Radio polarisation measurement of meteor trail echoes during the Perseids 2012

S. Ranvier[1], M. Anciaux[1], H. Lamy[1],
J. De Keyser[1], S. Calders[1] and E. Gamby[1]

(1) Belgian Institute for Space Aeronomy (IASB-BIRA), Brussels, Belgium

aeronomie.be

Federal science policy

.be

Outline

- Motivations
- Measurement setup
- Stokes parameters
- Examples
- Statistics
- Conclusions

Motivations

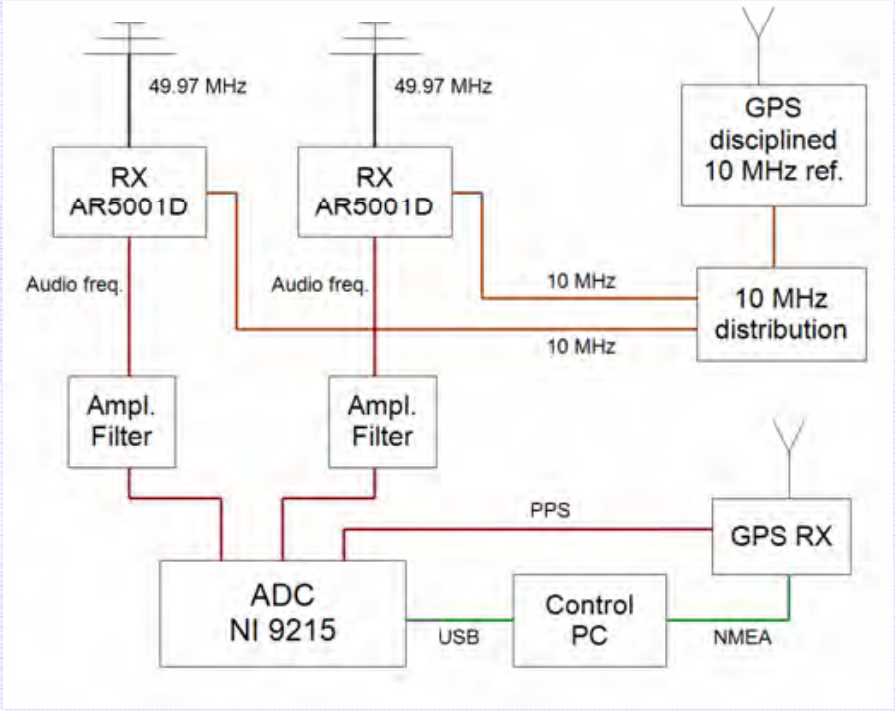
- Gain insights into the physical phenomena that produce the meteor echoes
- Analyse electron densities: in principle, the time variation of the polarisation of meteor echoes can provide information about electron densities in the meteor trail
- Study multiple branch echoes (e.g. Epsilon), since their occurrence is not well understood

Measurement setup

- **Beacon**: crossed dipoles with 8mx8m ground plane
  ⇨ Circularly polarised wave, towards zenith
- **Receiving station**:

  Dual polarised antenna (unlike other BRAMS stations): 2 crossed 3-element Yagi, sensitive to all polarisations

  2 RX synchronized with external 10 MHz reference. Signals from the 2 RX and PPS from GPS sampled simultaneously at 11025 Hz



Antenna in Uccle (Brussels)

Beacon in Dourbes, Belgium

aeronomie.be

Stokes parameters

Stokes parameters: set of values that describe the polarisation state of EM waves

$$\vec{S} = \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}$$

$$\begin{aligned} I &= |E_x|^2 + |E_y|^2, \\ Q &= |E_x|^2 - |E_y|^2, \\ U &= 2\mathrm{Re}(E_x E_y^*), \\ V &= 2\mathrm{Im}(E_x E_y^*), \end{aligned}$$

$Ip = \sqrt{Q^2 + U^2 + V^2}$ = degree of polarisation

where E_x and E_y are the received signals from the dual polarised antenna (orthogonal polarisations)

Extreme cases:

$\begin{pmatrix} 1 \\ 1 \\ 0 \\ 0 \end{pmatrix}$: Linearly polarized (horizontal)

$\begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix}$: Linearly polarized (vertical)

