LOFAR and the ING

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Special thanks to:
ASTRON staff,
Members of LOFAR key science programs

Questions also to: Matt Jarvis, Marc Verheijen

Overview

- Introduction
- Building of LOFAR
- Challenges and some recent results
- Surveys of the low frequency sky
  - Science case
  - Need for optical follow-up work


Early July 2008


September 2008


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Building first LOFAR station

March 2009

International Station Rollout

Station/Item	Cabinet	LBA	HBA	Fibre	CEP connection	Validated
CS302						2 L, 1H n
RS307						1 L nok
RS503						
RS106						
RS208						
CS030						1 L, 3H n
CS401						3 H nok
CS021						1 L nok
CS032						1 L nok
RS306						2 H nok
CS301						
CS501						
RS509						
CS103						1L, 4H n
CS001						2L, 5H n
CS002						2 L, 1 H n
CS003						1 L, 3 H n
CS004						1 L nok
CS005						2 H nok
CS006						
CS007						3 L, 2 H n
CS024						~4 H nok
CS201						
CS101						
CS026						
RS205						
CS017						
RS104						
RS210						
RS310						
RS404						
RS406						
RS407						
RS409						
RS410						
RS508						
Effelsberg						
Tautenburg						
Garching						
Potsdam						
Juelich						
Nancay						
Onsala						
Chilbolton						
Totals	31	28	25	29	26	21

Faroe Islands
Norway
Onsala
Latvia
Lithuania
Baltic Sea
Belarus
Denmark
København
Edinburgh
North Sea
Torun
Amrum
Station 5.9
Station 1.7
Station 14NL
Station NL17
Potsdam
Jodrell Bank
Zielena Gora
Ukraine
Lords Bridge
Krakow
Juelich
Tautenburg
Praha
Chilbolton
Effelsberg
Luxembourg
Luxembourg
Garching
Wien
Romania
München
Austria
Jersey
Nancay
Liechtenstein
Switzerland
Ljubljana
Serbia
Milano
Medicina
Bosnia and Herzegovina
Montenegro
Macedonia (FYROM)
San Marino
Monaco
Italy
Albania
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(Vatican)
© 2008 Tele Atlas
Greece
Google
Pointer lat 50.800384 lon 11.545824
Streaming 100%

LOFAR opens up the last "unexplored" part of the spectrum

- Very Low Frequencies: 10-240 MHz
  - Detection of extremely distant objects, new physics, serendipity
- High angular resolution: 1" at 200 MHz
  - Morphologies, Identification of sources
- Nano second time resolution
  - Cosmic rays
- Enormous Field of View
  - Rare (transient) objects
- Sensitive polarization measurements
  - Magnetic fields
- Low-Frequency Radio Spectroscopy
  - Neutral gas in the early universe

