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Netherlands Institute for Radio Astronomy

Lightning studies with Transient Buffer Boards

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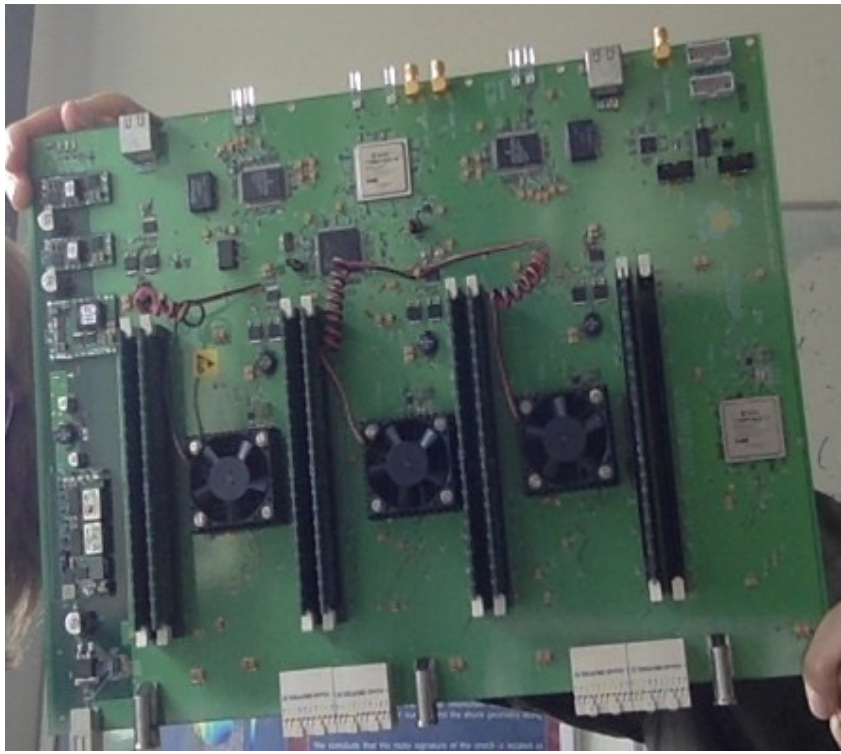
LOFAR Data School 2024



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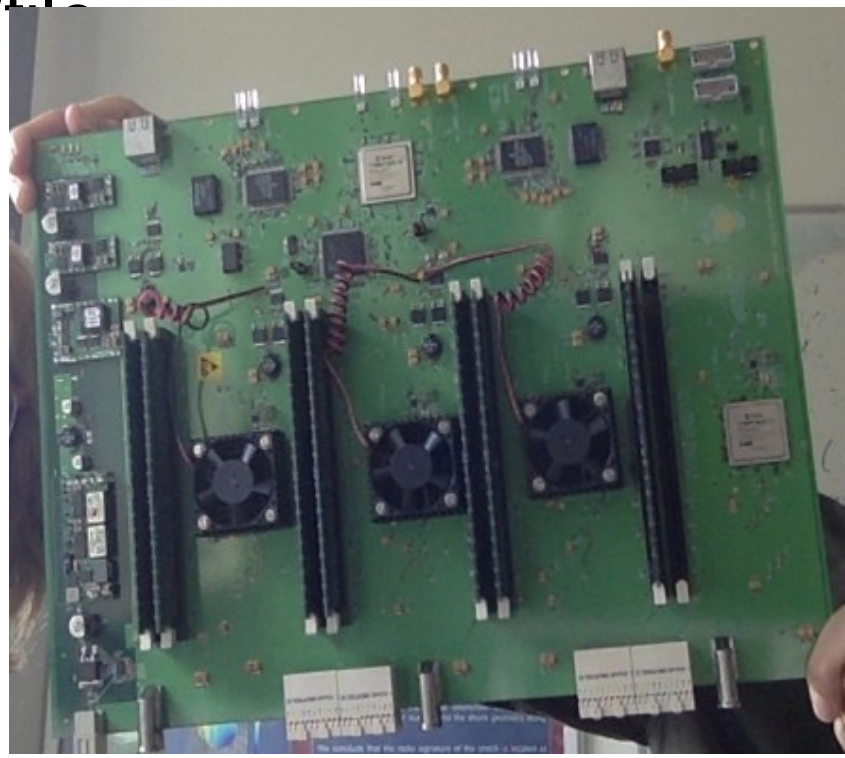
Outline

- Introduction to transient buffer boards and it’s science
- Demo of data analysis

Transient Buffer Boards

- Store signal of individual channels (antenna/tile)
- Stores raw data (200 MHz, 5ns samples)
- 5.2 second buffer
  - (most intenational stations 1.3 s)



