SHARP: Search for HI absorption with APERTIF

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and the Apertif Imaging Team (led by Betsey Adams)

RadioLife

European Research Council
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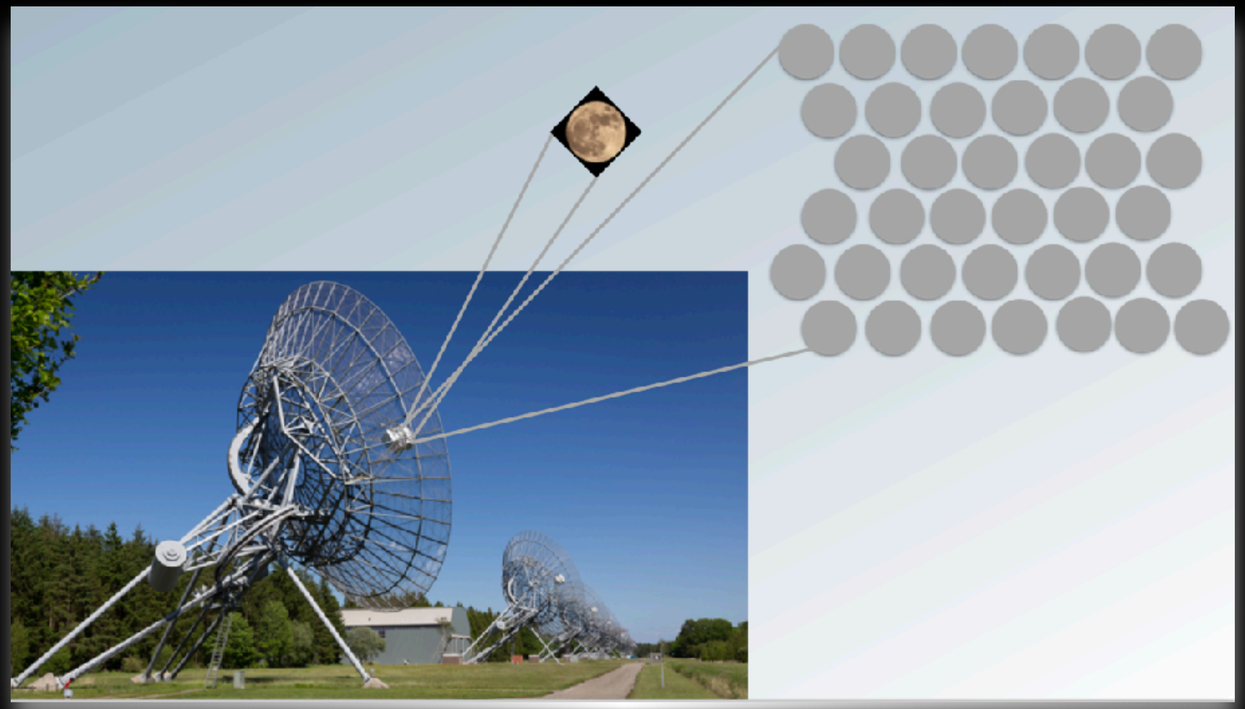
APERture Tile In Focus (APERTIF)

Can do in a day what before took a month
Synergy with LOFAR



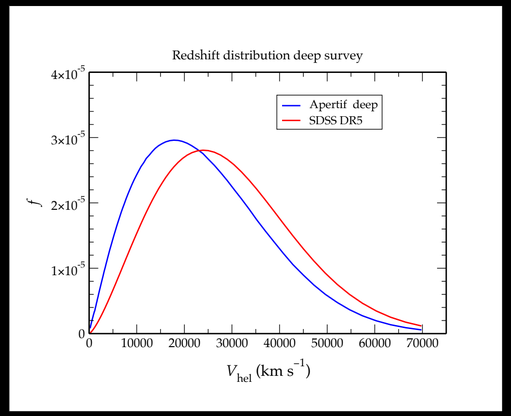
121 receptors (60+61)
39 beams on the sky
FoV 6 deg^2
Range freq: 1130 – 1700 MHz
T_{sys} 70 K
Aperture efficiency 75%
Bandwidth 300 MHz
24576 channels - 4-5 km/s resolution
12 dishes

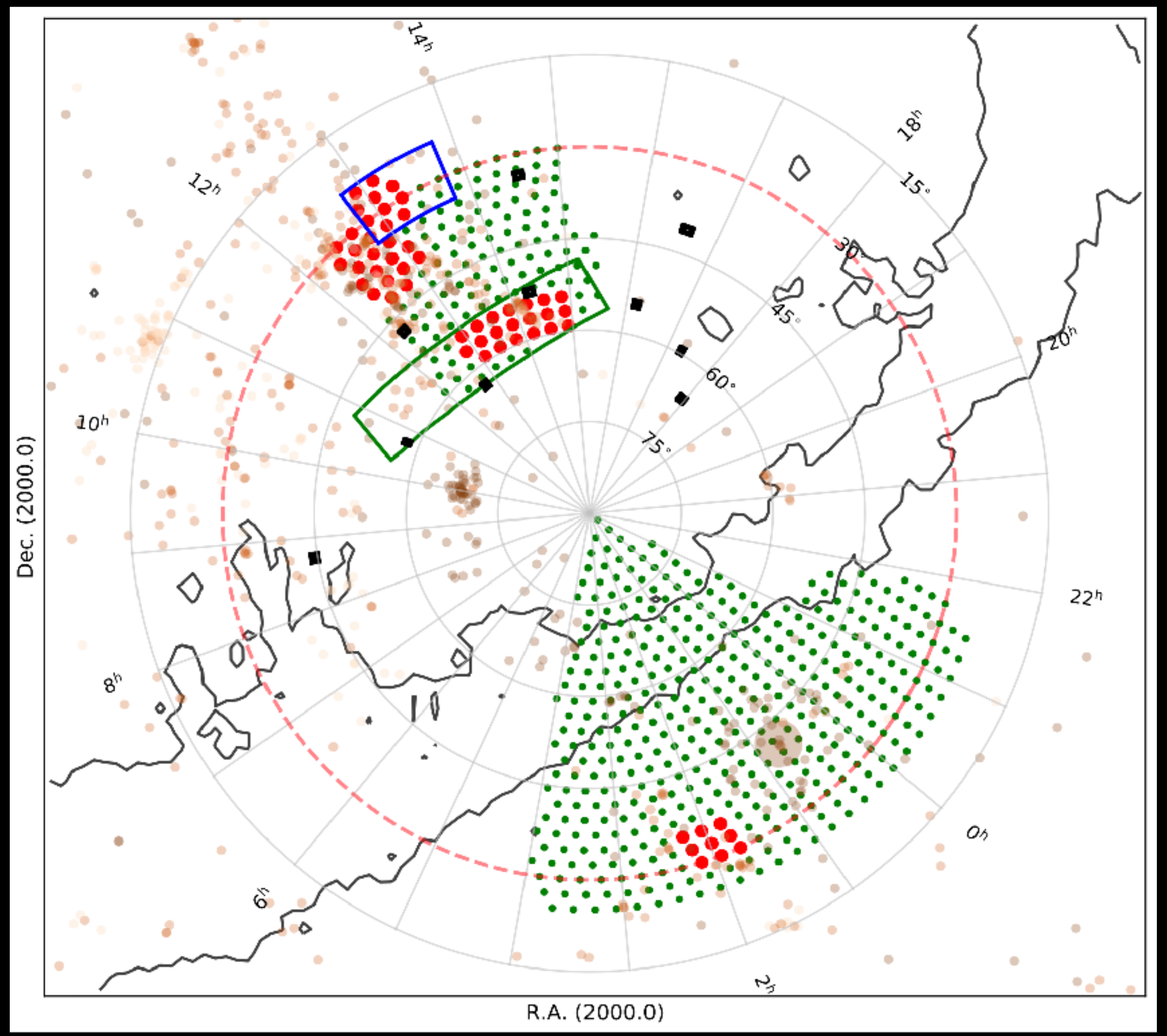
APERture Tile In Focus (APERTIF)

Opening of Apertif on September 13, together with the celebration WSRT 50

Apertif Surveys

- definition driven by science AND efficiency
  - large-area shallow imaging survey 3500 deg^2
  - medium-deep imaging survey 450 deg^2
  - transient survey
  - will revisit strategy after 1 year.
    better to go deep or go for area?
  - *lack of good optical data in part survey area*