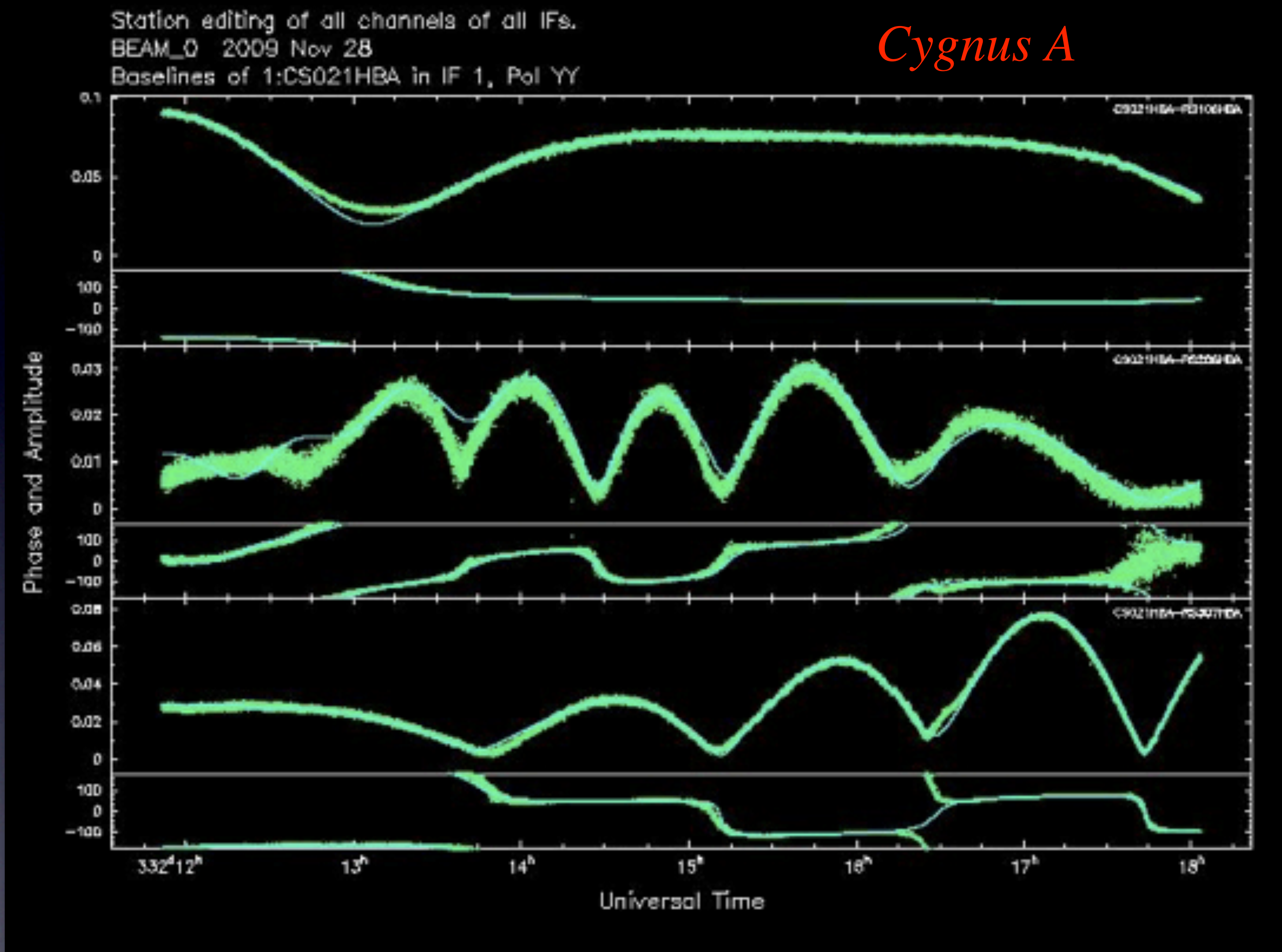
Science Areas

- Cosmic ray showers
- The epoch of reionization
- The bursting and transient Universe
- Cosmic magnetism
- Sun
- The distant Universe

Imaging with LOFAR

- Station beamforming
- Correlation of ~ Tbyte of station beams
- Removal Radio interference
- Calibration
- Removal ionospheric corruption
- Deconvolution
- Widefield imaging

