Polarisation Busy Week observations:

1) Analysis of amplitude (in)stability in LBA and HBA data

2) Some RFI mitigation results

3) Separating cable, clock, ionosphere and source visibility contributions

Ger de Bruyn

LOFAR Status meeting, 15-July-09

Polarization Busy Week from 6-10 July 2009

Local: Michiel Brentjens, Marijke Haverkorn, Ger de Bruyn, George Heald, Johan Hamaker, Jan Noordam, Ronald Nijboer, Wim Brouw

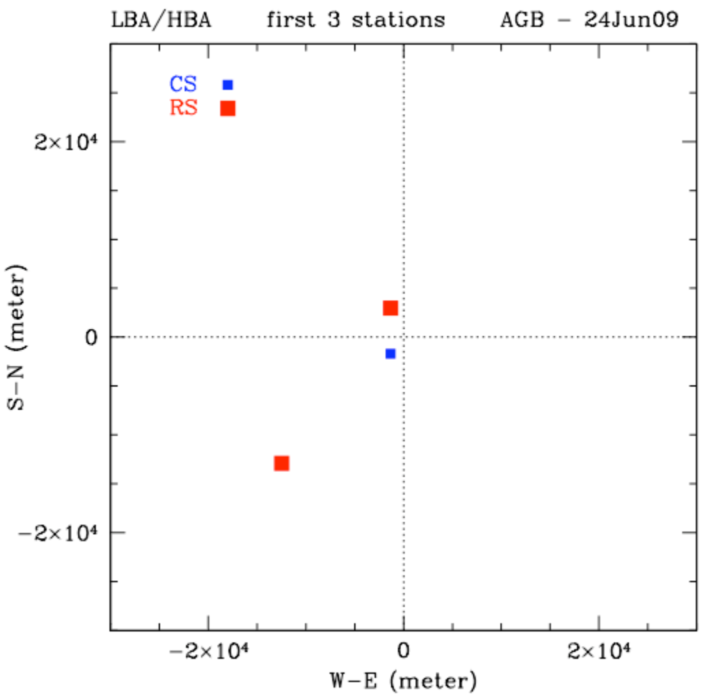
Visitors: Anna Scaife, Enno Middelberg, Bas van der Tol

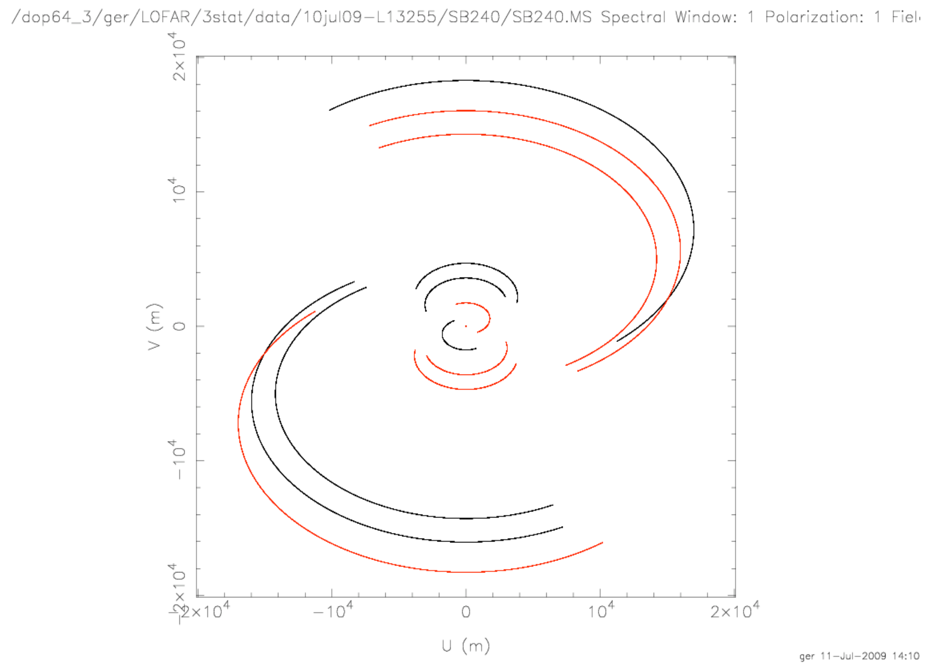
Summerstudents: Louise Ker, Francesco de Gasperin

Some ideas for activities (in preparation…)

- observations with LBA and HBA
- pulsars and discrete sources
- differential refraction, Faraday rotation, multi-beam tests
- ‘mozaicing’ over frequency / sources ? SAS/MAC/CEP overhead
- closure phase (check on instrument and discrete nature of source!)
- discussions on short/medium/long term efforts
- planning& coordinating commissioning/modeling efforts over the summer

uv-coverages for a 3-station array in July 2009





Specifications of Pol BW observations

Tracking CygA, 1s time-resolution, 248 subbands

CS010	LBA	and	4 HBA tiles (summed)
CS302	LBAinner	and	24 HBA tiles
CS503 and CS307	LBAinner	and	48 HBA tiles

