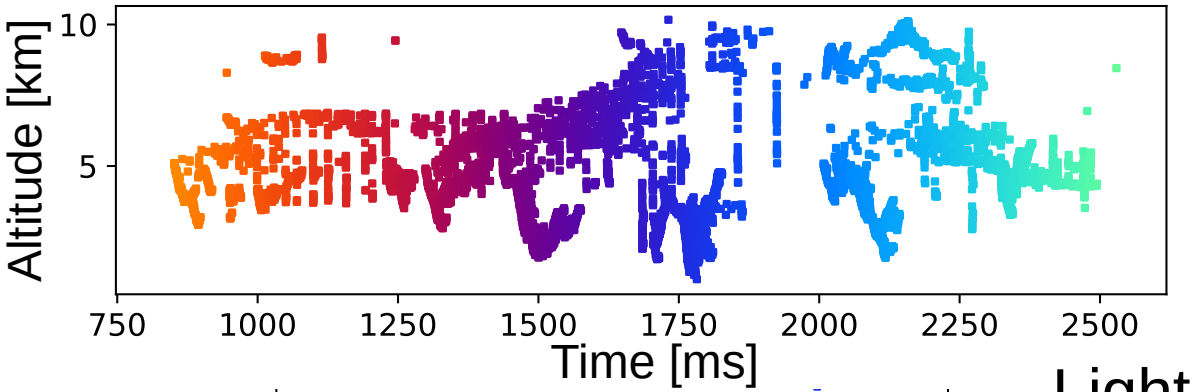
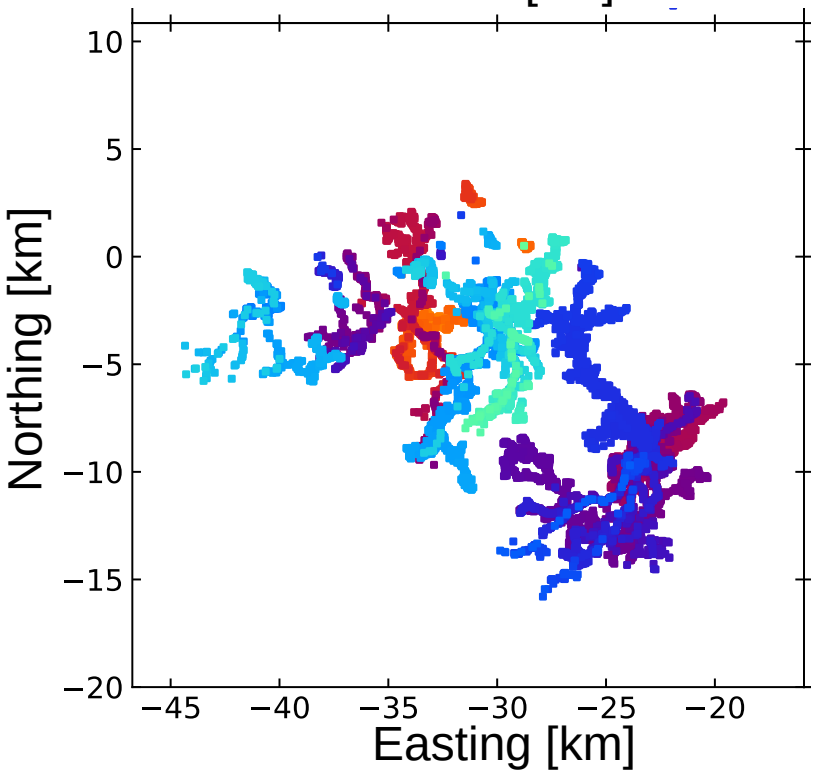
The 3D Polarization of Recoil Leaders

Brian Hare,
Olaf Scholten, Joe Dwyer,
Ningyu Liu, Chris Sterpka,
Stijn Buitink, Sander ter Veen