Starting of the Apertif surveys expected early 2019

Organisation of the Apertif project

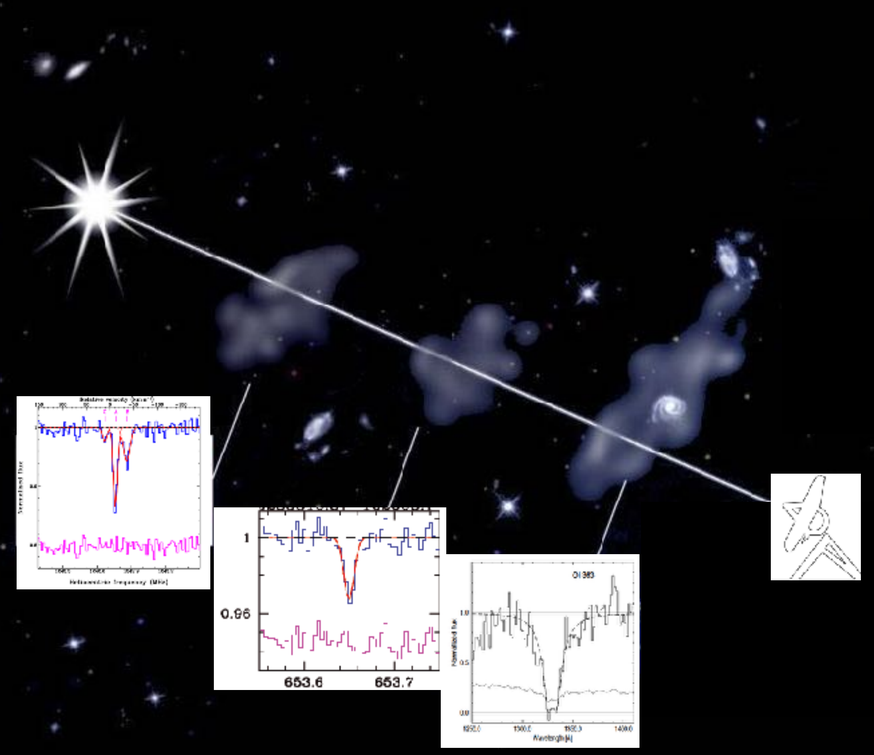
- Organisation different from others SKA pathfinders
- Low-budget project (in the “shadow” of LOFAR…)
- Imaging Team has to run the surveys, develop/run pipeline+quality control and ingest data in the archive ➜ and do the science!
- Requires commitment and resources ➜ level of participation linked to this

What we will do*

- Continuum (and polarisation) ➜ expected ~12 arcsec spatial resolution,
  ~20-30 microJy noise in the shallow survey)
- HI emission (largest science case/group)
  ➜ dwarfs, nearby galaxies (synergy with Manga and WEAVE-IFU),
  groups/interaction/environment …
- HI absorption ➜ SHARP survey

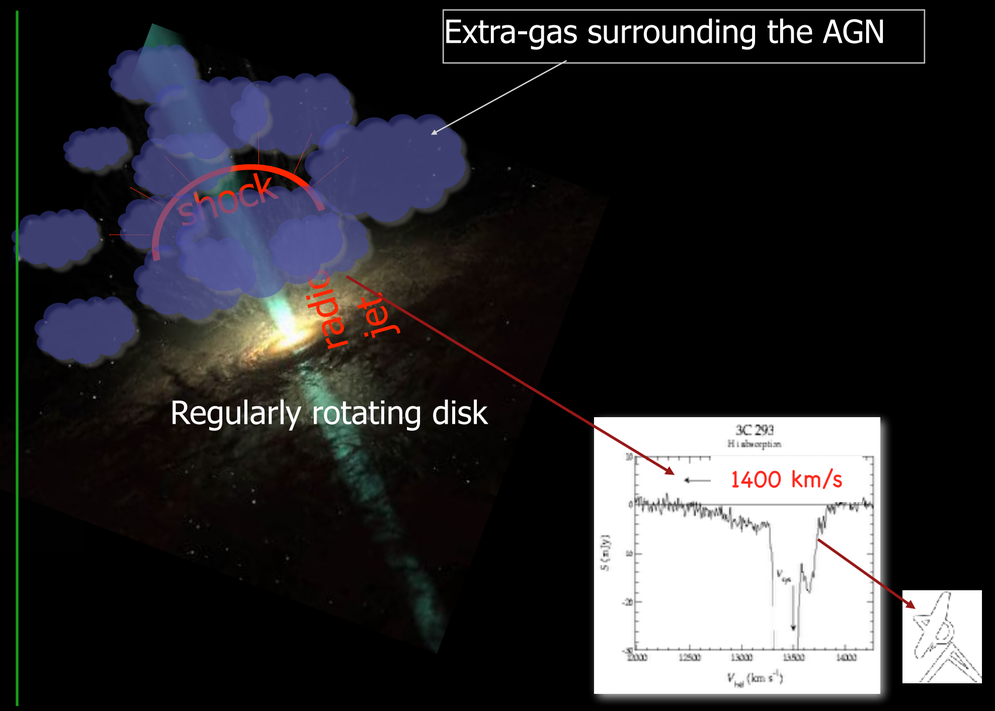
*Imaging part, time domain PI Joeri van Leeuwen

Tracing HI with absorption: intervening and associated



Tracer of *cold* neutral hydrogen in the distant universe, can detect and
probe gas within **normal** galaxies out to very high redshift:

- *Typical size and mass of galaxies as function of redshift ➜ test galaxy formation scenarios*
- *Evolution of neutral gas content with redshift ➜ explore relation HI content and SFR*



Tracer of the gas in the inner parts of the galaxy close to AGN

- *Tracer of circumnuclear disks*
- *Infalling gas ➜ feeding*
- *Outflowing gas ➜ feedback*

Plans for SHARP

- Piggyback on all Apertif surveys
  (maybe also from observations with poor imaging performances, i.e. during “transients” configuration or with no full-12h tracks ➜ mode transient&imaging simultaneously)

- **“Blind” unbiased search** ➔ extract spectrum for every continuum sources

  ➔ *shallow survey (12h each pointing), coverage to z=0.26 and noise ~0.5 mJy/b chan width 30 km/s* ➔ *down to at least 10 mJy* ➔ *optical depth* $\tau \sim \Delta S_{abs}/S_{cont} = 0.15\ (3\sigma)$ *interesting also for stacking*

  ➔ *medium-deep survey will be used to explore a new parameter space: low HI optical depth and/or HI in low power sources*

  - Cubes and continuum spatial res 12”
  - Velocity 2.4 km/s but we will smooth the extracted spectra to lower resolution (~30-50 km/s)

Advantages and disadvantages of SHARP

- Apertif covers only low redshifts
- Impact of RFI

+ Availability of SDSS for optical identifications (and WEAVE coming up)

+ Synergy with LOFAR

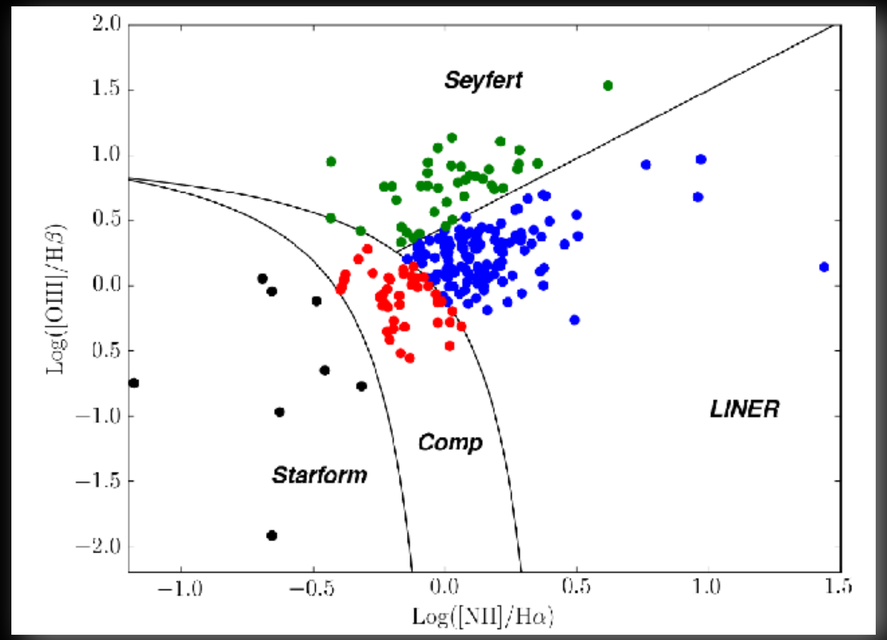
+ VLBI network (including eVLBI) for follow up