9/10 July 2009:	LBA	30-78 MHz	L2009_13244	~10 h
10/11 July 2009:	HBA	120-168 MHz	L2009_13255	~12 h

Types of analysis being pursued on Pol BW data:

Michiel Brentjens:	various ….
Louise Ker and Francesco de Gasperin	DPPP testing, BBS calibration/imaging
George Heald (+ Enno Middelberg)	Frequency dependent closure phase analysis
Ger de Bruyn:	Amplitude stability on various timescales
Andre Offringa (Groningen)	RFI flagging at 137 MHz (LEO's)
Sarod Yatawatta:	Predicting visibilities, Calibration and Imaging
others …	

Estimating the amplitude (gain) stability

Many different timescales:

~ 12h ionospheric opacity, LNA, tilesummator, stationBF, projection

~ 1h same as above

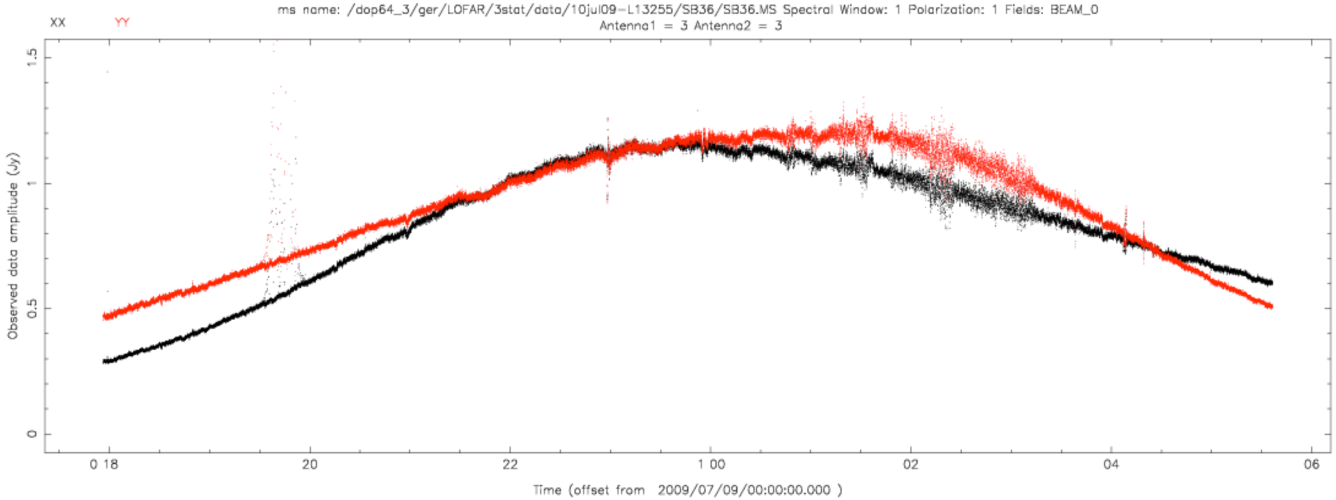
~ minutes as above, plus RFI and ionosphere

~ seconds RFI, lightning, ionospheric scintillation,

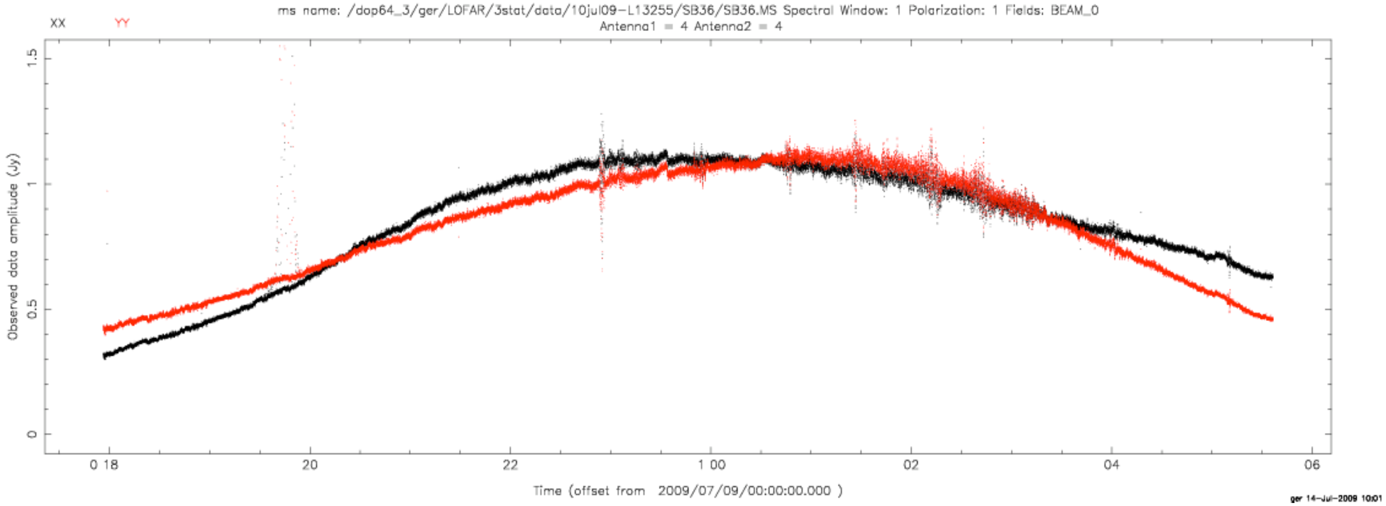
Stability of autocorrelations (HBA, 48tile-sum)

