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
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)](image1)

![Beacon in Dourbes, Belgium](image2)
Stokes parameters

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

\[
\mathbf{S} = \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} I \\ Q \\ U \\ V \end{pmatrix}
\]

\[
\begin{align*}
I &= |E_x|^2 + |E_y|^2, \\
Q &= |E_x|^2 - |E_y|^2, \\
U &= 2\text{Re}(E_x E_y^*), \\
V &= 2\text{Im}(E_x E_y^*),
\end{align*}
\]

\[I_p = \sqrt{Q^2 + U^2 + V^2} = \text{degree of polarisation}\]

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

**Extreme cases:**

- \[
\begin{pmatrix} 1 \\ 1 \\ 0 \\ 0 \end{pmatrix} : \text{Linearly polarized (horizontal)}
\]
- \[
\begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix} : \text{Linearly polarized (vertical)}
\]
- \[
\begin{pmatrix} 1 \\ 0 \\ 1 \\ 0 \end{pmatrix} : \text{Linearly polarized (+45°)}
\]
- \[
\begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix} : \text{Linearly polarized (-45°)}
\]
- \[
\begin{pmatrix} 1 \\ 0 \\ 0 \\ 1 \end{pmatrix} : \text{Right-hand circularly polarized}
\]
- \[
\begin{pmatrix} 1 \\ 0 \\ 0 \\ -1 \end{pmatrix} : \text{Left-hand circularly polarized}
\]
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
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
• 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, $I_p$ decreases
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, \( I_p \) fluctuates
- Part 3: from R-H circular to elliptic, \( I_p \) decreases
Example 5/6

- Over dense
- $I_p$ fluctuates
- From clearly linear $+45^\circ$ to clearly R-H circular to elliptic
Example 6/6

- Over dense
- Strongly polarised
- From clearly linear -45° to clearly linear vertical
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
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 !!