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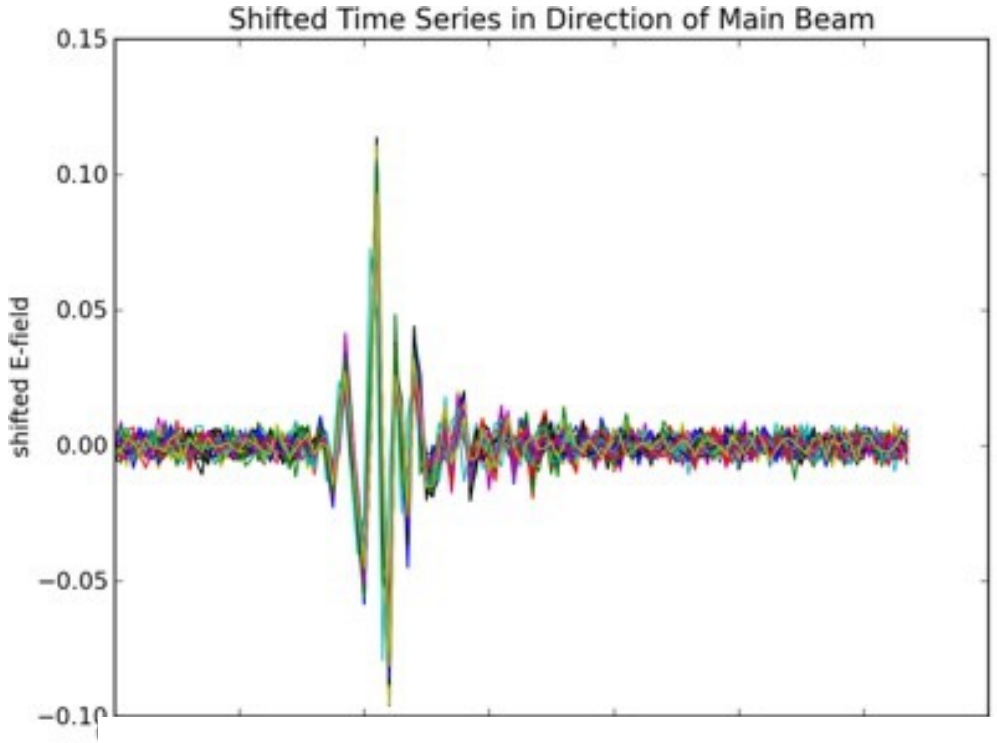
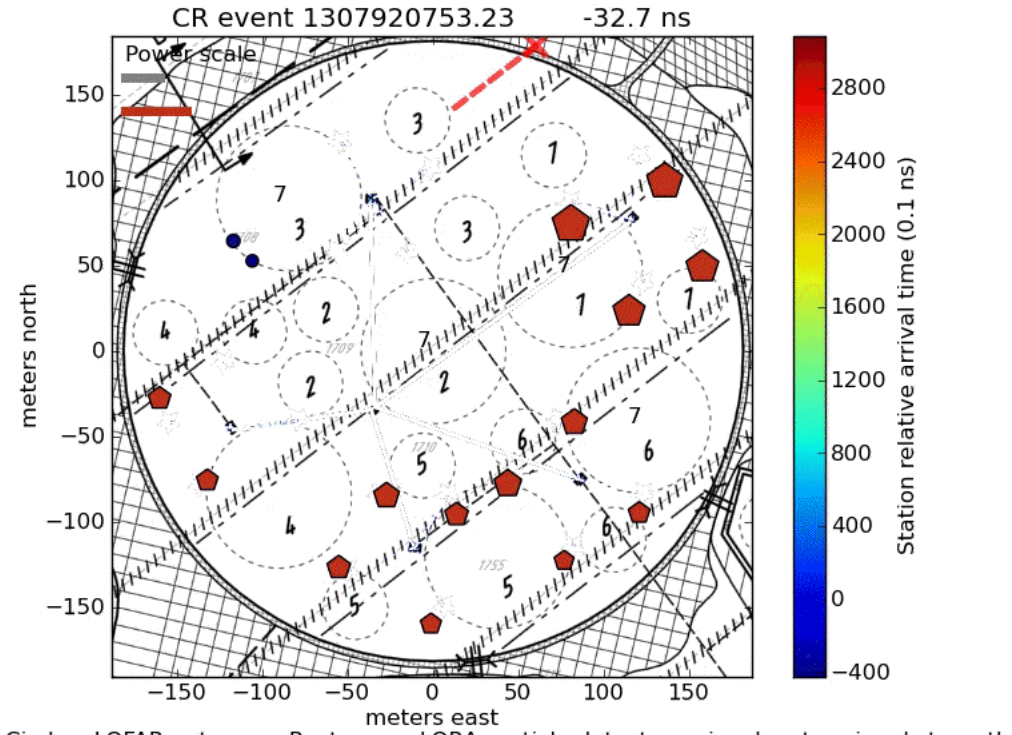
Triggered observations

- Use external source to decide there will be interesting data
- Freeze buffers ASAP
- Read out relevant part of the data (e.g. 2 ms or full 5 seconds)

Phenomenon	Trigger source	Trace duration
Cosmic Ray	Particle detector Radio self-trigger	2 ms
Lightning	www.lightningmaps.org Radio self-trigger	2 s
Fast Radio Burst	Detection on LOFAR beam formed data Detection with another telescope (e.g. APERTIF)	5 s

Single antenna – cosmic ray data





Circles: LOFAR antennas, Pentagons: LORA particle detectors, size denotes signal strength

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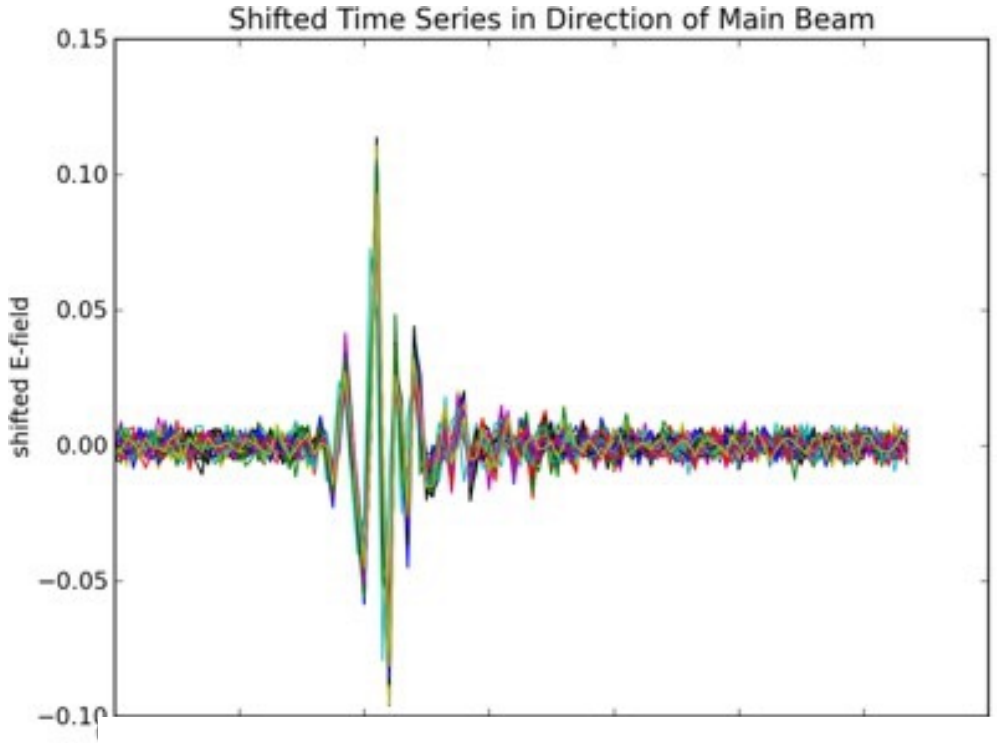
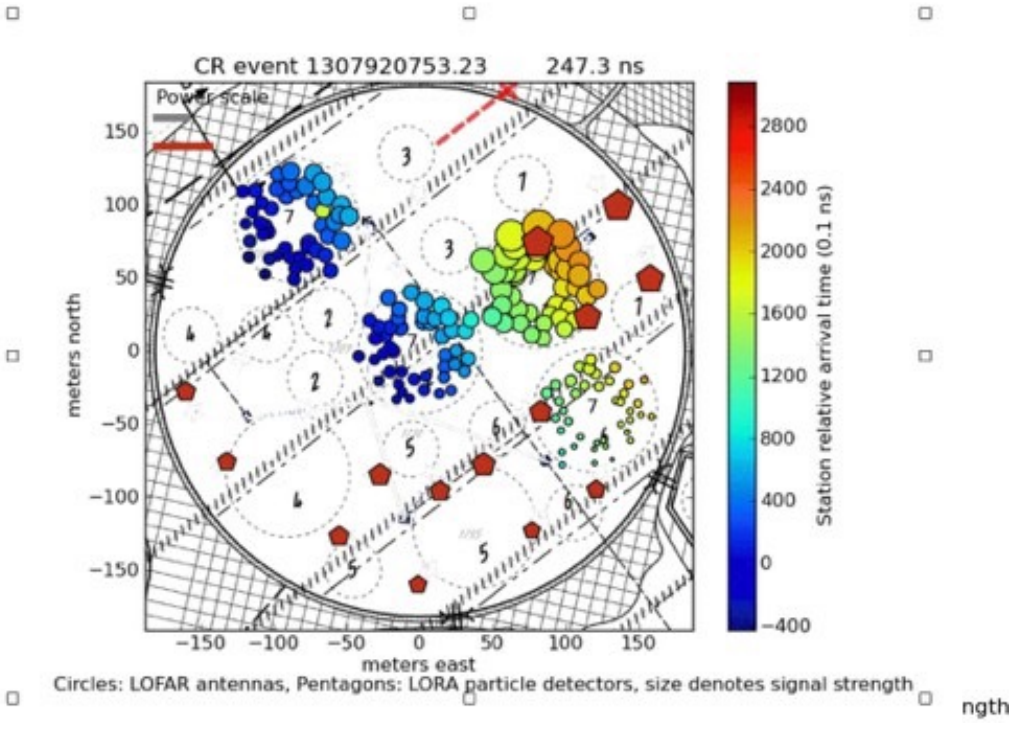
Single antenna – cosmic ray data





