LOFAR and Long Baselines for GSM and MS^3

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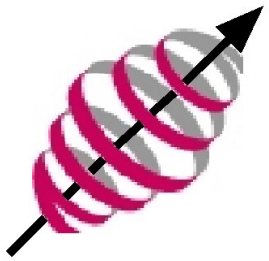


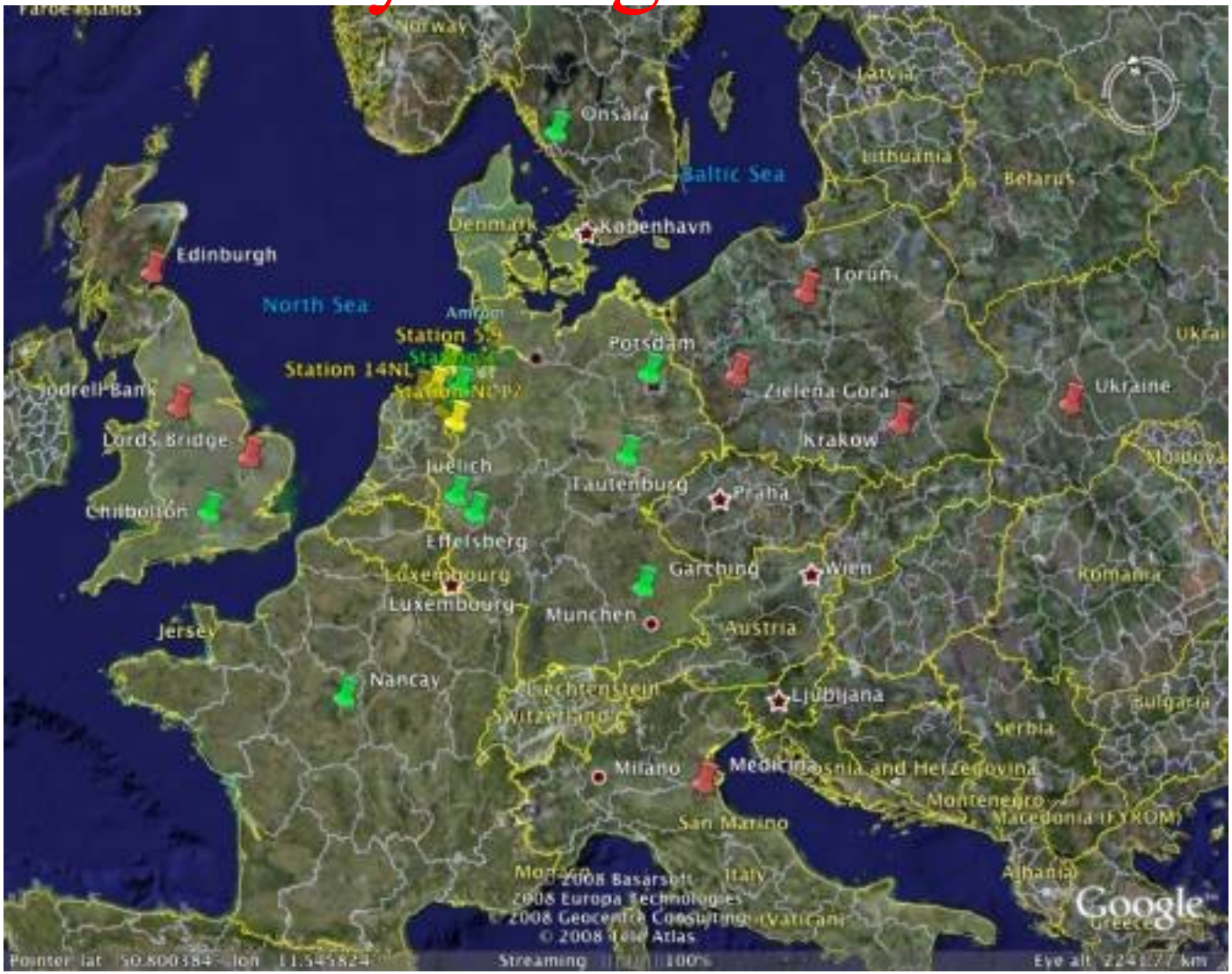
LOFAR

MAX-PLANCK-GESELLSCHAFT

Suggestion: Always Include Long Baselines for MS^3 and other Commissioning Obs

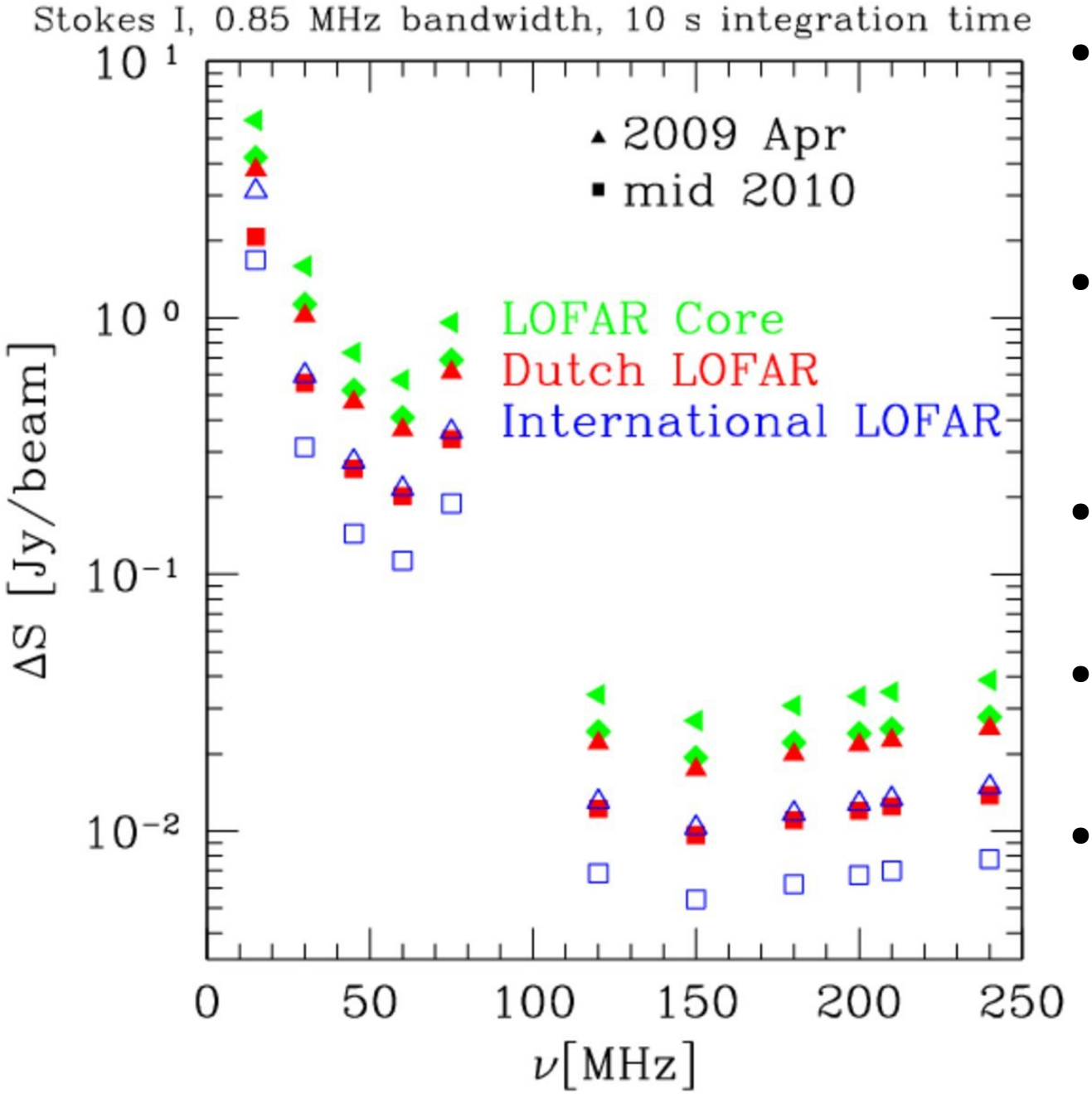
- Long baselines need commissioning tests too
- GSM at high resolution/position precision
- International and Remote stations need long baselines for polarization calibration (?)
  - Needed for later polarization commissioning (Magnetism KSP)
- Problems:
  - Number baselines greater by ~ 2
  - Requires higher time and frequency resolution
    - But see notes from Jap
  - Extra load on software and processing
    - Need to deal with load anyway as more stations come on line
    - Must write and debug software for long baselines at some point