IMPORTANCE of SDSS

- Very important for associated absorption:
  searching sources at low radio flux means many more identifications

On 4000 sq deg > 10 mJy: ~1500 sources
> 5 mJy: ~3000 sources
(compared to the 248 from Filippo's sample)

→ *relevant for stacking…*



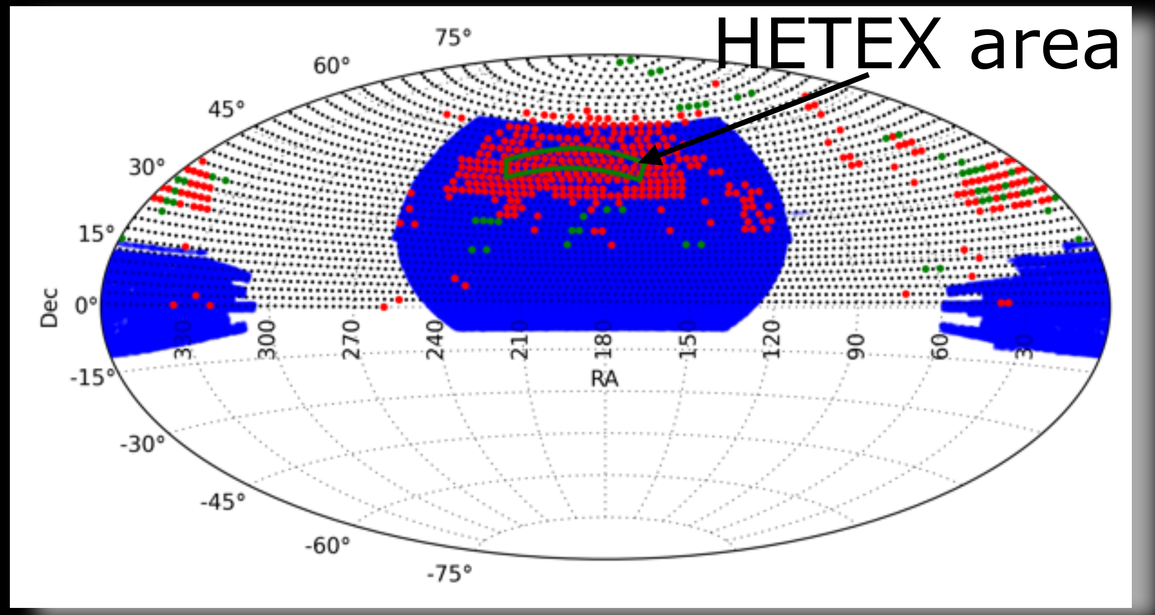
Santoro 2018

Synergy with LOFAR

LoTSS - Tier 1

All-sky @ 150 MHz (HBA)
48 MHz bandwidth
~0.07 mJy median noise
6 arcsec resolution

Synergy LOFAR-WEAVE



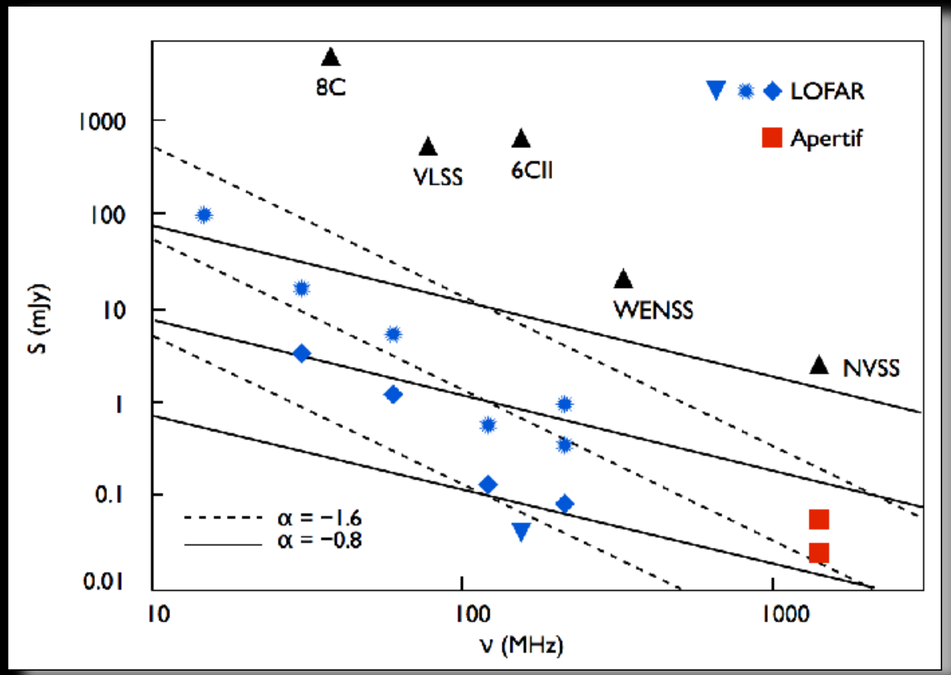
the blue region is FIRST, the green box is the HETDEX Spring Field, t
he red dots are observed and the green dots are scheduled

First data release HETDEX area (400 sqdeg)

Shimwell et al. 2018 "The LOFAR Two-metre Sky Survey -- II. First Data Release" A&A submitted

Duncan et al. 2018 "The LOFAR Two-metre Sky Survey -- IV. First Data Release: Photometric redshifts and rest-frame magnitudes" A&A

Williams et al. 2018 "The LOFAR Two-metre Sky Survey -- III. First Data Release: Optical identifications and Value-added catalogue" A&A



Changes since last year…

The Apertif room!

Where are we now…

✔ Element beams, 135 MHz, single polarisation, RT2-RTB

Compound beams

RTC & RTD, 200 MHz

Online calibration (real-time beam weights and gain transfer between beams)