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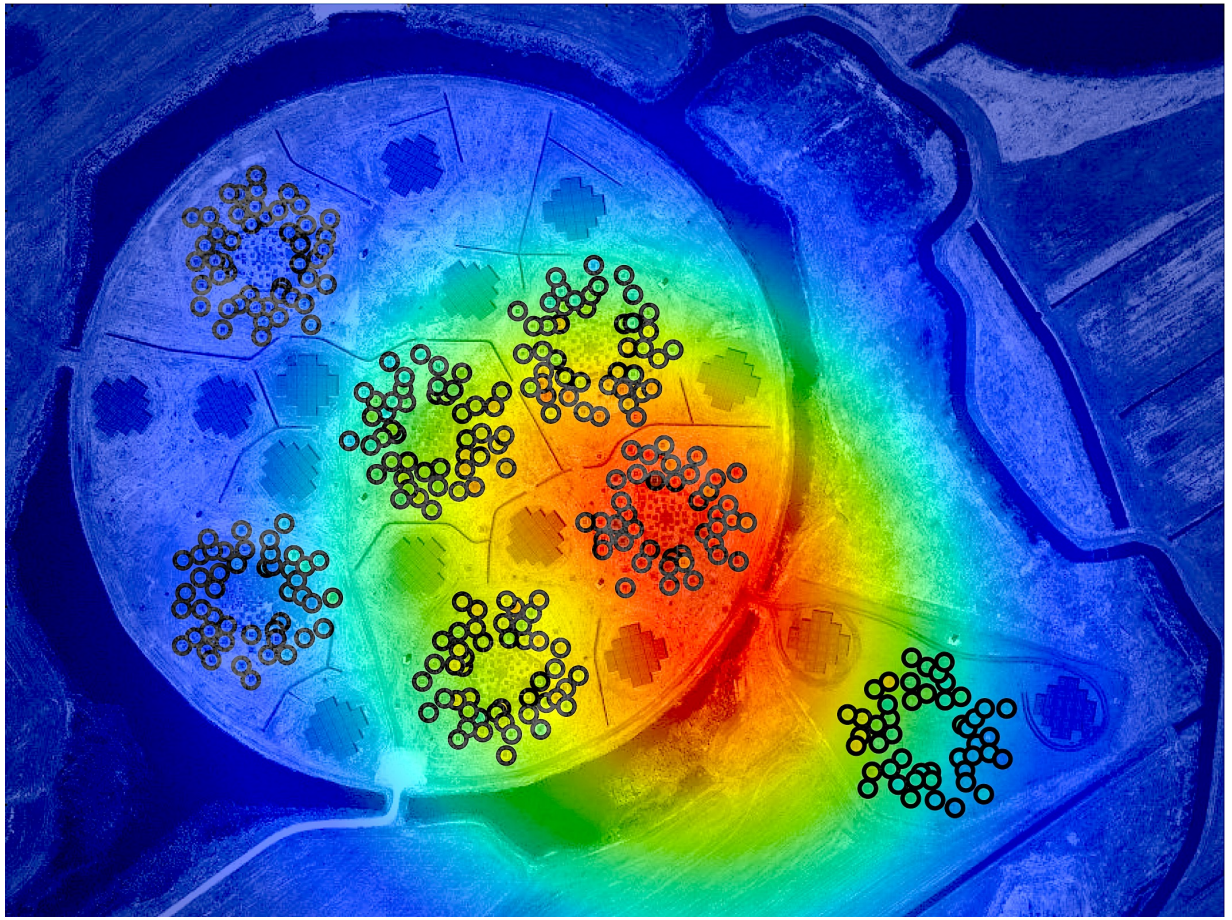
Cosmic ray analysis – matching data (in circles) with simulations (background)



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Localisation Fast Radio Burst