$\begin{pmatrix} 1 \\ 0 \\ 1 \\ 0 \end{pmatrix}$: Linearly polarized (+45°)

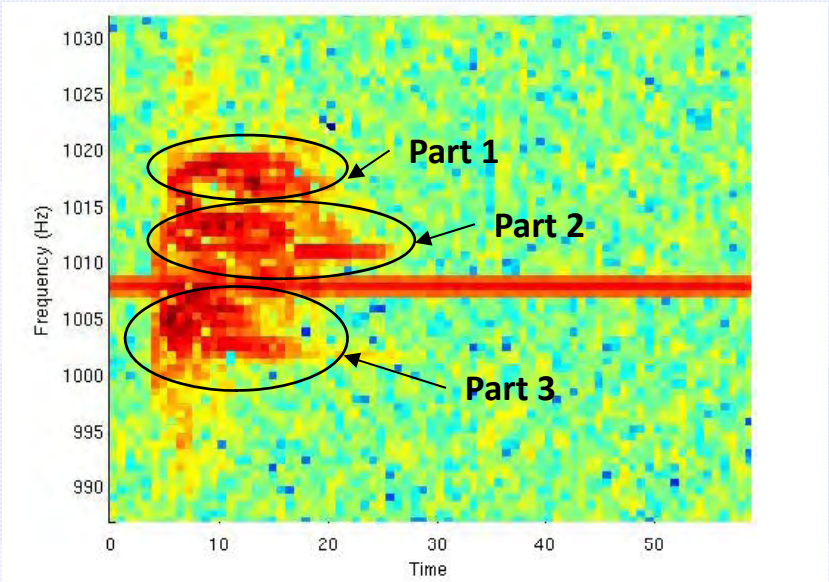
$\begin{pmatrix} 1 \\ 0 \\ -1 \\ 0 \end{pmatrix}$: Linearly polarized (-45°)

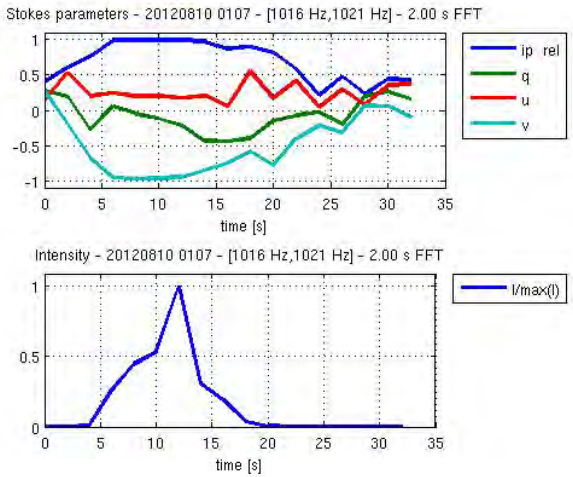
$\begin{pmatrix} 1 \\ 0 \\ 0 \\ 1 \end{pmatrix}$: Right-hand circularly polarized

$\begin{pmatrix} 1 \\ 0 \\ 0 \\ -1 \end{pmatrix}$: Left-hand circularly polarized

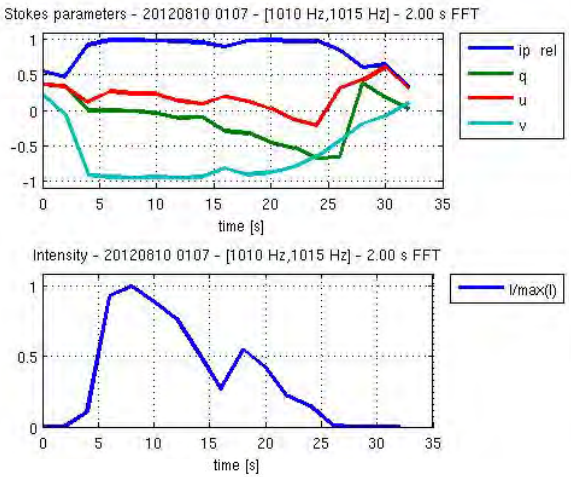
Example 1 / 6

- Multiple branch echo (Epsilon)
- 3 parts strongly polarised
- Fairly similar polarisation state at the beginning: left-hand circular
- Part 1: from L-H circular to elliptic at the end
- Part 2: all quite constant till t=16, then more and more linear -45°
- Part 3: fairly stable from t=4 to 14

