The prospects of a focal-plane array at the WSRT

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This presentation

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- Why this talk?
- Description of Apertif
- Options
- Performance
- Science with Apertif
- Impact on current WSRT science
- Other issues

Possible upgrade to the WSRT: Apertif

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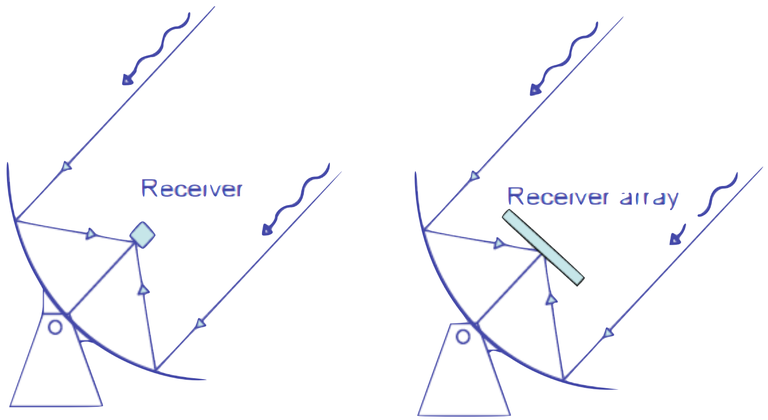
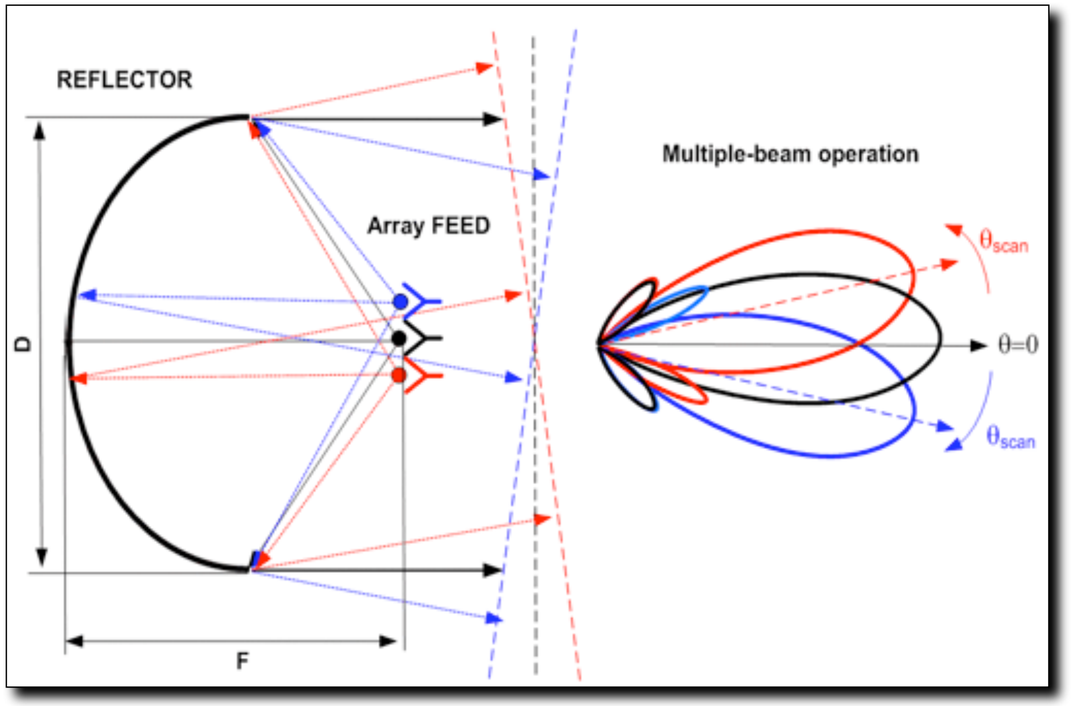
- Under consideration: enlarge field of view of WSRT by large factor (25) by replacing single-pixel feeds by focal-plane arrays
- Increase bandwidth to 300 MHz ($\geq$16000 channels, $\leq$ 8 km s^{-1})
- L band only (1000-1700 MHz)
- WSRT will become survey instrument (SKA pathfinder). Survey speed ~20 times that of WSRT.
  what you now do in a year, with Apertif you do in a few weeks
- Also single-dish modes are interesting
- A lot of what of what the WSRT is being used for now will not be possible anymore
- Relevant for (future) role of Astron (and the Netherlands) in SKA
- Aim of this talk: start discussion in the community about whether we should do this. And if so: how

How to make a large FoV?





- Replace single-pixel detector with array of detectors and turn dish into a camera
- Form many beams on the sky
- Image each beam

