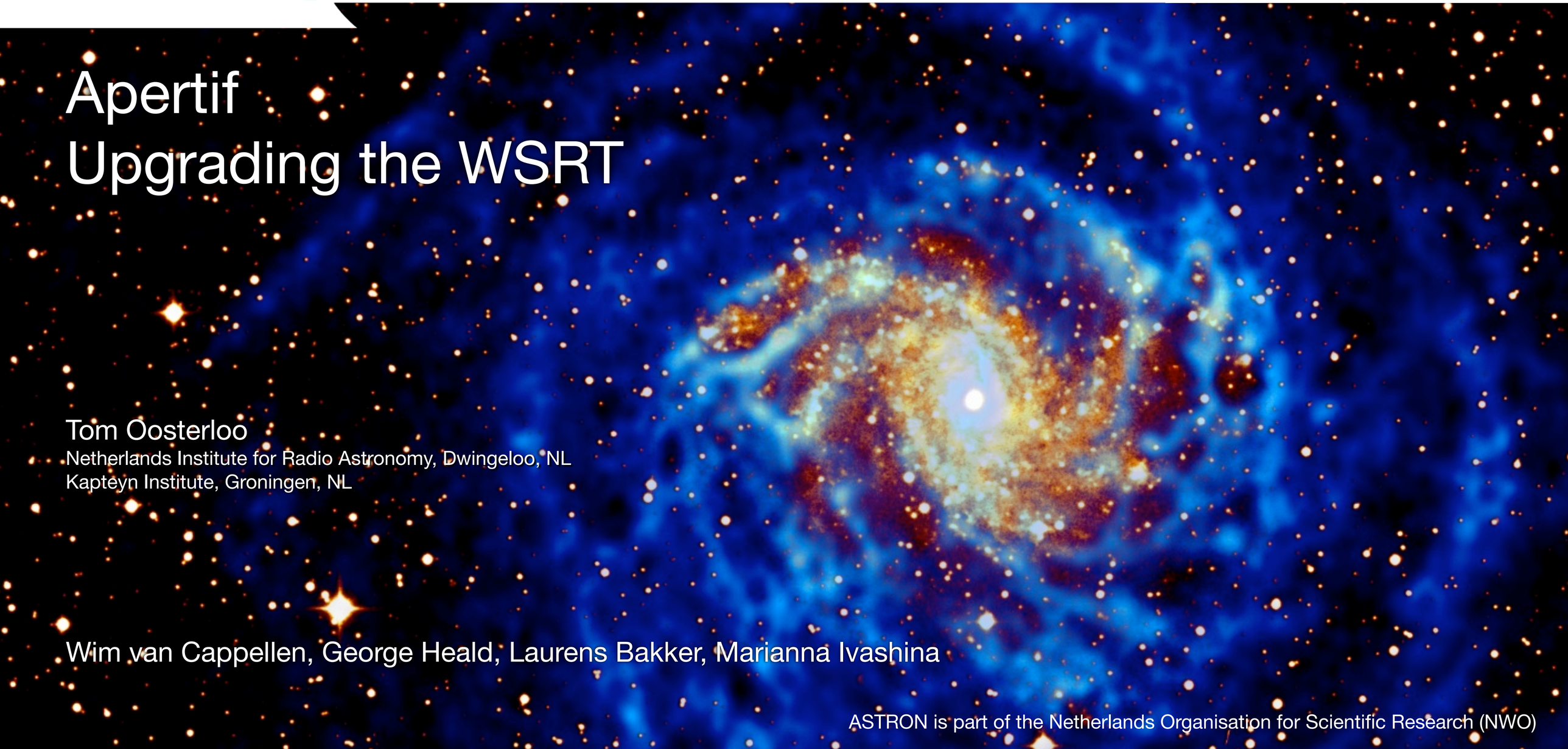
Apertif
Upgrading the WSRT



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ASTRON is part of the Netherlands Organisation for Scientific Research (NWO)

Citius, Altius, Fortius

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Radio astronomy is a very successful branch of astronomy.

To keep on doing well, we continuously have to improve the telescopes to open up new areas of radio astronomy.

Need for something bigger and better

- More collecting area
- More bandwidth
- “New” frequencies
- Larger field of view

SKA will have all this in 2020. In the mean time….

How to make a large FoV at 21 cm?