Beam formed data

on PSR B0834+26

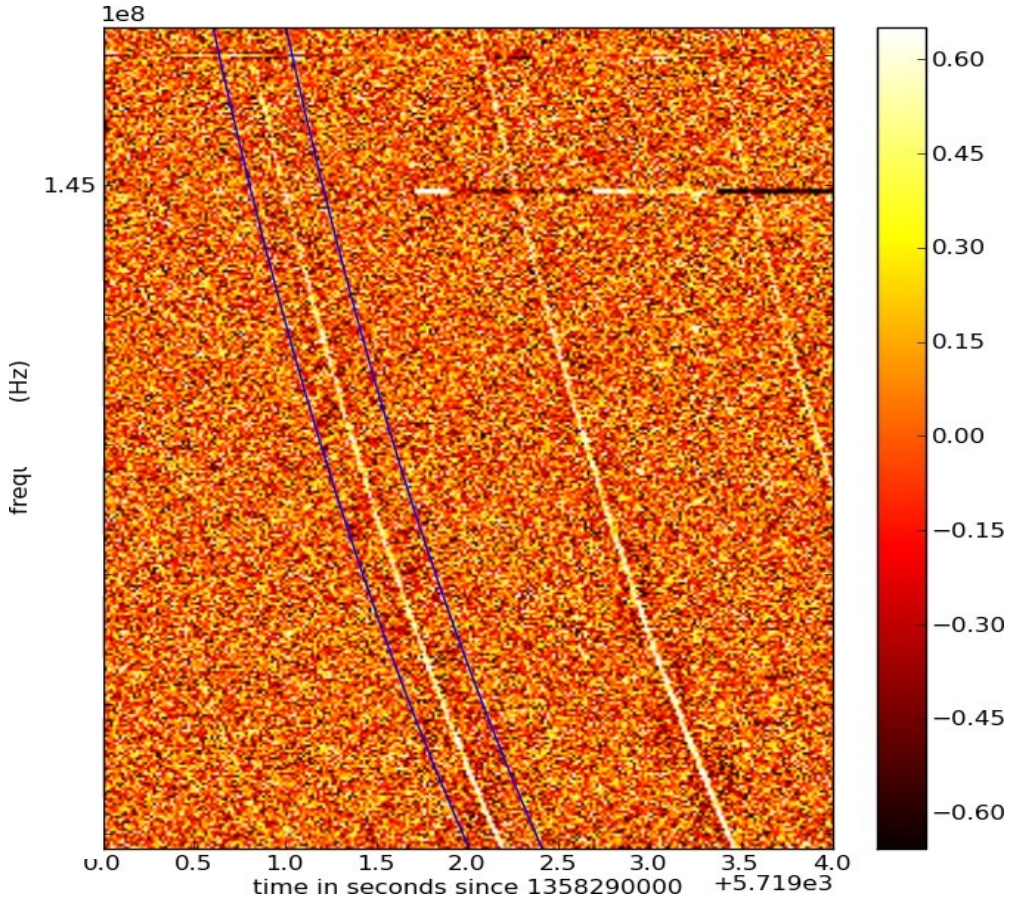
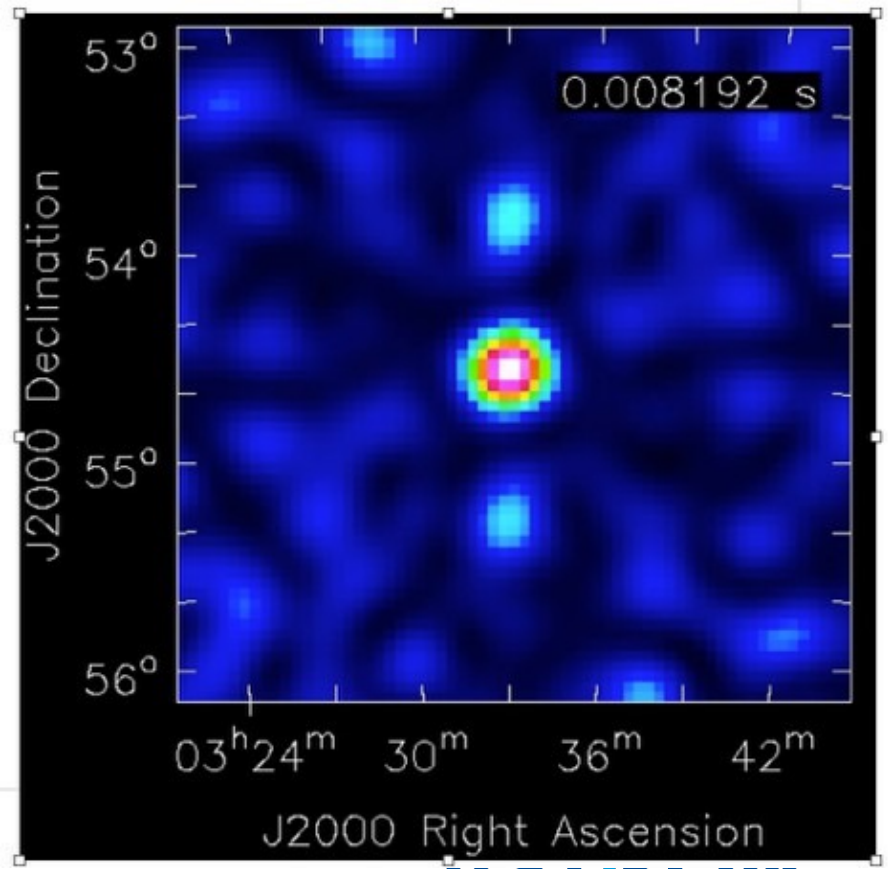