Prototype in RT5

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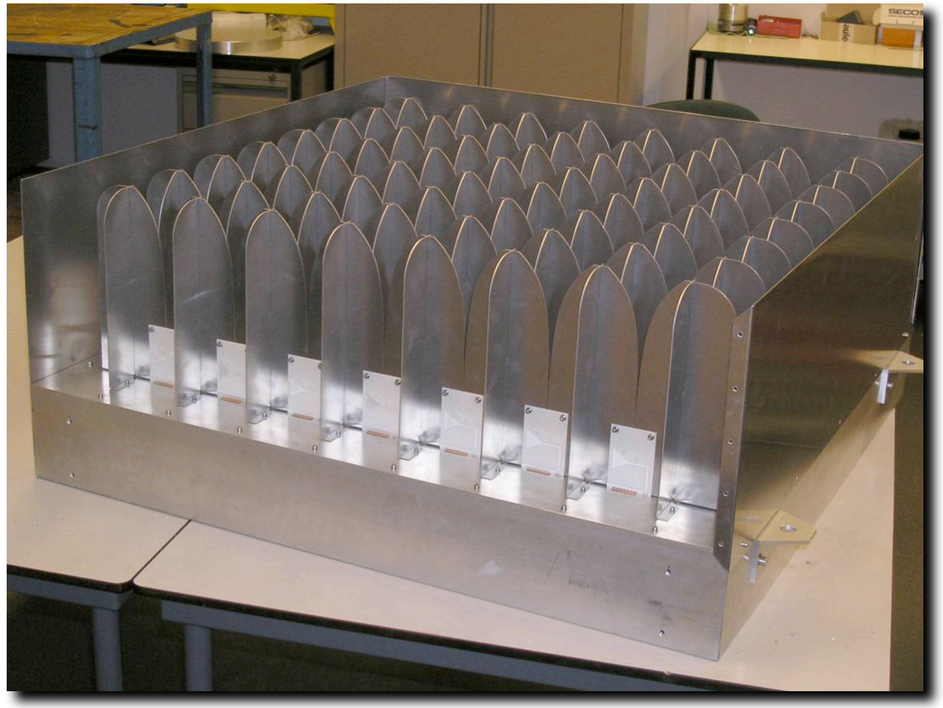
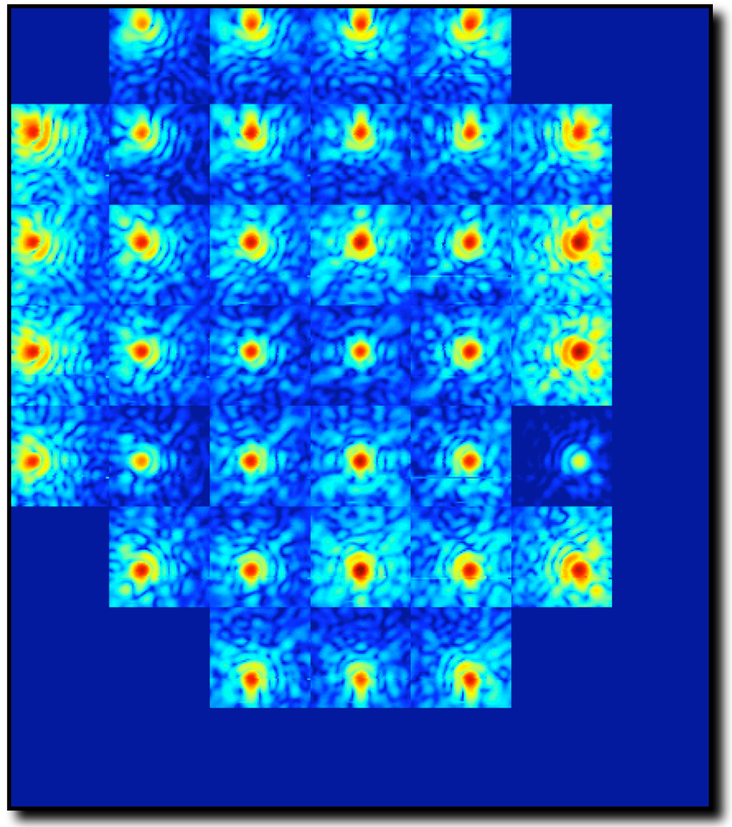


Each element is looking to another part of the sky

Optimal beam forming

Difference with classic multifeeds:

- Dense sampling of focal plane - beam overlap on the sky
- Can optimise beam in a given direction
- Can do this multiple times



Each panel 3˚ x 3˚

Element patterns on sky

Focal plane + elements

Optimal beam forming

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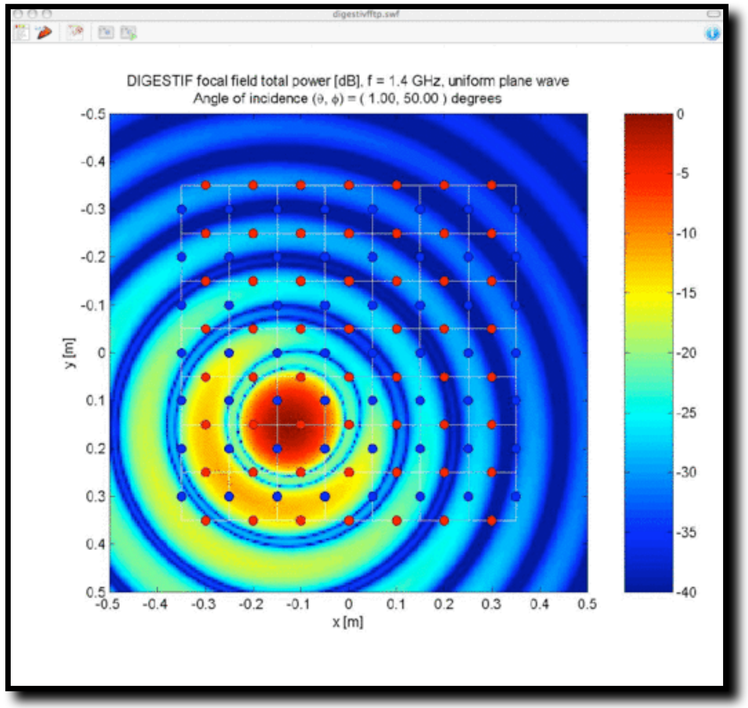
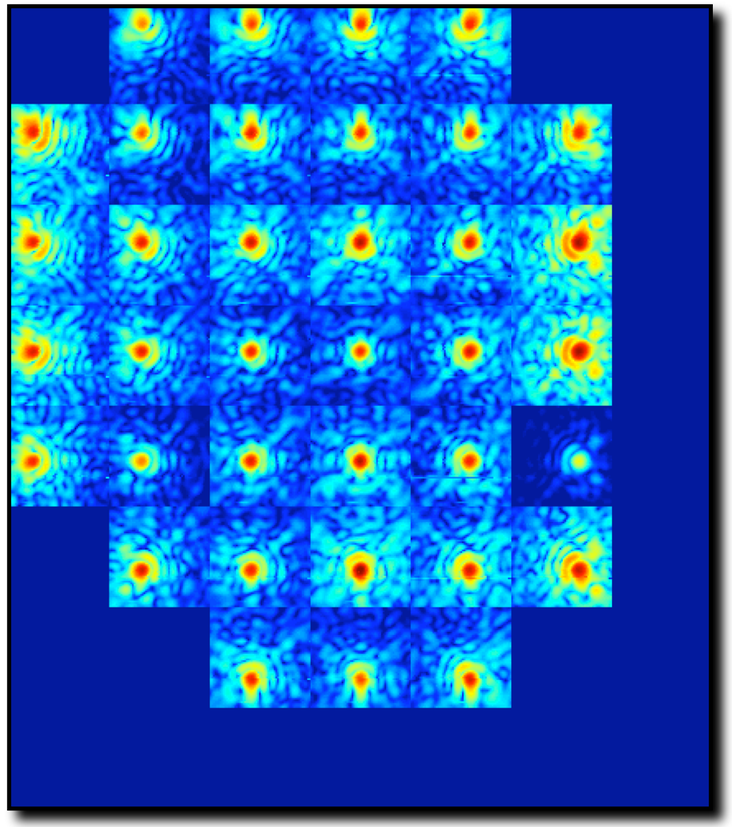


