Overview of 3D Radio Techniques

Dr Bärbel Koribalski

25 September 2017

CSIRO Astronomy and Space Science
www.csiro.au

The Australia Telescope Compact Array

- **ATCA**: 6 × 22-m dishes (freq. 1 – 105 GHz, baselines up to 6 km; high-res. imaging of the Galactic and Extragalactic sources)
- celebrating 29 years of operation now in September 2017
- ATCA's **data rate** is **~24 TB/yr** raw data (default: 1.4 GB/h; max: 230 GB/h; average 1.6 GB/h)
- **AT On-line Archive** (ATOA) currently stores **~80 TB**; users download data, meta data & software; process on modern laptop

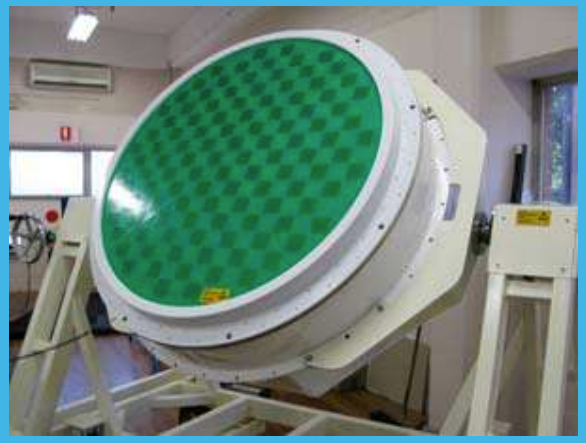
The Atacama Large Millimetre Array

- **ALMA**: 66 ×12-m dishes (5000m altitude; freq. 84 – 950 GHz, baselines up to 160 km; high-res. imaging of the "cool Universe")
- now in full operation (official opened on 13 March 2013)
- ALMA's **data rate** is **96 Gbit/s**; raw data **~200 TB /yr** is currently stored and mostly downloaded & processed by the users
- **ALMA correlator** (delivering **17 PetaOPS** - fastest of its kind)
- partnership between Europe, North America & East Asia + Chile