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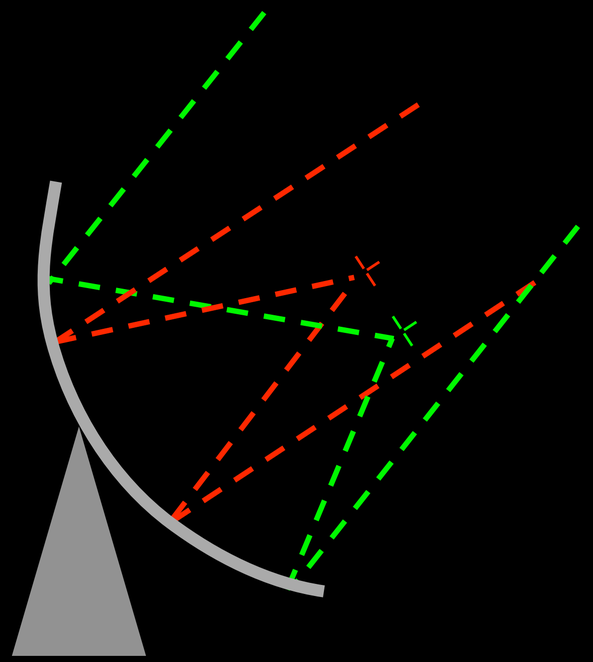
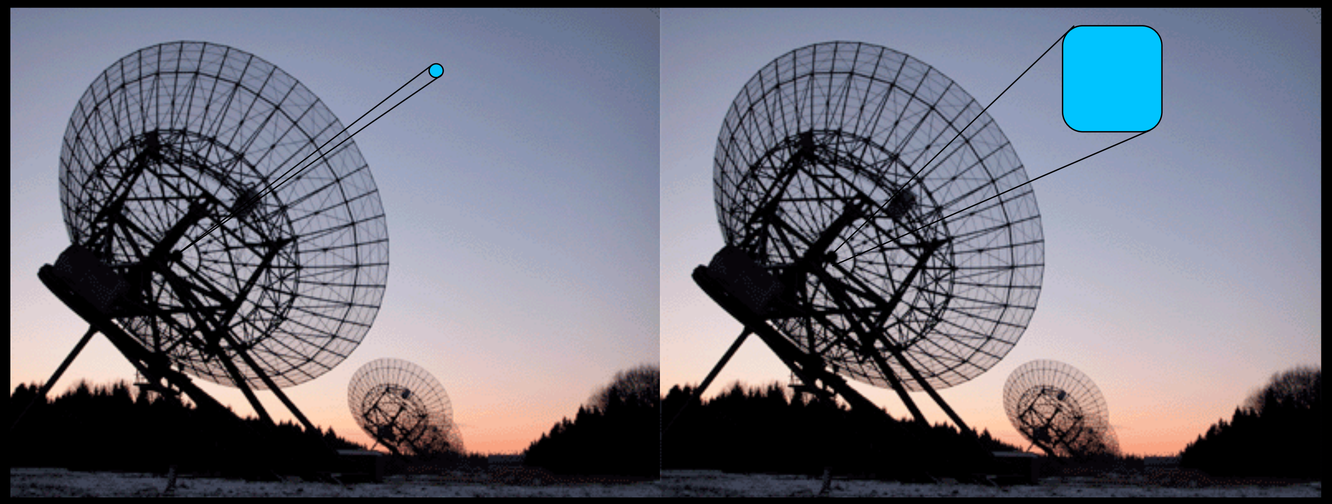
Small field of view of current radio telescopes is a major limitation.
Makes it expensive to build up large survey volumes with high resolution





Replace single-pixel detector with array
of detectors and turn single dish into a camera

➪ Apertif & ASKAP

Apertif: APERture Tile In Focus

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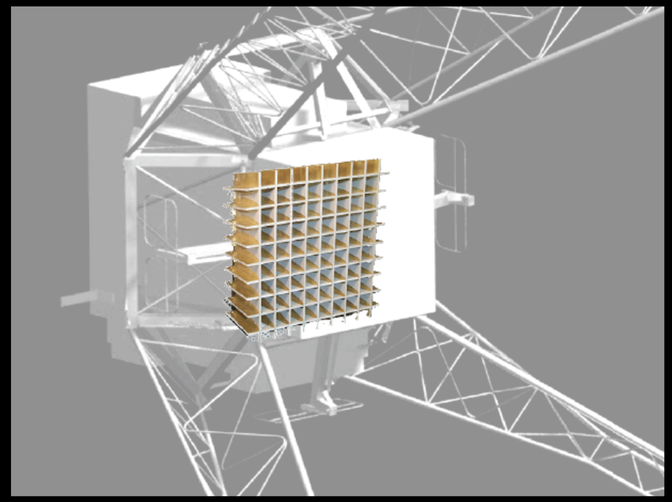
Enlarge field of view of WSRT using *focal plane arrays*:
array of densely packed Vivaldi receptors in each WSRT dish to fully sample focal plane