Focal plane + elements



Each panel 3˚ x 3˚

Element patterns on sky

Apertif: APERture Tile In Focus

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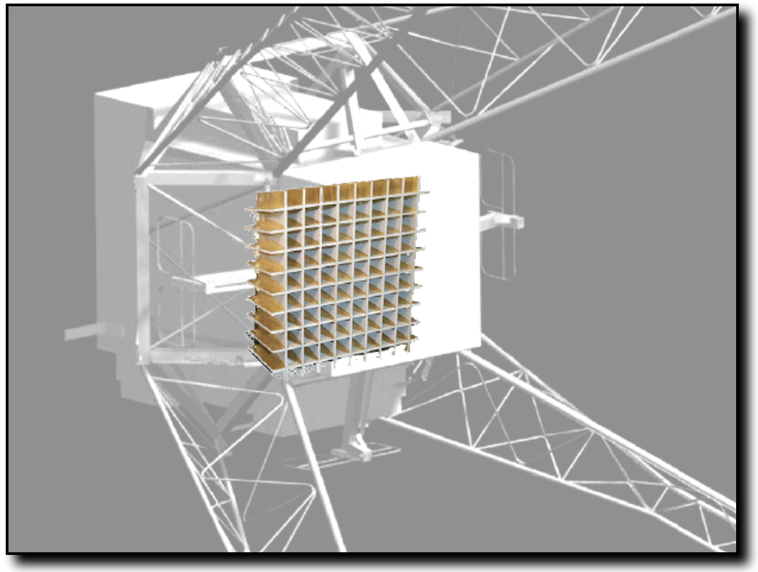
Receptor array in each WSRT dish

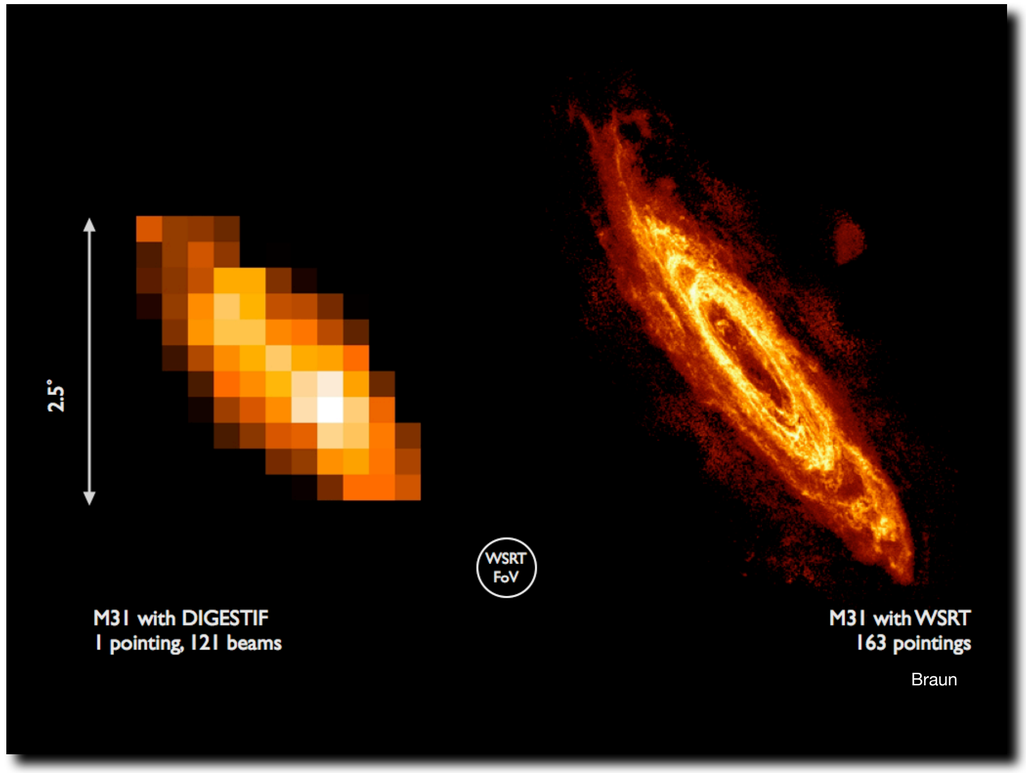
	Apertif	WSRT
	8x8 (x2) elements	1 (x2)
	25 beams on the sky	1
ν:	1000 – 1700 MHz	117 – 8650 MHz
$T_{sys,21}$:	50 K	30 K
$\Delta\nu$:	300 MHz	160 MHz
A_{eff}:	75%	55%

Survey speed increases by factor 18-24

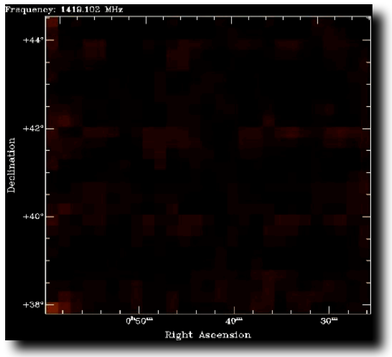


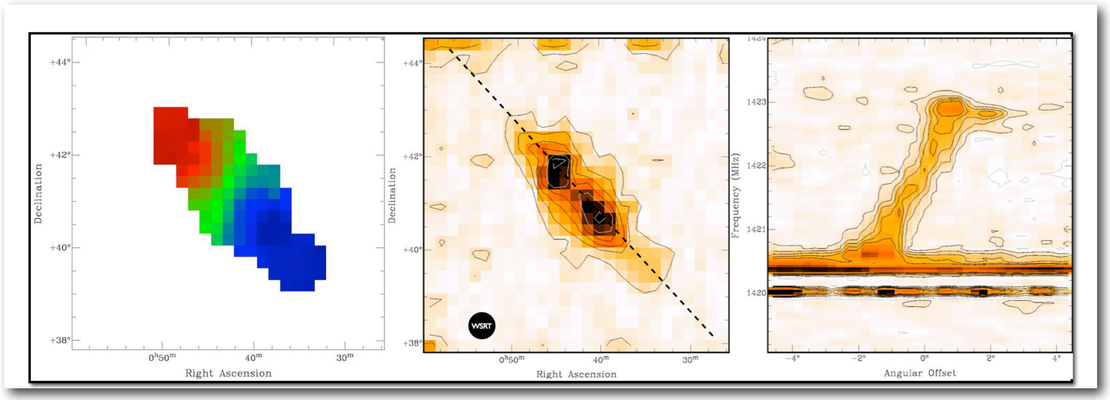
	MeerKat	Apertif	ASKAP	WSRT
A/T	3	1	0.5	1
FoV	3	25	120	1
Survey speed	25	20	80	1