university of groningen





-Lightning event imaged with Impulsive Imager

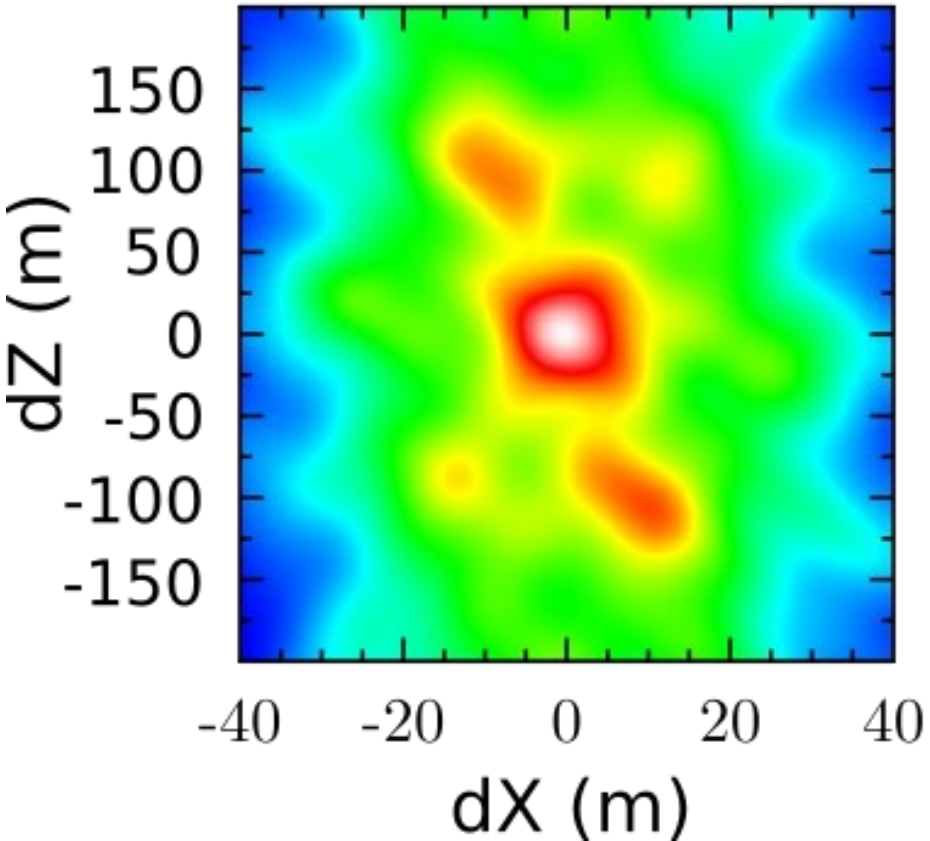
-142,400 located VHF sources

-Resolution limited by overlapping sources

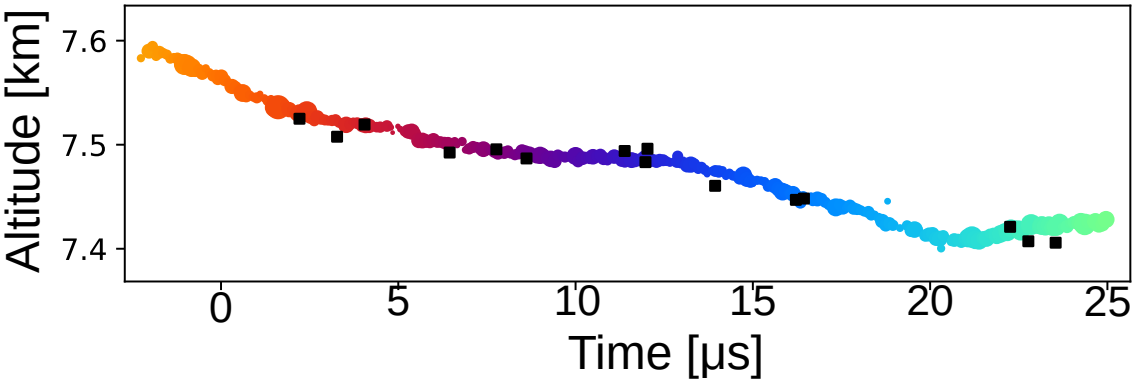
NEED 3D INTERFEROMETRY!!

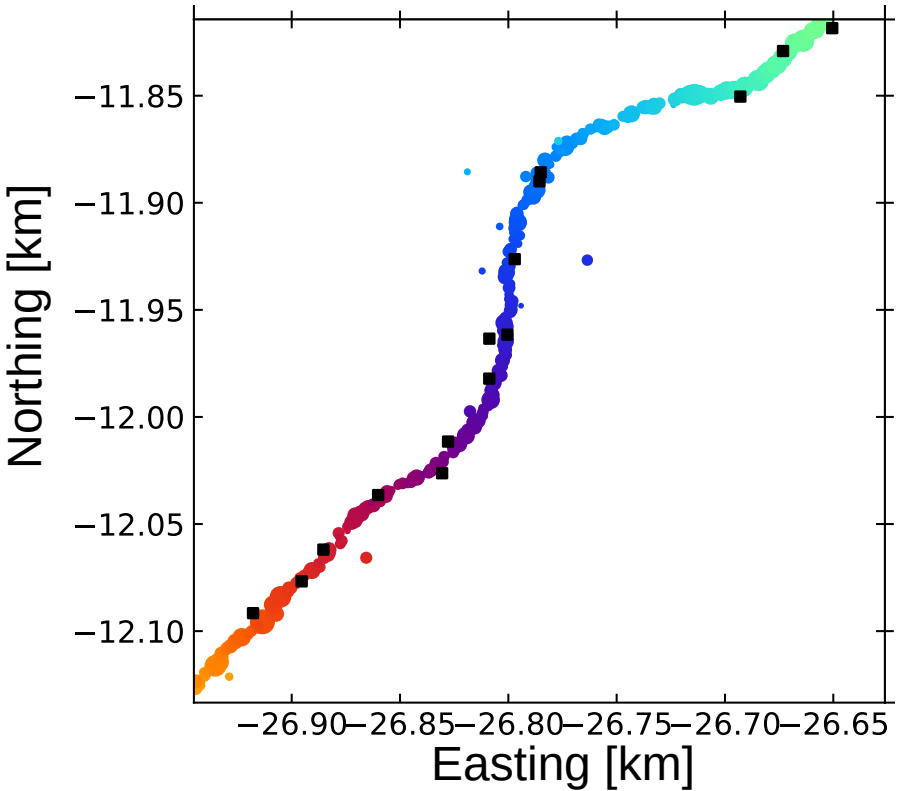
3D interferometry

Beamformed Image
Sliced at R = 30 km



- Sum measured E-fields
  - Account for time delays
  - Account for polarization
    - This is very tricky
- Form 3D image
  - Integrate over 100 ns
- Choose point of highest intensity