Apertif	WSRT
8x9 (x2) elements	1 (x2)
37 beams on the sky	1
Range ν: 900 – 1700 MHz	117 – 8650 MHz
T_{sys} 50 K	30 K
Aperture efficiency 75%	55%
Bandwidth 300 MHz	160 MHz



Survey speed increases by factor 20 - 40 - very similar to ASKAP & MeerKat

Science: large field of view ➪ surveys

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- All-sky surveys of H I & OH, of Local Volume out to $z = 0.4$
  - Relation gas content & galaxy assembly ⇄ evolution star formation
  - What are the gas properties of the smallest (and smaller) galaxies
  - Interface galaxies ⇄ IGM

- Pulsars survey
  - Apertif will find > 1000 new pulsars. Complement to Lofar pulsars

- Transients (Fly's Eye mode has FoV of 100 deg^2!!)

- Continuum & polarisation survey. Nice complement to Lofar surveys

Digestif: prototype FPA in RT5 of WSRT

Prototype to study beamforming, performance, etc
Leading to final design of Apertif FPA

Recycle Lofar ITS hardware

Stand alone, record realtime signals for later processing in software

7x8x2 elements of which 60 can be used

Noisy LNA (T_{sys} = 125 K)

Can integrate for 6.7 sec...

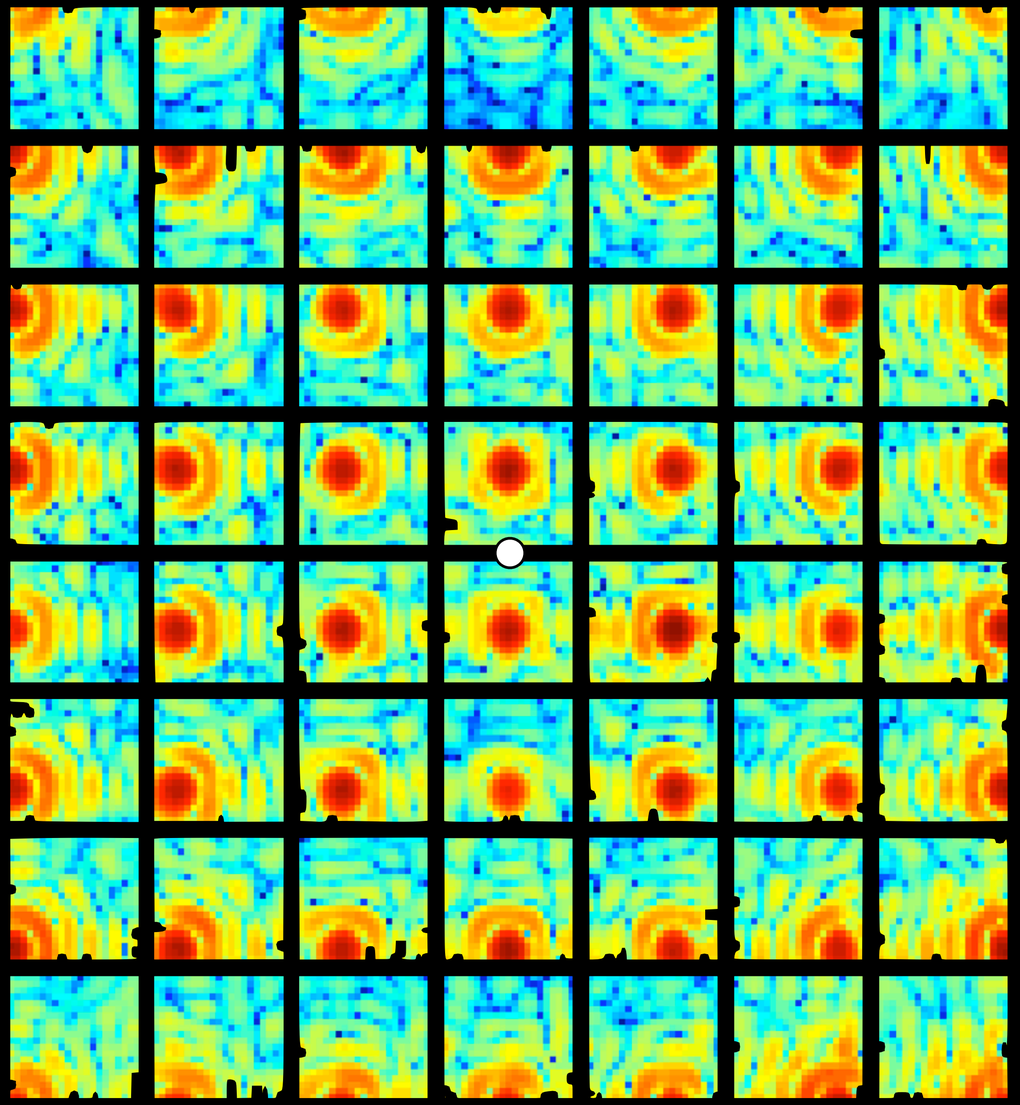
Processing can take up to 40 minutes…

So far most experiments in single polarisation

This summer new prototype: Digestif75 (8x9 & 75 K)