Dual (full) polarization

Anti-aliasing

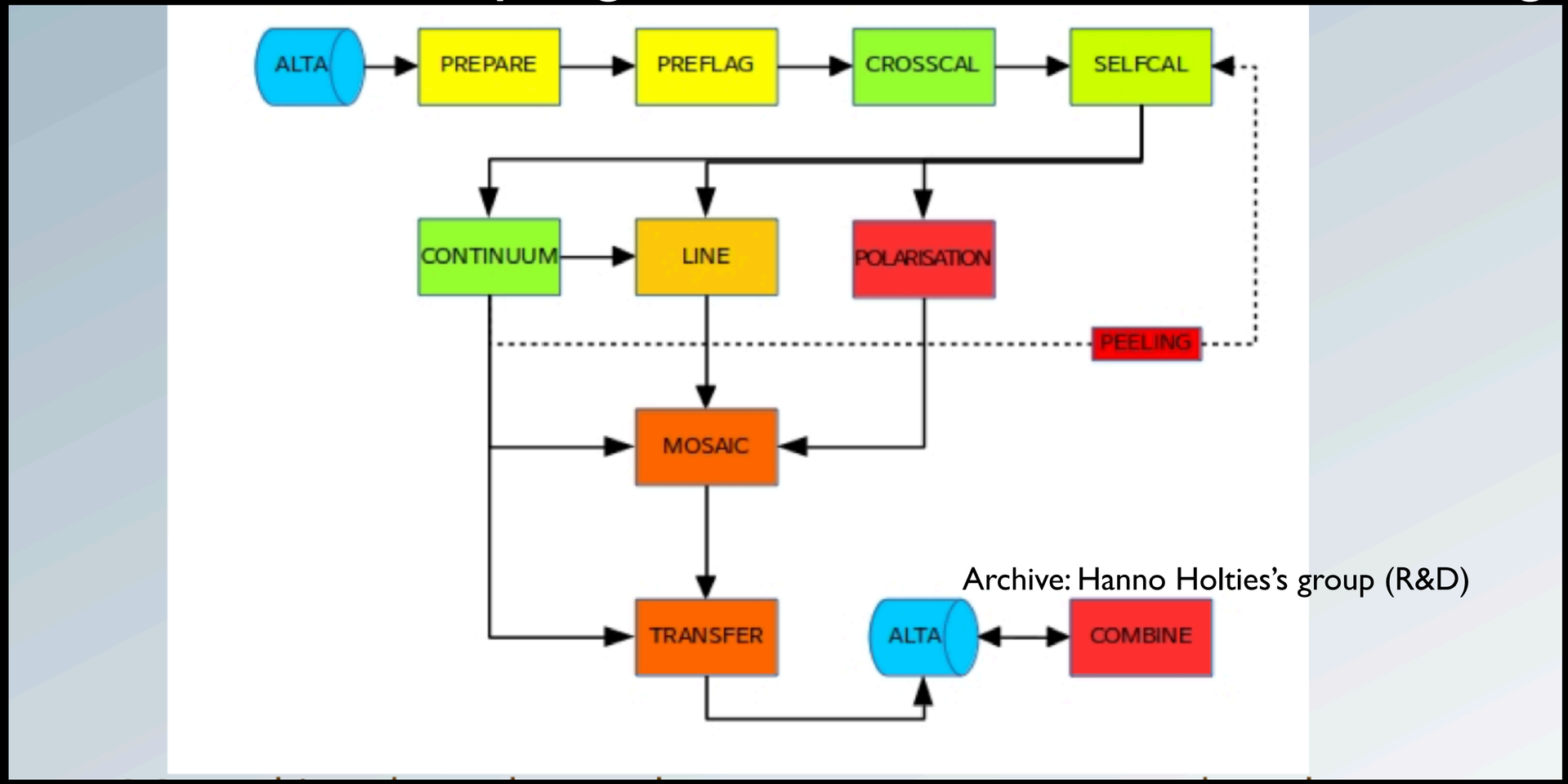
300 MHz

Continuous improvement of the data quality:

phases remarkable stable making calibration relatively easy

Currently commissioning instrument and pipelines

Imaging Pipeline:
in progress and under commissioning



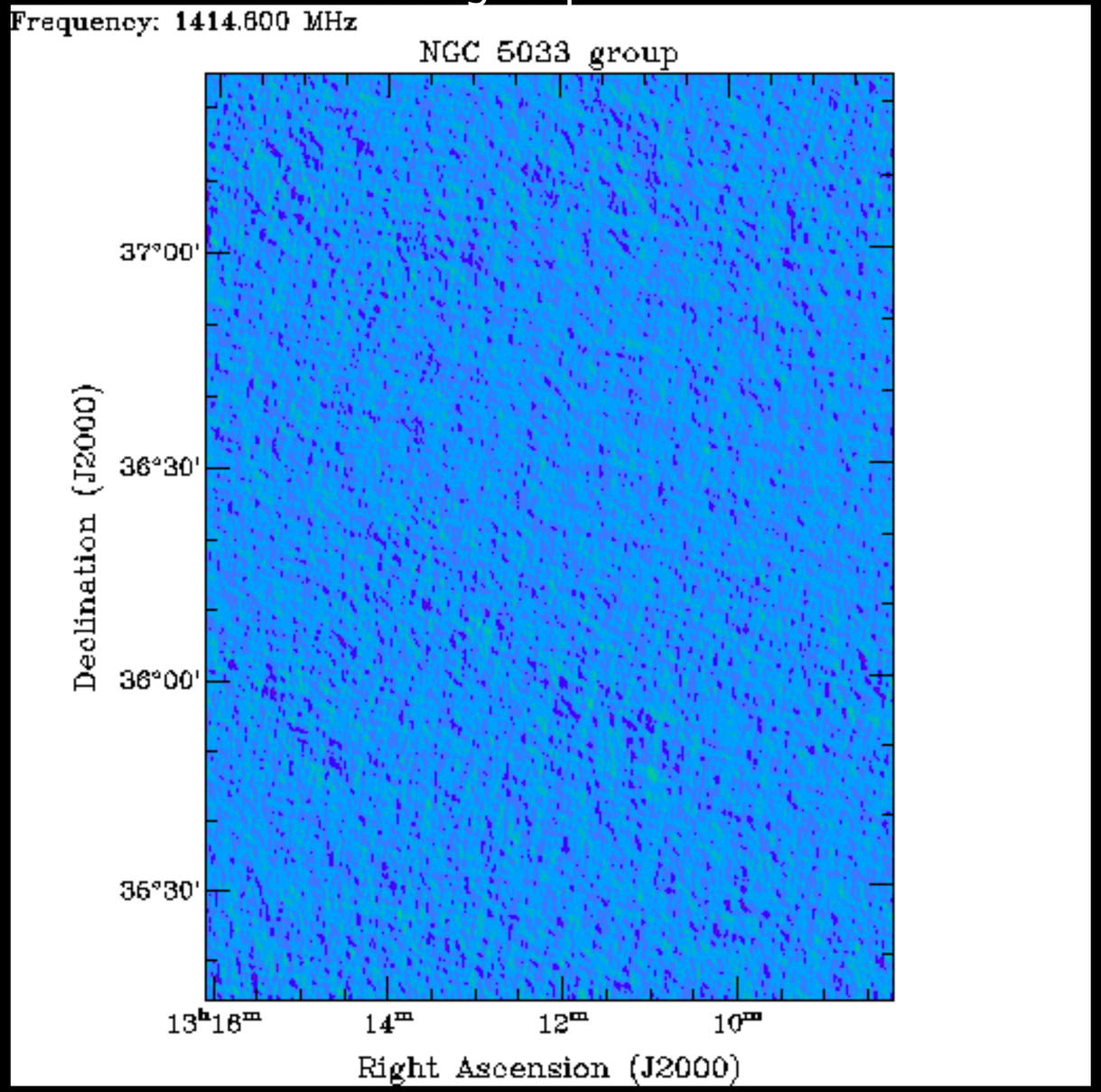
Miriad/python-based; runs in jupyter notebooks

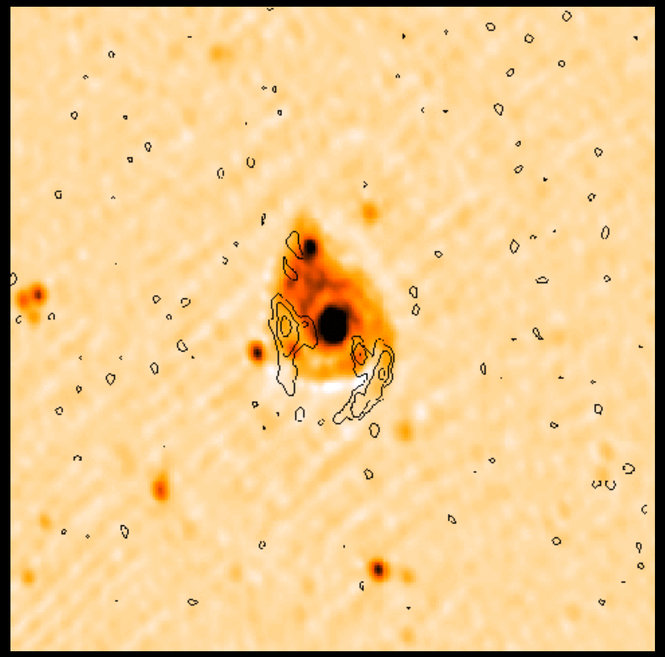
Developed by: Björn Adebahr, Brad Frank, Nicholas Vilchez (to be continued by: A. Kutkin)

Under the supervision of T. Oosterloo (and based on work of P. Serra, G. Josza)