SB36

127 MHz



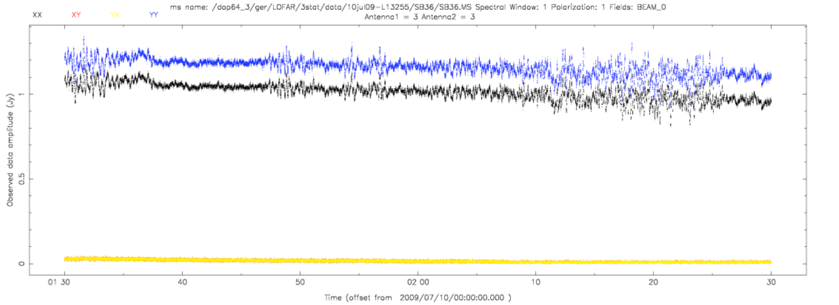
RS307



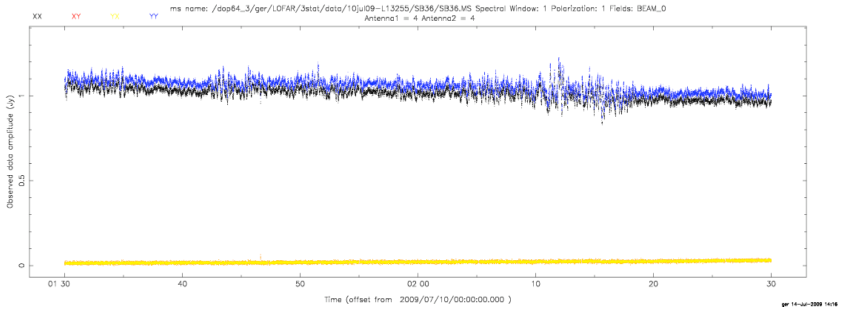
RS503

Fast amplitude variations in HBA (SB36, 96 and 240)

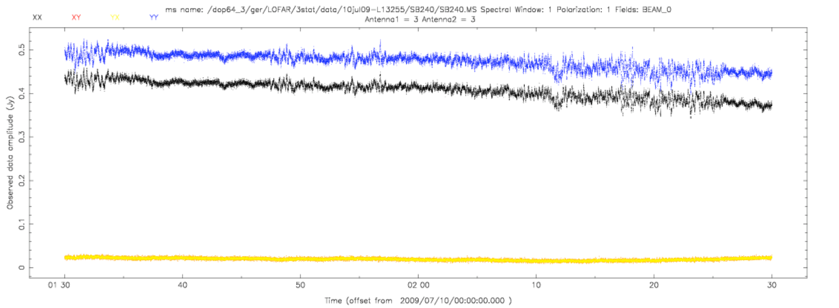
RS307



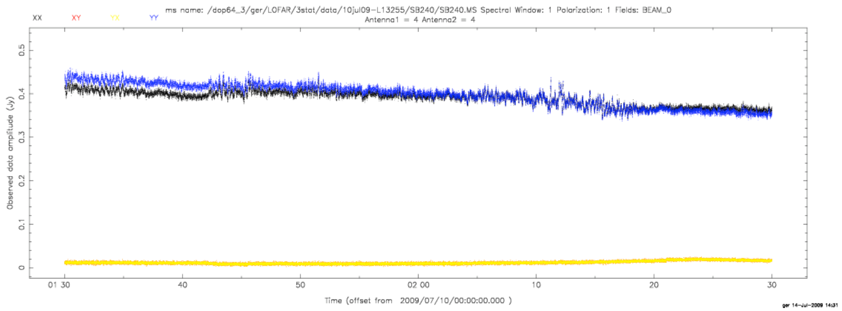
RS503



RS307



RS503



SB36 127 MHz

1h of data

many periods of ~10m

+-10% peak-to-peak variations

SB240 168 MHz

Possible causes for very fast fluctuations

Observational facts:

- excellent correlation between XX and YY, but no fluctuations in XY
- uncorrelated variations between stations ~20 km apart
- both +ve and -ve fluctuations
- (very) broad band (>40 MHz) phenomenon
- no strong RFI anywhere in HBA at those times
- no obvious associated phase fluctuations

This combination of properties strongly points to ionospheric scintillation

Conclusion and consequences:

- very fine scale ionospheric phase screen effects (also) in HBA
- fast sampling (1s) required to selfcalibrate this, but subband averaging OK
- probably not possible to calibrate (= interpolate !) in more than one direction ?

Ionospheric scintillation

The physics of ionospheric scintillation is quite complicated.

