APERTIF

A P E R T I F

status & straw man surveys

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+ Apertif team

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DETAILED ANATOMY OF GALAXIES

7th PHISCC meeting, Dwingeloo, 17-19 March 2014

APERTIF a grand proposal

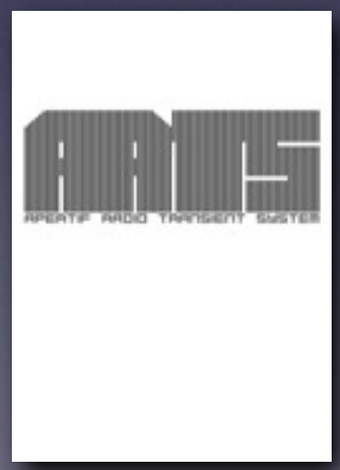
WSRT upgrade - SKA pathfinder

After 45 years of service,
transform the WSRT into
an efficient 21cm survey facility
using phased-array technology.

Winning community support + 3 NWO/NOVA investment grants

2006 5 M€

2008 2.5 M€



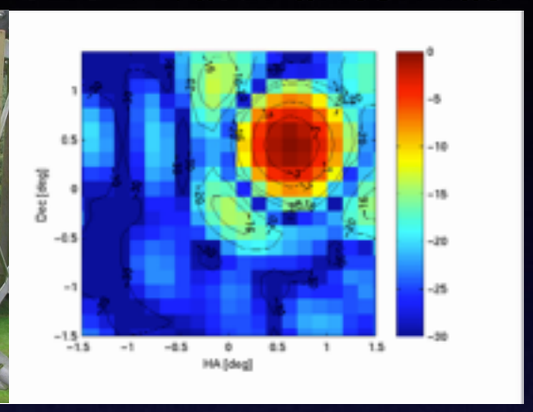
2013 1.3 M€

+ 3 ERC grants:

- HIstoryNU - van der Hulst, 2.5 M€
- RadioLife - Morganti, 2.5 M€
- ALERT - van Leeuwen, 2 M€

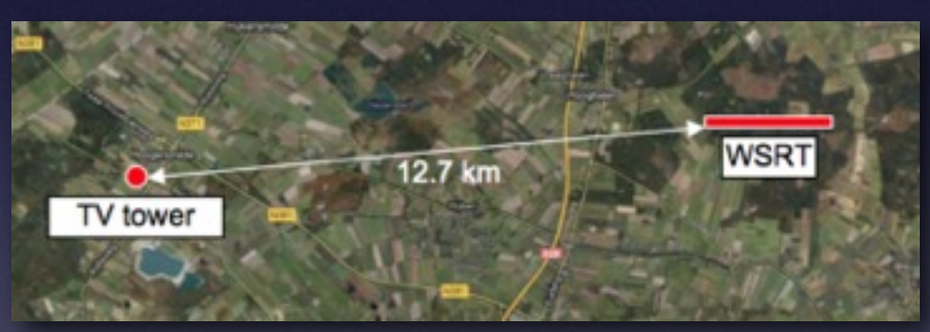
APERTIF specifications & performance

121 Vivaldi antennas



PAF : 37 'compound' beams - 8 deg^2 FoV
12x25m-dishes, Θ=15"x15"/sin(δ)
1130−1730 MHz, 300 MHz bandwidth
16,384 channels, R=7.7 km/s, full pol.

Some bad luck :



RFI : digital TV , airplanes
→ pre-/post-LNA filters
→ $T_{sys} \lesssim 70K$ (25% increase)

Lots of good news :

- standing waves eliminated
- 75% aperture efficiency
- 8 deg^2 confirmed
- beam & pol. stability OK

	(A	FoV	BW	SS
Apertif	1	1	1	1
ASKAP	0.62	3.7	1	2.5
MeerKAT	23	0.096	1.7	3.8
JVLA	11	0.028	0.77	0.23

APERTIF specifications & performance

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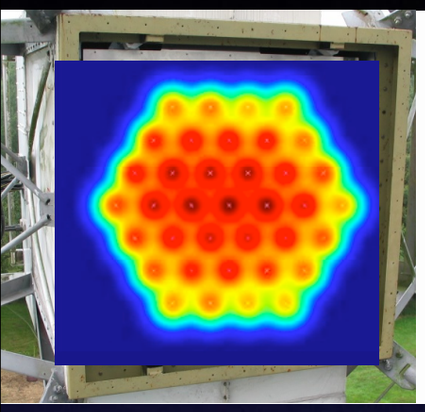

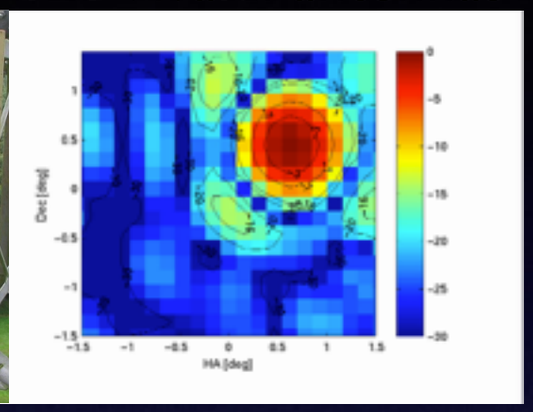

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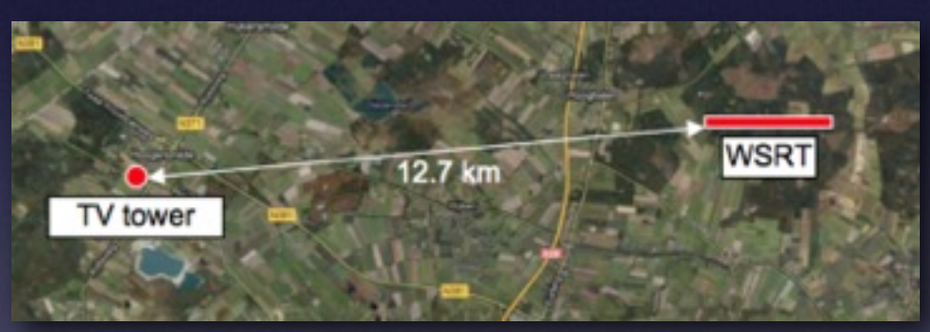