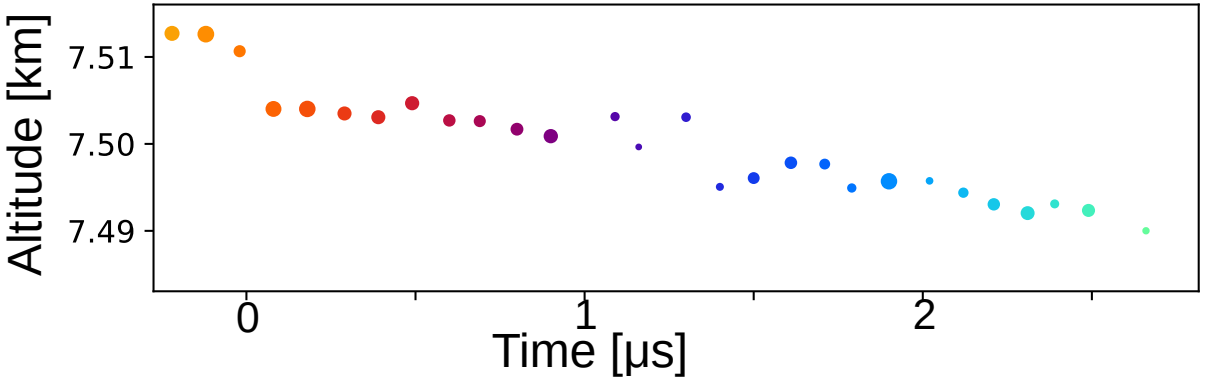
Small Section of Recoil Leader

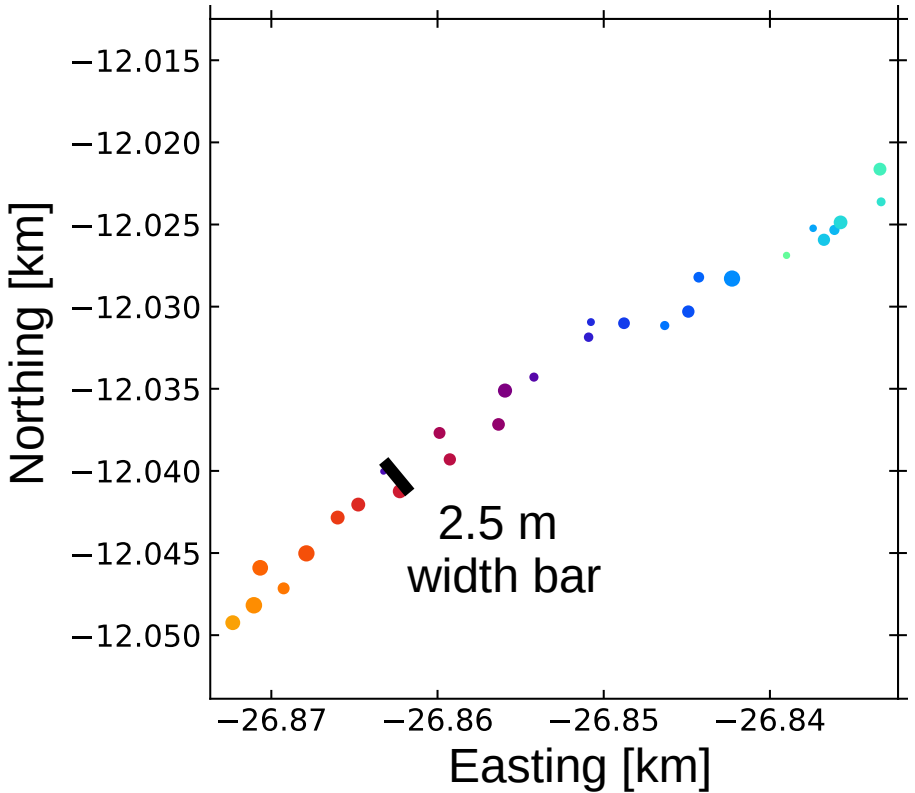
-One of our cleanest events

-Black dots are previous technique
- -Impulsive Imager

-Colored dots are interferometry
- -Significantly higher detail

-no evidence of stepping (in this recoil)