Relevant physical scales to describe this process at the height D of the ionosphere are:

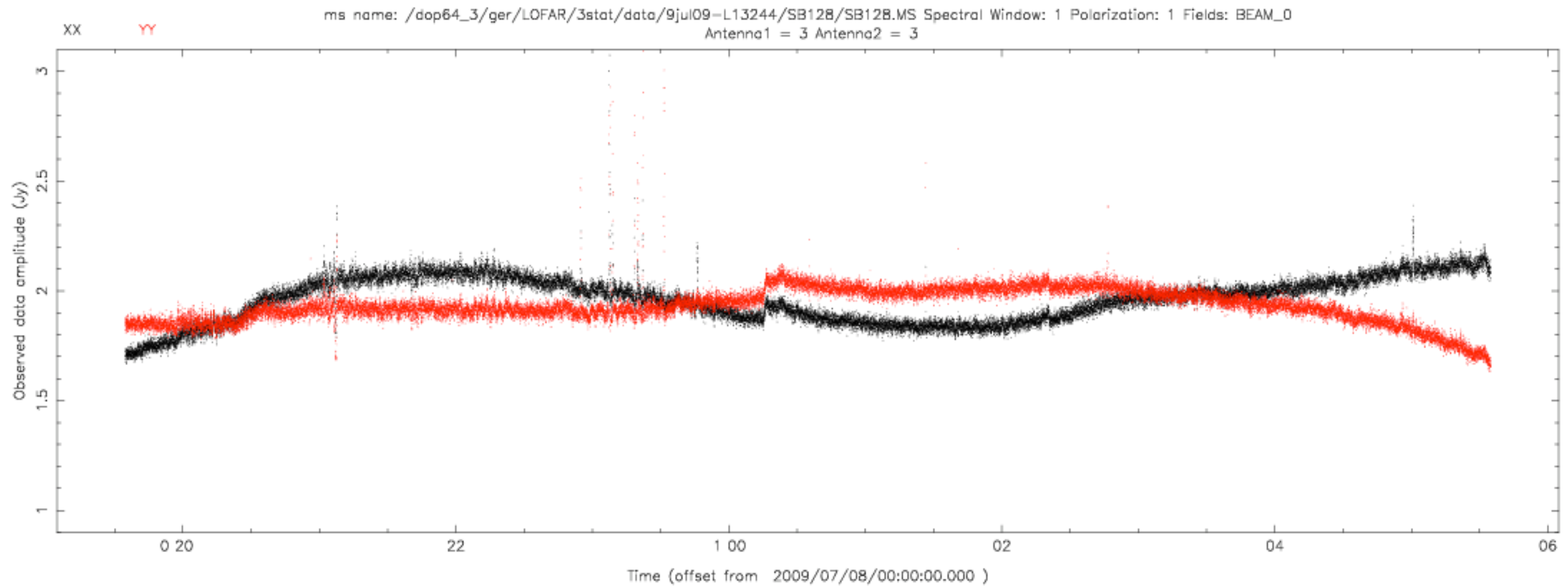
- R_{diff} : the horizontal scale over which the phase changes by 1 radian
- $R_{Fresnel}$: the Fresnel scale at the height D, $R_F = (2D\lambda)^{0.5}$
- R_{source} : the projected scale of the source at height D

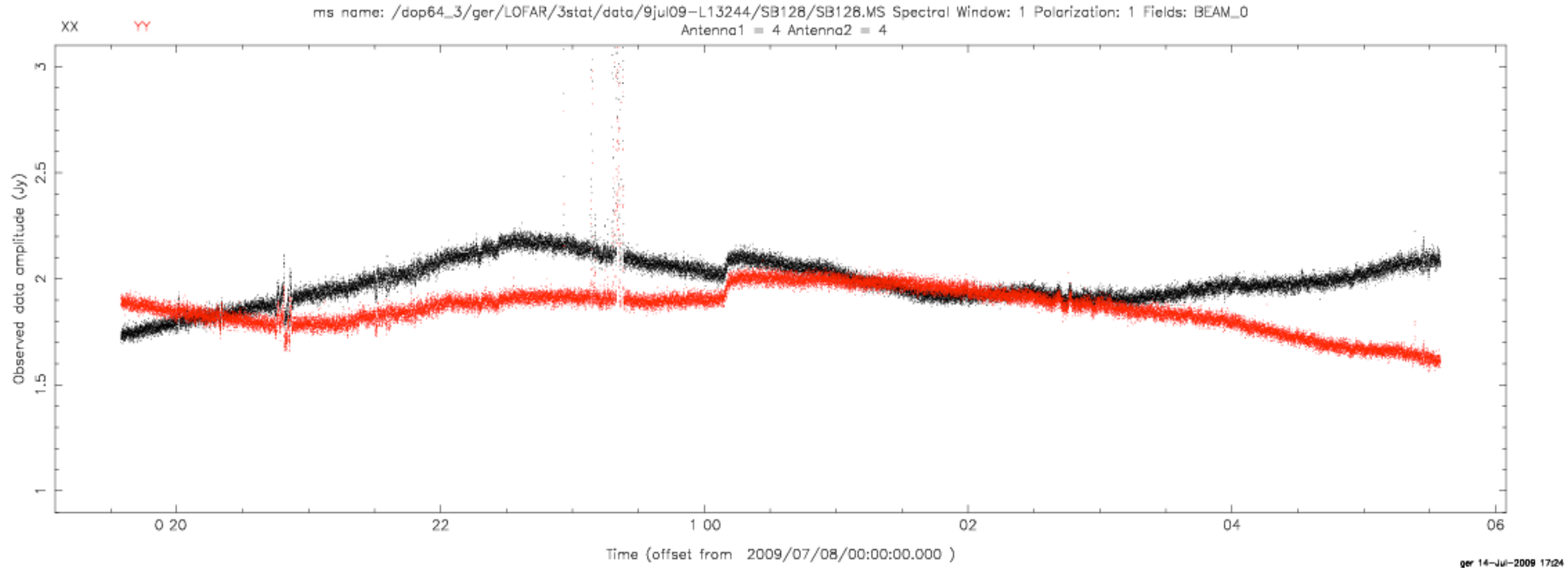
If $R_{diff} < R_F$ we will observe interference on earth and amplitude scintillations on a scale of R_F will be observed. This scintel pattern (frozen for ? seconds) will move with high speed in the direction of the projected ionospheric turbulence.