First images with prototype



M31



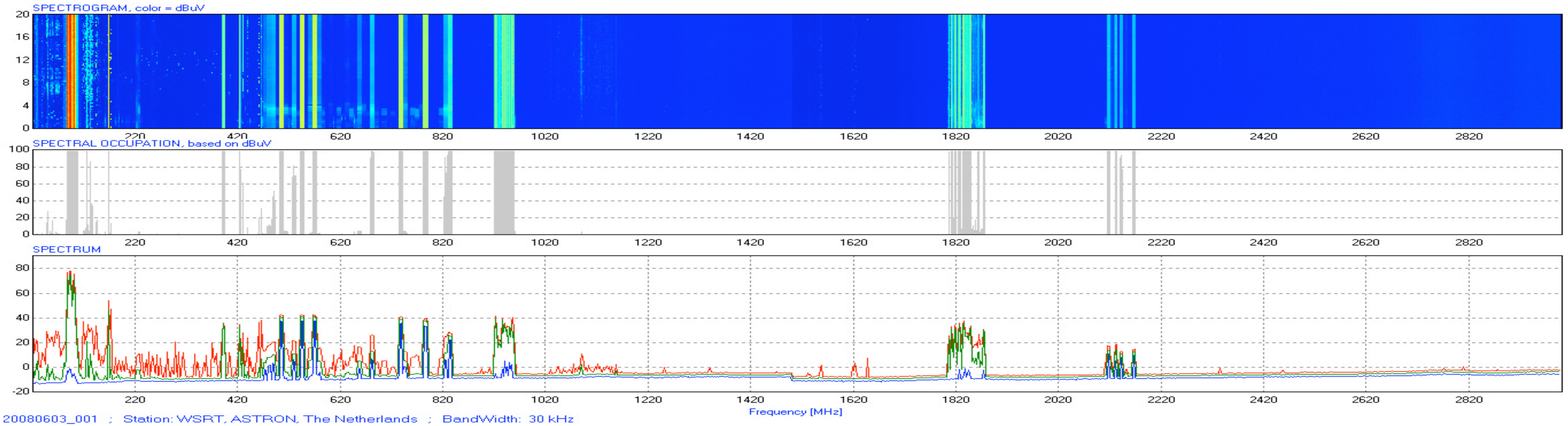


Demonstrated feasibility

Options

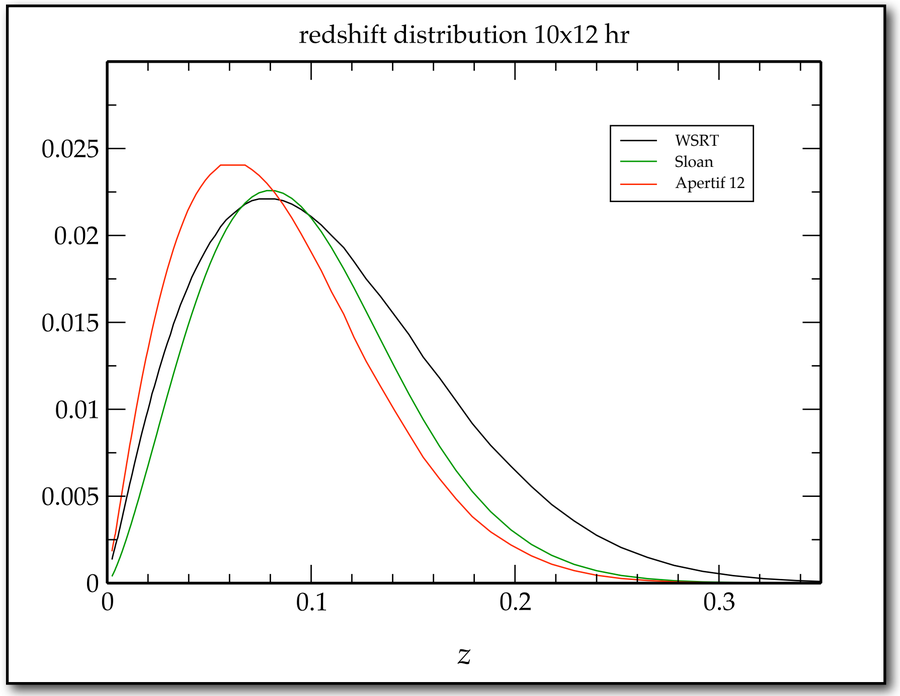
- 3 M€ available for frontends
- Original plans are slightly too expensive
- Fewer dishes or less bandwidth
- To lower frequencies?
  will cost >0.5 M€ for better analog system,
  higher T_{sys}

N_{dish}	N_{beams}	Δν [MHz]	Noise line	Noise cont	Sspeed	Cost per dish	Total cost
MFFE	1	160	1	1	1		
14	25	160	1.39	1.39	12.9	€216743	€3034402
12	25	300	1.64	1.20	17.7	€262484	€3149808
14	25	300	1.39	1.01	24.1	€262484	€3674776



Performace: Line

- Apertif will double or triple integration times
- Resolution ~8 km s^{-1}, better (factor 4?) seems feasible
- 10^9 $M_\odot$ detectable out to z=0.04 (MFFE z=0.05) in single 12 hr
- 5x10^9 $M_\odot$ detectable out to z=0.08 (MFFE z=0.10) in single 12 hr
- With 10x12 hr good overlap with SDSS spectroscopic galaxies
- A single 12 hr observation will detect ~200 galaxies
- 10x12 hr will detect ~1000 galaxies
- Large survey will give few x 10^5 detections