Early Long Baselines



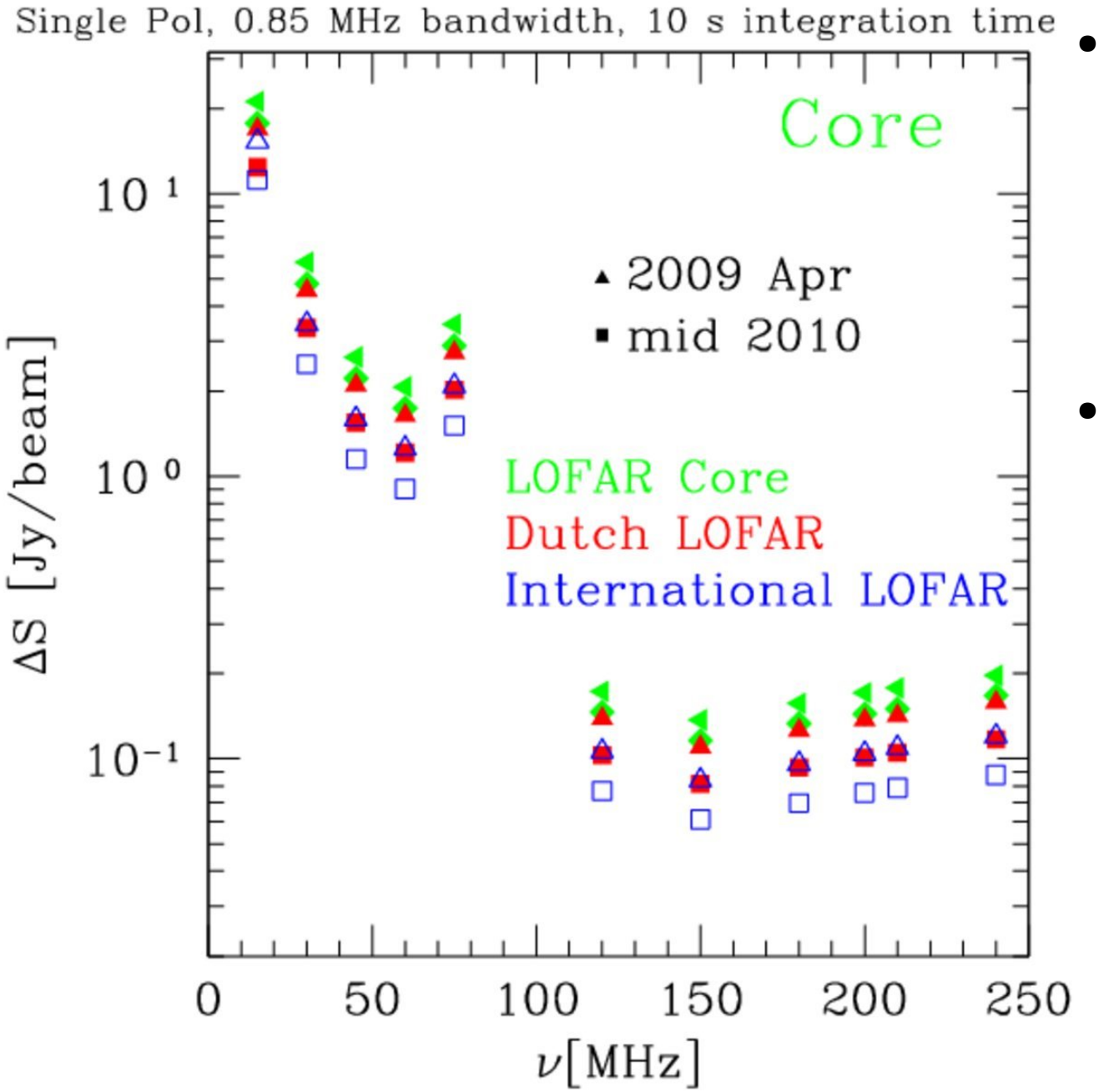
- Status of green pins not totally clear
- Ignore red pins for the next year