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timeline

2006 : Apertif grant (5 M€, PAF development & construction)

2007 : Digestif PAF prototype in RT5

2008 : Apropos grant (2.5 M€, correlator, pipeline, archive)

2009 : Preliminary Design Review

2010 : - Call for Expressions-of-Interest
- workshop with EoI teams

2012 : workshop with EoI teams

2013 : - ARTS grants (pulsar/transient backend)
- start refurbishment of dishes

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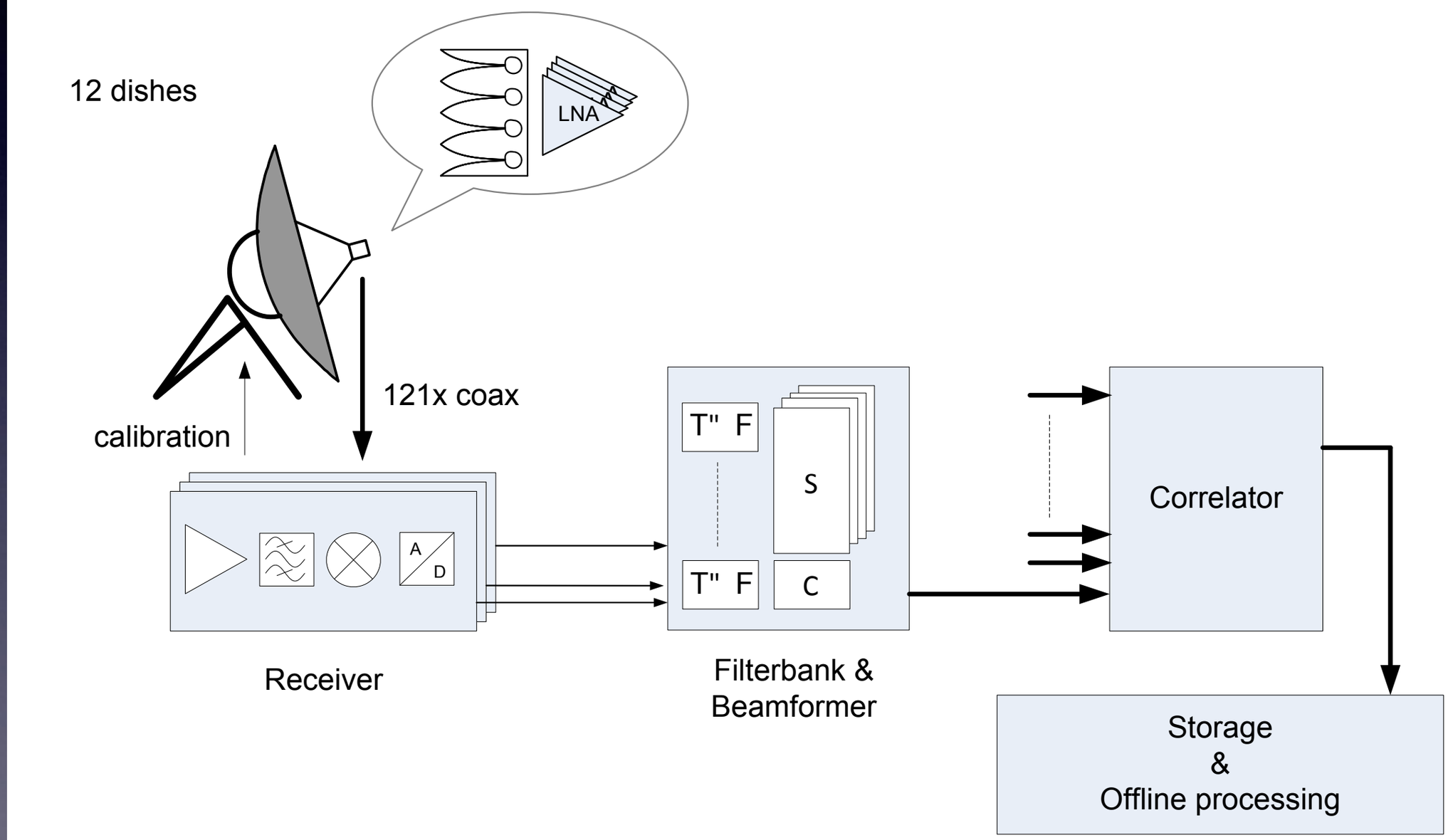
hardware developments