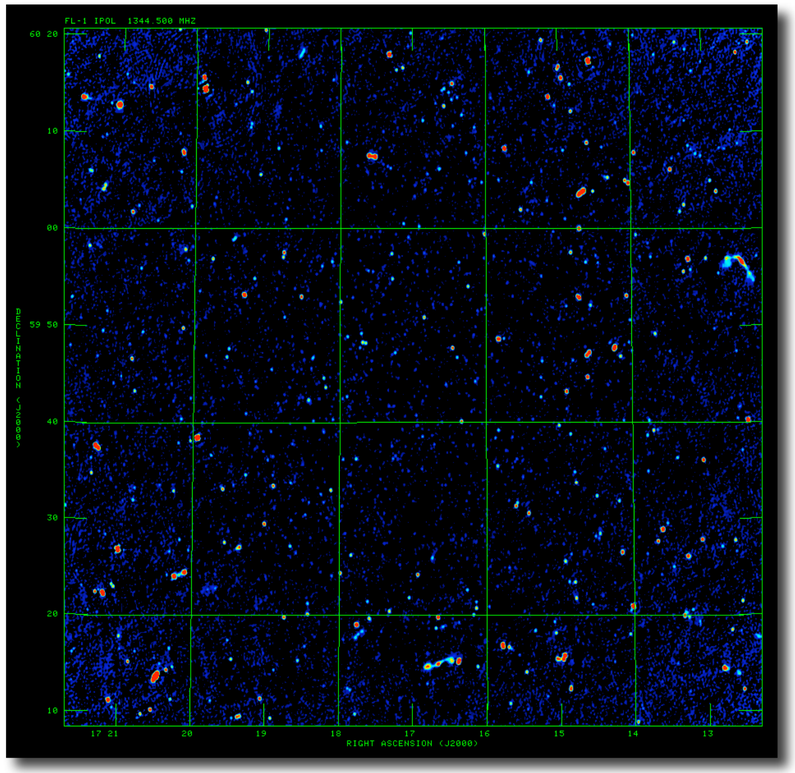
Performance: continuum

- With 300 MHz band, continuum sensitivity will be more or less that of the current WSRT
  15-20 μJy beam^{-1} after 12 h

- Continuum images of deep H I observations will be confusion limited in Stokes I

- Continuum survey will >30 times deeper than NVSS

- Such a survey could give few x 10^6 detections



Morganti et al.
Spitzer First Look field
8 μJy beam^{-1} noise

Science: H I

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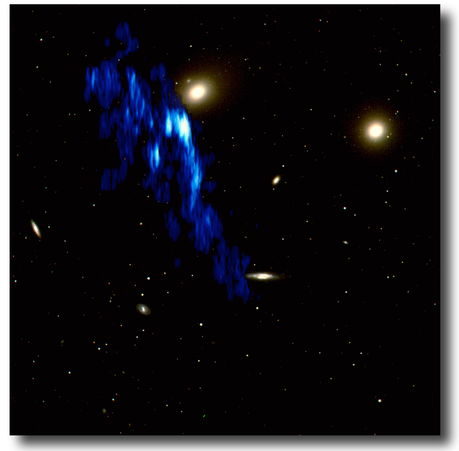
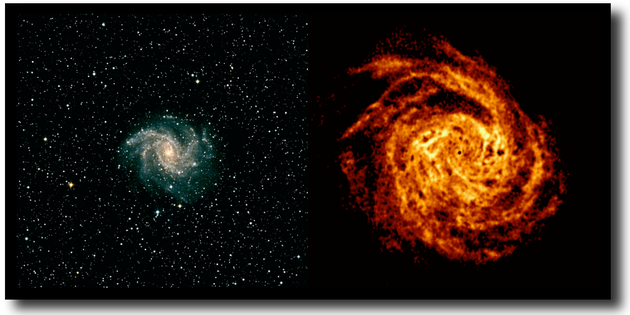
- Major new opportunity: can image the entire sky at high resolution, high sensitivity and out to large (for H I standards) distances



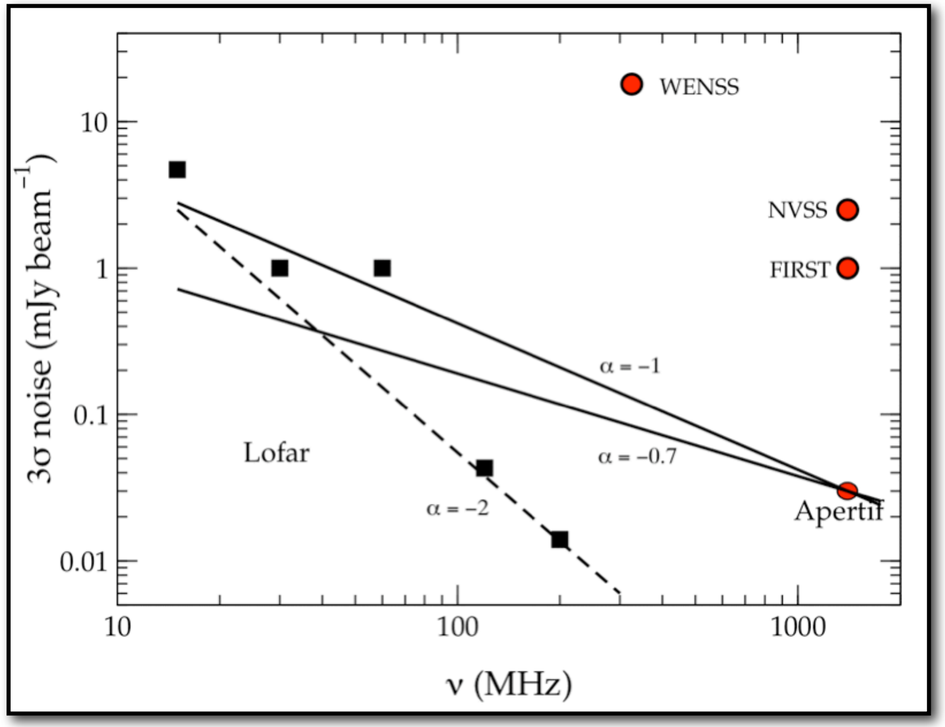
- Current state: we know about the H I of few x10^4 galaxies, almost all with ‘resolution’ of 5-15 arcminutes, ~100 above z = 0.1
- Apertif: few x10^5 galaxies, out to z ~ 0.2, with 15 arcsec resolution, many above z = 0.1
- Start to address evolution of H I & connection with evolution of star formation. Relation with environment, type, etc etc. Overlap with SDSS



- Combine with Local Volume & low-mass end of H I mass function: down to few x 10^5 $M_\odot$. Dark galaxies???
- Single-dish mode: 21-cm Intensity Field: cosmic structure on very large (>100 kpc) scales