Calibration Sensitivity: *I*



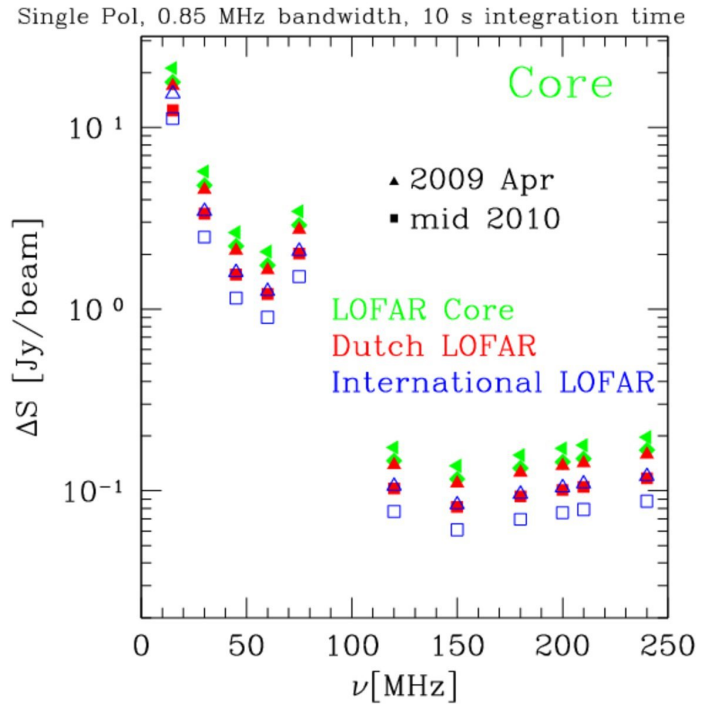
- 10 s is approximate timescale for ionospheric changes
- Several beams, MHz of bandwidth dedicated to calibration observations
- HBA sensitivity roughly flat
- LBA system peaks around 56 MHz
- Noise increases rapidly to low frequencies
  - But so may flux density ...