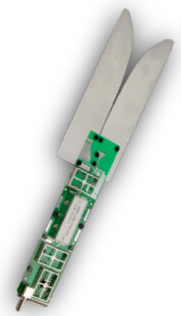
top level block diagram

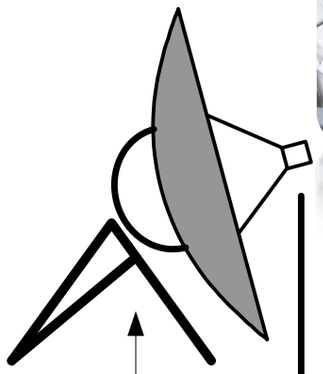


hardware developments

top level block diagram

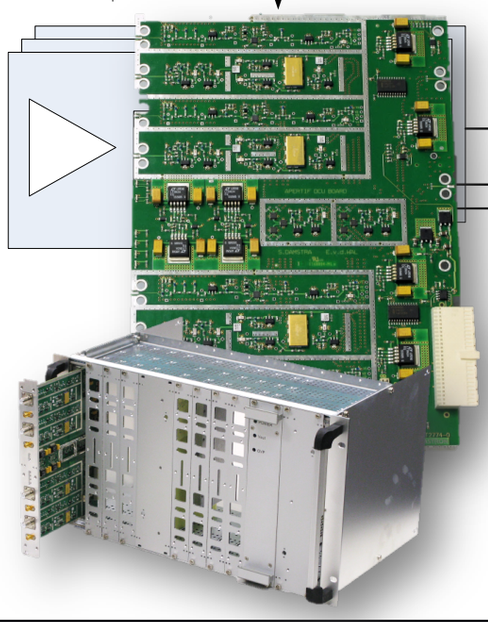
12 dishes

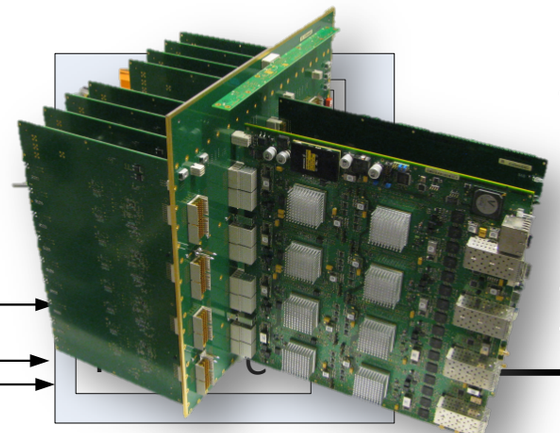




121x coax

calibration





Filterbank &
Beamformer

Storage
&
Offline processing

designing straw man surveys

Guiding principles:

- public, legacy-type surveys
  based on ideas from 18 Expressions-of-Interest++
- collaborate, compromise, consolidate
- be ambitious yet realistic
- simplicity
  few observing modes, fixed pointing grid
- staged delivery of data and science
- maximum ancillary data availability
- community involvement & commitment

APERTIF consolidated straw man surveys

Based on community input via EoI's:

- shallow 'π-of-sky' survey
- medium-deep, wide-area survey
- pulsar search survey
- Galactic plane survey
- commensal transients search survey

Realistic: 4-year survey period (2016−2020), 25% open time,
75% observing efficiency, ¼ of time dedicated to a survey

→ 6600^{hr} = **550×12^{hr} per survey**

Ambitious: 8-year survey period until 2024 (SKA-2 is ready 😀)

shallow 'π-of-sky' survey

Survey the northern sky at δ>+27°

(requires ~1600 pointings,
or 20.000^{hr} if 12^{hr}/pointing…)

Observables of interest:

- HI redshifts, line widths, gas masses and kinematics of galaxies
- HI absorption statistics and properties
- radio continuum sources (LOFAR counterparts)
- OH mega-masers
- rotation measure grid
- fast radio transients

shallow ‘π-of-sky’ survey

Science of interest:

- HIMF, velocity function, (B)TF relation, angular momentum
- Large scale structure, spin alignments, cosmic flows
- AGN outflows/feedback
- star formation vs AGN (spectral index of LOFAR sources)
- starbursts and (major) merger rates
- the Galactic magnetic field
- extreme physics and rare objects
- + …

Q: How is science affected by 6^{hr}/pointing or 5.000 deg^2?

APERTIF medium-deep, wide area survey

Survey 500 deg^2 at $N_{HI} \lesssim 5 \times 10^{19}$ with 15"x20"x25km/s resolution.

(requires ~60 pointings or 8.640^{hr} if 12x12^{hr}/pointing…)

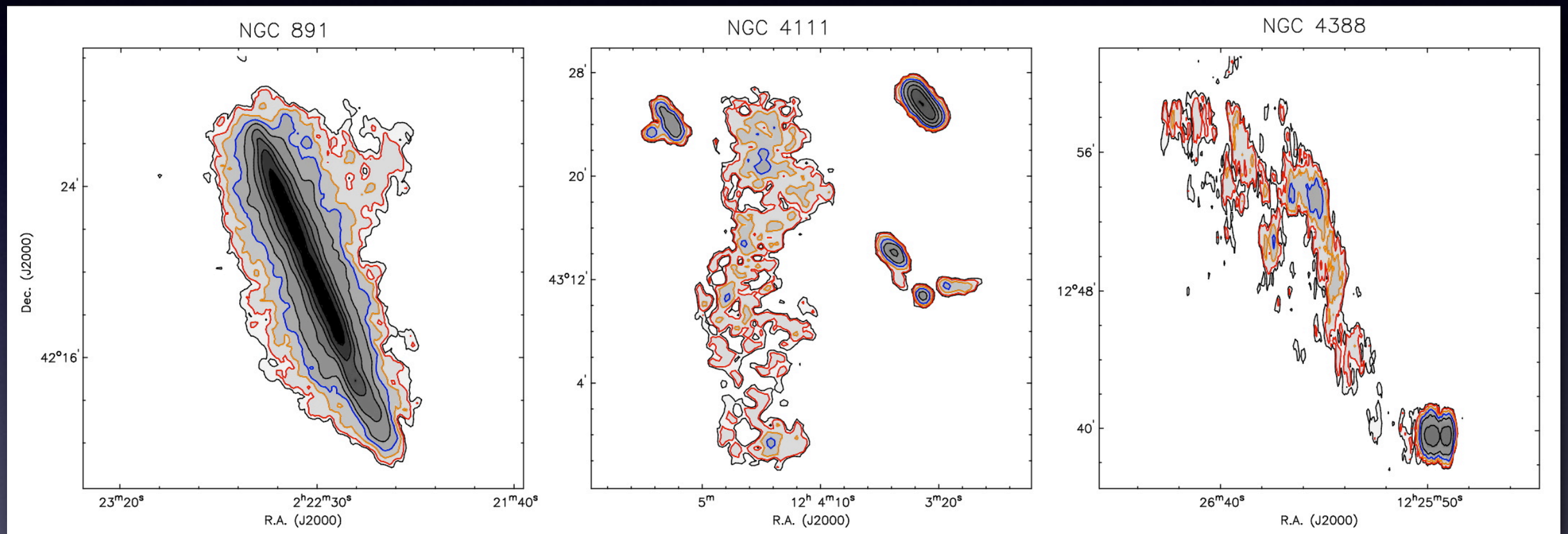
Survey area is required to minimize cosmic variance.