Some numbers relevant to scintillation:

- at 150 MHz (λ=2m) at D=200 km the Fresnel scale R_F ~ 1 km.
- with V ~ 300 m/s (1000km/h) this scale leads to ~ 1 km/0.3 km/s ~ 3 s
- CasA at 200 km height projects to 4'/3440' x 200 km ~ 250 meter. It therefore is unresolved (< R_F) and its scintillations will not be quenched
- scintillation is chromatic and has a coherence bandwidth (depends on weak or strong scintillation)

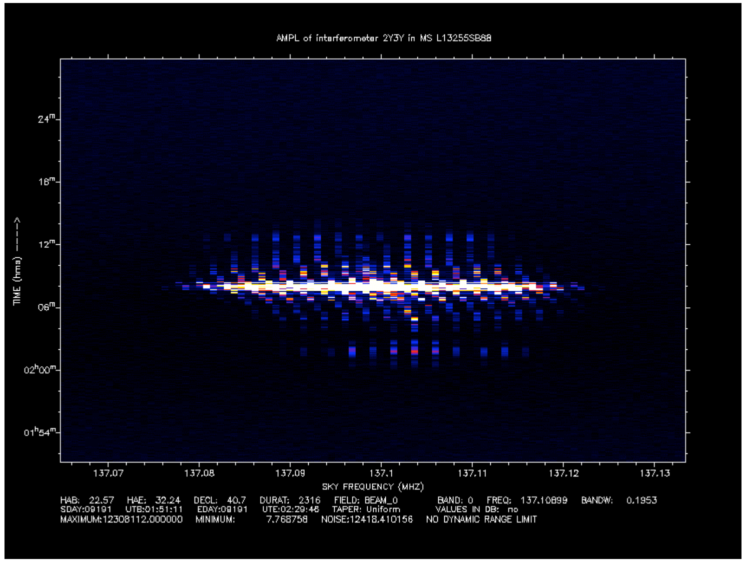
LBA SB128 = 55 MHz RS307 & RS503 10h



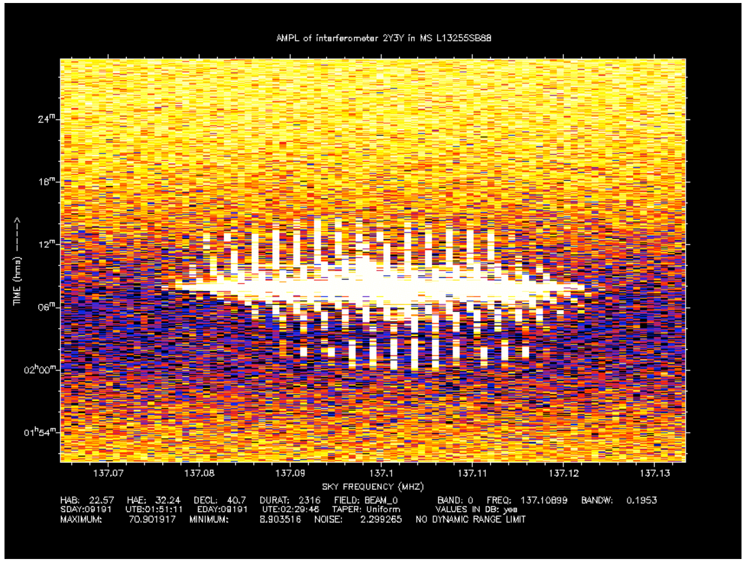