Science: continuum

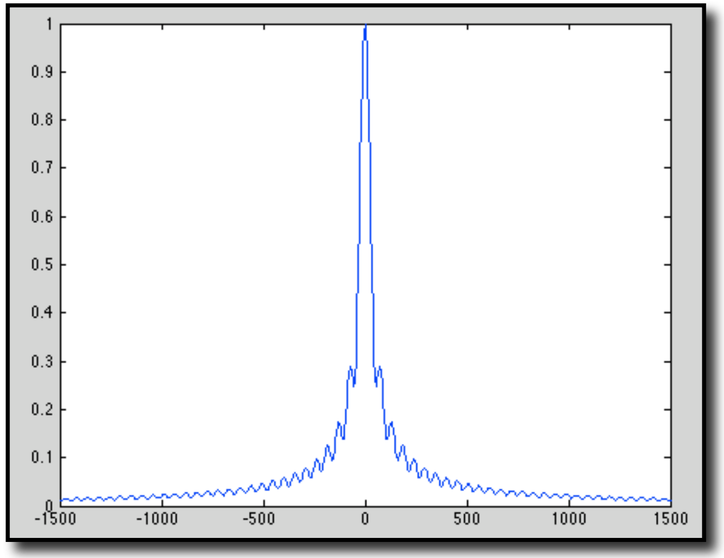
- Large-area survey, >30 times deeper than NVSS, few million detections
- Complement to Lofar
- Many of the detections will be star forming galaxies at intermediate redshift: fits nicely with H I survey



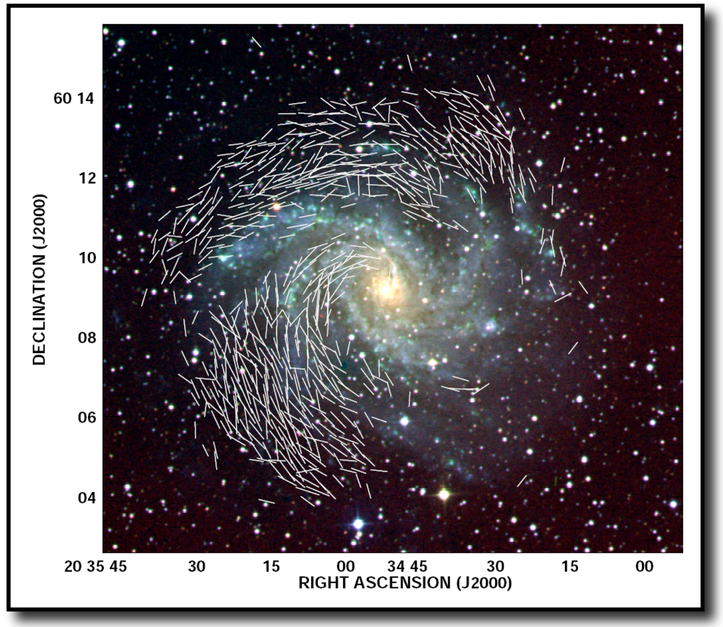
Science: magnetism

- Rotation Measure Grid with spacing ~10 arcminutes
  Galactic magnetic field

- Single dish: Global Magneto-Ionic Medium Survey (GMIMS): all-sky full polarisation from 300 to 1800 MHz
  Apertif could do 800-1300 MHz



RM synthesis of many many nearby galaxies
300 MHz: 94 rad m^{-2} FWHM
700 MHz: 59 rad m^{-2} FWHM
(SINGS 144 rad m^{-2} with strong sidelobes)



Science: pulsars

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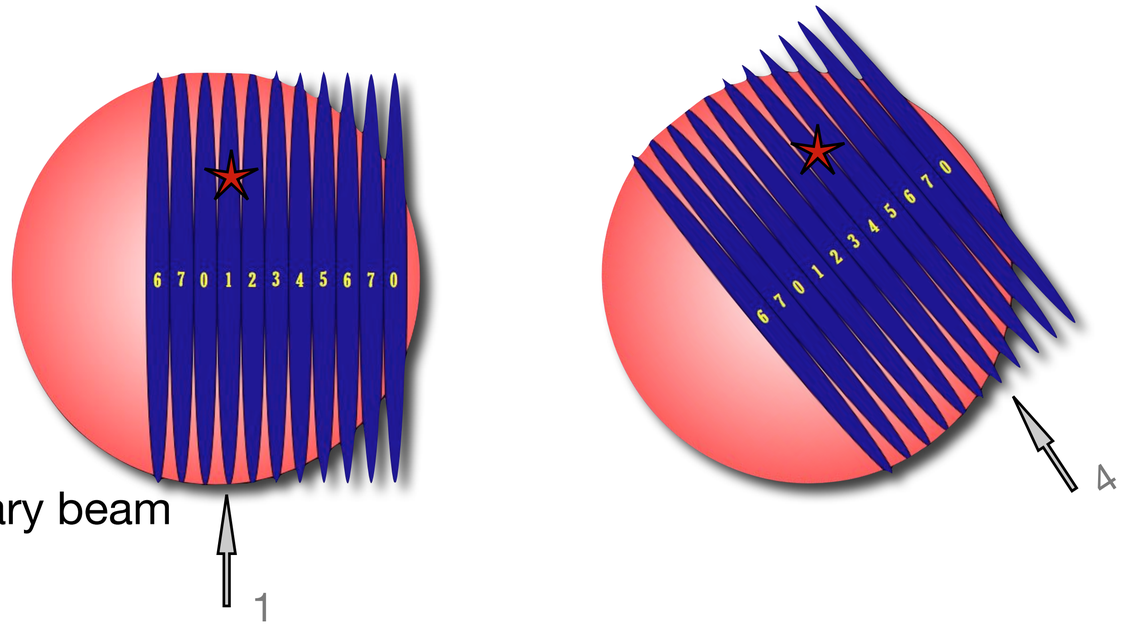
- Apertif+WSRT is very efficient pulsar machine
  Can use field of view of primary beam to find pulsars

- Thousands of new pulsars!!!!