Observables of interest:

- all π-of-sky observables but 5x deeper
- low N_{HI} structures in outer disks, filaments, tails
- slow transients (12 epochs)
- polarized extended continuum
- RRL's in external galaxies
- M^*_{HI} at z=0.2

APERTIF medium-deep, wide area survey

Motivation for $N_{HI}<5x10^{19}$:

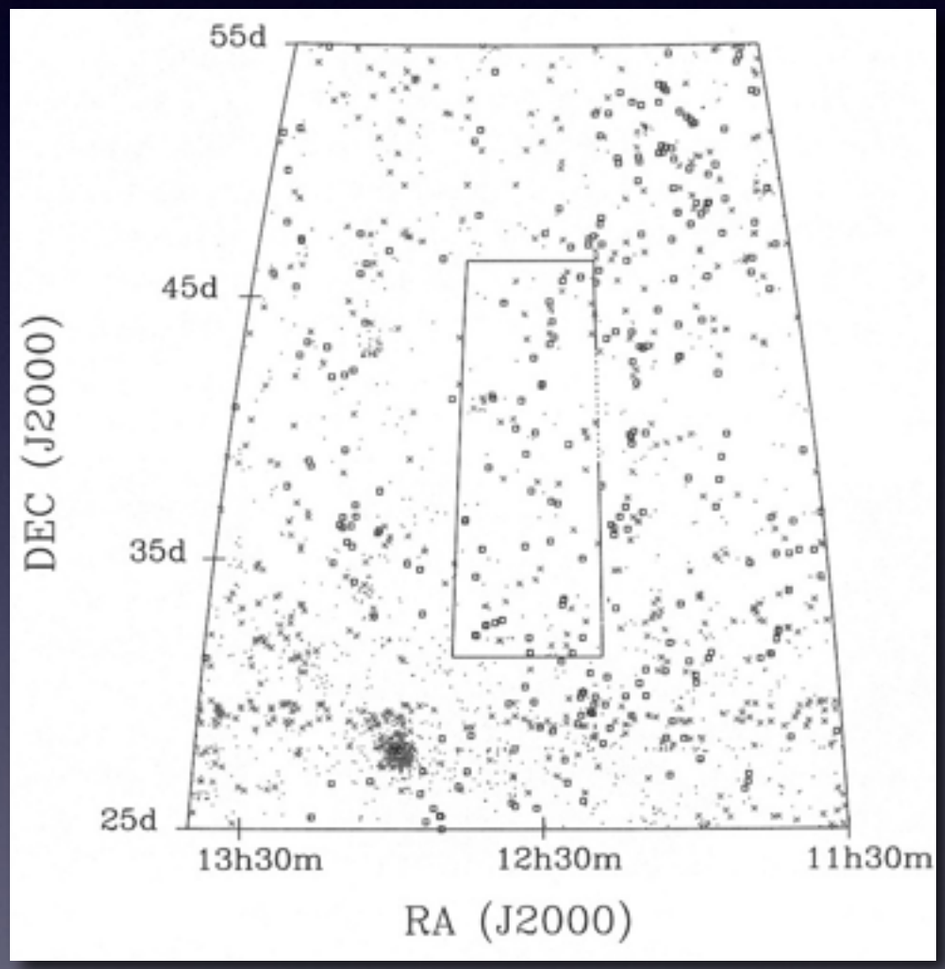


$2x10^{19}$ (atoms/cm^2)
$5x10^{19}$ (atoms/cm^2)
$10x10^{19}$ (atoms/cm^2)

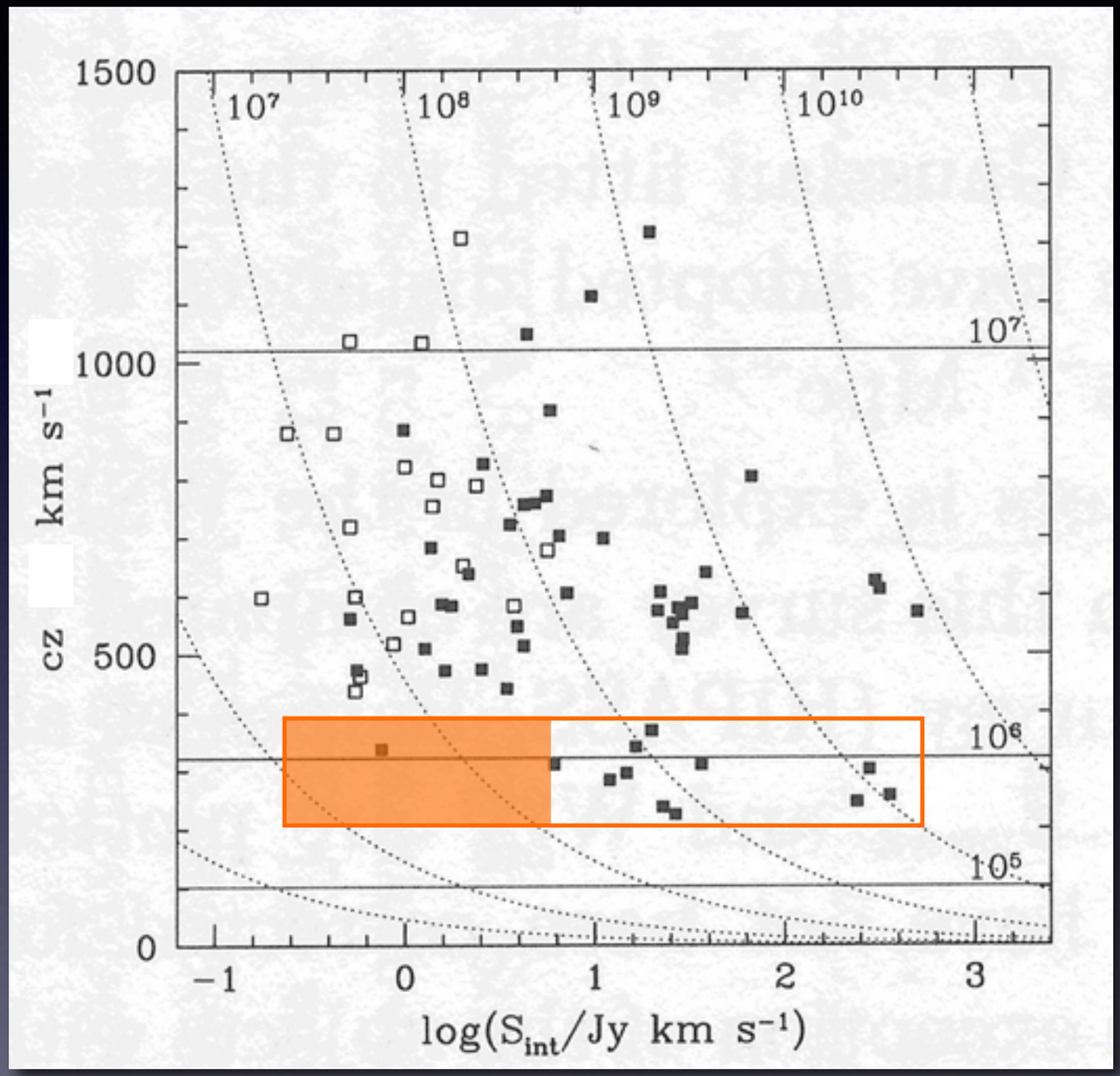
Gas disks are responsive to environmental influences and reveal processes not easily observed otherwise.