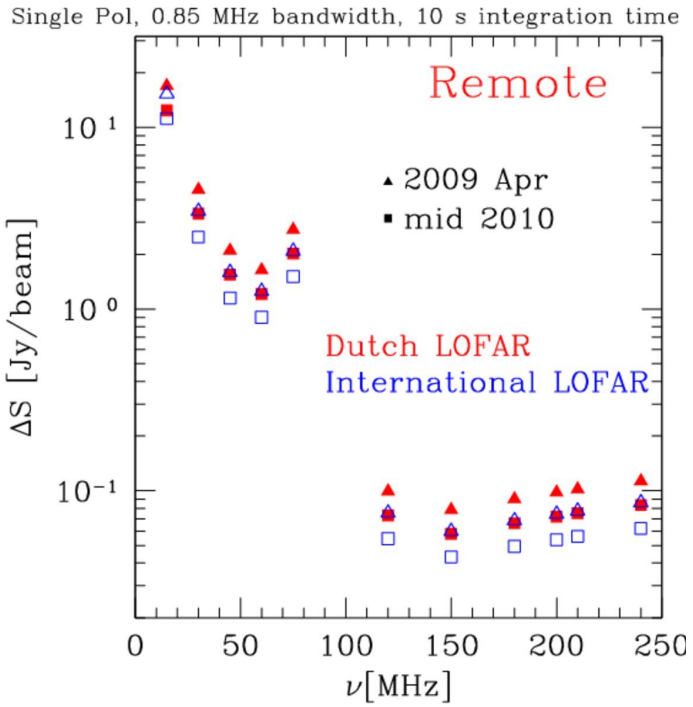
Single Pol Selfcal Noise Level

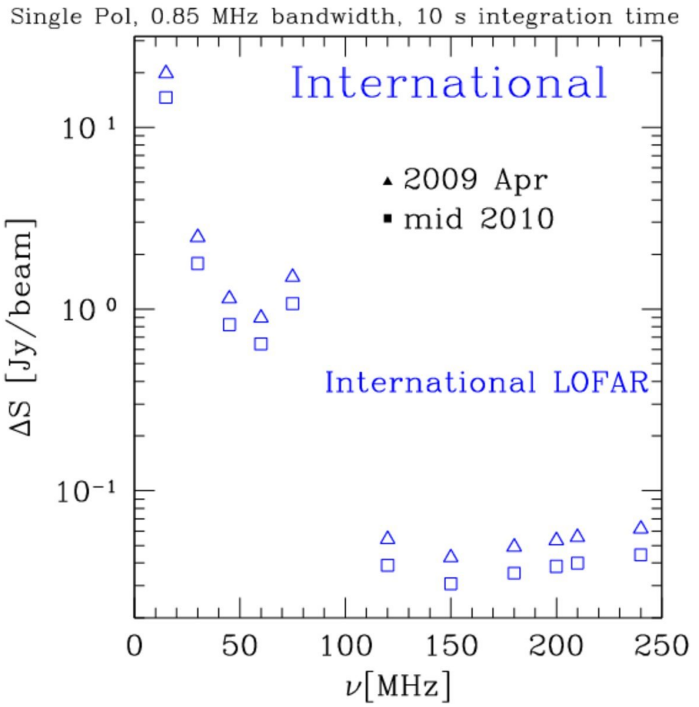


- Selfcal equivalent flux density for a single station (ear) naturally larger than image sensitivity
- Inclusion of longer baselines assumes that sufficient flux density can be found at high resolution

Selfcal for Different LOFAR Stations (Ears)







- Noise level (generally) decreases going to the more distant stations, as they have more collecting area
- But flux density rapidly drops off for long baselines
- LBA system (< 100 MHz) difficult to calibrate for 1000 km baselines
  - Very few ~several Jy sources at that resolution
  - Need many short baselines to every International LOFAR station

Calibration Details (Future Development)

- Clock offsets (1 param)
  - LOFAR is a VLBI instrument
- Ionospheric Terms
  - Ionospheric delay (MIM)
  - Faraday refraction (MIM)
  - Ionospheric absorption (derived)
  - Ionospheric refraction (derived)
    - Also changes station position for (u,v,w) calculation depending on frequency
- Troposphere
  - Delay (standard model or MIM)
  - Pressure information from station weather data may be good enough for modeling, but must be calculated over wide-field
- Station position offsets (3 param)
  - Weather fronts, ocean loading, and so on produce significant station position offsets even on Dutch baselines
- Instrumental terms
  - Complex station/tile/dipole gains (several param + model)
  - Beamformer sawtooth
  - Beamformer delays
  - Dipole/Tile/Station delay and phase offsets
  - Reception location depends on incidence angle (extra station position shift)

Long Baseline Issues

- Find fringes on long baseline
- Verify BlueGene correlation (+,- signs, fringe rotation, etc.)
- CALC (or newer variant) integration with correlator delays
- Fringe fitting integration into BBS
  - Required for ALL LOFAR imaging, SPAM, Core operation
- Software testing for long baselines
  - What breaks with long baselines, high resolution?
- Disk recording needs to remain an option
  - Commissioning tests
  - Include Nancay, Northern Cross, ...
- Ionosphere
  - SPAM probably won't work (baseline length, number sources, ...)