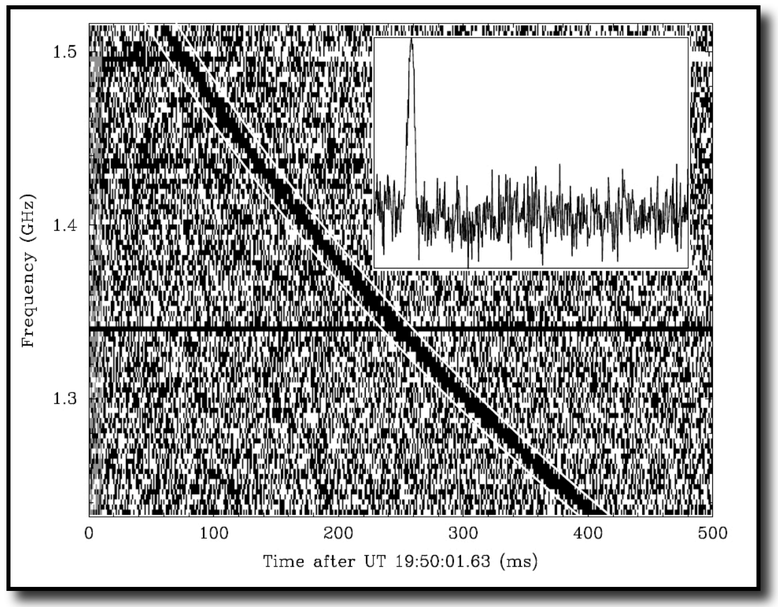
WSRT 8gr8 mode:

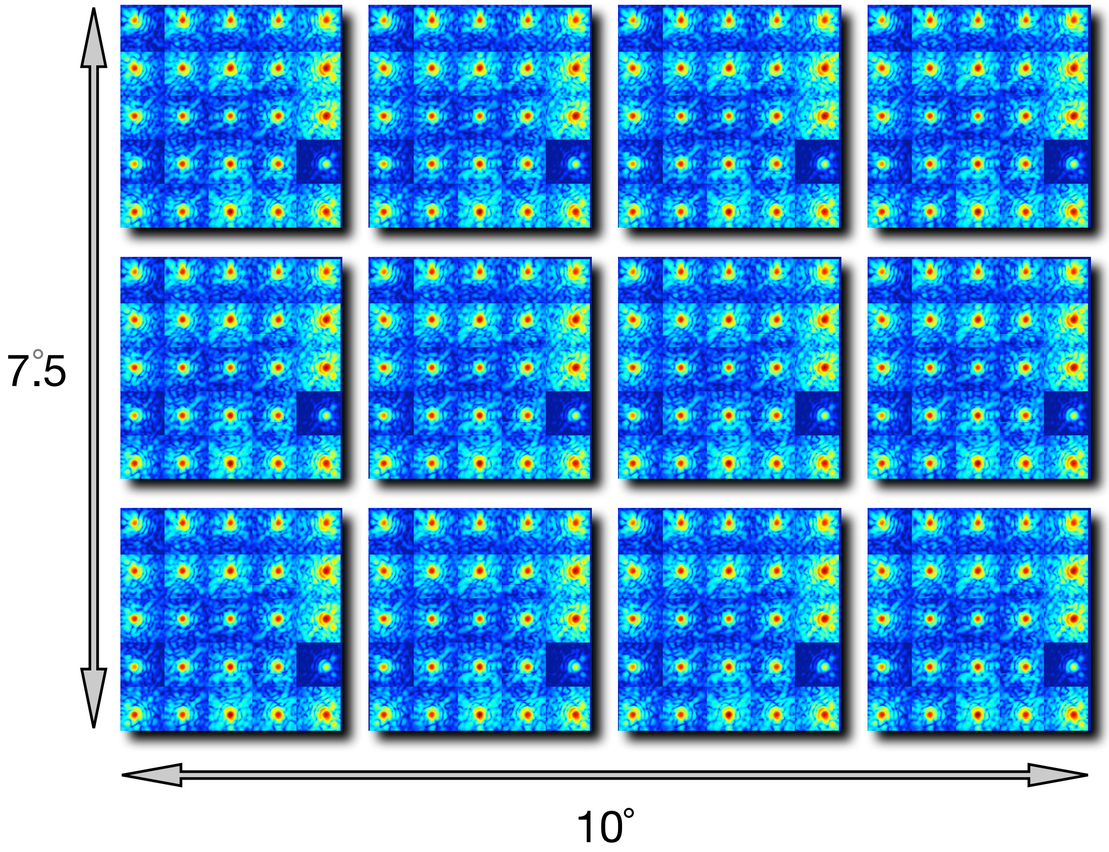
8 bands form 8 sets of repeating fan beams cover primary beam
Earth rotations lets them intersect to determine location

If Apertif has the right backend, this can be done over 7 degree^2

Science: transients

- Fly's eye mode: 12 (14) x 25 beams on the sky: can cover (>)75 deg^2 in one observation
- Detect 1 "Lorimer burst" every few weeks...





What is lost?

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- Because Apertif only works in L band: current observations in other bands will not be possible anymore
- Questions to you: How bad is this? Solutions? Alternatives?
- If you want to say something about this: speak up!!!
- Important for context: long term future (>2012) of WSRT not secure
- Option: Apertif on 12 dishes, 2 keep MFFE