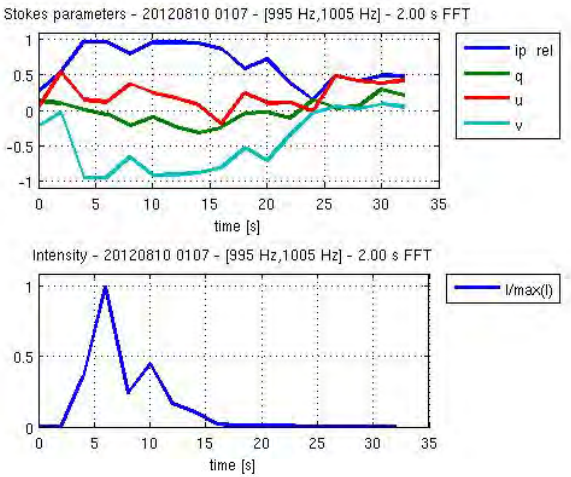




Part 1



Part 2



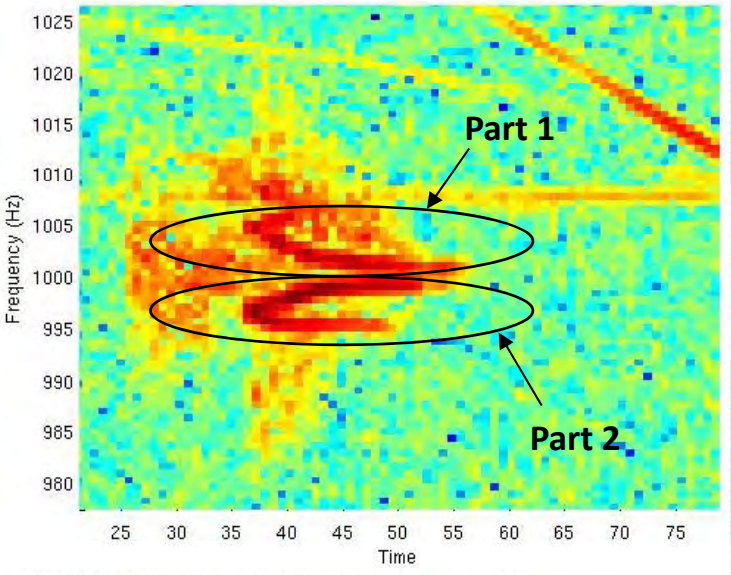
Part 3

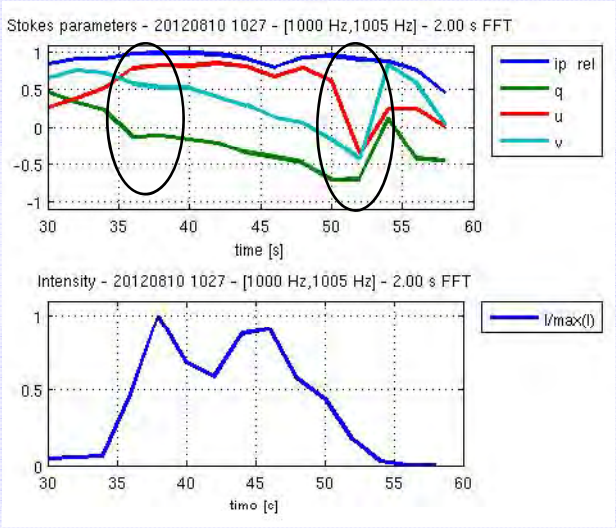
aeronomie.be

.be

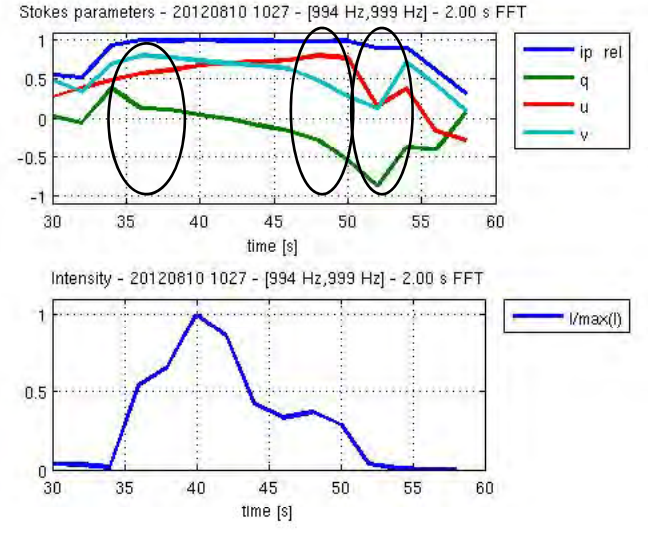
Example 2 / 6

- Multiple branch echo (Epsilon)
- 2 parts strongly polarised
- Slightly different polarisation state at beginning
- Part 1 : from rather linear +45° to almost linear vertical