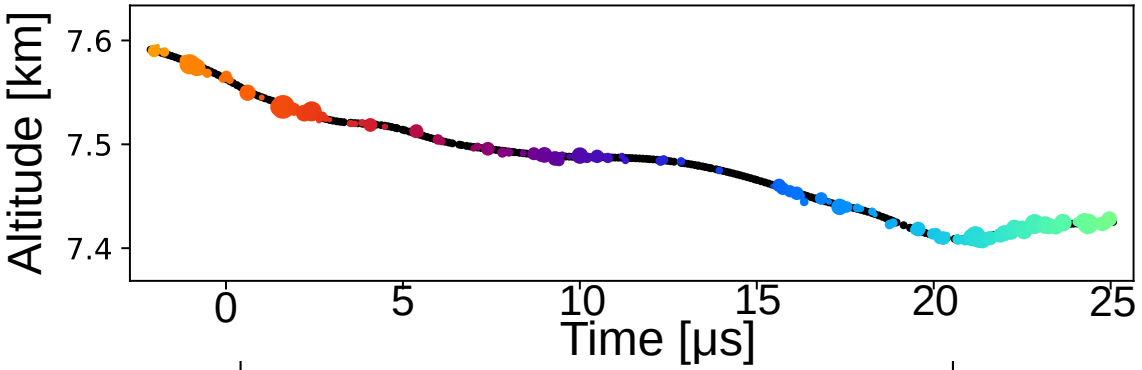


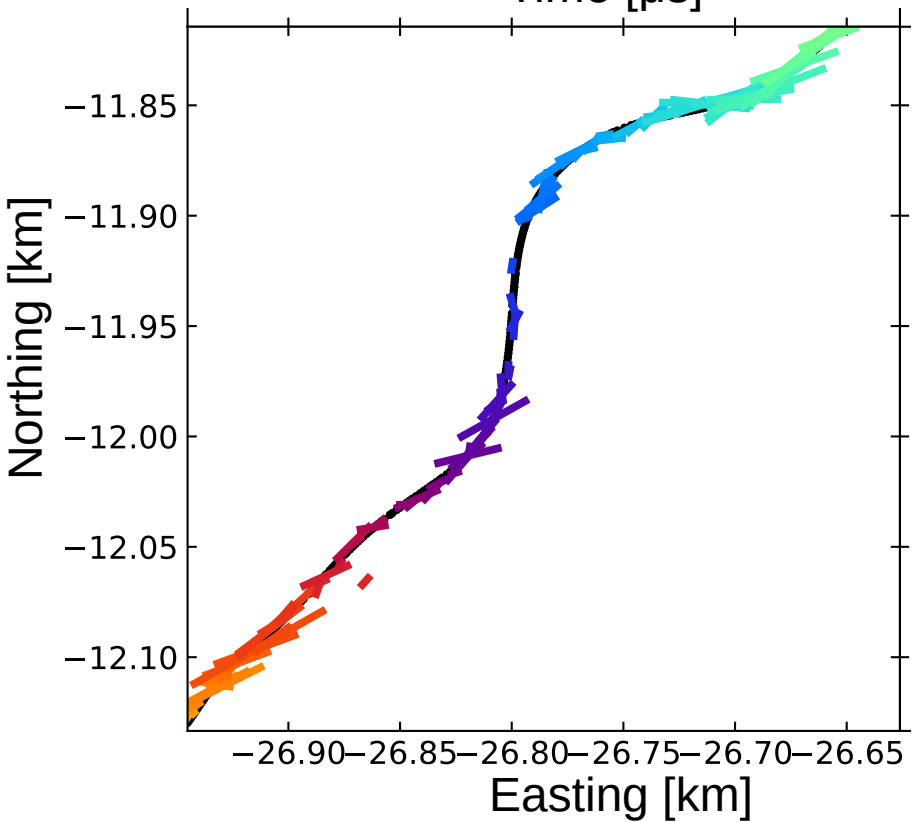


- Zoom-in to previous plot

- VHF width is about 2 m
  -consistent with location accuracy

-Significantly smaller than corona region
  (order of 20 m width)