Element beam patterns

Each panel is the same 3x3˚on the sky and shows the reception pattern of an element of the FPA on the sky



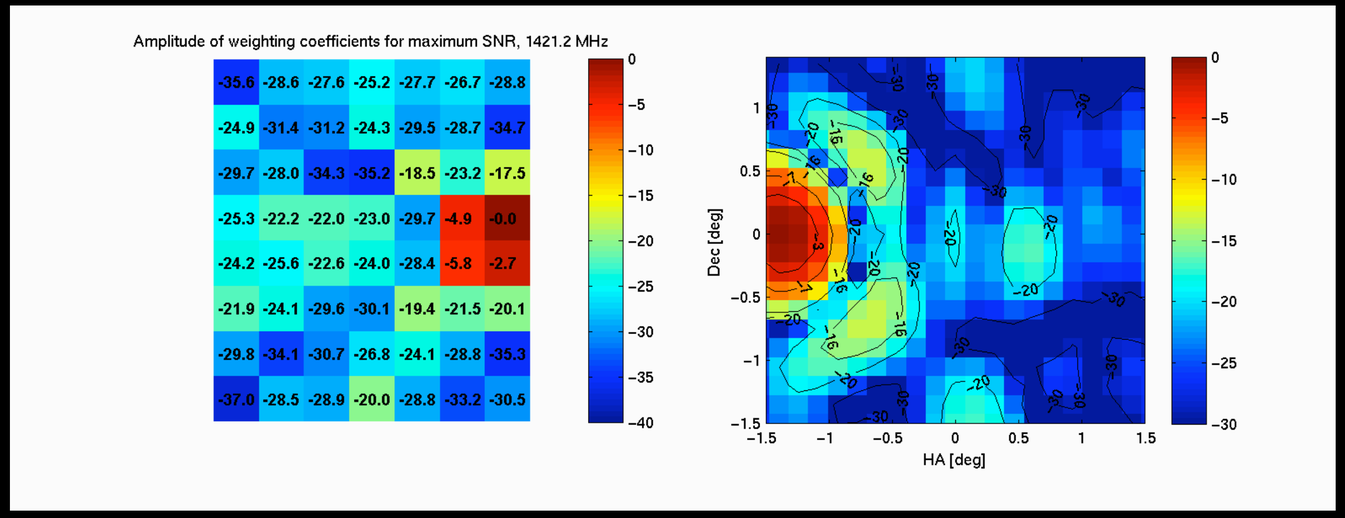
Note:

- no on-axis beam
- *X* and *Y* elements *not* co-located

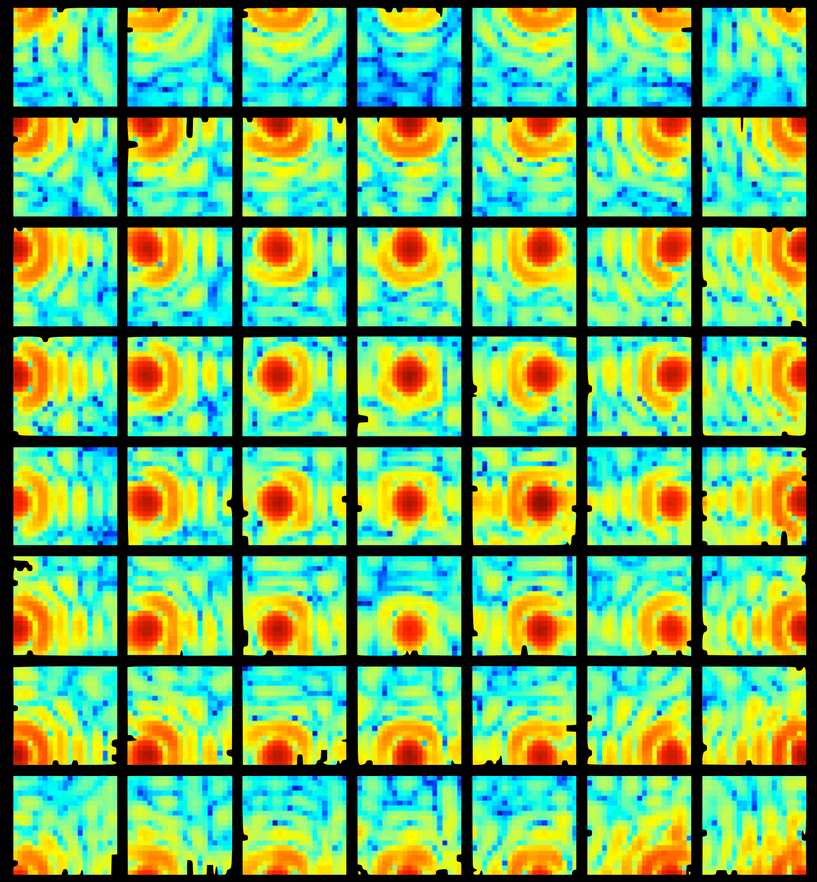
Compound beams

Tile FoV with 37 separate *compound* beams,
using weighted sum of all elements for each compound beam.
Manipulate dish illuminations to optimise for:

- Optimum S/N
- Low instrumental polarisation
- Low sidelobe level
- …



Same colourscale



Element beams are ugly, but compound beams are very well behaved

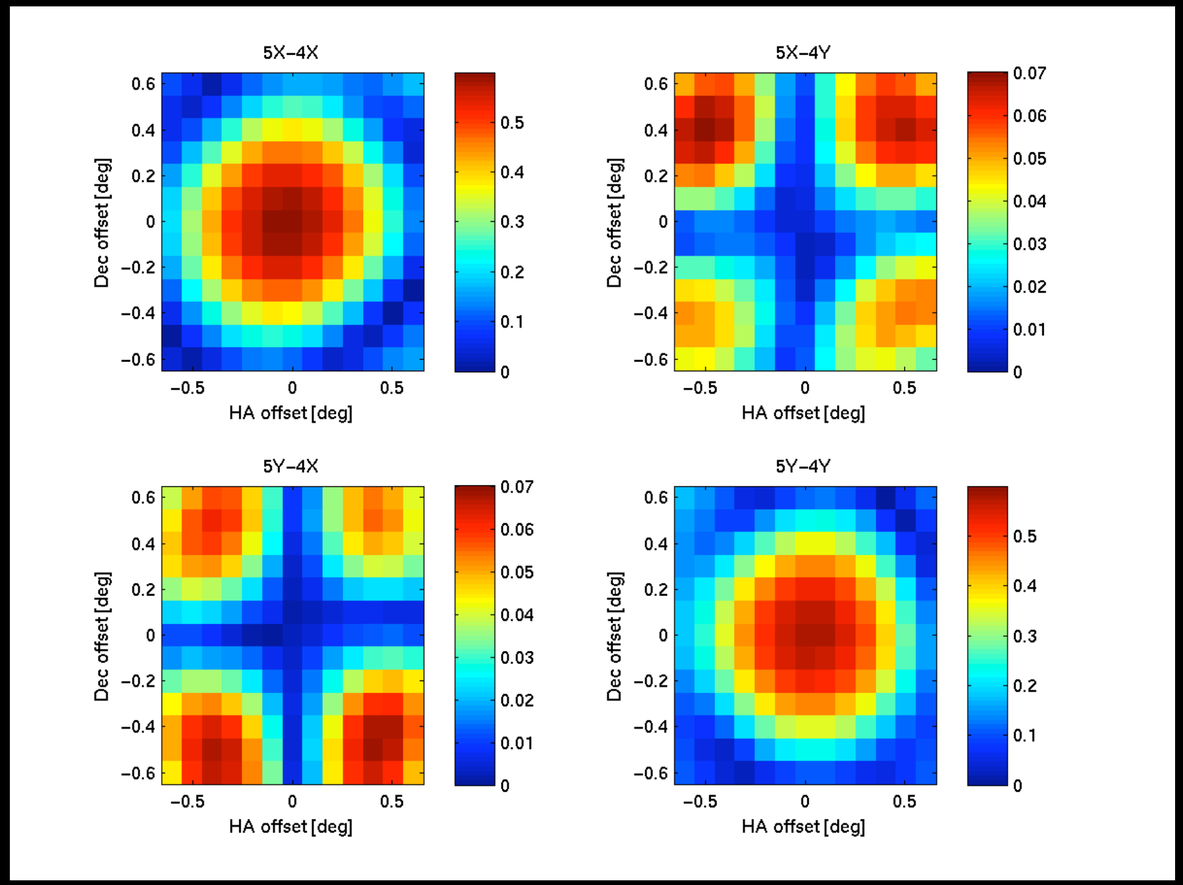
First dual polarisation results

XX beam

XY beam

YX beam

YY beam

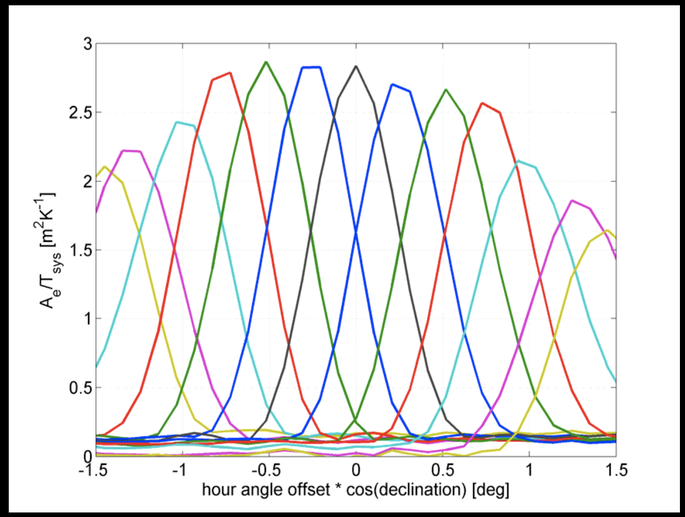


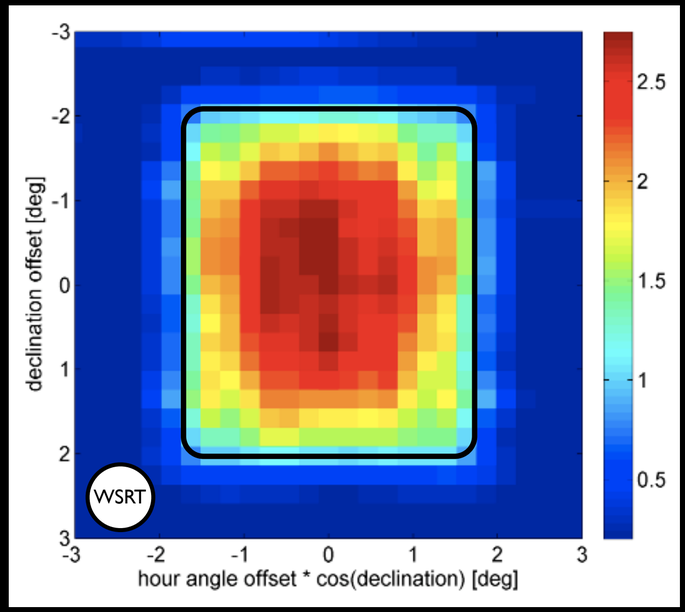
Very similar to “old” WSRT behaviour

Next: optimise for low instrumental polarisation

Sensitivity - Field of View

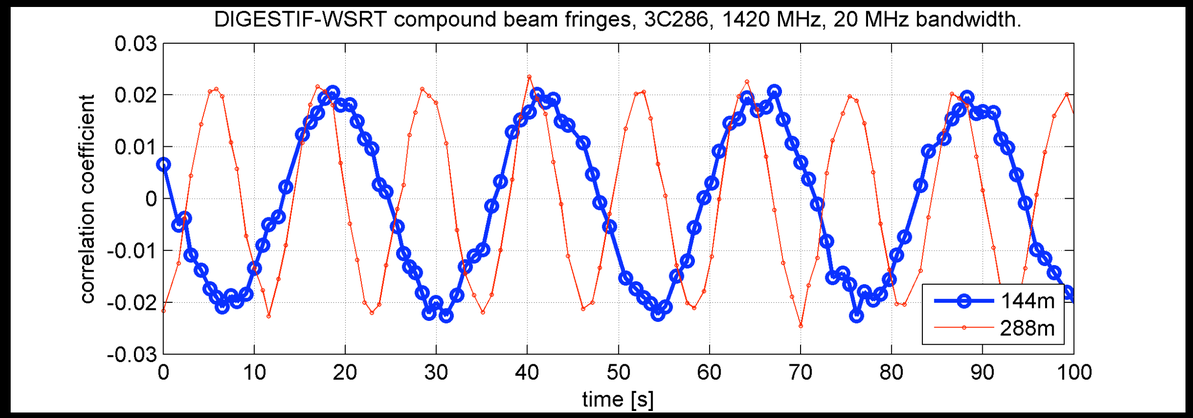
- Achieved aperture efficiency of 75%
  (compared to 55% of "old" WSRT)
- Expected T_{sys} of Apertif 50-55 K (uncooled LNA)
  (compare with 30 K of WSRT)
- A/T of Apertif will be ~0.8 times that of WSRT
- Smooth variation of sensitivity over sky
- Have achieved field of view of 8 degree^2 with 25-m dish
  (compare with 0.3 degree^2 of WSRT)