What is lost: pulsars

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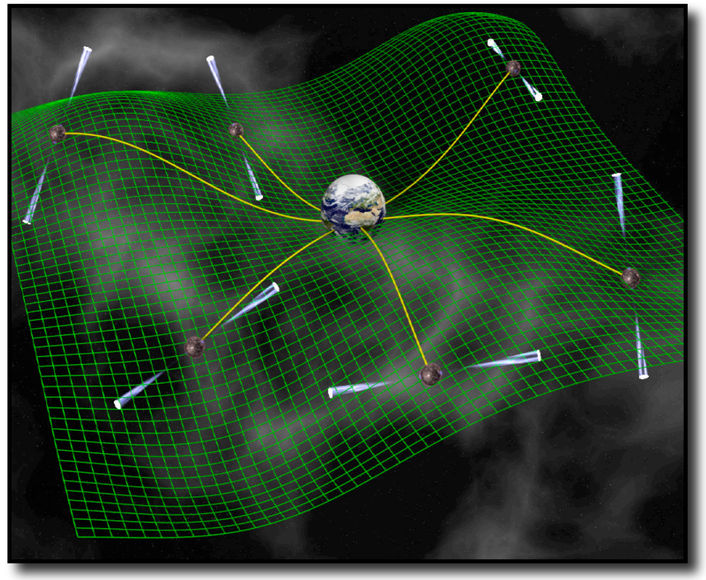
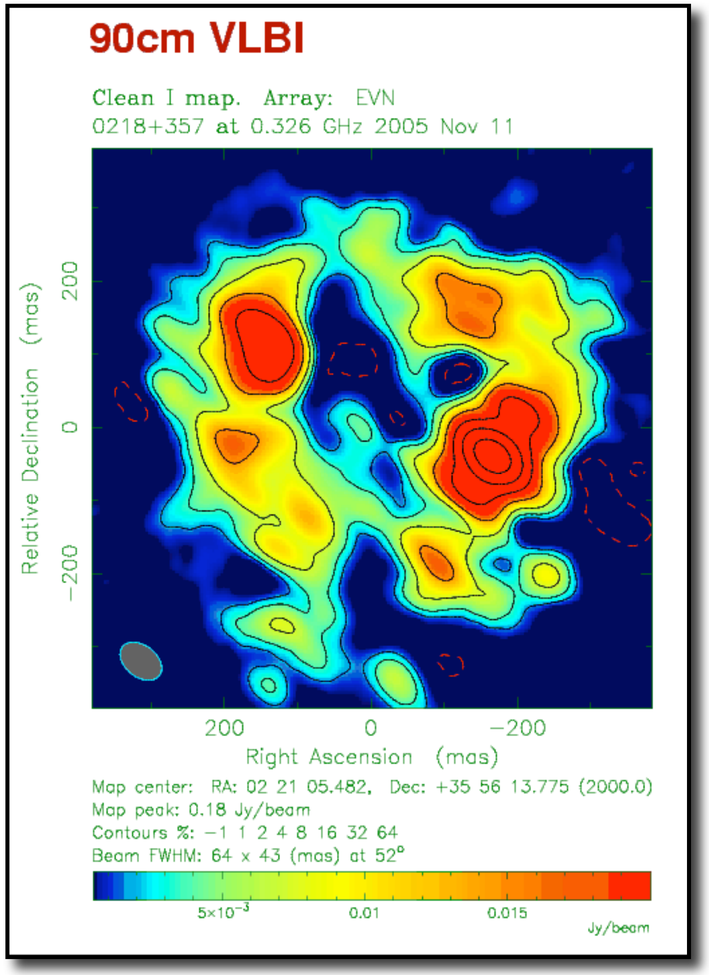
- WSRT timing is done at 92 cm. Sardinia can take over?



What is lost: VLBI

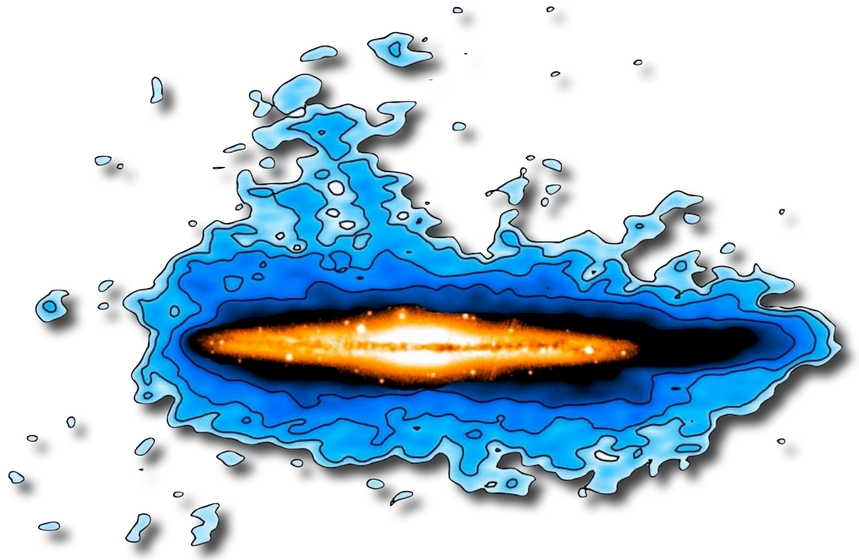
- Lose 6-cm phased array main problem
- Only 2 dishes available for VLBI at non L band?
- Things will have to change, regardless of Apertif



What is lost: deep H I

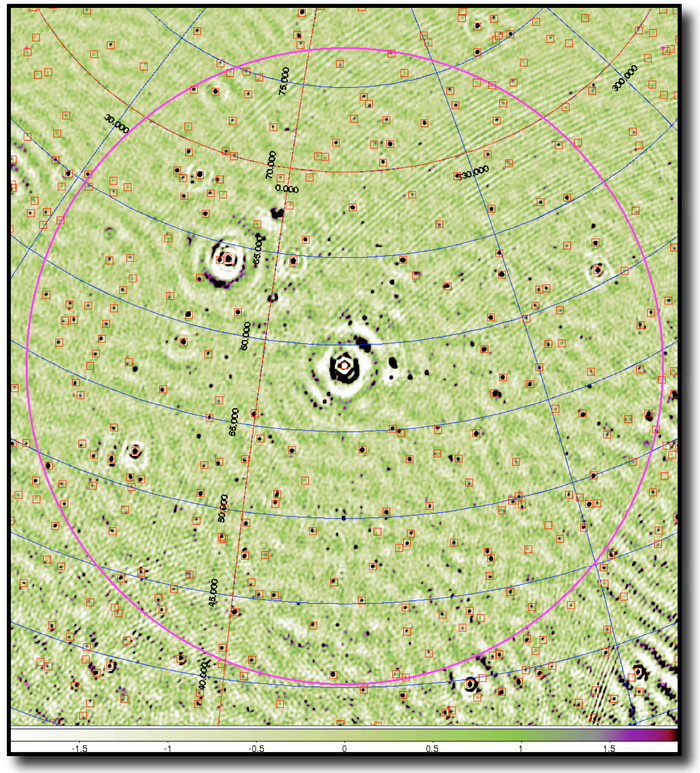
- Deepest H I observations ever done are with WSRT (20-100 x 12 hr)
  Currently niche application of WSRT

- EVLA will not do really better, current WSRT results will last until 10% SKA



What is lost: Lofar related observations

- WSRT not available for non L-band Lofar follow up
- EVLA, but...



Open issues

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- Money: no money yet for correlator & backends. Combine with e-VLBI, Lofar???
- How will time on WSRT+Apertif be allocated?
- Who will do the surveys: Keyprojects? (like Lofar?), or Legacy mode?, or … ? European context?
- If Apertif will be installed: what *has* to be observed with MFFEs before Apertif?
- Future of WSRT if Apertif will not happen?