APERTIF medium-deep, wide area survey

Blind WSRT Survey of CVn
86 deg^2 , 1372 pointings
60x12 hrs, 80 min/pointing



Kovač, 2007 (thesis, Groningen)



Where are these low HI-mass dwarfs?

APERTIF will efficiently survey local volumes to greater depth.

medium-deep, wide area survey

Science of interest:

- low-mass end of the HIMF at $<10^6$ $M_\odot$
- properties of the ISM and resolved SF in external galaxies
- gas accretion and minor merger rates
- environmental influence on gas in/around galaxies
- extra-planar gas, warps, streaming motions
- Ω_{HI} at $z=0.2$
- faint continuum sources (viz-a-viz LOFAR)
- magnetic fields in external galaxies
- radio halos in galaxy clusters
- the variable radio sky (in concert with Palomar Transient Factory)

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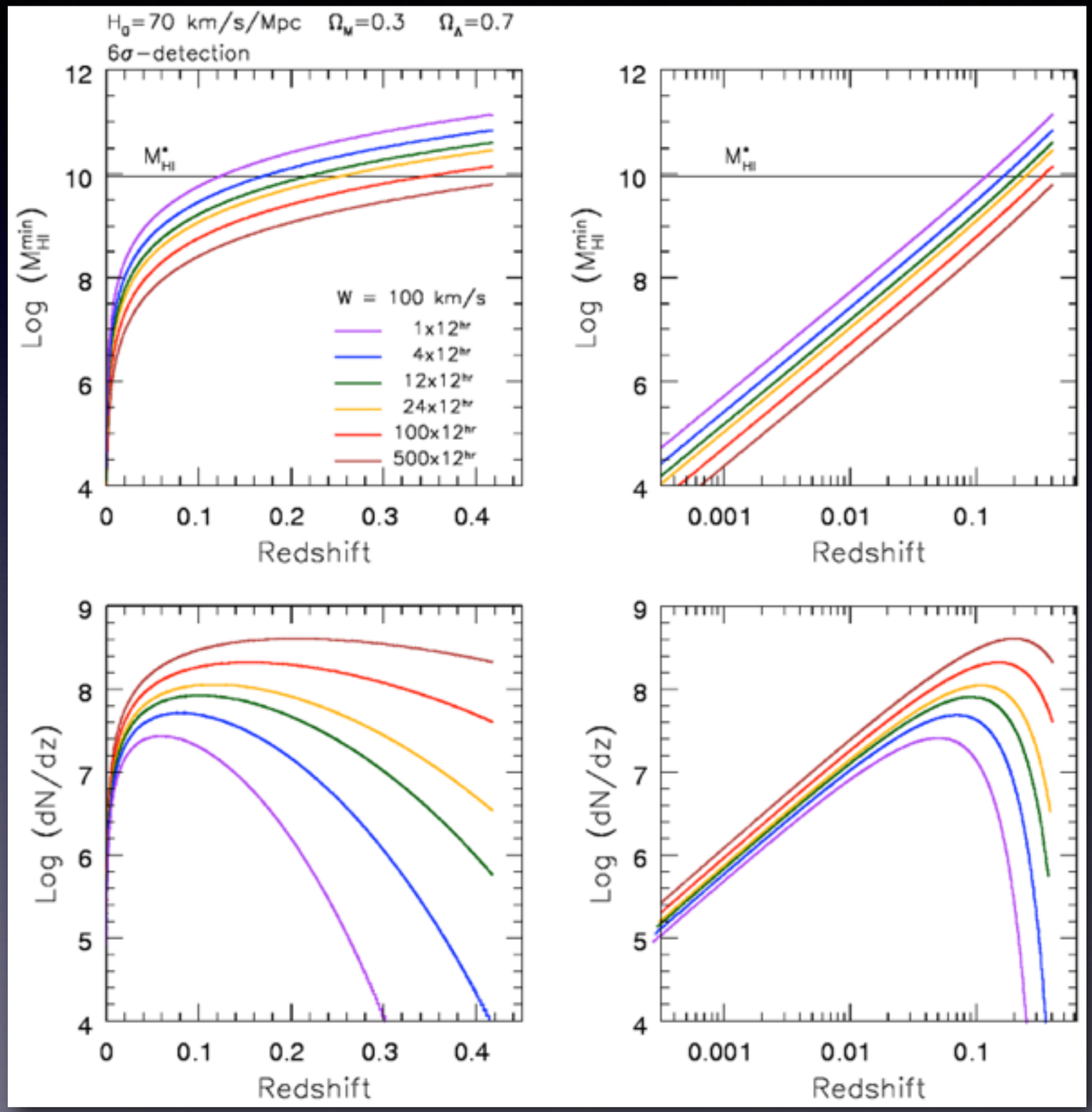
sensitivities & source numbers

- 100 km/s line width
- 6σ detection
- spatially unresolved
- optimal velocity smooting
- based on z=0 HIMF