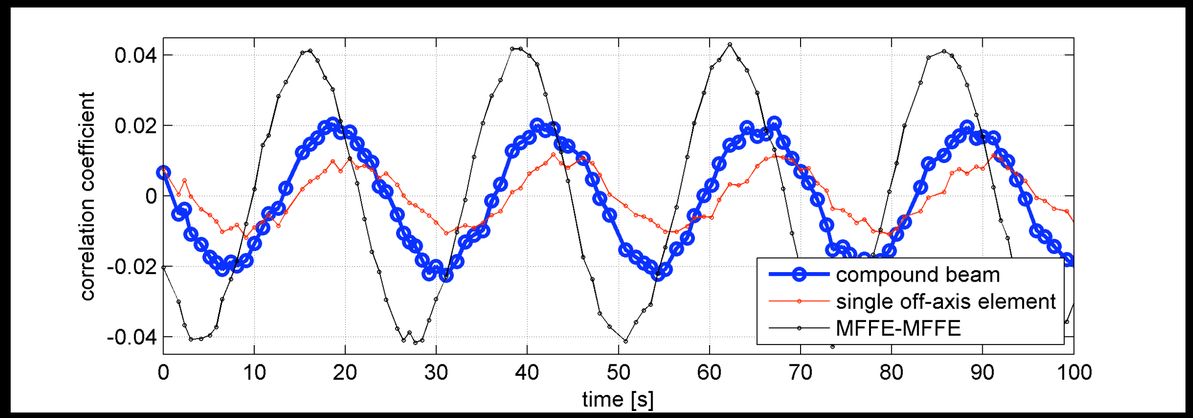




First fringes

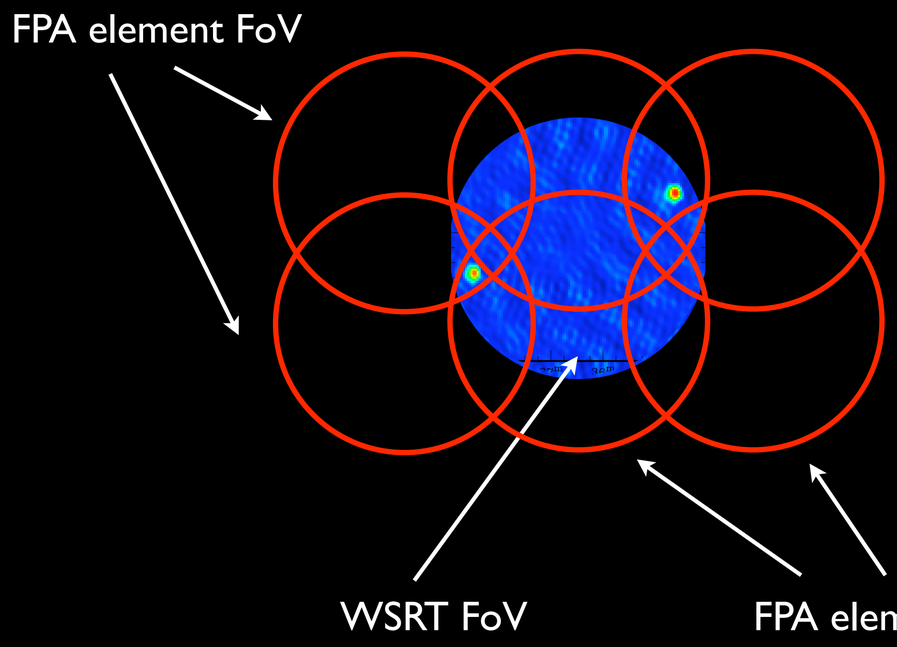
- Digestif has 60 backends, 1 correlator and 56 elements (in 1 pol)
- Plug 4 WSRT (single pixel) dishes into Digestif backend using cabling of "spare IF" (one cable broken, so only 3 WSRT dishes connected)
- 3 baselines Digestif-WSRT
  3 baselines WSRT-WSRT
  144-m and 288-m baseline measured both with Digestif-WSRT and WSRT-WSRT
- Correlations computed off-line in software (Lofar ITS correlator)
- Note increase of fringe amplitude for compound beam