- Part 2 : from rather R-H circular to almost linear +45° to clearly linear vertical





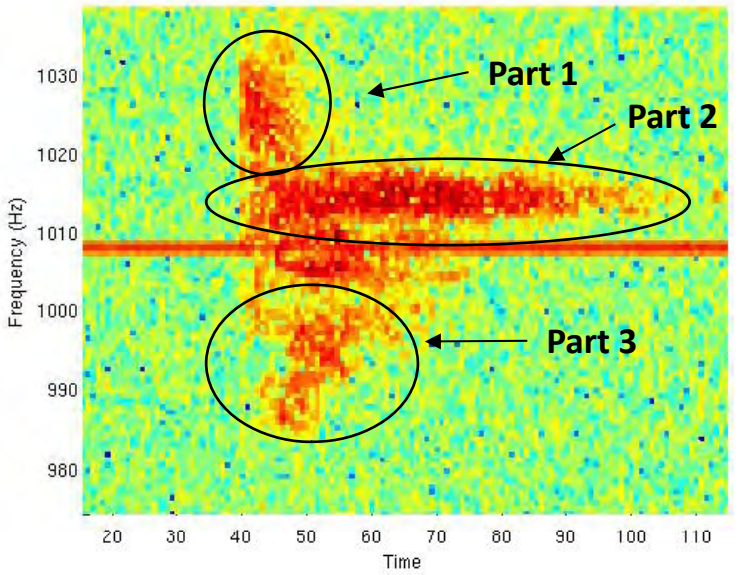
Part 1

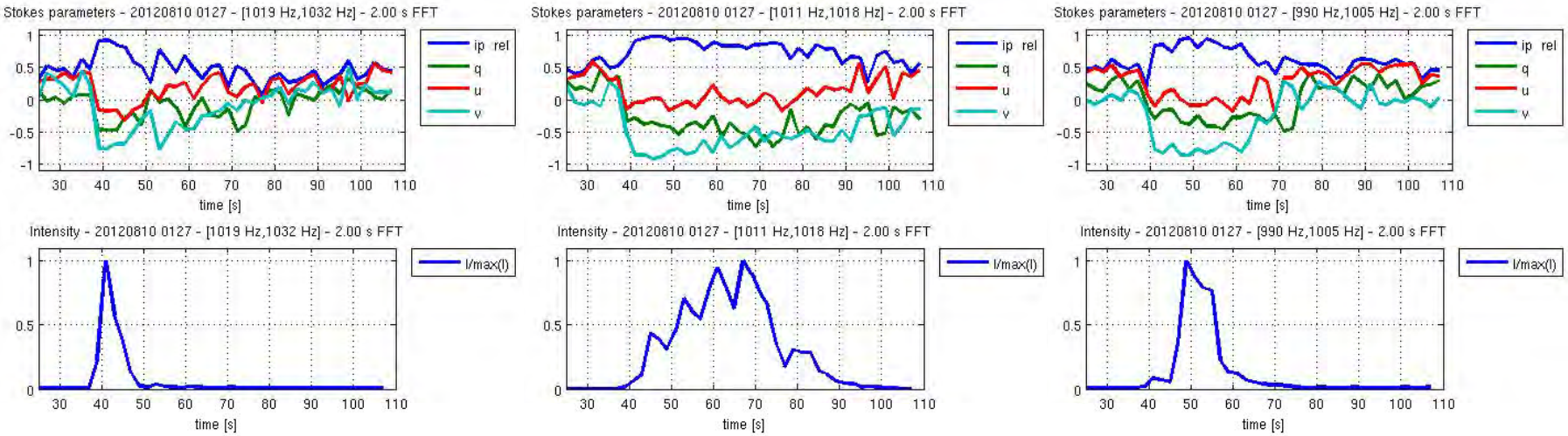


Part 2

Example 3 / 6

- Multiple branch echo
- 3 parts strongly polarised
- Fairly similar polarisation state at the beginning : Left-hand circular
- Parts 1 and 3: fairly stable
- Part 2: *Q* and *V* increase, more and more elliptic, *Ip* decreases