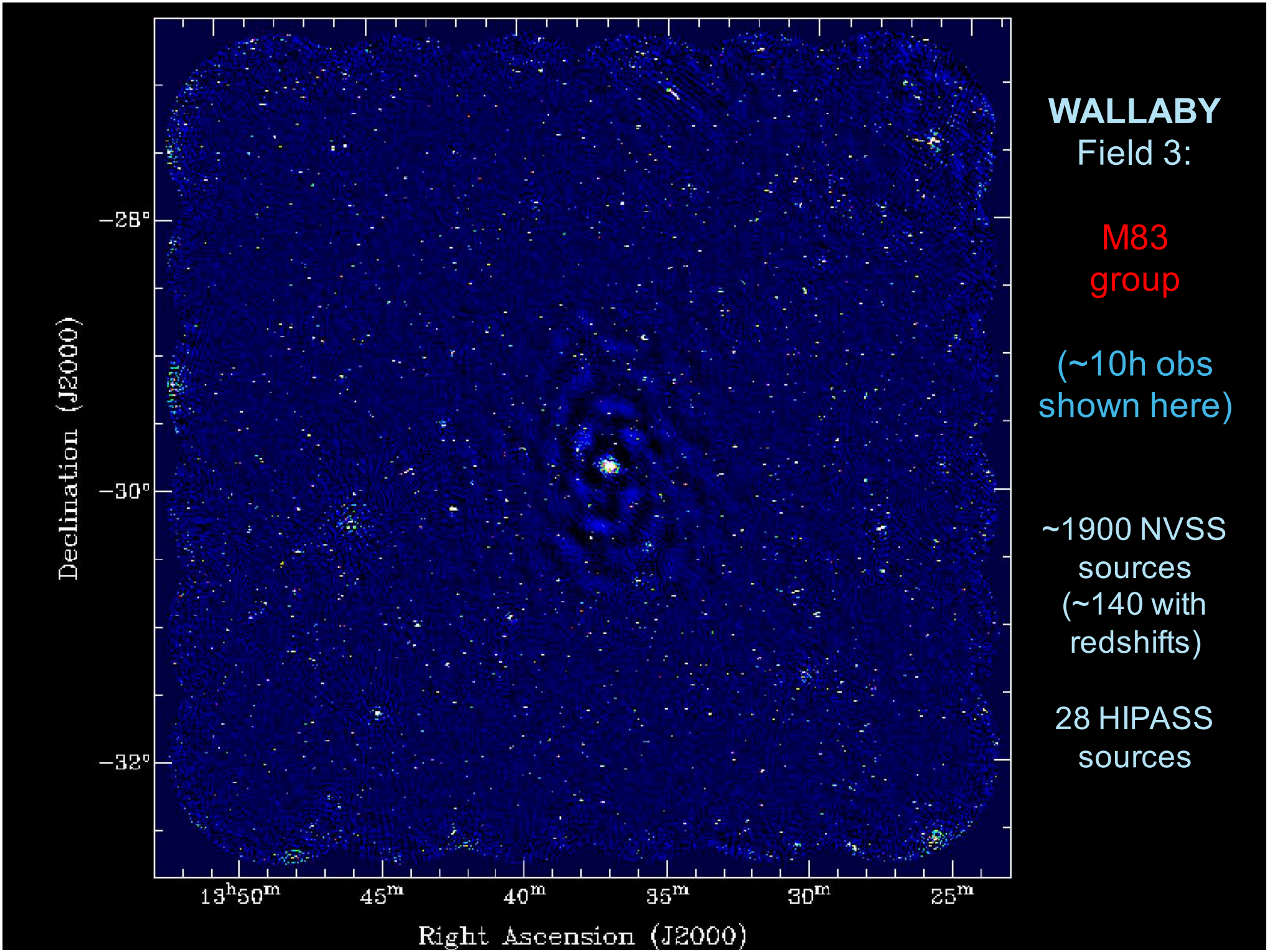
The Australian SKA Pathfinder

- **ASKAP**: 36 ×12-m dishes (freq. 0.7 – 1.8 GHz, baselines up to 6 km; e.g., mapping the 21-cm line of neutral atomic hydrogen gas)
- ASKAP's **data rate** is expected to be **72 Tbit/s** (once fully operational), data output **~500 PB /yr**, raw data will be stored only temporarily, archive data outputs (images/cubes) long term
- **ASKAP correlator** (delivering **340 Tflop/s**)

First generation Phased Array Feed (PAF)



ASKAP MkII Phased Array Feed



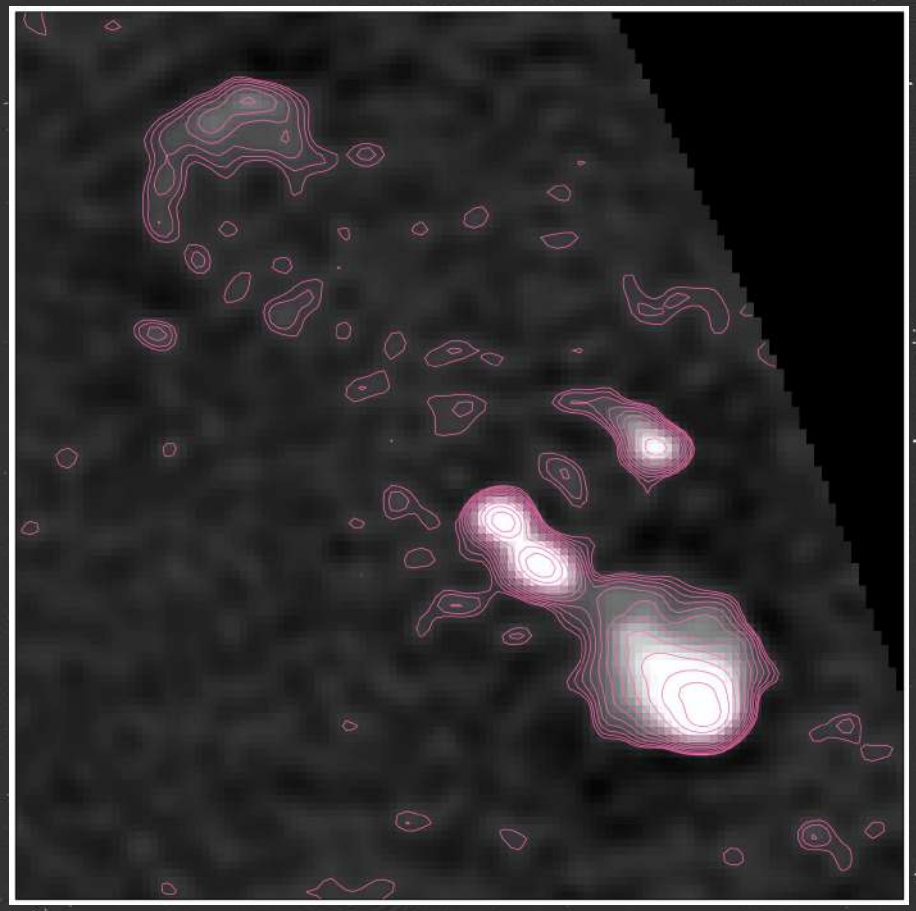
WALLABY
Field 3:

M83
group

(~10h obs
shown here)

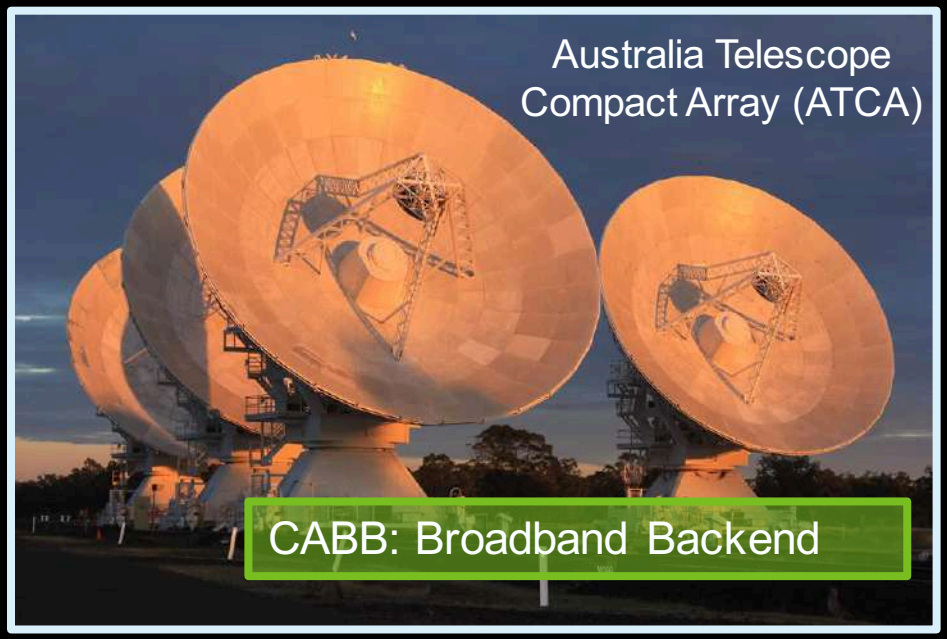
~1900 NVSS
sources
(~140 with
redshifts)

28 HIPASS
sources



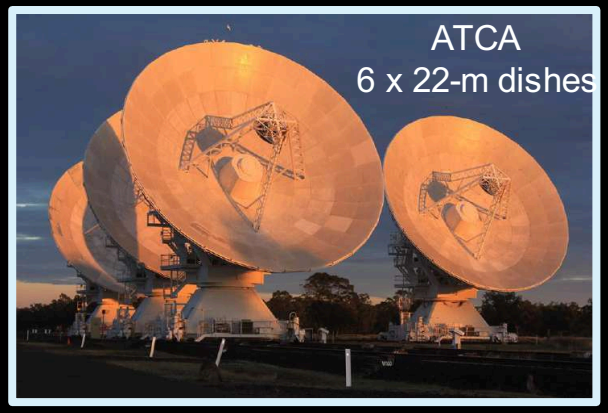
Thanks to Ian Heywood and the ASKAP/WALLABY team