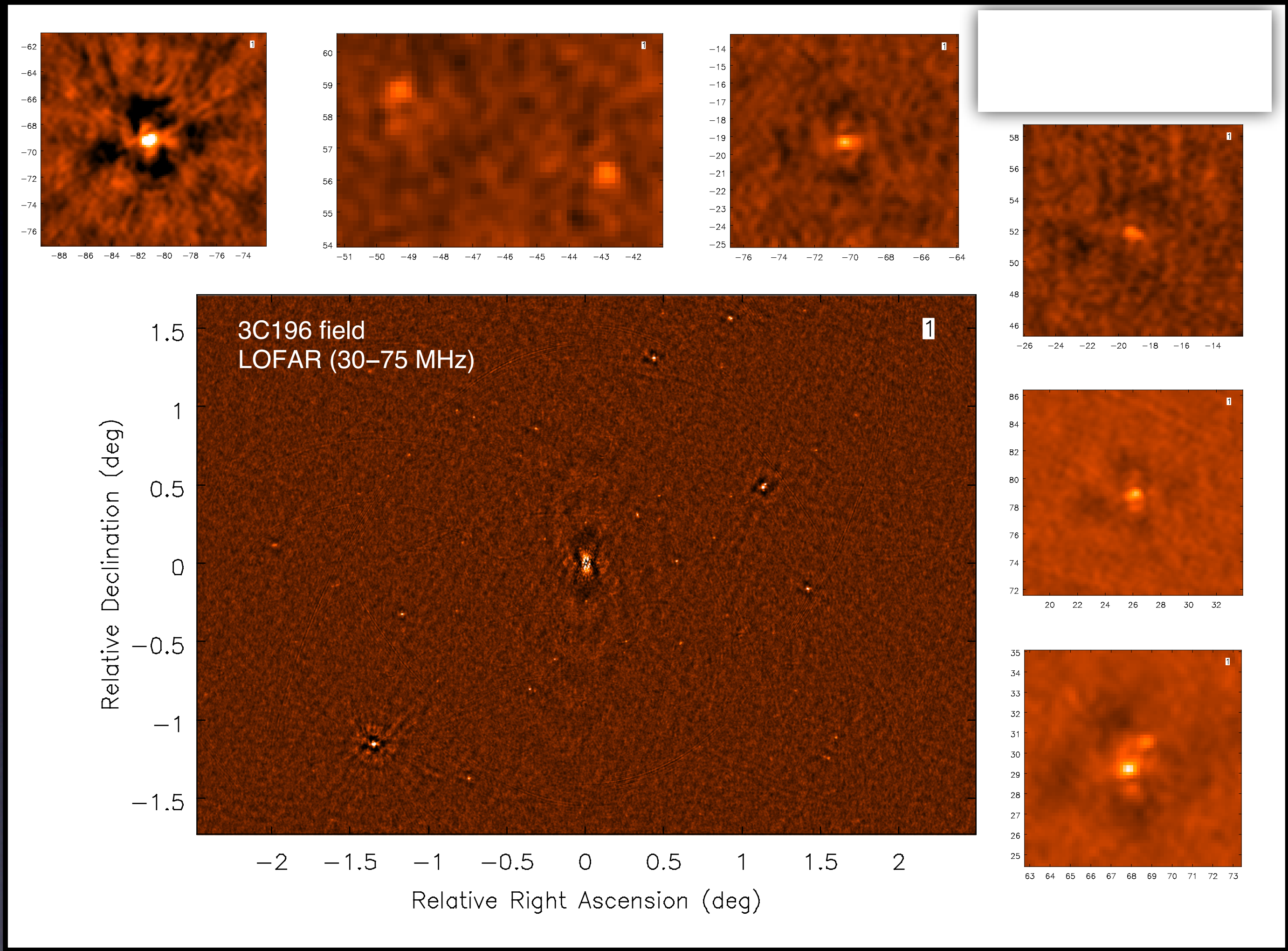
Recent Data Quality



(courtesy N. Jackson, J. Conway)