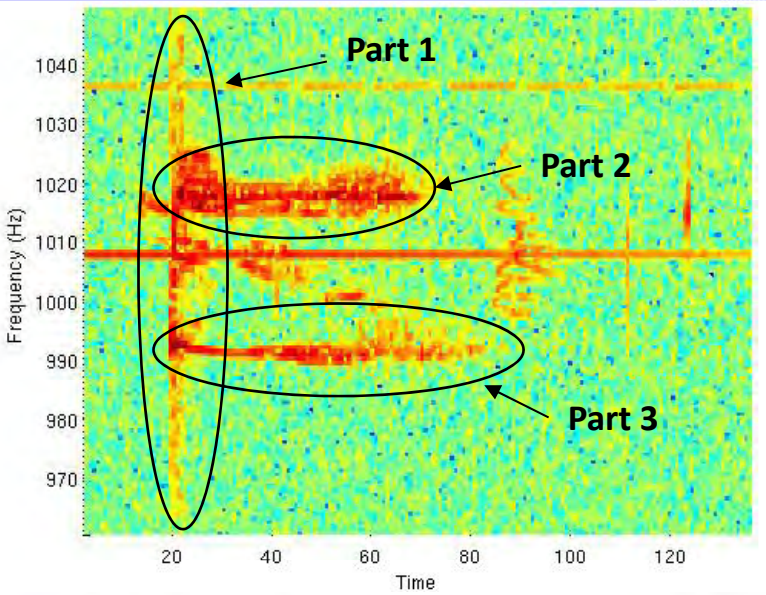


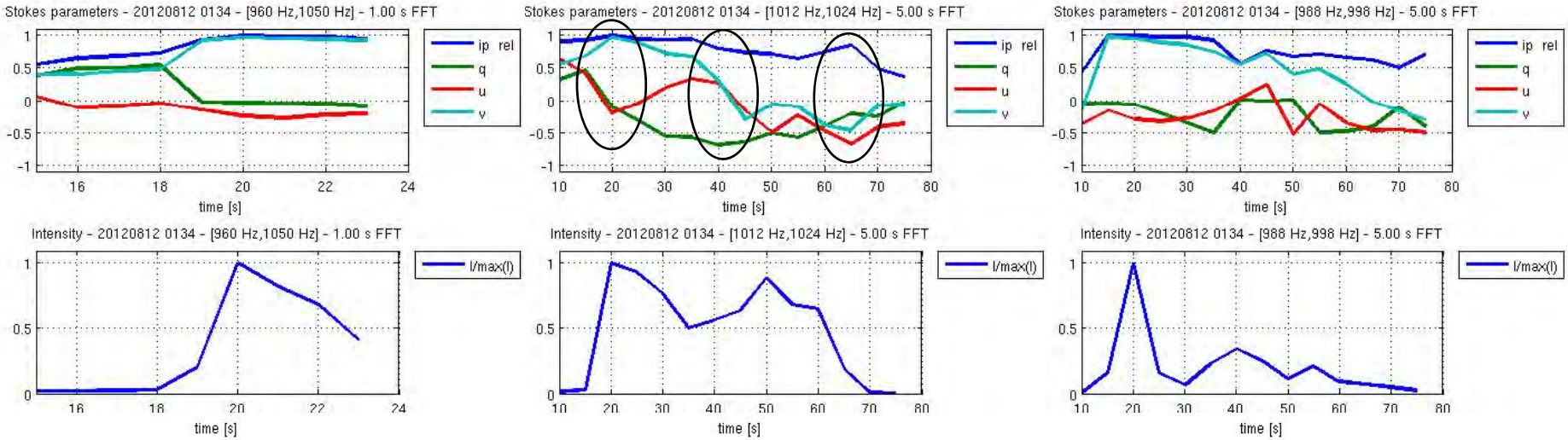


Part 1 Part 2 Part 3

Example 4 / 6

- Multiple branch echo
- 3 parts strongly polarised at beginning
- Similar polarisation state at beginning: right-hand circular
- Part 2 : from R-H circular to almost linear vertical to elliptic, *Ip* fluctuates
- Part 3: from R-H circular to elliptic, *Ip* decreases