LOFAR and the Ionosphere

- SPAM needs an initial calibration before it can take over
- Need to separate ionosphere from other effects
  - Position determinations require broadband observations
  - Suggest 40—80 MHz and 120—180 MHz for MS^3
- Much of the required software is not yet in place
- These issues are common for all LOFAR imaging
- Longer baselines will need something beyond SPAM
- Height profile of ionosphere needs observations with large viewing angle separations
  - Very different from packed hexagon shown by Ger
- Faraday rotation modeling has very little testing with real data, especially for long baselines
  - GPS-based model critical for early operations

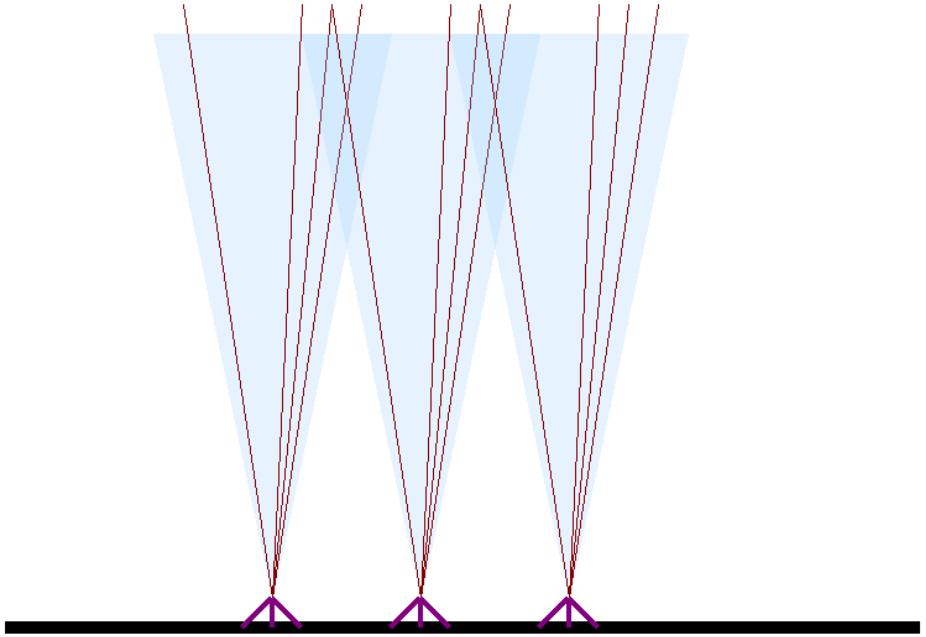
Early VLBI Operational Issues

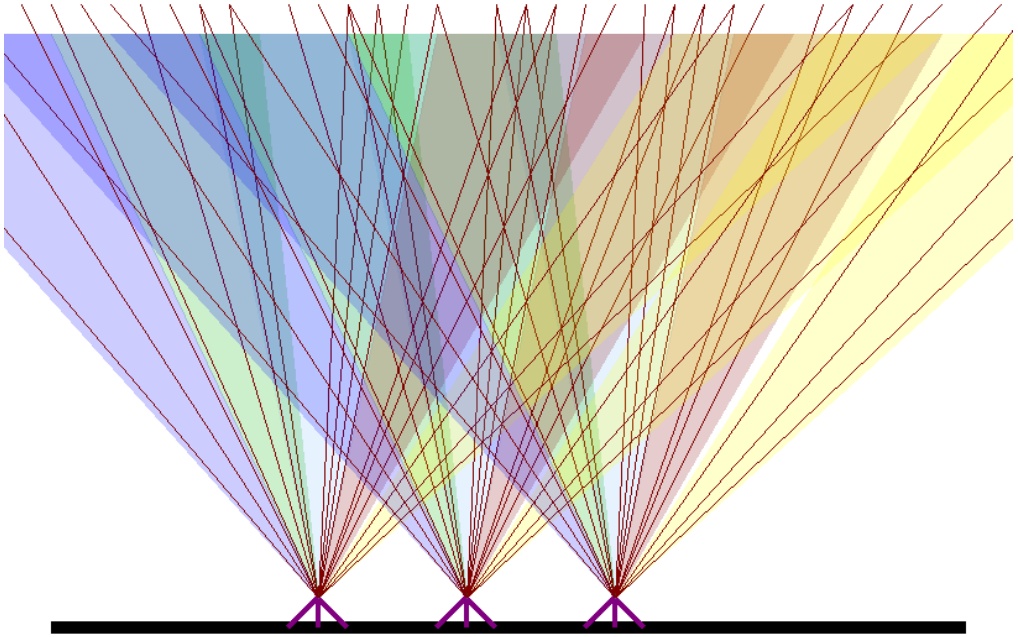
- Data rates
  - < 1 kHz frequency resolution required for RFI
  - Ionosphere (TIDs, low elevation delay change) limit integration time to < 2 s, perhaps < 1 s
  - Ionosphere model not incorporated into correlator (?)
  - Realtime ionosphere tracking not ready
- Positions unknown
  - Self-cal on bright sources to determine flux levels comparatively easy
  - Determining positions requires geodetic type observations
    - Requires different observing strategy than currently envisioned
- Human resources
  - Press gang operation in Hamburg?