14 HBA stations (10 split core + 4 remote)
Solutions fit in Difmap

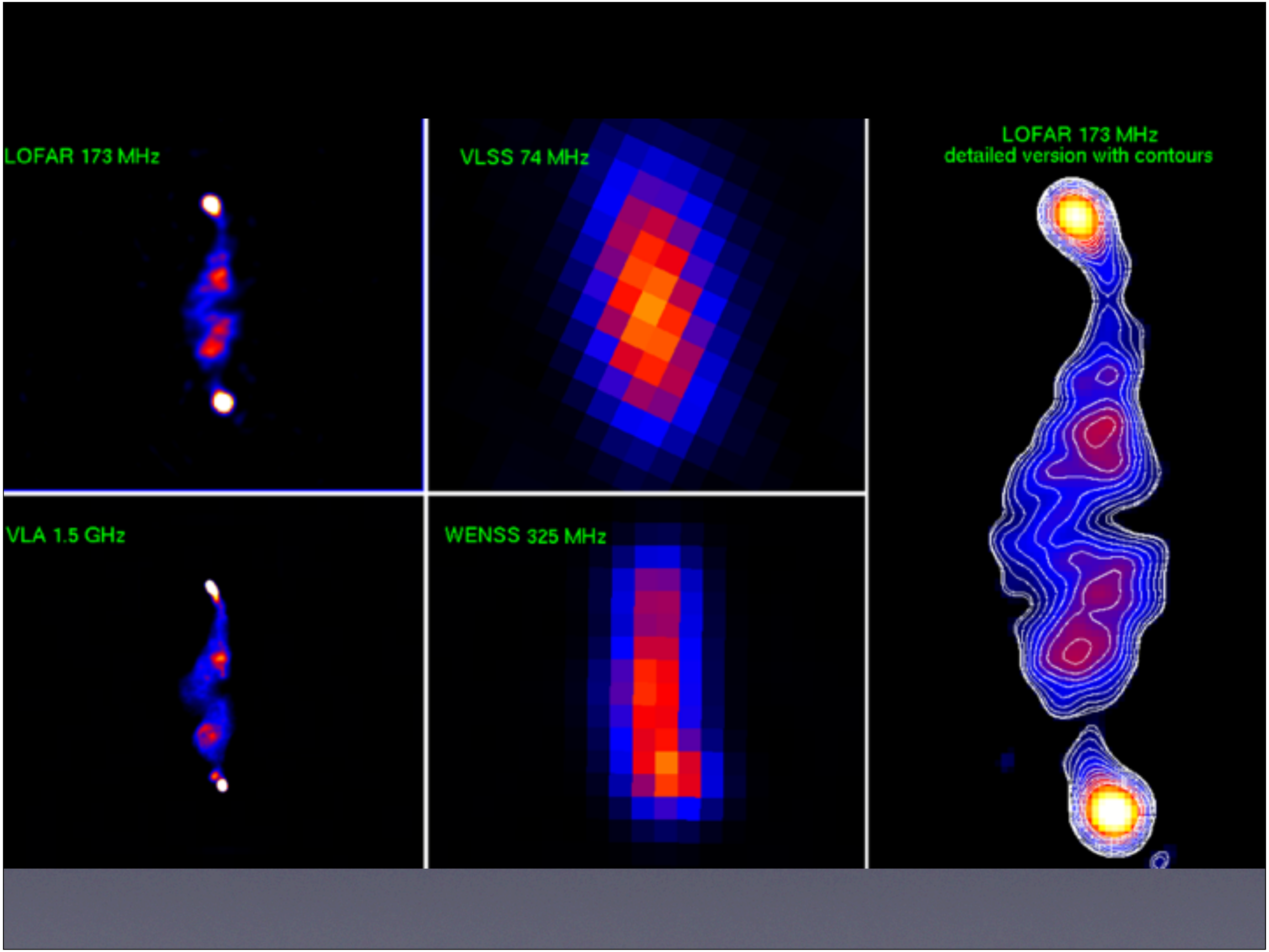
Pipeline Processing



(courtesy J. McKean)

Fully automated processing, 72 sub-bands, ~4 hrs

Included DPPP, additional flagging pass, BBS, solution flagging, imaging


LOFAR 173 MHz
VLSS 74 MHz
LOFAR 173 MHz
detailed version with contours
VLA 1.5 GHz
WENSS 325 MHz

LOFAR surveys and its Main Drivers

- 100 z ~ 6 radio galaxies

  Formation and evolution of massive galaxies, black holes and clusters at/near the epoch of reionisation