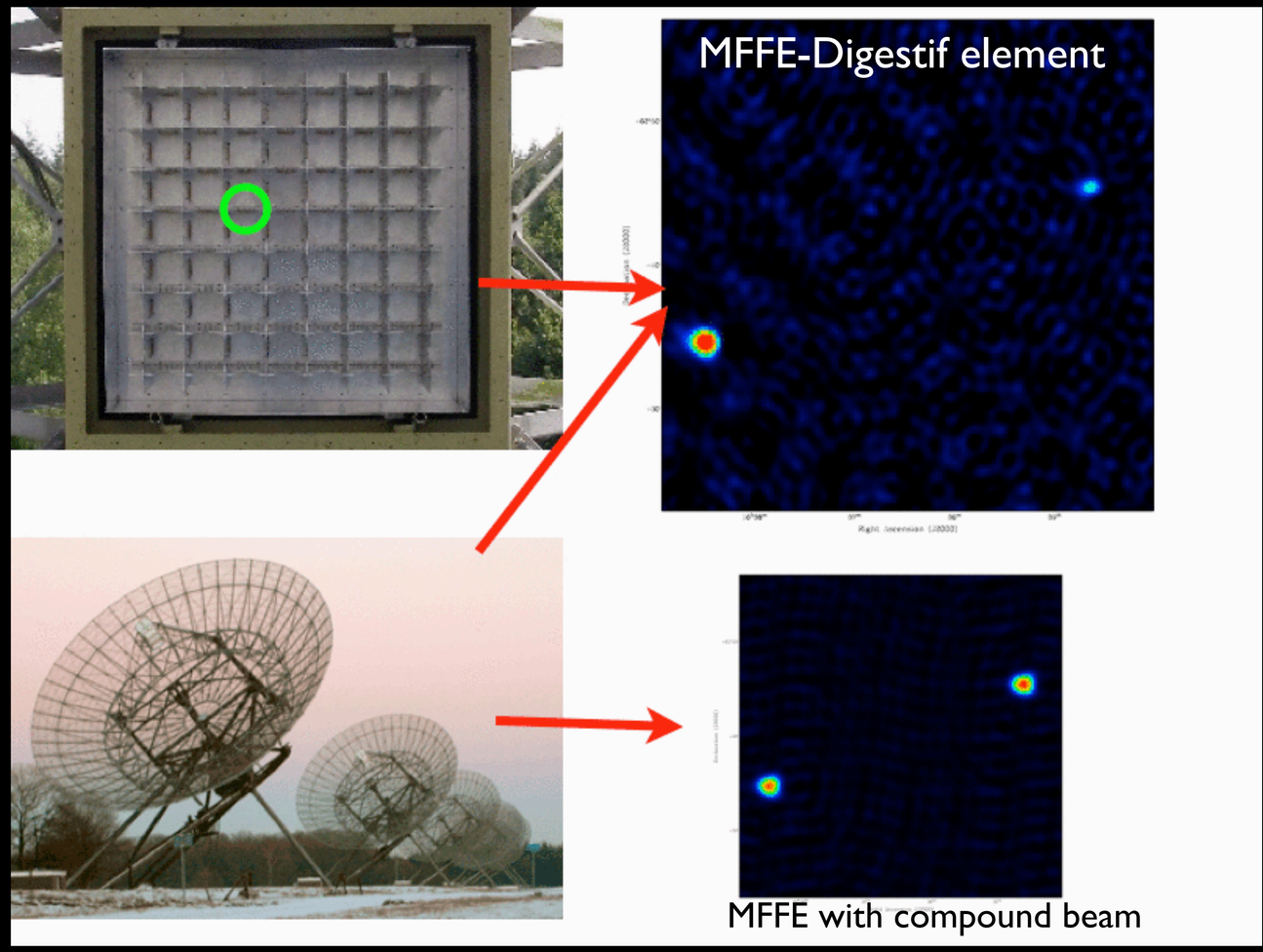


More images...

- Different FPA elements look at different parts of the sky
  Have different overlap with WSRT beam
- Different images obtained from
  the same observation



Images made with 3 baselines



3C343 and 3C343.1

Timeline etc

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- Not yet fully funded…
  - Are confident we can build and run Apertif….
  - Collaboration with GMRT on correlator (FPAs on GMRT?)
    - prototype available end 2009, Digestif75 will become part of WSRT
  - Recycle Lofar effort
- PDR of FPA & beamformer in aug 2009. After PDR: significant increase in effort
- On sky in 2012(?)
- Each survey takes very large amounts of time (1-2 yr observing time)
  - Can do only a few surveys!!!! Access to survey data not limited to one group of people
  - Important to optimise for multi-purpose surveys
- ~25% open time - Open model for surveys, regular data releases
  - All-sky continuum, HI & OH
  - Medium deep continuum, HI & OH on smaller region
  - Pulsar & Transients

Summary

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- Radio astronomy needs application of new technology to stay alive and to find new areas of research

- Focal-plane arrays effective for making large FoV in radio telescopes, at low cost

- Apertif prototype shows that desired performance of FPAs can be achieved
  - High aperture efficiency
  - Large FoV
  - Good Tsys

Observational astronomy is about exploration.

Focal plane arrays open up large discovery spaces so they will give us lots of *new astronomy*