Some highlights of the commissioning

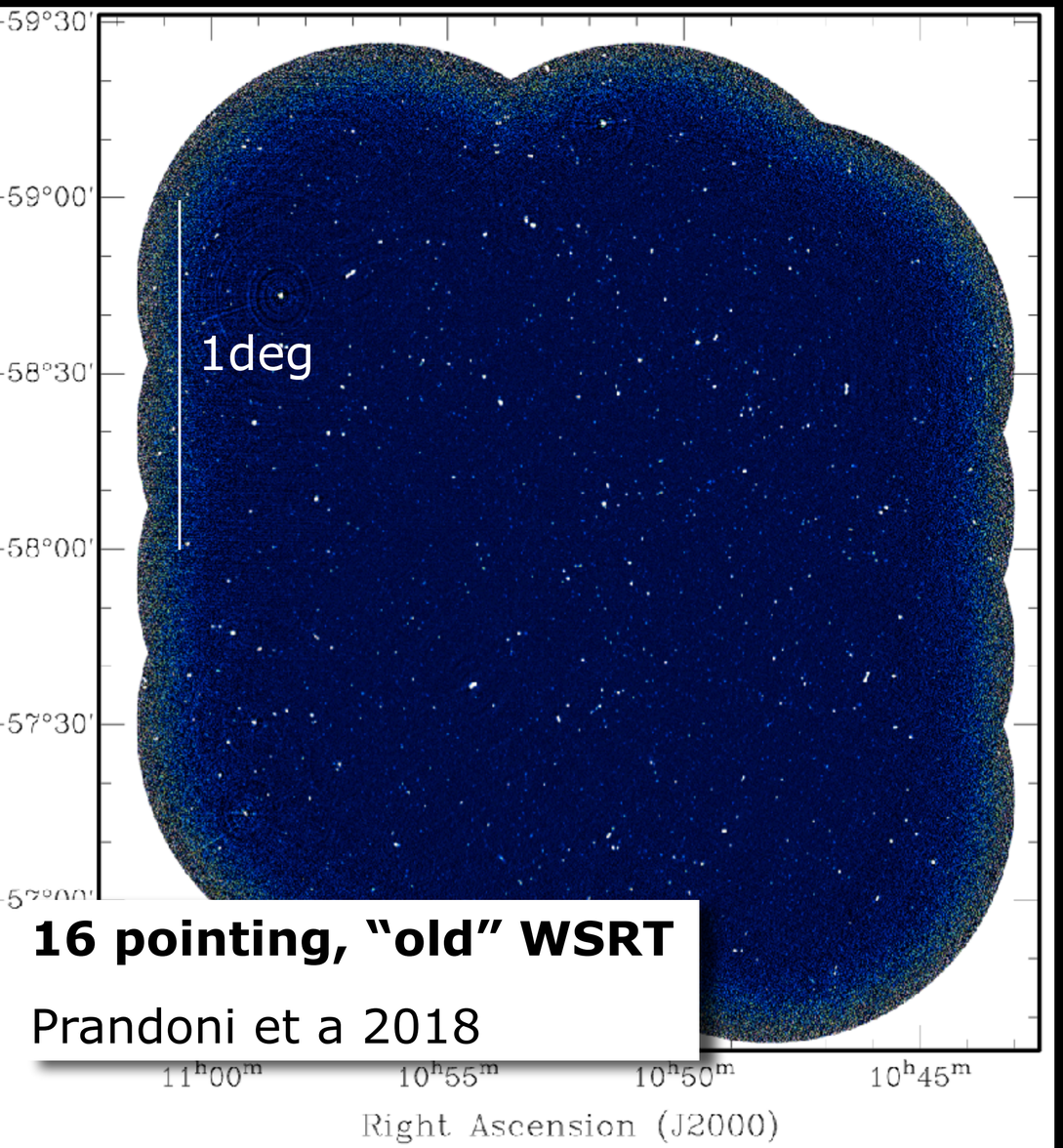
HI channels of N5033 group





- HI channels of M51

The Lockman hole area as “reference” field

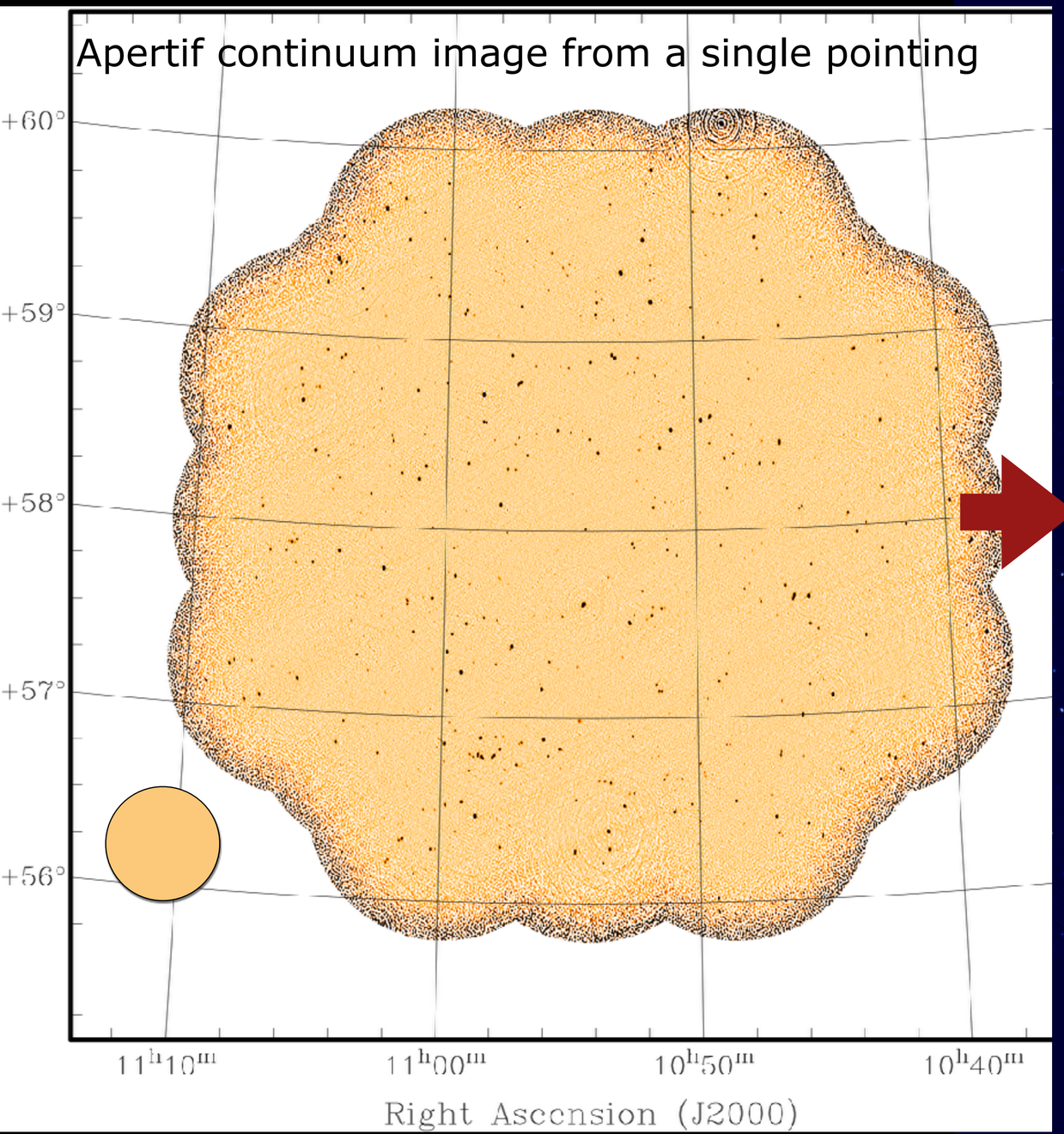