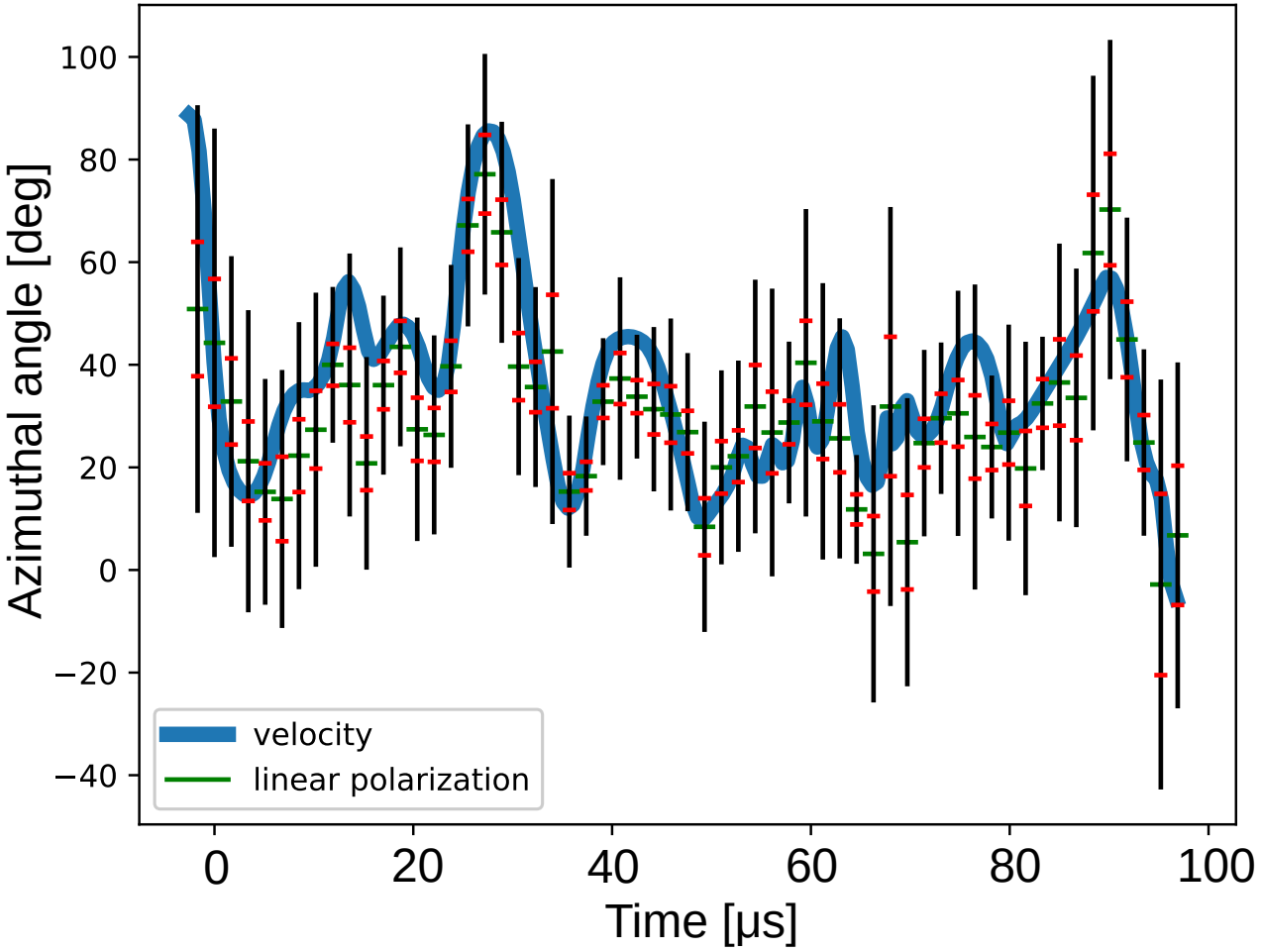


-Colored lines show linear polarization
  - only strongest pulses shown

-Black line shows spline to recoil track

-Polarization is parallel to leader!

-This type of plot is misleading
  -Statistics on next slide



-Blue line shows azimuthal angle of the spline

-Each bar is a bin of polarization
- center is average
- black bar is standard dev.
- red bars are standard error

- Polarization clearly follows the leader

Conclusions

- New interferometry technique
  - Full 3D
  - Accounts for 3D polarization
  - Significantly higher resolution than any previous technique

- Applied to recoils
  - VHF emission region is smaller than corona region
  - Linear polarization parallel to channel
    - RESULT: significant streamer activity in old channel
  - Probably not general to all recoils

Notable Publications

- “Interferometric imaging of Intensely Radiating Negative Leaders”
  Physical Review D, DOI: 10.1103/PhysRevD.105.062007

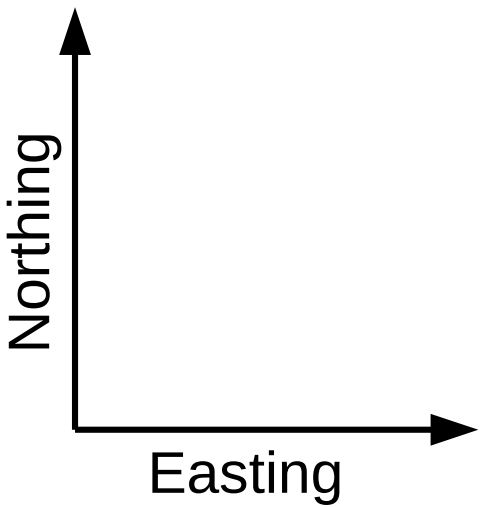
- “The Spontaneous Nature of Lightning Initiation Revealed”
  GRL, DOI: 10.1029/2021GL095511

- “Time Resolved 3D interferometric imaging of a section of a negative leader with LOFAR”
  Physical Review D, DOI: 10.1103/PhysRevD.104.063022