Miscellaneous RFI results: LEO at 137.1 MHz

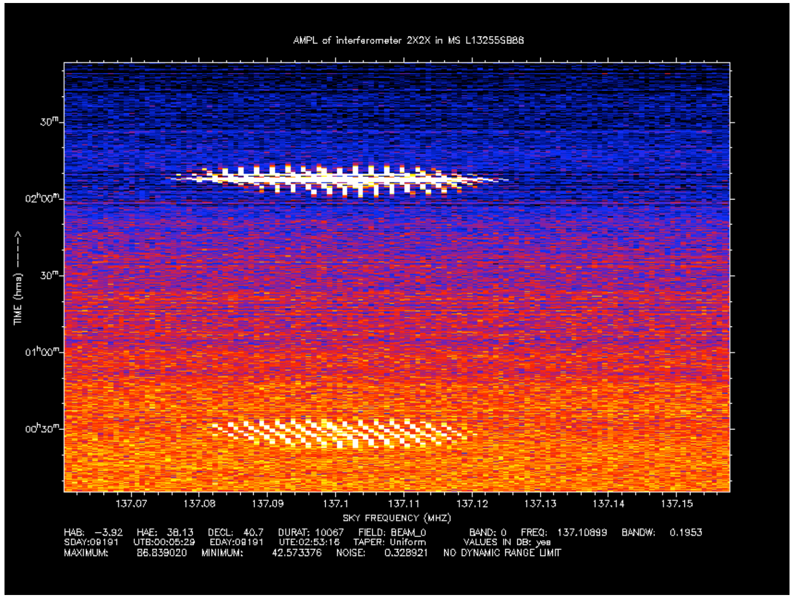
Linear scale



Logarithmic scale

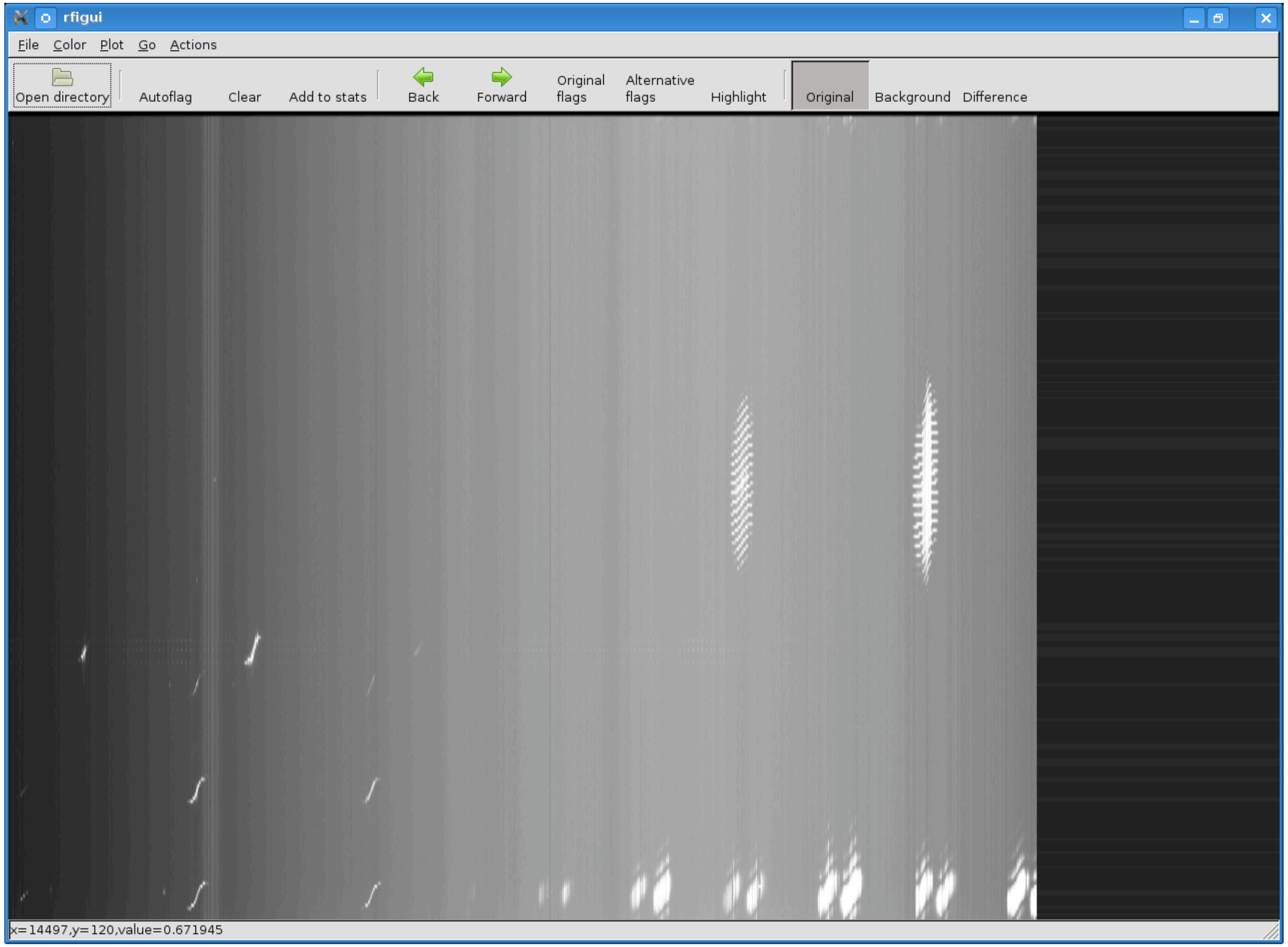


40m



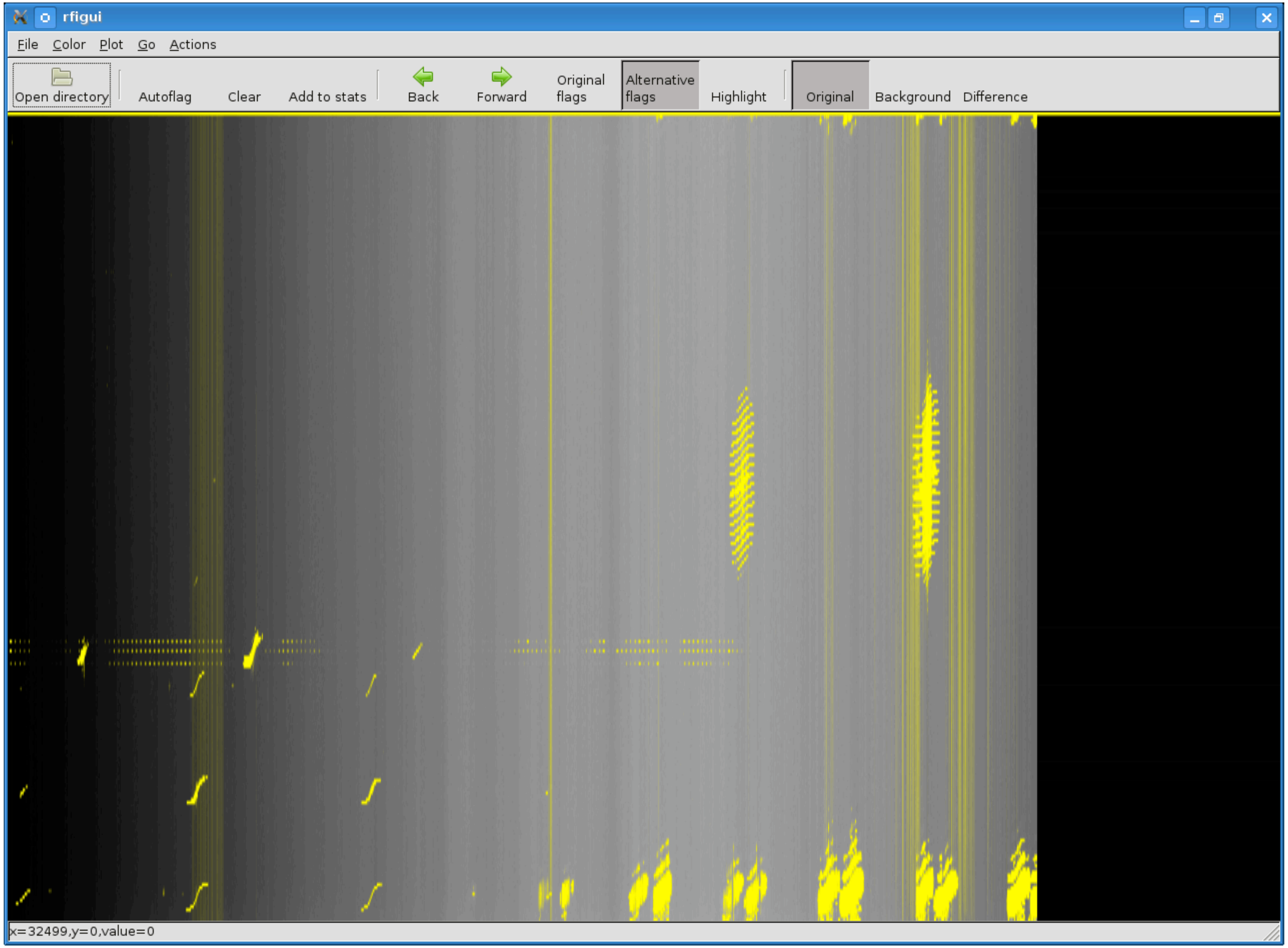
3h

RFI flagging on HBA SB88 (Andre Offringa, Groningen)