Image from TBB data

of Crab Pulsar



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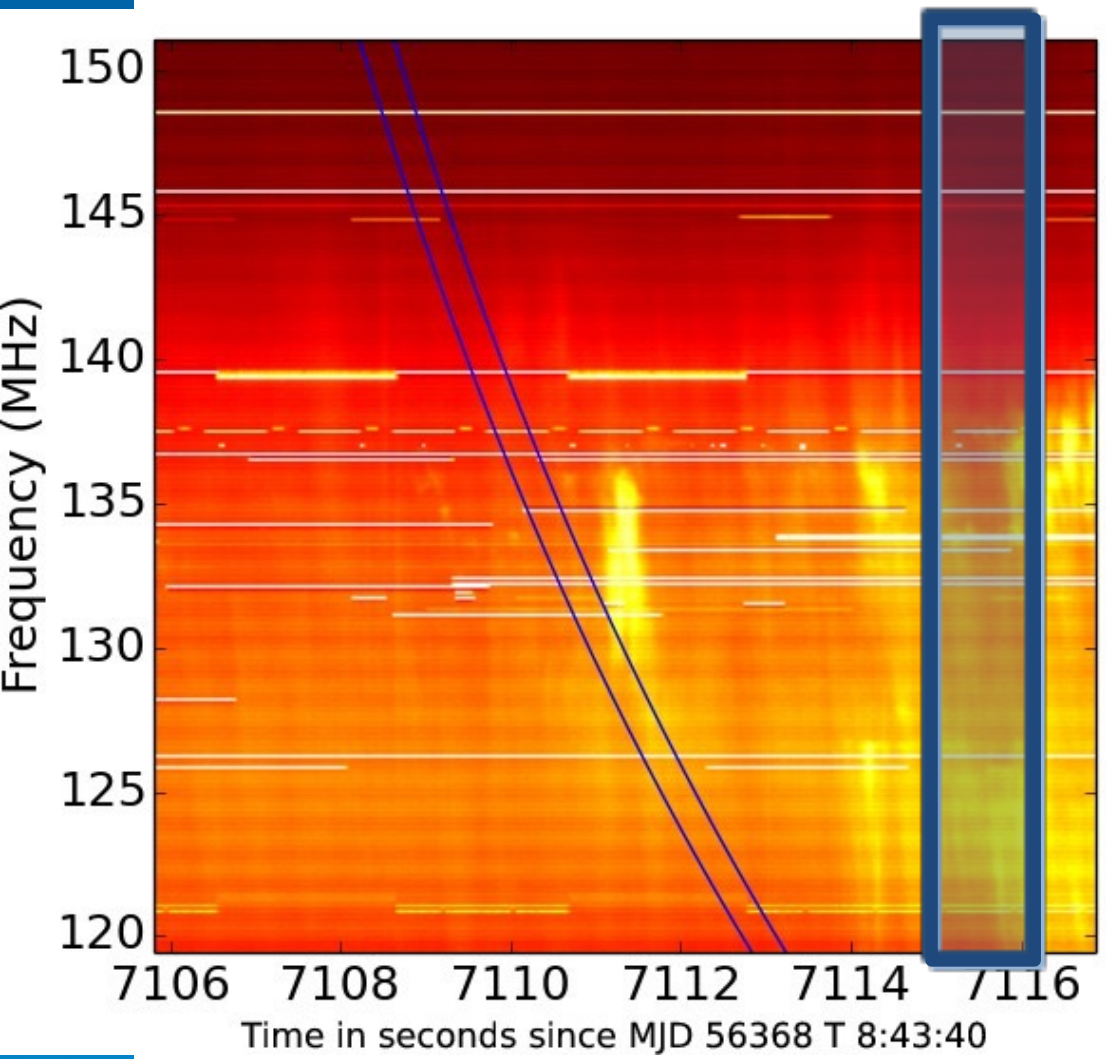
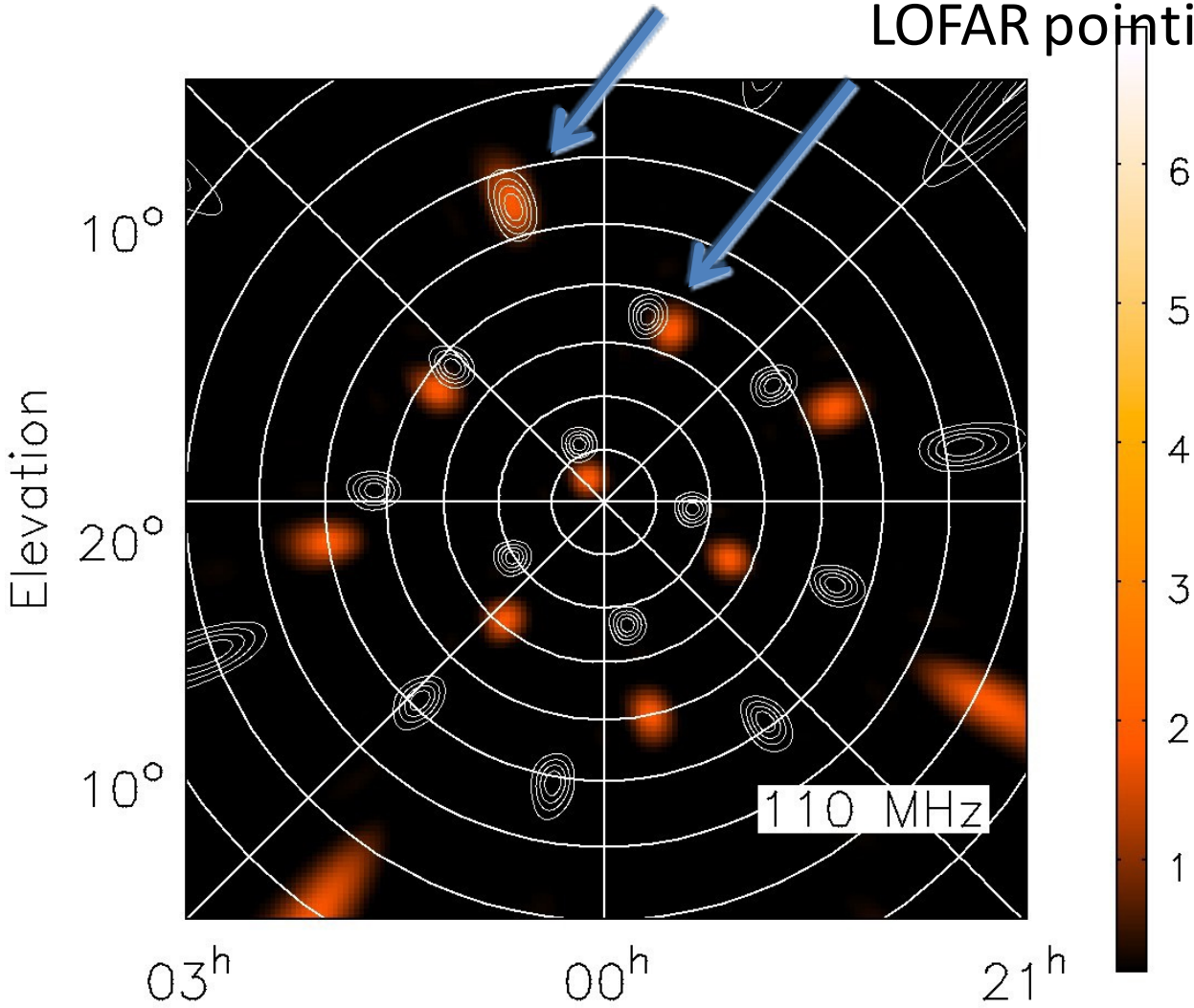
Solar Radio Burst