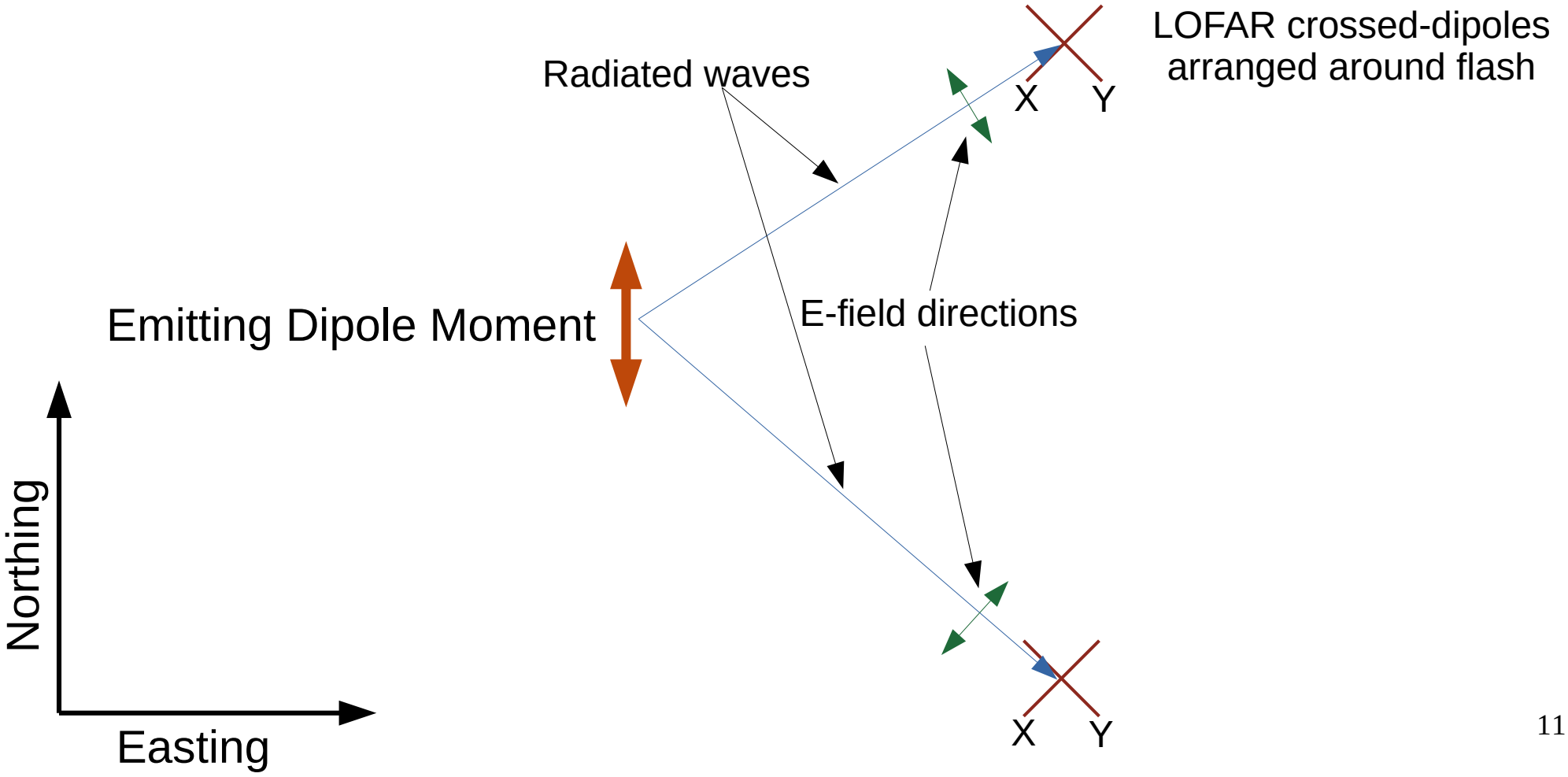
Why polarization is hard

LOFAR crossed-dipoles arranged around flash

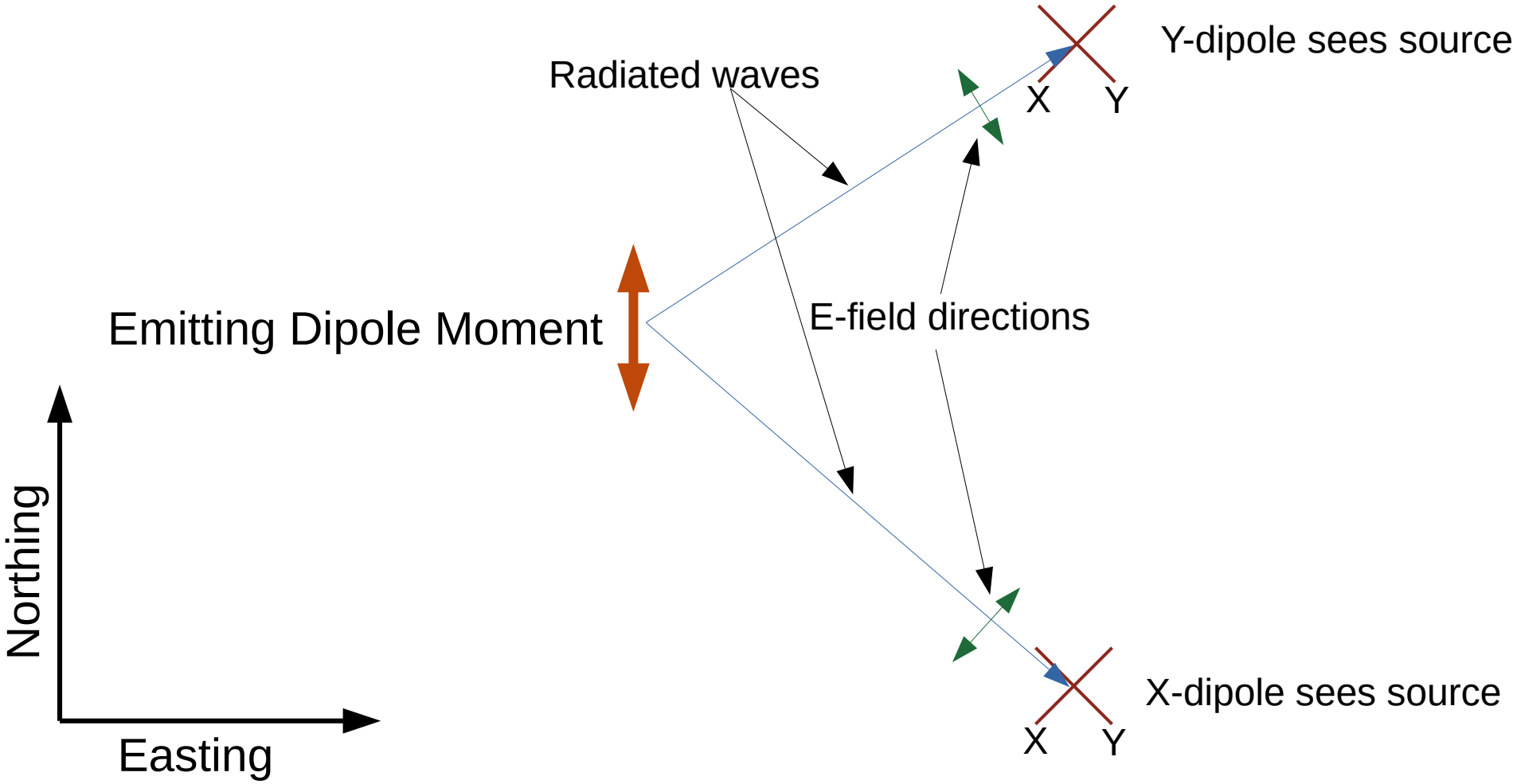
Emitting Dipole Moment



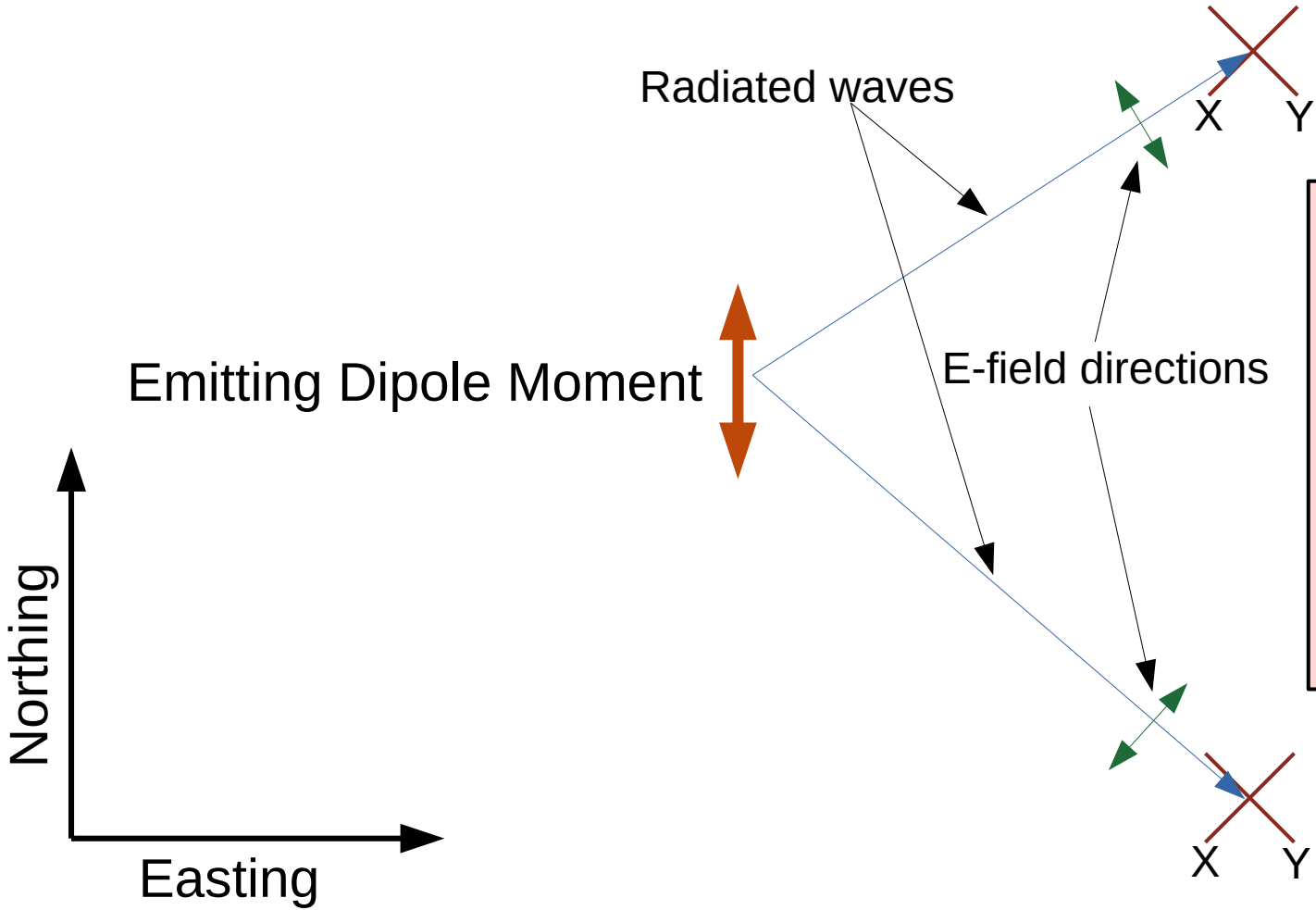
Why polarization is hard



Why polarization is hard