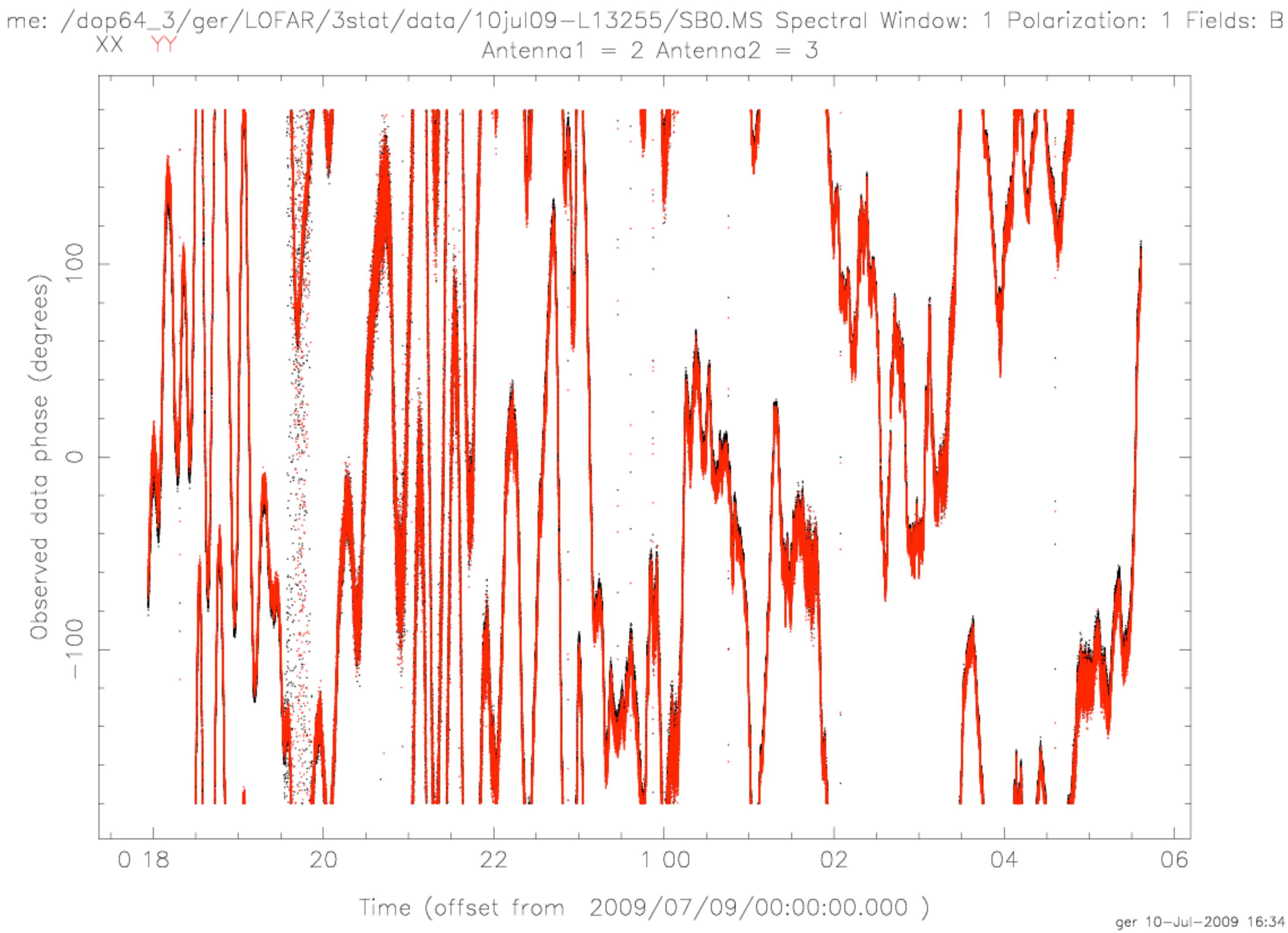
- thresholding, sliding windows (t,f), Gaussian kernel, background fitting …..
- works on WSRT & LOFAR data equally well
- took few minutes per baseline to do 12h in one subband (multiple iterations)

RFI flagging (Andre Offringa, Groningen)



Phase excursions in 12h on 15 km baseline: CS302-RS307

due mostly to ionosphere, and partly clock and partly source structure



120 MHz

Phase contributions: separating clock and ionosphere

The observed delay (in ns) on a given baseline i-j is composed of the following contributions, which could be time and frequency dependent:

- cable/station delays	a	# presumably constant in time
- ionospheric delay	b	# to 1st order scales with frequency $^{-2}$
- clock errors	c	# depending only on time
- source visibility phase	d	# depending on uv coordinate, hence time, and frequency

The total delay is: $\Delta t_{ij}(t,\nu) = a_{ij} + b_{ij}(t) + c_{ij}(t)\,\nu^{-2} + d_{ij}(t,\nu)$ [nanosec]

In degrees phase: $\Delta\phi_{ij}(t,\nu) = \{a_{ij} + b_{ij}(t)\}\,\nu + c_{ij}(t)\,\nu^{-1} + e_{ij}(t,\nu)$ [deg phase]

Forming closure phases around a triangle i-j-k cancels all a,b and c terms. If we observe a dominant pointsource we can also forget about $e_{ij}(t,\nu)$.

We can then solve for the $a_{ij}+b_{ij}(t)$ and c_{ij} terms by fitting for their frequency dependence. Doing this for a large number of baseline pairs i-j we can then separate the individual station contributions. [Within the core we can use a beam on CasA (LBA)].

Finally, separating a_{ij} and b_{ij}, and eliminating a_{ij} from all future data, assuming it indeed to be constant, probably requires long term averaging to eliminate the clock. Possibly we can use the limited array redundancy as well as the superterp stations to help here (?)