Beam formed data

Actual source=Sun

LOFAR pointi



Azimuth

TBB Image

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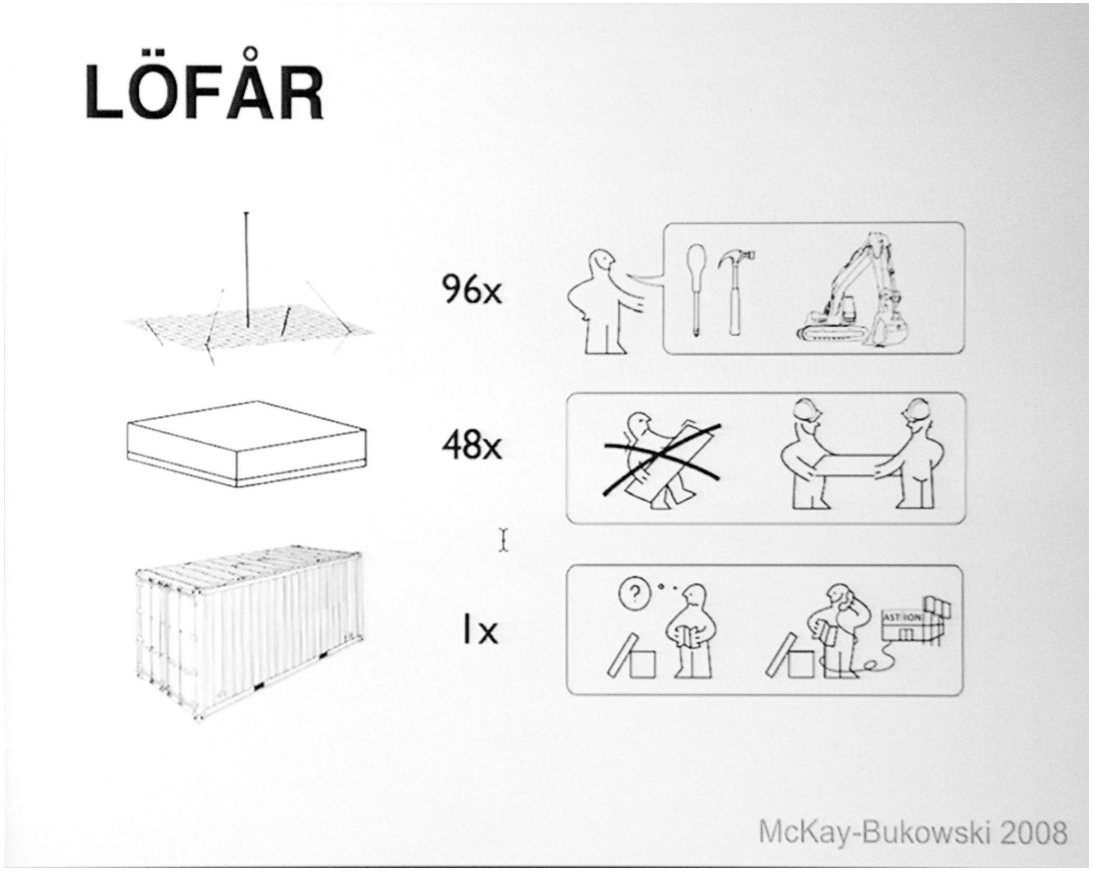
Mapping Lightning with LOFAR

- Lightning is very different from astronomy data
  - Broadband / impulsive, pulses are 100 ns wide
  - Sources are at near horizon
  - Shape of the pulse can change between antennas
  - Over 100,000 pulses in one flash
- LOFAR is best instrument in the world for mapping lightning
  - Save full trace data
  - Large baselines
  - Dual-polarized

Transient buffer board data analysis

"Build your own telescope"



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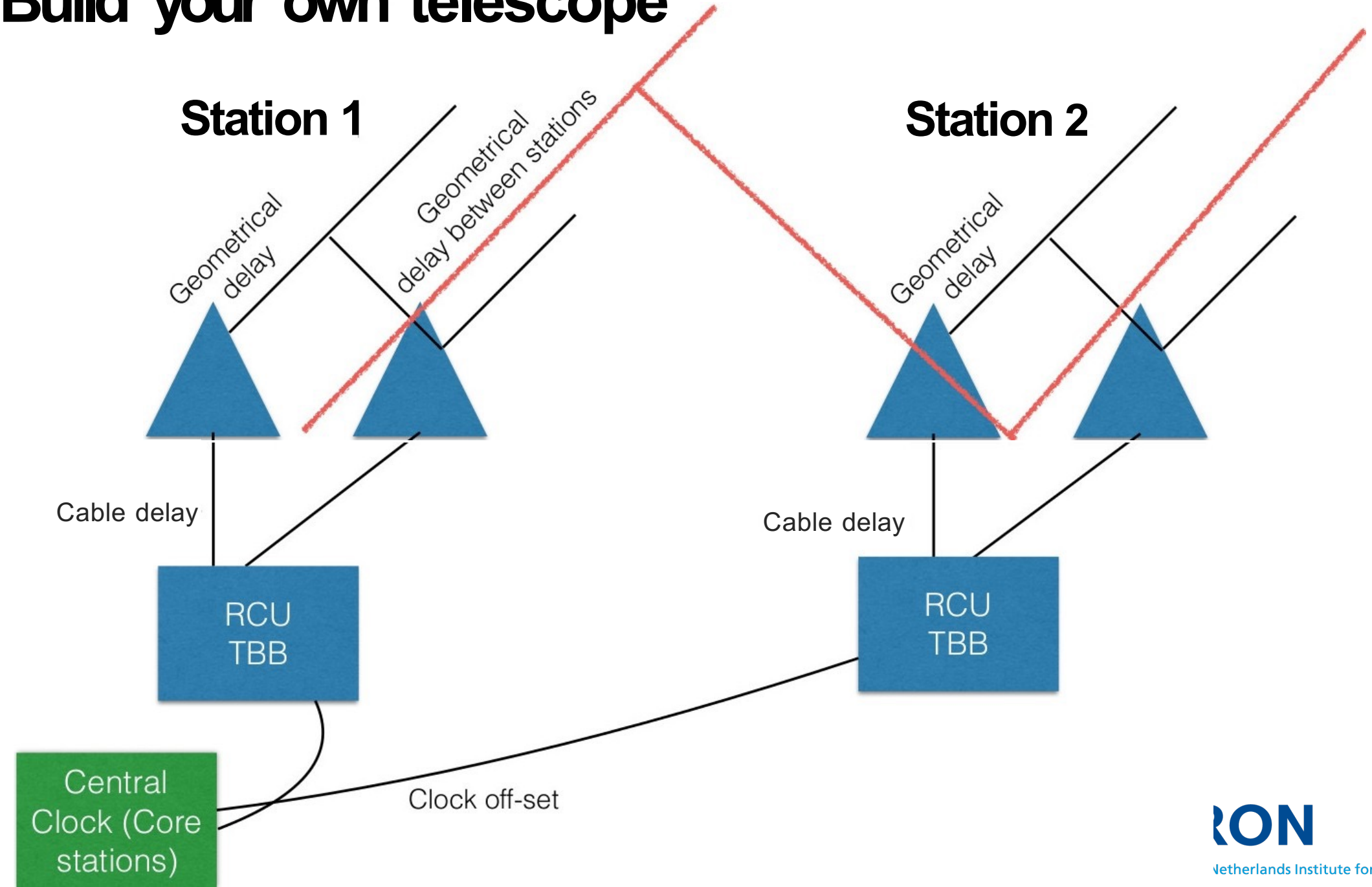
Build your own telescope