- 100 cluster radio sources at z > 0.6

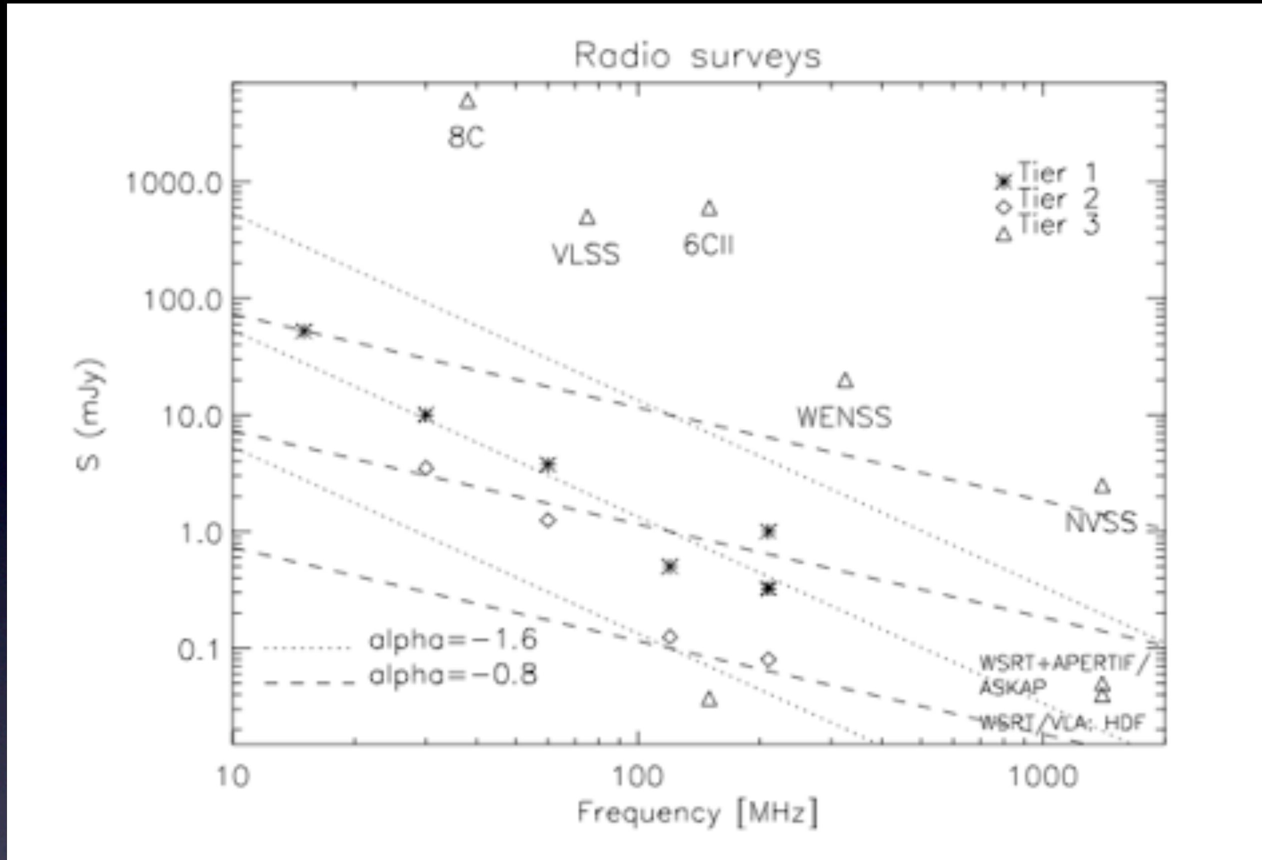
  Dynamics of cluster gas, evolution of cluster wide magnetic fields

- 10 clusters of starbursts starbursts at z>2

  SFR ~ 10 M0/yr at z=2-3

- Serendipity

  << 30 MHz



50 million sources at key frequencies 15,30, 60, 120, 150, 200 MHz

Science groups

- The highest redshift radio sources - George Miley
- Starforming galaxies at moderate and high redshifts- Matt Lehnert/Peter Barthel
- Clusters and cluster halo sources - Marcus Brüggen/Gianfranco Brunetti
- AGN at moderate redshifts - Philip Best
- Gravitational lensing - Neal Jackson
- Detailed studies of low-redshift AGN - Raffaella Morganti
- Nearby galaxies - John Conway/Krzysztof Chyzy
- Cosmological studies - Matt Jarvis/David Bacon
- Galactic radio sources – Marijke Haverkorn / Glenn White

Marc’s email:

ING is considering the construction of a wide-field MOS for WHT prime focus, and we particularly welcome your comments about the field of view, multiplex factor, wavelength range/s and spectroscopic resolution/s you would like to see on this instrument.

Relevant topics

- Starforming galaxies at moderate and high redshifts
- AGN at moderate redshifts
- Clusters and cluster halo sources
- Cosmological studies

Radio/optical IR survey of XMM/LSS (Tasse etal)

- z~ 0.6 Radio galaxies with Log(M/Mo) > 10.5
    - Similar space density as locally
    - Located in overdensities of scale 450 kpc
    - Do not have IR excess

  Identify with accretion of hot gas

- z~0.6 radio galaxies with Log(M/Mo) < 10.5
    - Factor of ~10 higher space density as locally
    - located in overdensities of scales of 75 kpc
    - Have an IR excess