Why polarization is hard



CONCLUSION

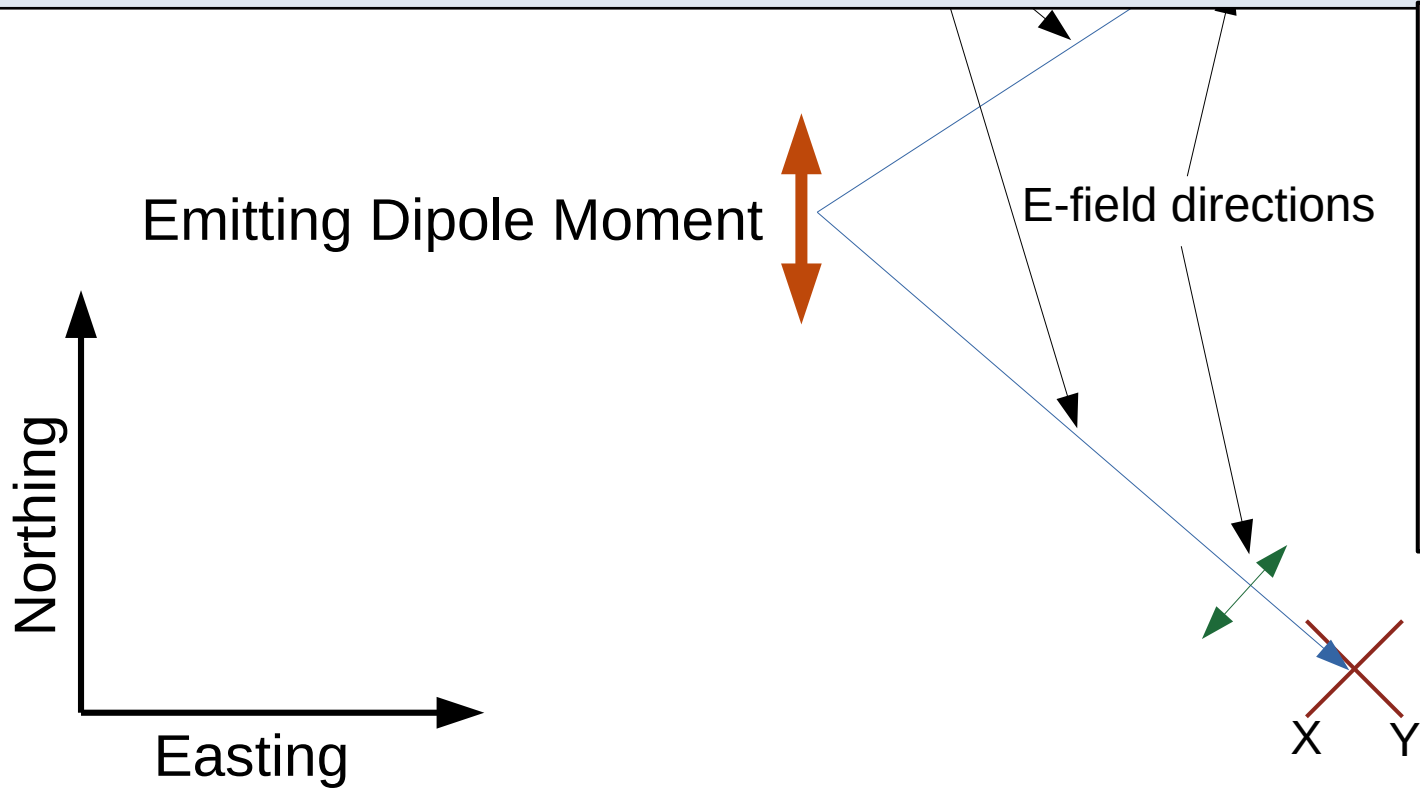
- Observed fields are in different directions from each other!
- Observed fields are in different directions from source!!

See paper:

"Interferometric imaging of Intensely Radiating Negative Leaders"

Physical Review D, DOI: 10.1103/PhysRevD.105.062007

For solution to polarization problem, and interferometry details



CONCLUSION

- Observed fields are in different directions from each other!
- Observed fields are in different directions from source!!