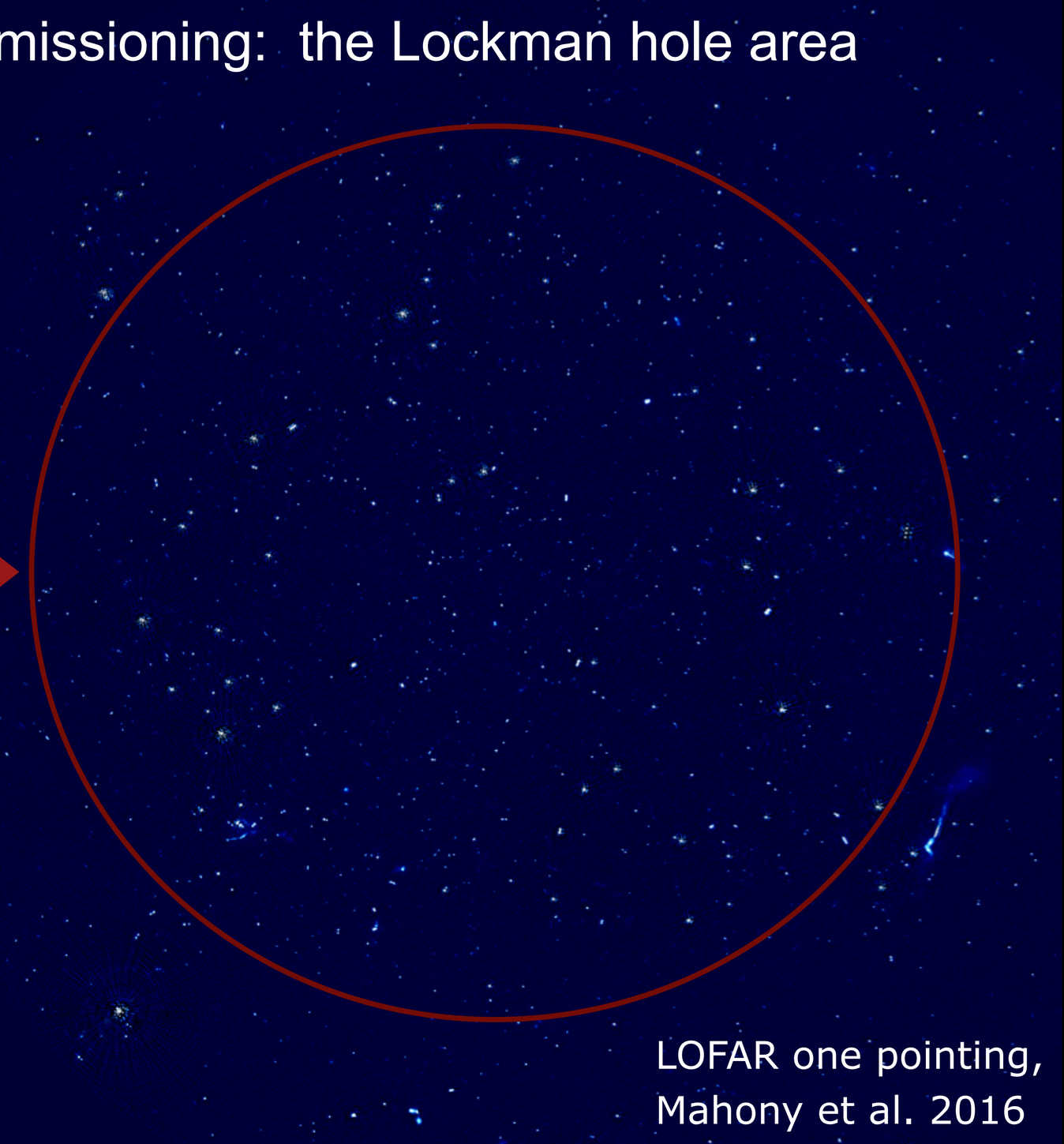
16 pointing, “old” WSRT

Prandoni et a 2018

LOFAR one pointing,
Mahony et al. 2016

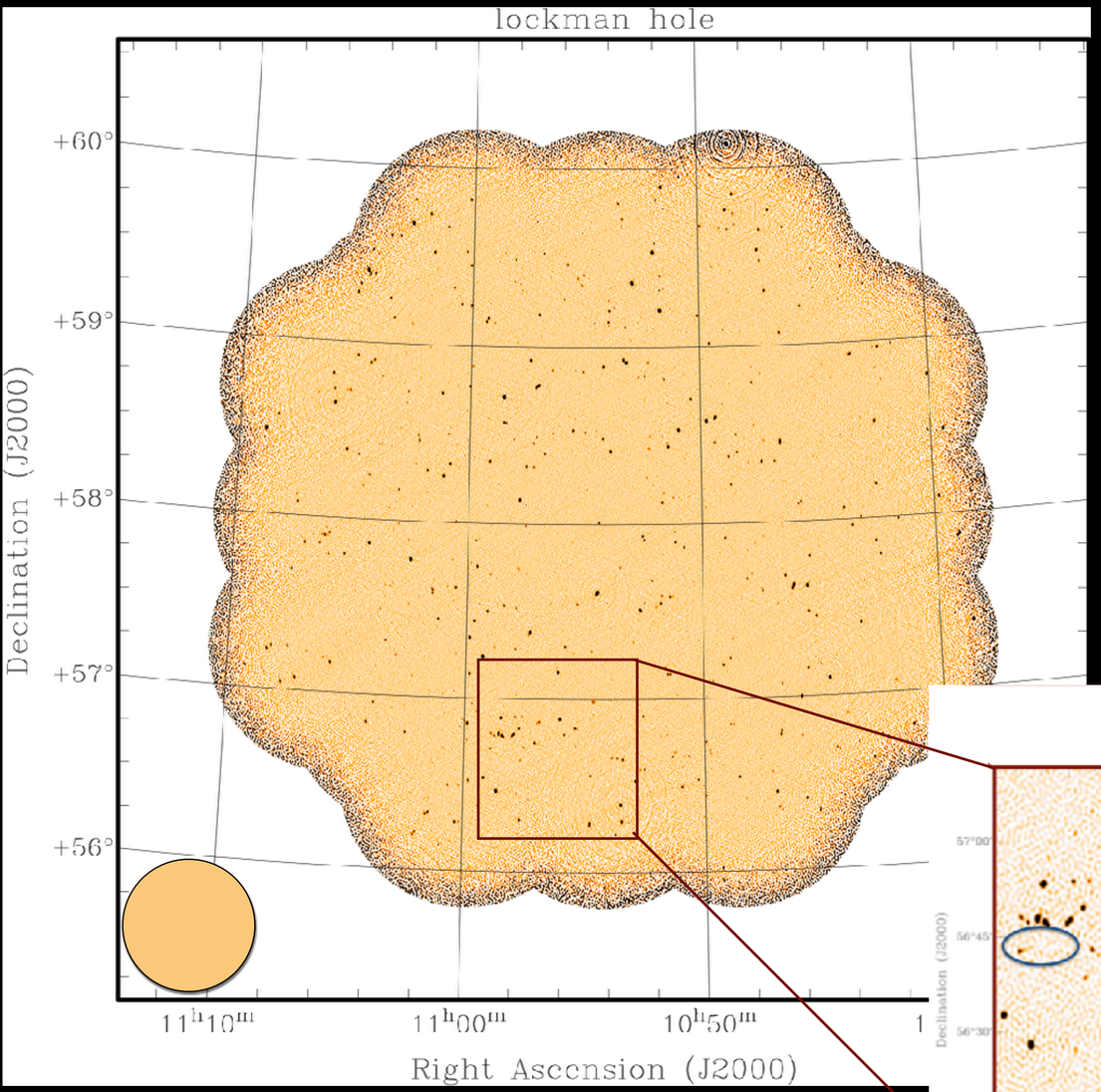
Some highlights of the commissioning: the Lockman hole area