  Identify with merging event driving cold gas to the center

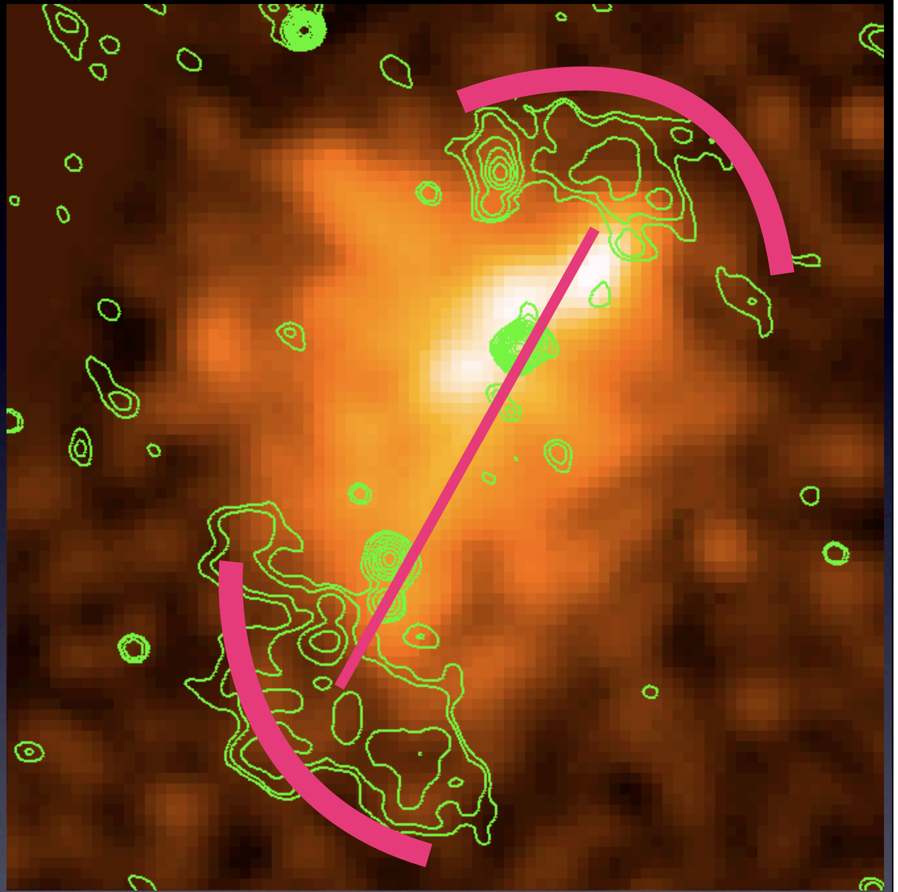
Starforming galaxies at moderate and high redshifts/

AGN at moderate redshifts

- Science
  - Interrelated: AGN and galaxy formation
- Needed, for 10^7 galaxies up to z~2
  - redshift, mass, starformation, dust content, density of environment,
  - radio loudness, radio power, radio morphology
- Instrumentation: LOFAR+ wide area IR surveys

Clusters of Galaxies

- Clusters grow by mergers and accretion of gas, both shock the intra cluster medium (ICM)
- Shocks have a profound impact
- LOFAR: few thousand shocked clusters up to z~0.8
- WHT map kinematics and relate to dark matter/shock structure



GMRT+Chandra:
Massive merger ZW12341.1 (z=0.3)
Van Weeren, HR, Raychaudhury, Bagchi et al.

Cosmology

- Weak lensing (doable with LOFAR?)
  - median z~1.4
  - Redshift for large numbers of radio sources
- Large scale clustering and the evolution of bias
  - 10,000 radio galaxies up to z=1
- Baryonic oscillations
  - to measure the BAO length-scale to an accuracy of ~ 2% at redshift z ~ 1; to achieve this, redshifts for a well-defined sample of at least several hundred thousand galaxies will need to be measured.

Final notes/conclusions

- z>6 radio galaxies, starbursts, and gamma ray bursts need a 10-m class telescope
- Meerkat, ASKAP and Apertif (WSRT) are survey facilities coming on line around 2015.
- LOFAR surveys need massive follow-up for their science
  - Both desirable:
    - Redshift machine
      - low resolution, large multiplexing
    - Large area IR surveys
      - accurate photometric redshifts