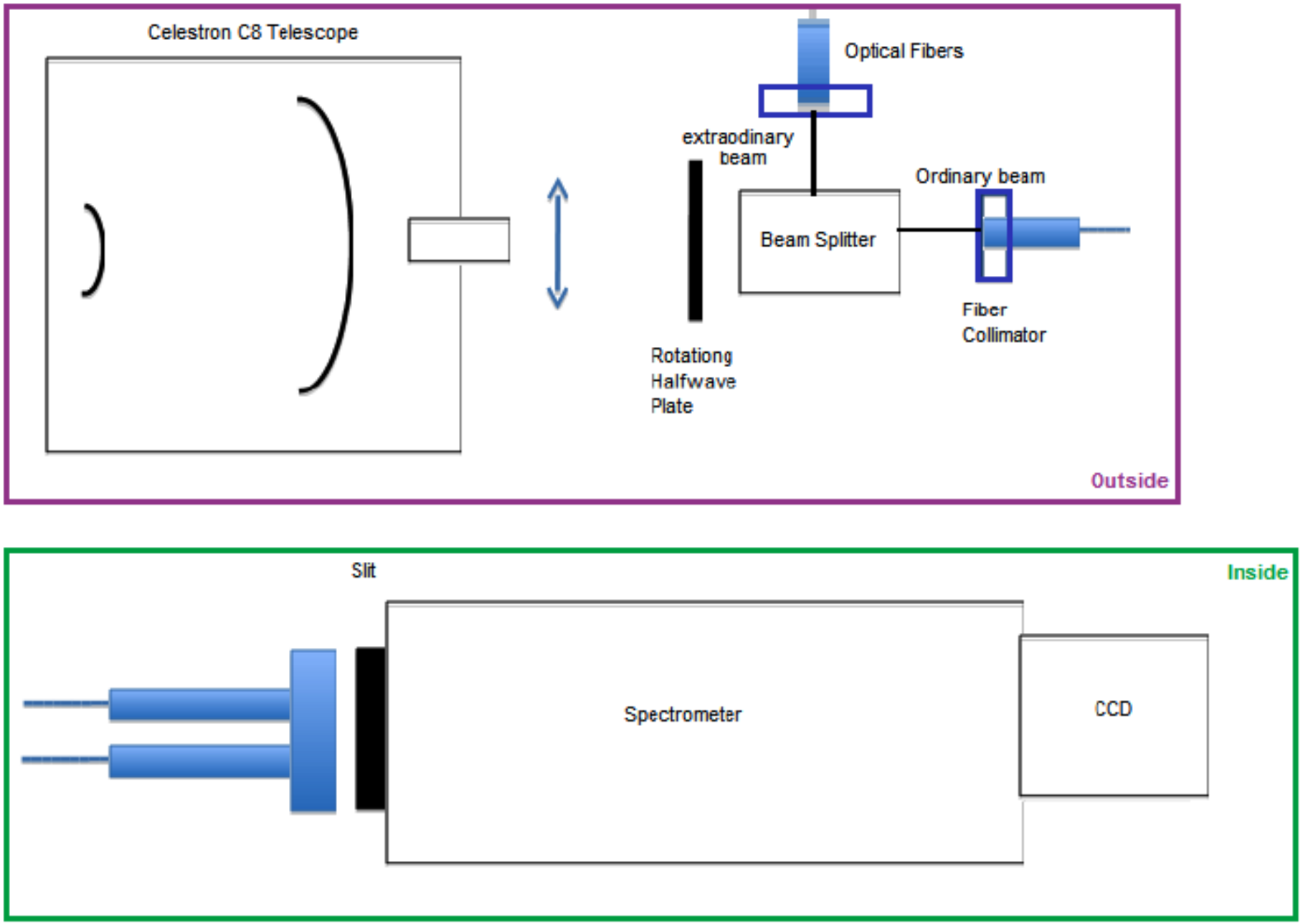
The polarisation could therefore constitute a new way to actually « see » the magnetic configuration in situ at 220 km. Can we monitor other altitudes ?

Lilensten, M. Barthélemy, G. Besson, H. Lamy, M.G. Johnsen, J. Moen, The thermospheric auroral red line Angle of Linear Polarisation, J. Geophys. Res. Space Physics, **121**, 7125 – 7134, doi:10.1002/2016JA022941, 2016


Premier Cru:

Can we explore the full spectrum, and not only the red line and therefore see other altitudes ?

Premier Cru was built (and is maintained) at BIRA with a strong STCE funding.