LOFAR one pointing,
Mahony et al. 2016

Some highlights of the commissioning: the Lockman hole area

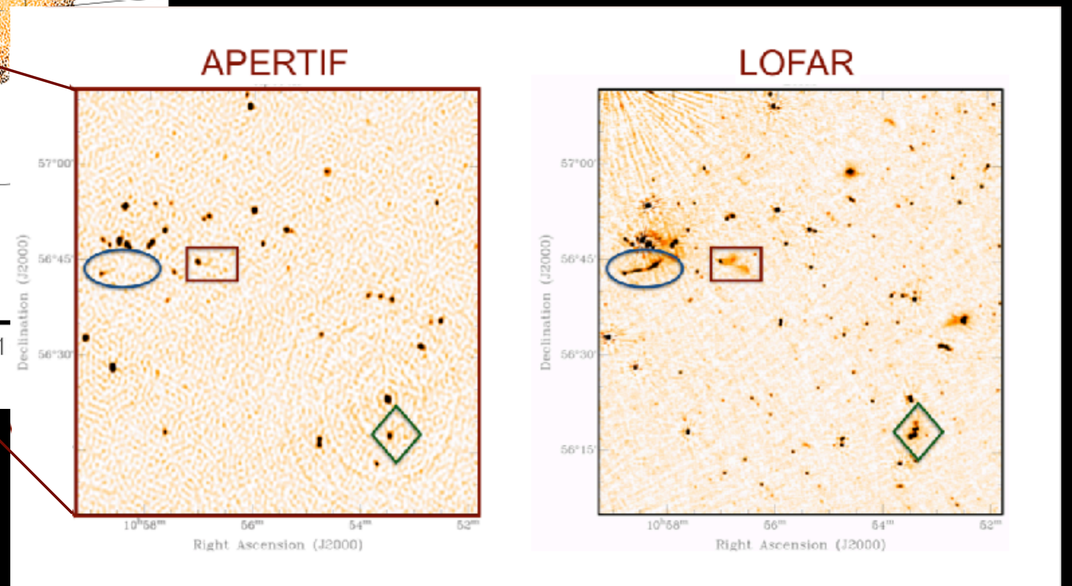


Continuum image Lockman Hole from a single pointing

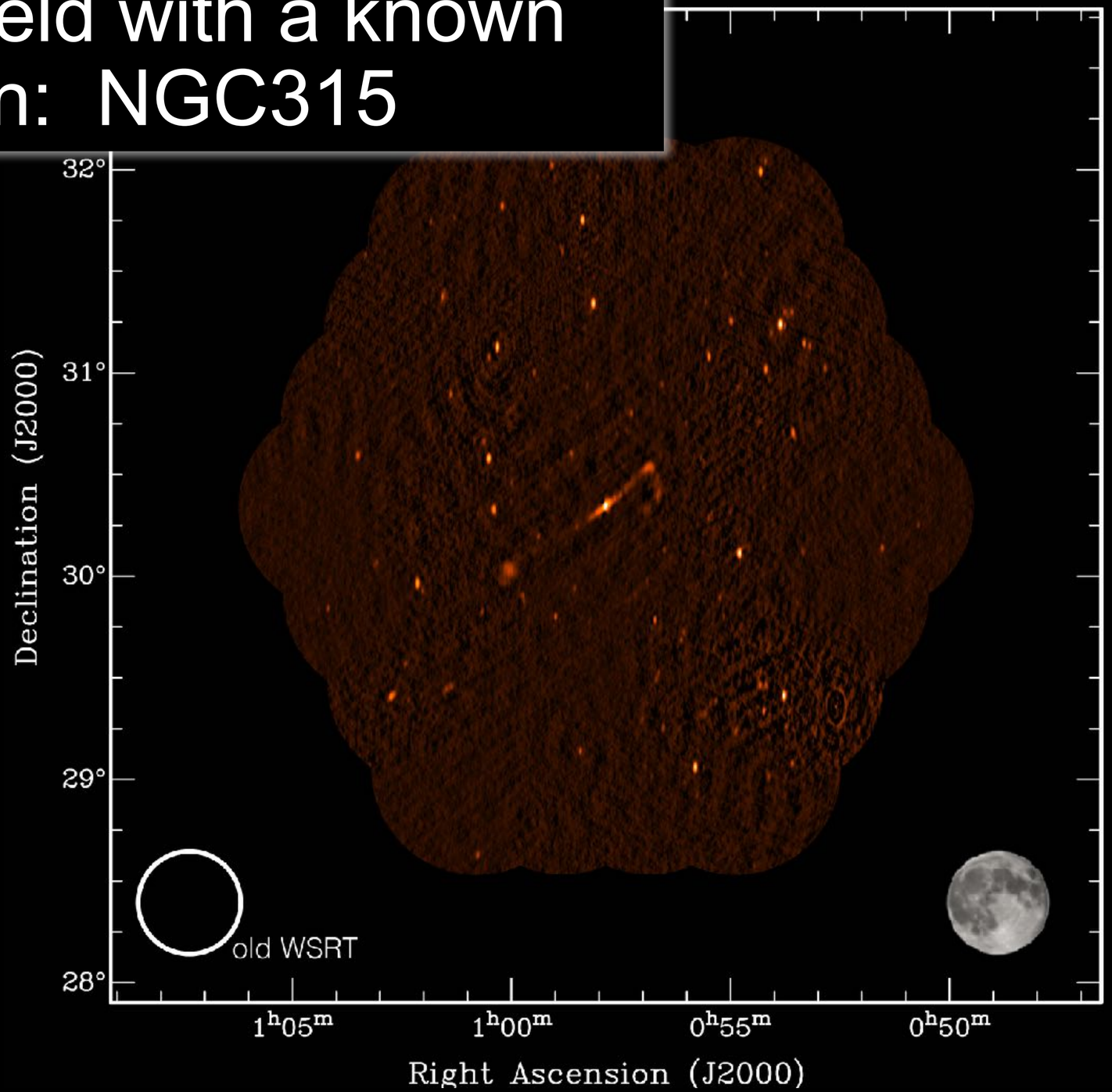
➜ About one year ago: the first wide-field (~10 deg^2) image taken using the individual PAF elements separately, a limited bandwidth (70 MHz) and one polarisation.

The noise in this image is 0.2 mJy/beam, and the final APERTIF system will be ~10x more sensitive

Very relevant for SHARP: for every continuum source we want to extract the spectrum and look for HI in absorption while, at the same time, learn about the properties of the continuum emission