Analysis demo

Fourier shift

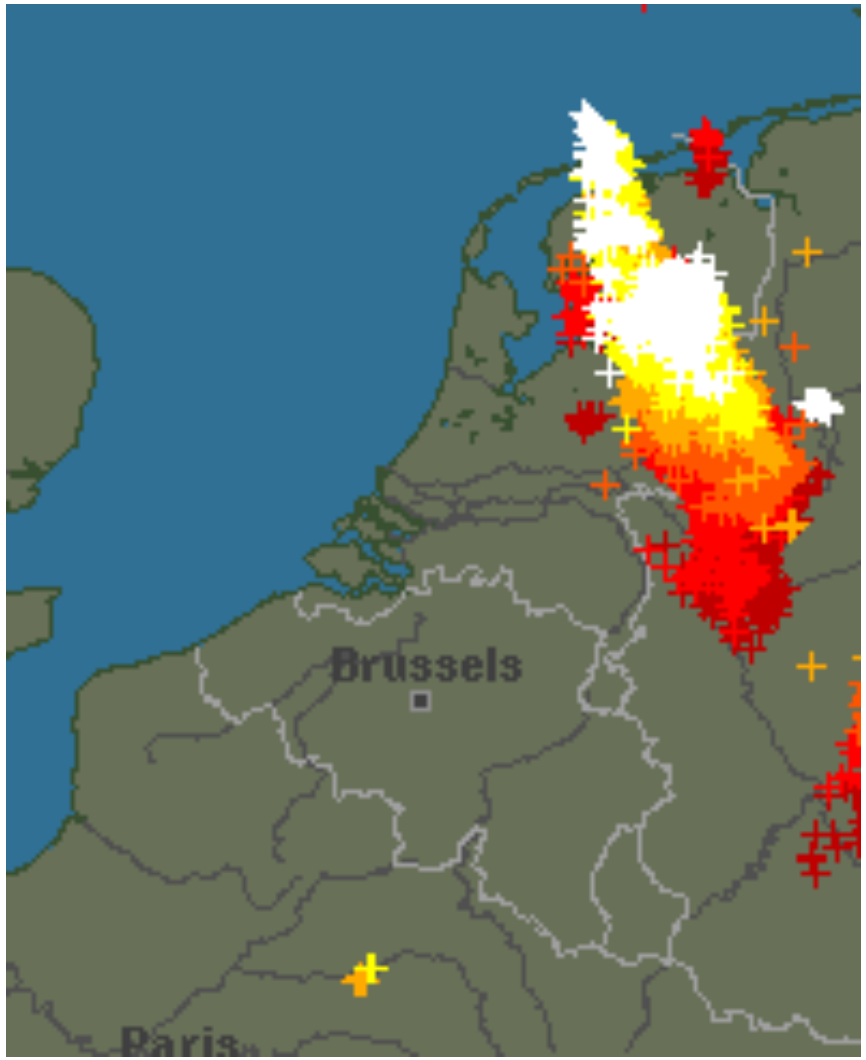
$$\mathscr{F}\{g(t-a)\} = \int_{-\infty}^{\infty} g(t-a)e^{-i2\pi ft}\,dt$$

$$= \int_{-\infty}^{\infty} g(u)e^{-i2\pi f(u+a)}\,du$$

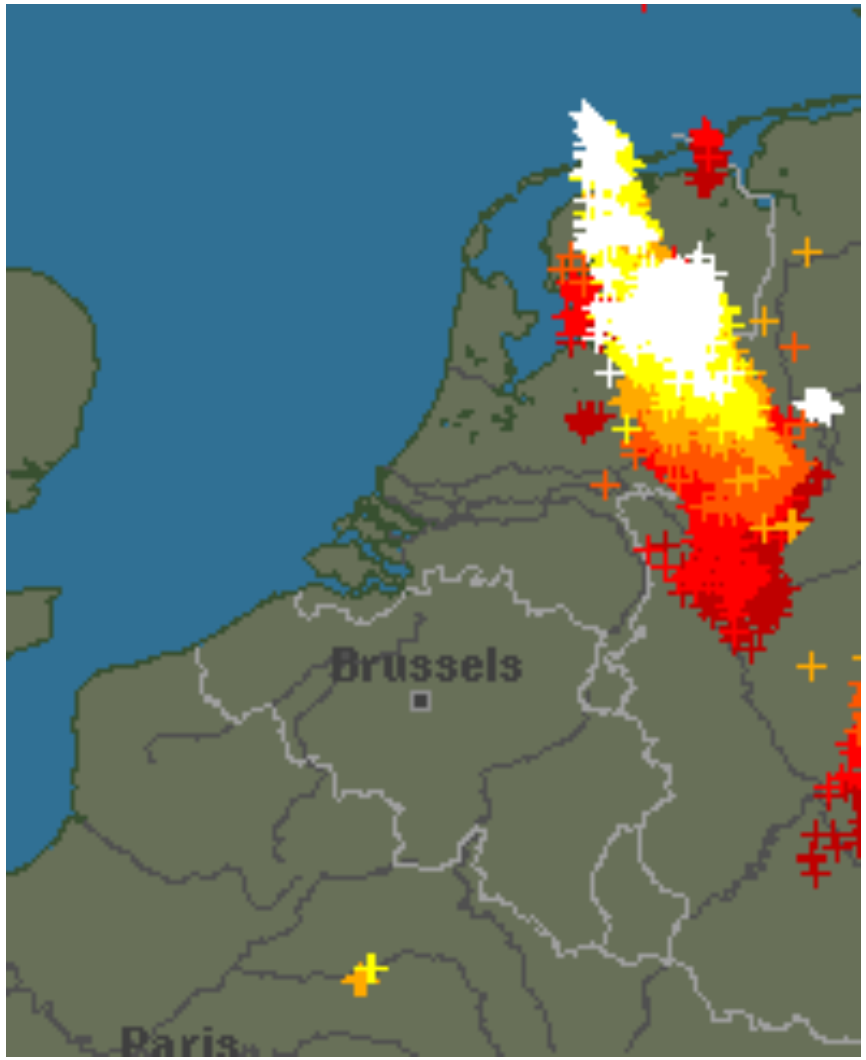
$$= e^{-i2\pi fa}\int_{-\infty}^{\infty} g(u)e^{-i2\pi fu}\,du$$