Celestron C8 Telescope
Optical Fibers
extraodinary beam
Ordinary beam
Beam Splitter
Fiber Collimator
Rotationg Halfwave Plate
Outside
Slit
Inside
Spectrometer
CCD


Premier
Cru
SPP

$$R_q^2 = \frac{\left(\frac{I_e}{I_o}\right)_0}{\left(\frac{I_e}{I_o}\right)_{45}} \qquad \text{and} \qquad R_u^2 = \frac{\left(\frac{I_e}{I_o}\right)_{22.5}}{\left(\frac{I_e}{I_o}\right)_{67.5}}$$

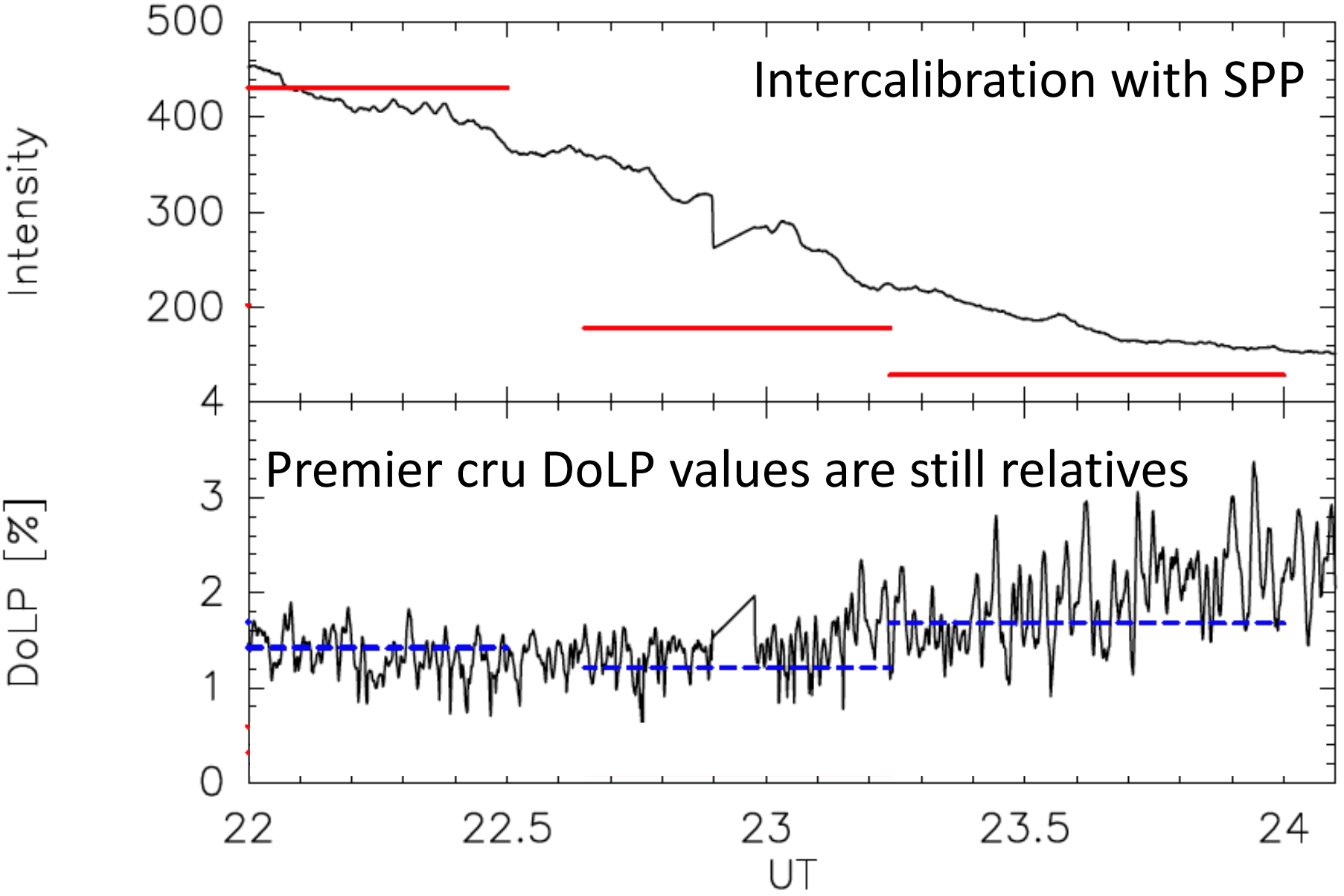
Where I_e and I_o represent the intensities of the lines in extraordinary and ordinary spectra at the position of the half-wave retarder indicates by the suffix on the bracket. Then,

$$q = \frac{R_q - 1}{R_q + 1} \qquad \text{and} \qquad u = \frac{R_u - 1}{R_u + 1}$$

Thus we can deduct the DoLP p:

$$p = \sqrt{q^2 + u^2}$$

The processing benefits from the fact that the green line is not polarised, which gives a permanent and absolute calibration


Intercalibration with SPP
Premier cru DoLP values are still relatives
Intensity
DoLP [%]
UT
500
400
300
200
4
3
2
1
0
22
22.5
23
23.5
24

First results : Other lines are polarized

- 636 nm (a fainter red line)
- 0-1 band of the N_2^+ first negative system at 427.8nm (blue emission) around an altitude of 85 km: DoLP about 2%

These results need confirmation and absolute calibration. If confirmed, we will have a way to monitor the space environment at at least 2 altitudes, in the E and in the F regions.

Measurements of the polarisation in N2+ 427.8 nm auroral band, Barthélemy M., Lamy H., Vialatte A., Lilensten J., Johnsen G. M., Cessateur G., Zaourar Boulasba N., submitted to GRL, 2017

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