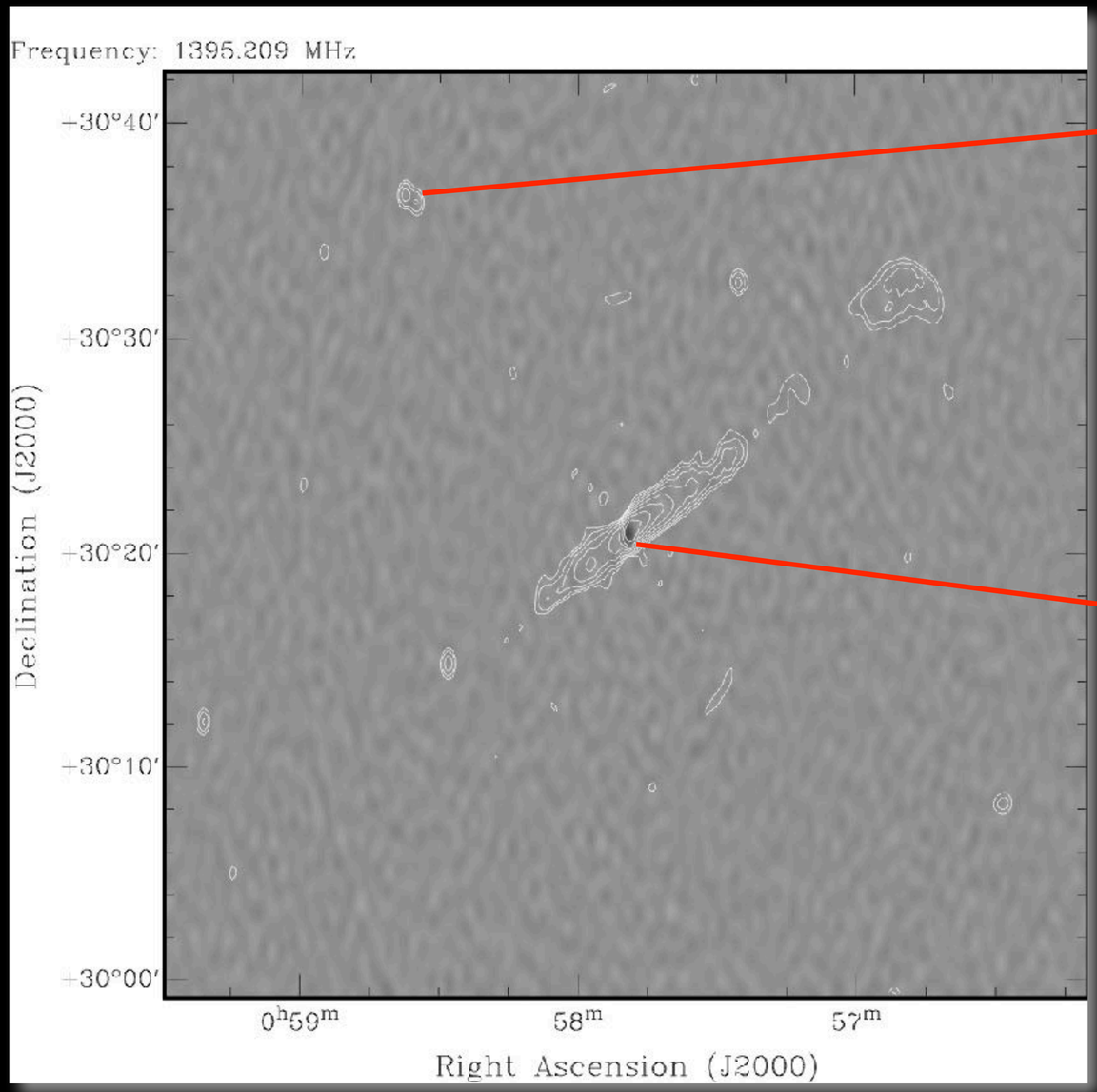


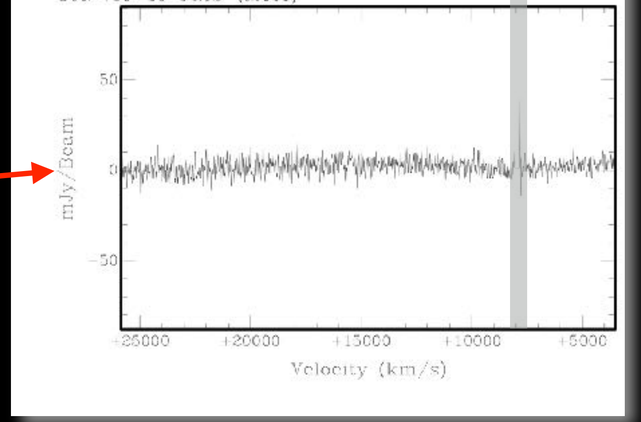
… an other test field with a known HI absorption: NGC315

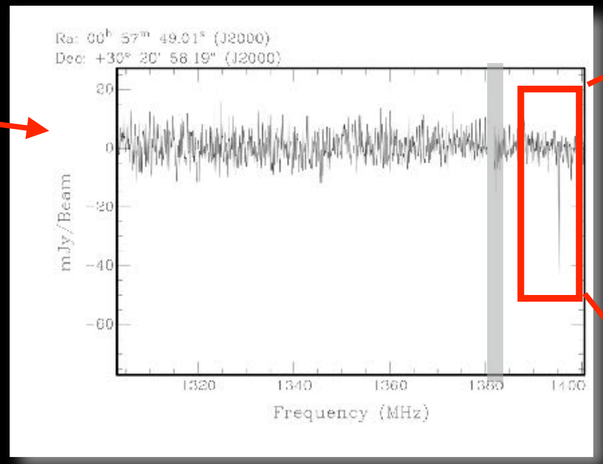


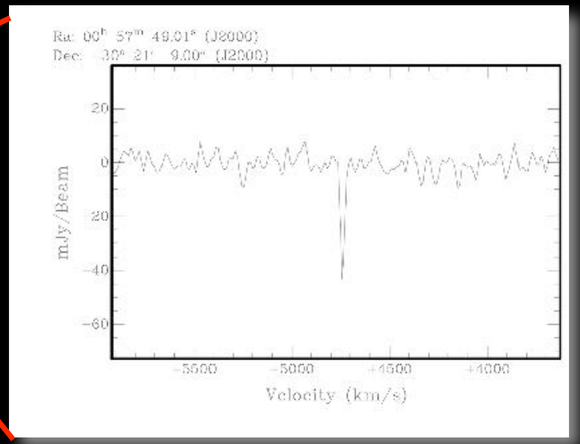
One of the first Apertif images…

NGC315 (Jan2018 - single pol, 135 MHz, 7 dishes)





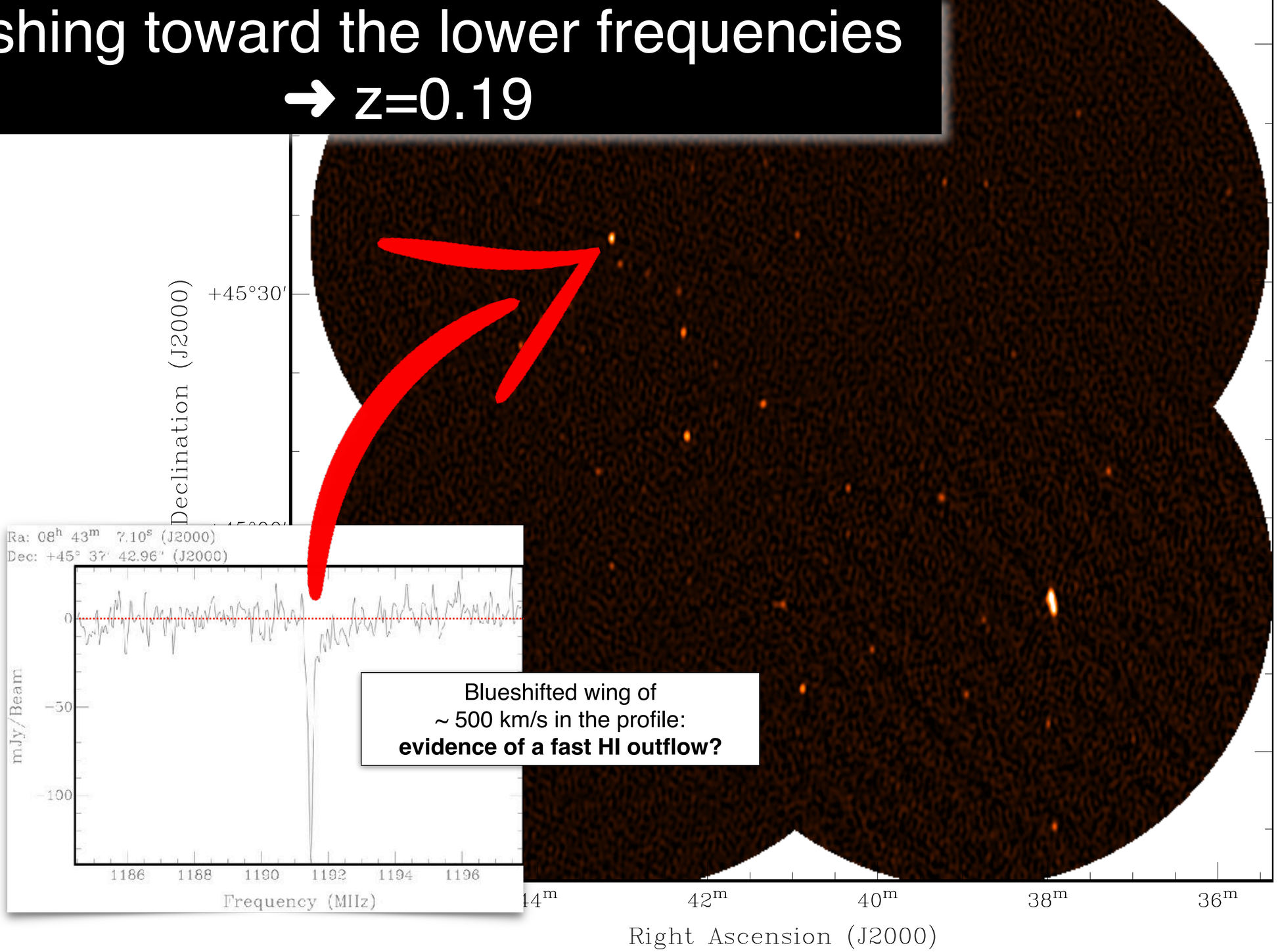




rms noise ~2 mJy/b chan=10km/s+Hanning

Use to test *Sharpener*, tool to identify location of continuum sources and search for absorption features in the cube ➜ see talk of Filippo Maccagni

Pushing toward the lower frequencies
➜ z=0.19



Blueshifted wing of
~ 500 km/s in the profile:
evidence of a fast HI outflow?

Now commissioning of the compound beams, polarisation, full array!

A number of new capabilities became available in the last weeks:

too much data to digest!

…but some highlights:

Full polarisation: looking good (YY still to be improved)

12 dishes: we get full resolution images at ~12arcsec resolution

Noise of compound beams: getting close to the expected noise

➜ 1.5 mJy/b for chan of 10 km/s (in XX)

(about 10-20% higher than expected)

… looking promising, but only a limited range of frequencies possible

(not the low-z Universe!) Limitation for early!

still a number of important issues to address before the surveys can start

Tools we need for the “blind” HI absorption surveys