$$= e^{-i2\pi fa}G(f)$$

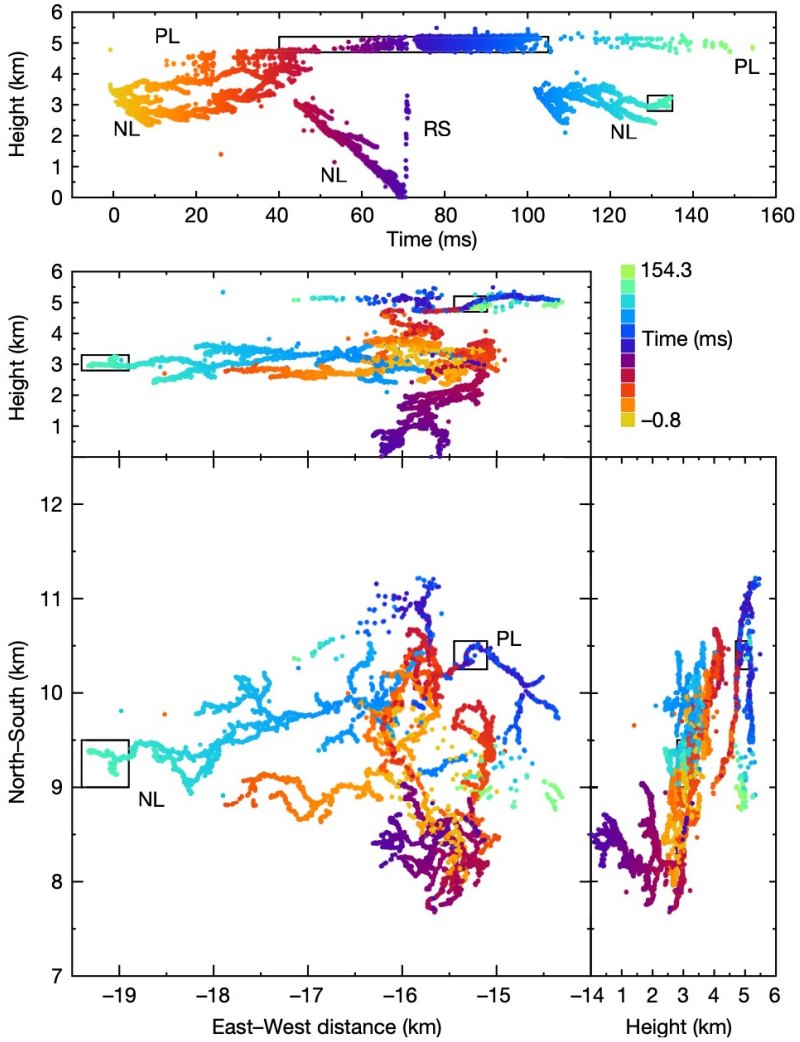
Analysis results



Analysis results



Mapping a full event



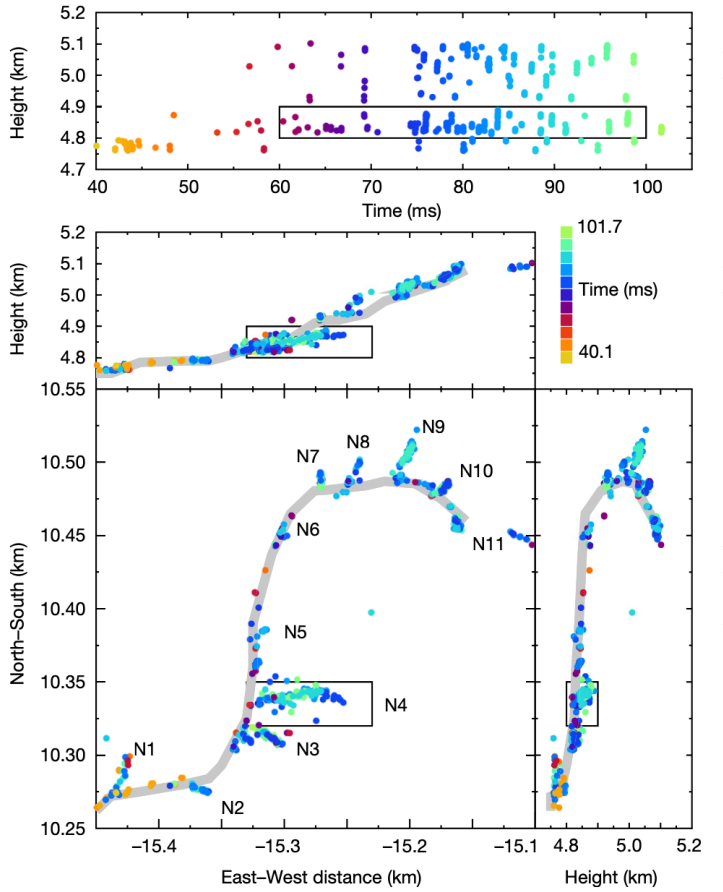


Fig. 2 | Expanded sections of Fig. 1, with a positive leader on the left and a negative leader on the right. The sources on the negative leader come almost solely from the imaged tip, while sources on the positive leader

3D movie

https://www.youtube.com/watch?v=UcKQSG_3MUk

https://www.youtube.com/watch?v=dkHJPOf3v5o