Sources

- Long baselines will need to target individual objects to study for MS^3
  - Cannot image full station beam size at high resolution
    - Data size
    - Processing power
  - Probably of order 5—10 sources per beam to be measured
- Target bright sources (3C, 4C, ...)
- Other steep spectrum sources
  - Pulsars
  - ?
- Target sources likely to show polarization?

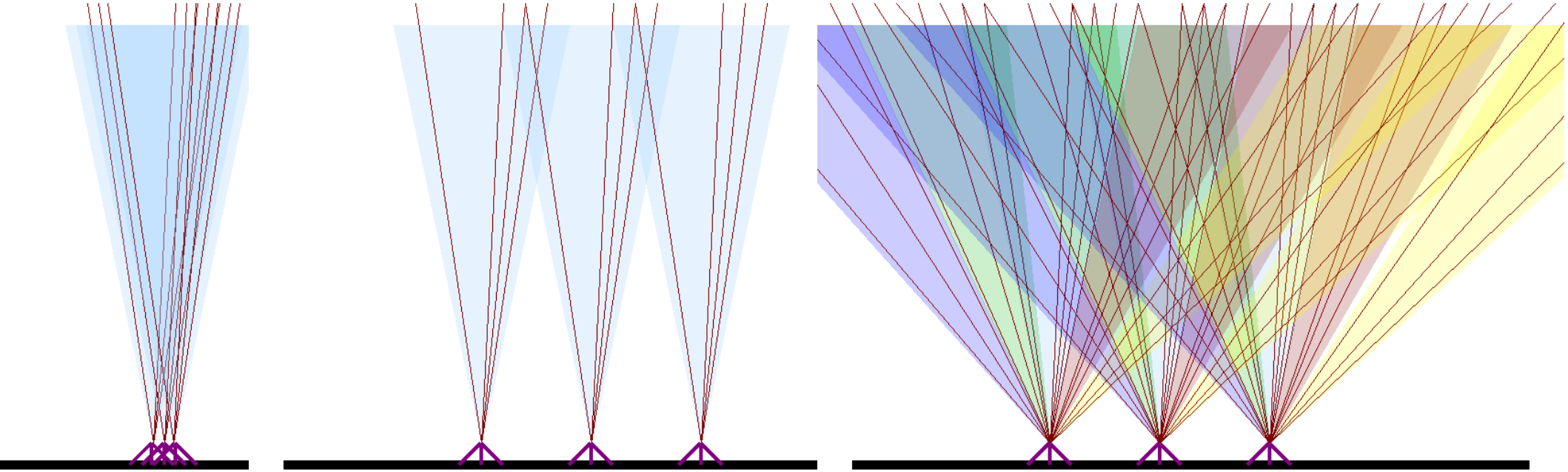
Crossing Points in Ionosphere





- Left: 1 beam with 3—4 sources Right: 5 beams with 3—4 sources each
- Extremely useful for 3-D tomography
  - Large amount of information at different heights
- LOFAR will be able to form up to 32 beams simultaneously
- New telescopes will see a calibrator source every 1—2 degrees over large part of the sky
  - Equivalent to 3—7 km spacing at 200 km height in ionosphere

Crossing Points in Ionosphere



- Left : 1 beam, small array
- Center: 1 beam, large array
- Right: 5 beams, large array