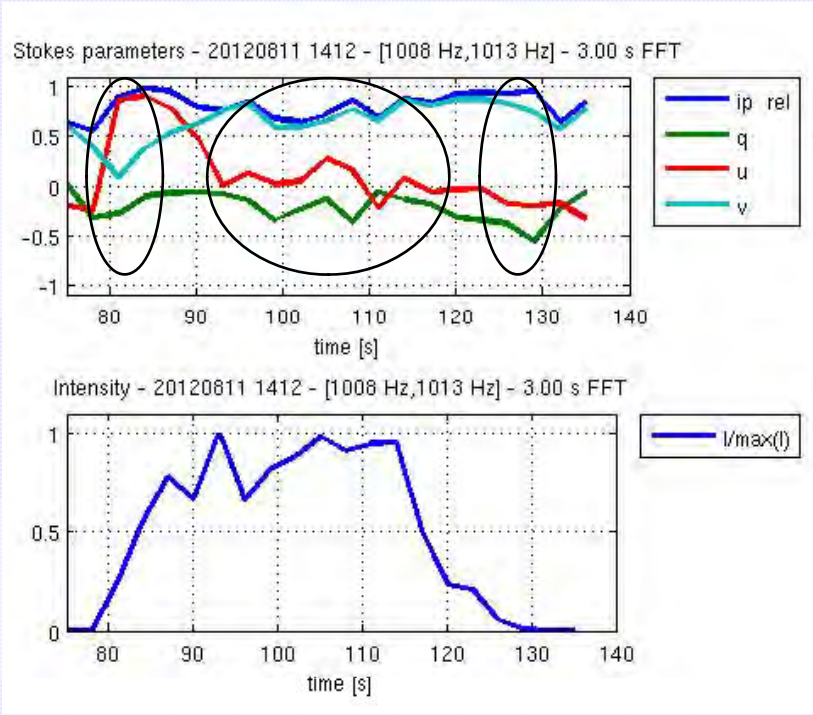


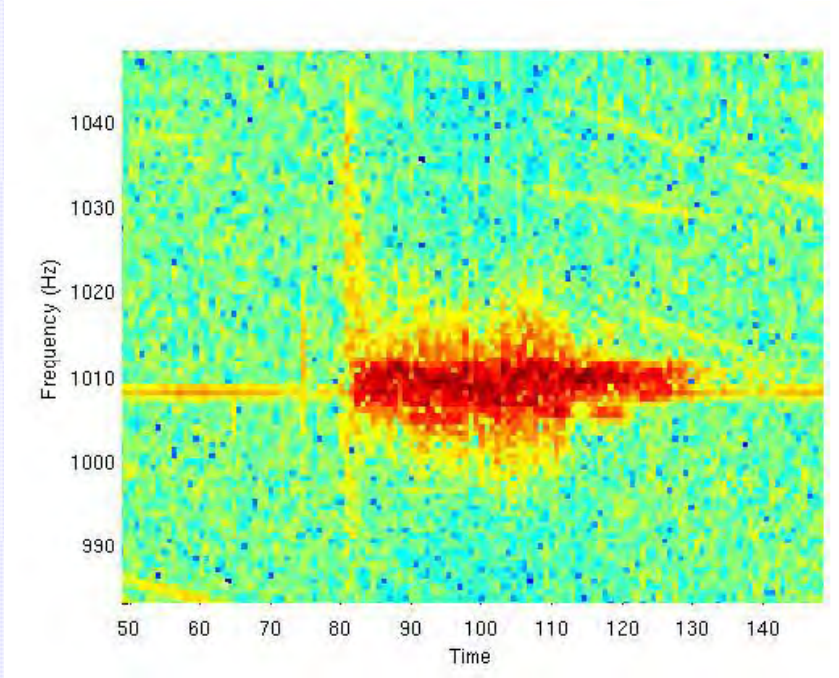


Part 1 Part 2 Part 3

Example 5 / 6

- Over dense
- *Ip* fluctuates
- From clearly linear +45° to clearly R-H circular to elliptic