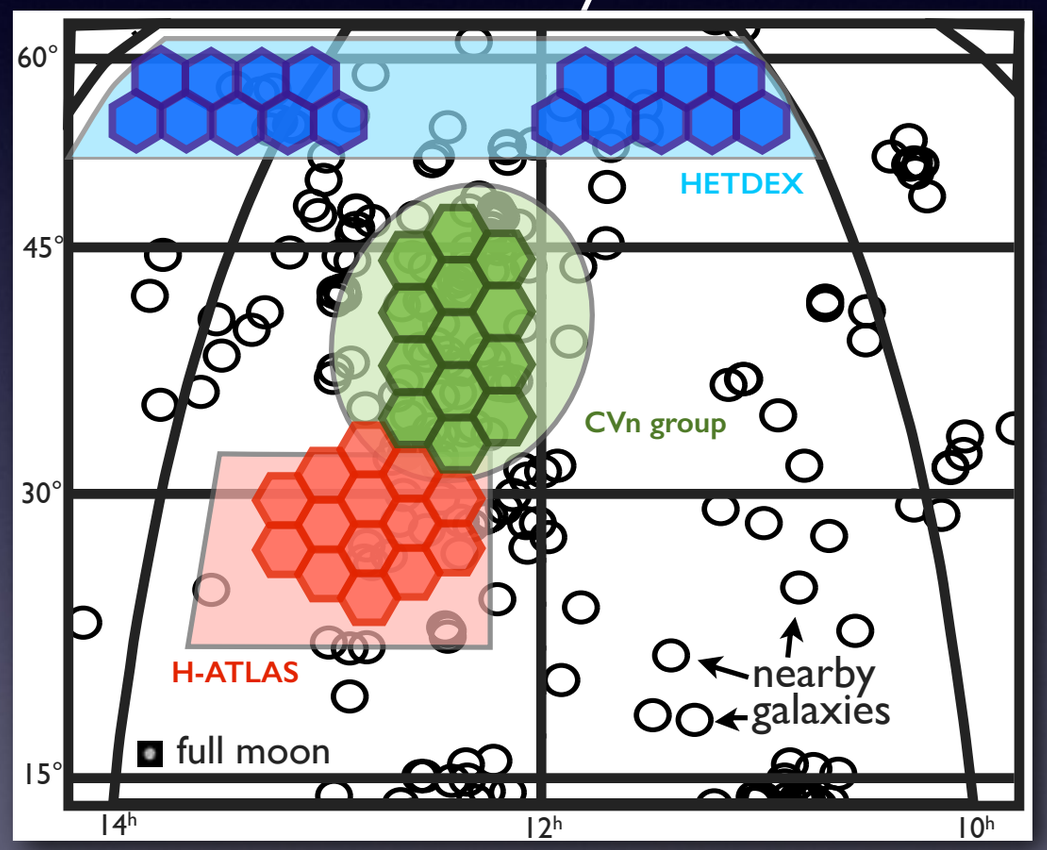


APERTIF medium-deep, wide area survey

Four areas comprise footprint of medium-deep survey, using existing ancillary data:

- Herschel-Atlas Northern Field
  SF, gas & galaxy evolution, Coma cluster
- CVn group of galaxies
  low-mass end of HIMF
- The HETDEX survey area
  2 million optical redshifts, stacking
- The Perseus-Pisces supercluster
  environmental effects, magnetic fields

sky areas of interest



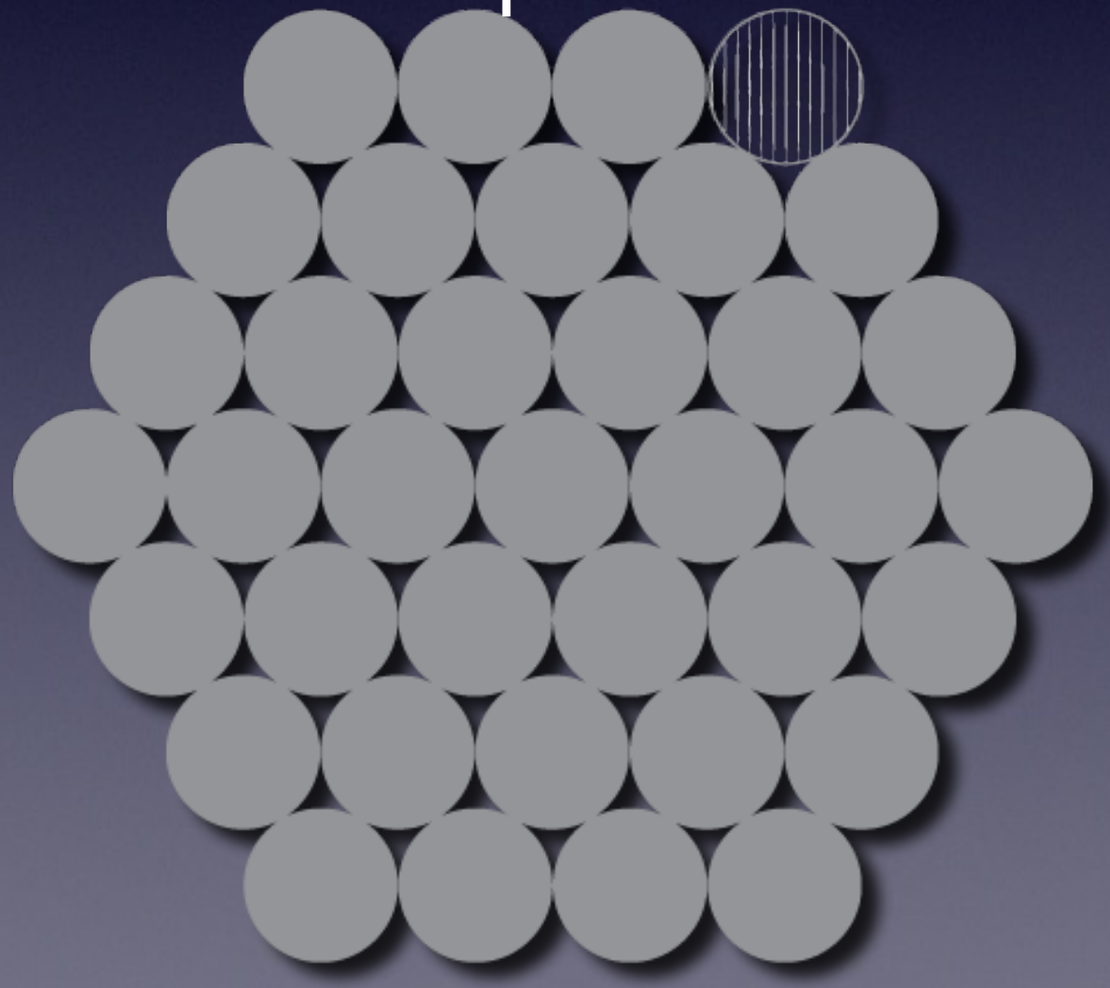
Spring fields are in SDSS with coordinated overlap with MaNGA, delivering resolved info on Stellar Pops, ISM, metallicities etc.