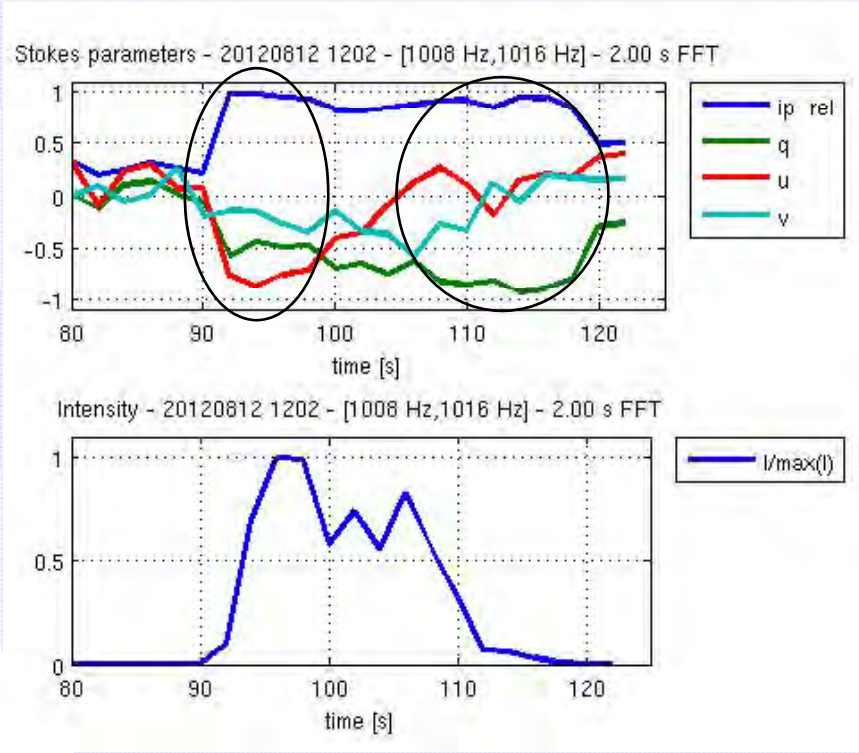


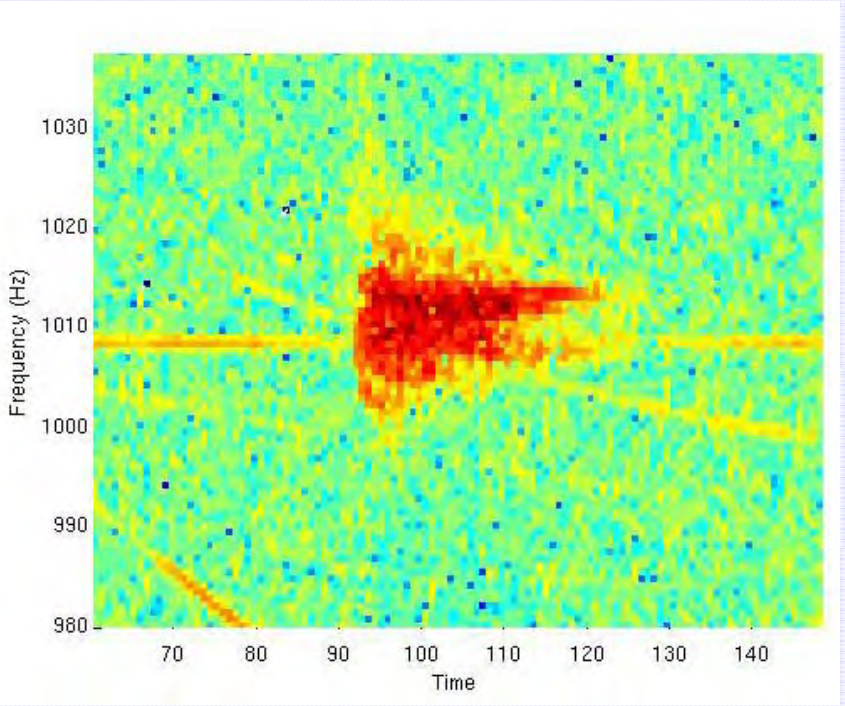


aeronomie.be

Example 6 / 6

- Over dense
- strongly polarised
- From clearly linear -45° to clearly linear vertical

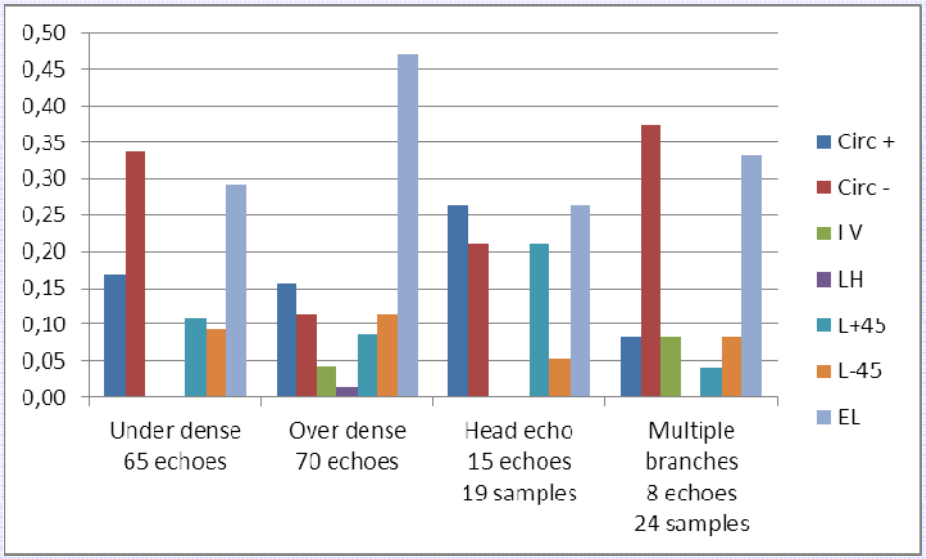


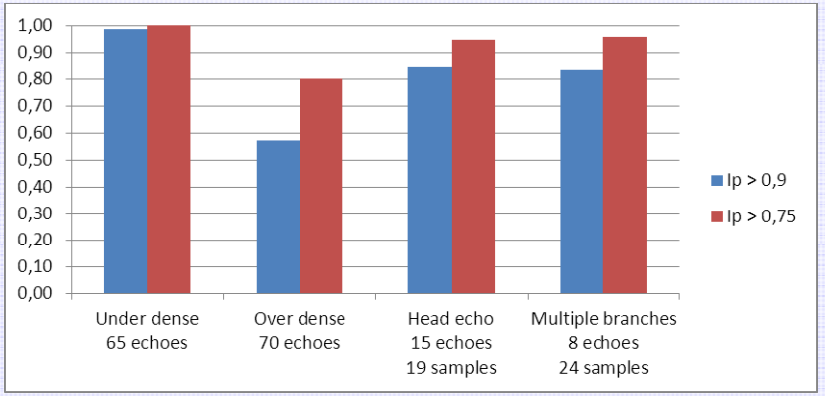


aeronomie.be

Statistics

- 158 echoes analysed during 10-12.08.2012
- 4 groups: under dense, over dense, head echoes and multiple branch





- For polarisation state, nothing systematic but some trends:

  For under dense and multiple branch: right-hand circular is dominant

  For others: more distributed

- For all categories most of the echoes are strongly polarised

aeronomie.be

Conclusions

From this preliminary analysis, it can be seen that:

- Most of the echoes are strongly polarised
- During long echoes large variations of polarisation state can occur
- In multiple branch echoes polarisation state of different branches are quite similar
- For under dense and multiple branch: right-hand circular is dominant
- For others: more distributed
- With the limited number of studied echoes, statistical results should be taken with caution
- In the future, we will try to compare our measurements with theoretical predictions
- Several calibration tests must be carried out:
  - Determination of relative gain of the 2 systems (antenna + receiver)
  - Accurate determination of phase shift between the 2 systems
  - Determination of error bars associated with the Stokes parameters
- Need to study over longer period and over much larger number of echoes, but this is very time consuming !!

Thank you !!

aeronomie.be

.be