pulsar searches with ARTS

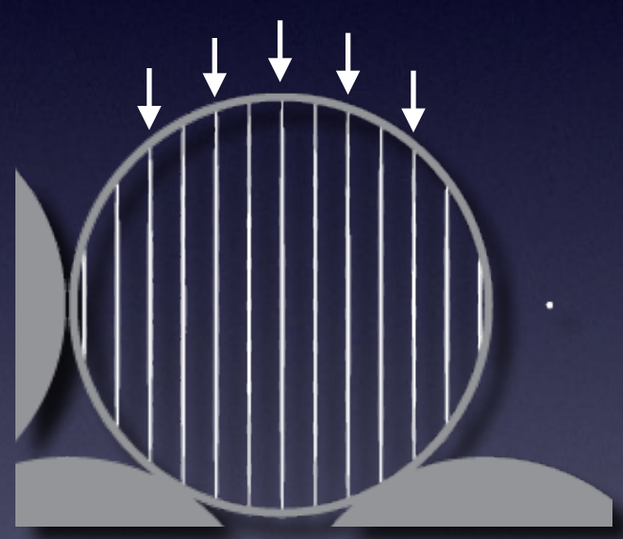
Expediate pulsar searches with Apertif's large FoV.

Use grating lobes to fill all 37 compound beams
with Tied Array Beams at high time resolution:

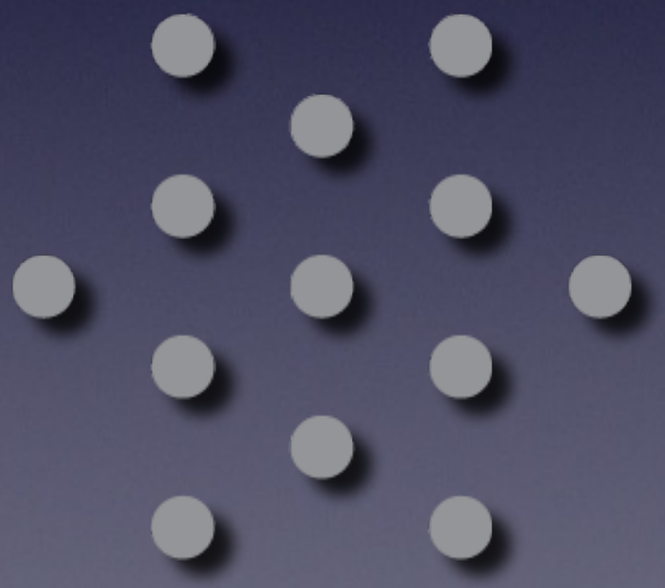
Apertif



grating lobes of one Tied Array Beam



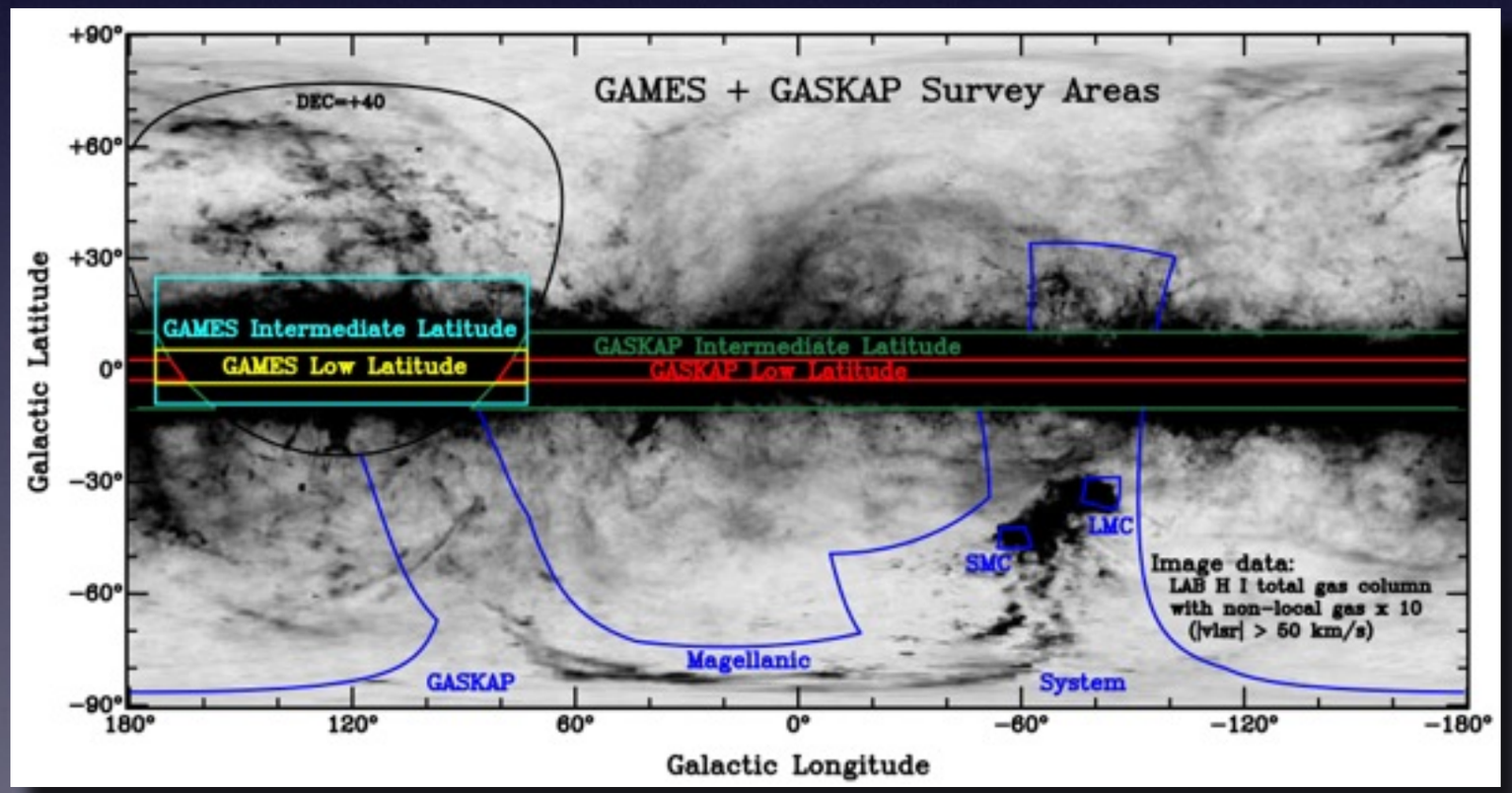
Parkes



Galactic Plane survey

Characterize the multi-phase ISM

- HI and OH lines
- Radio Recombination Lines (HI & He)



Special requirement: spectral zoom modes on selected lines. (R=0.2 km/s)

Correlator mode not available ab initio.

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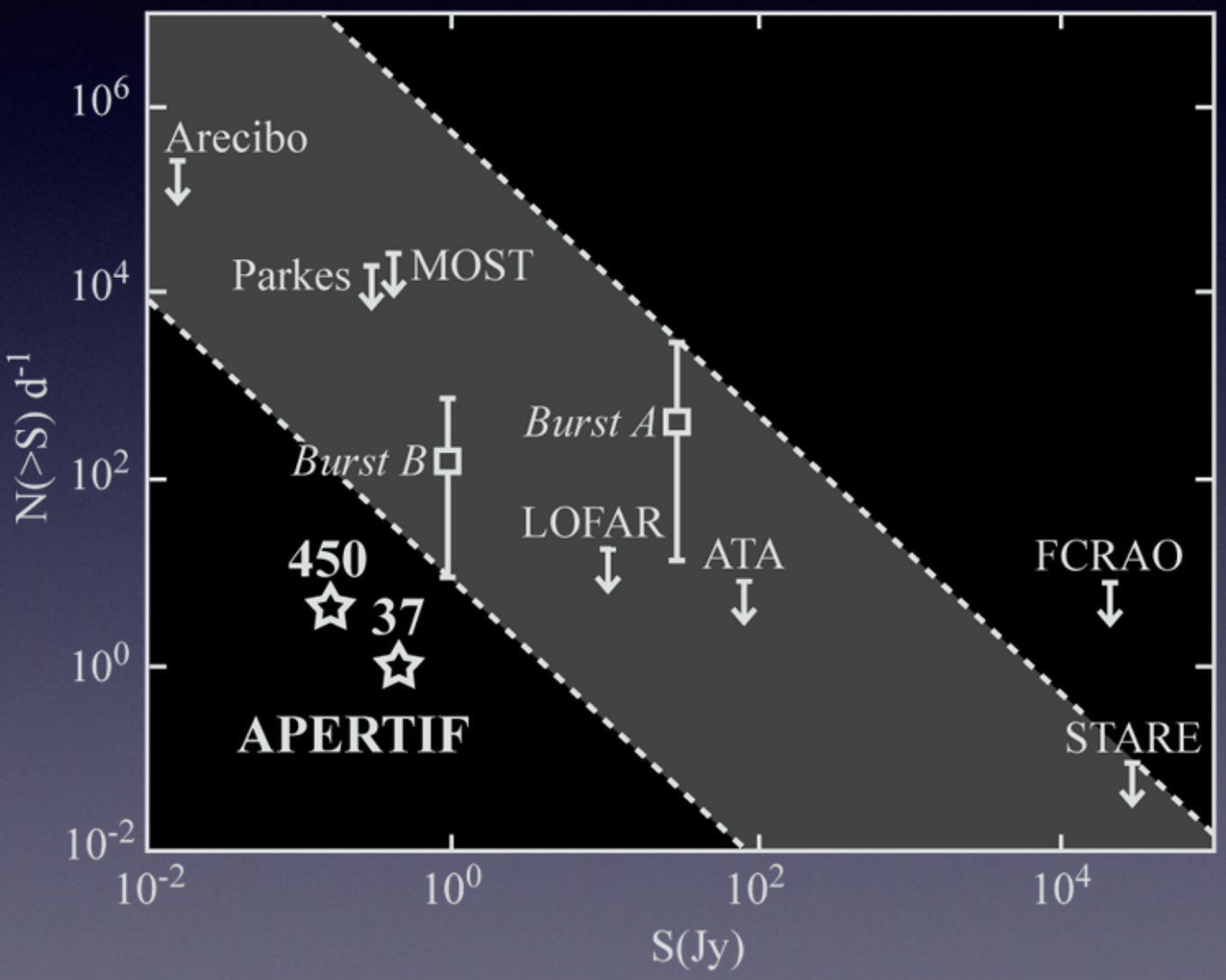
Fast Radio Bursts

Expect ~200 FRB's/day located in grey N-S strip.



With 450 coherent beams in a dedicated survey or 37 incoherent beams in a commensal survey, Apertif/ARTS will confirm the reality of FRB's.

Once a FRB is detected by Apertif, LOFAR will be triggered to localize the FRB as it arrives later at lower frequencies.

next steps

early/mid 2014 : Alpha-3 roll-out & performance tests

fall 2014 : Critical Design Review
publication of straw man surveys
go/no-go decision

2015 : roll-out of remaining 9 PAFs, full correlator
shake-down, commissioning, science verification

early 2016 : ramp-up of science teams
Early Science programs

mid 2016 : start of surveys