Australia Telescope National Facility



Australia Telescope National Facility


Parkes 64-m
telescope


ATCA
6 x 22-m dishes

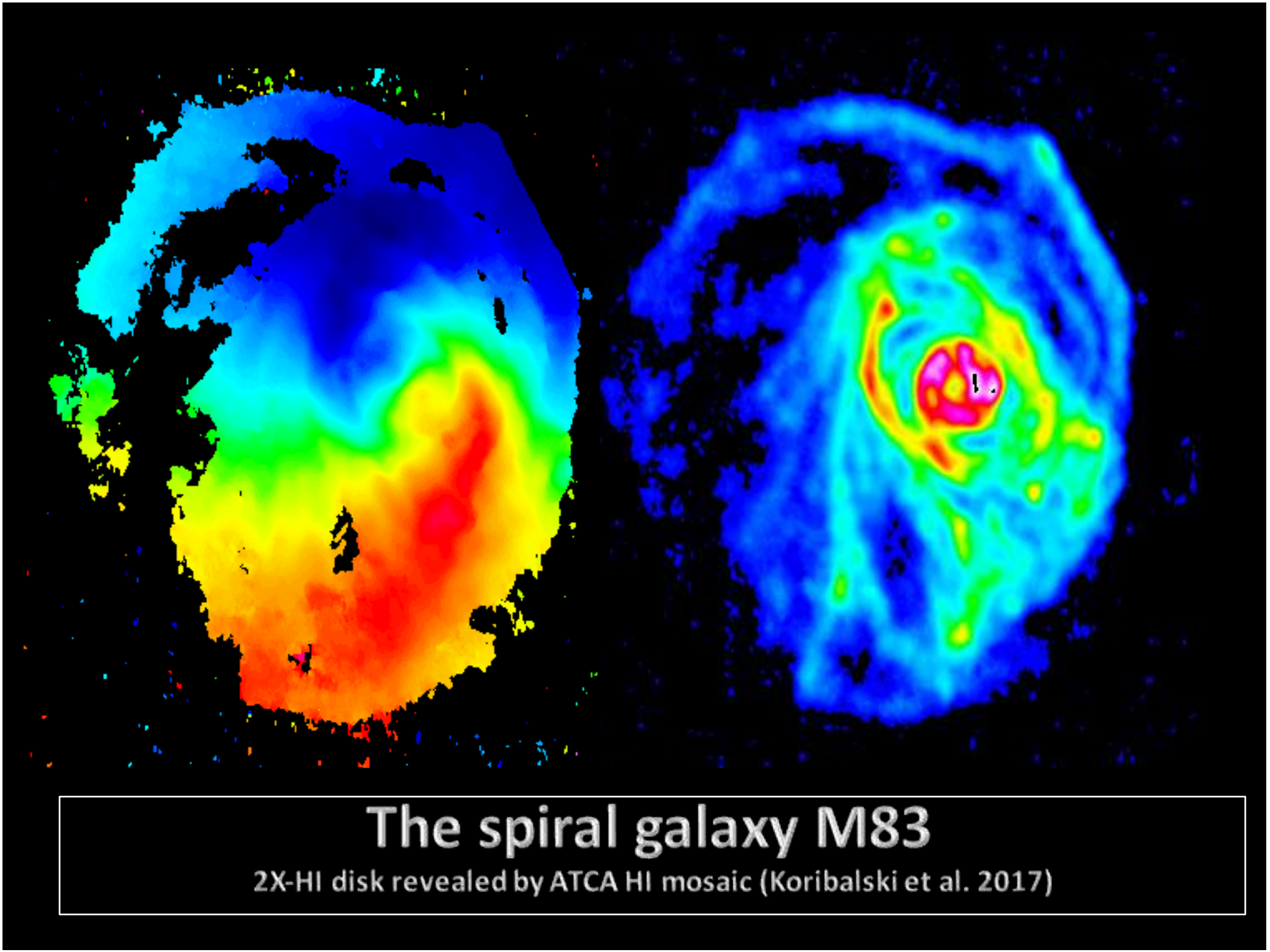

SKA-low


Murchison Widefield Array

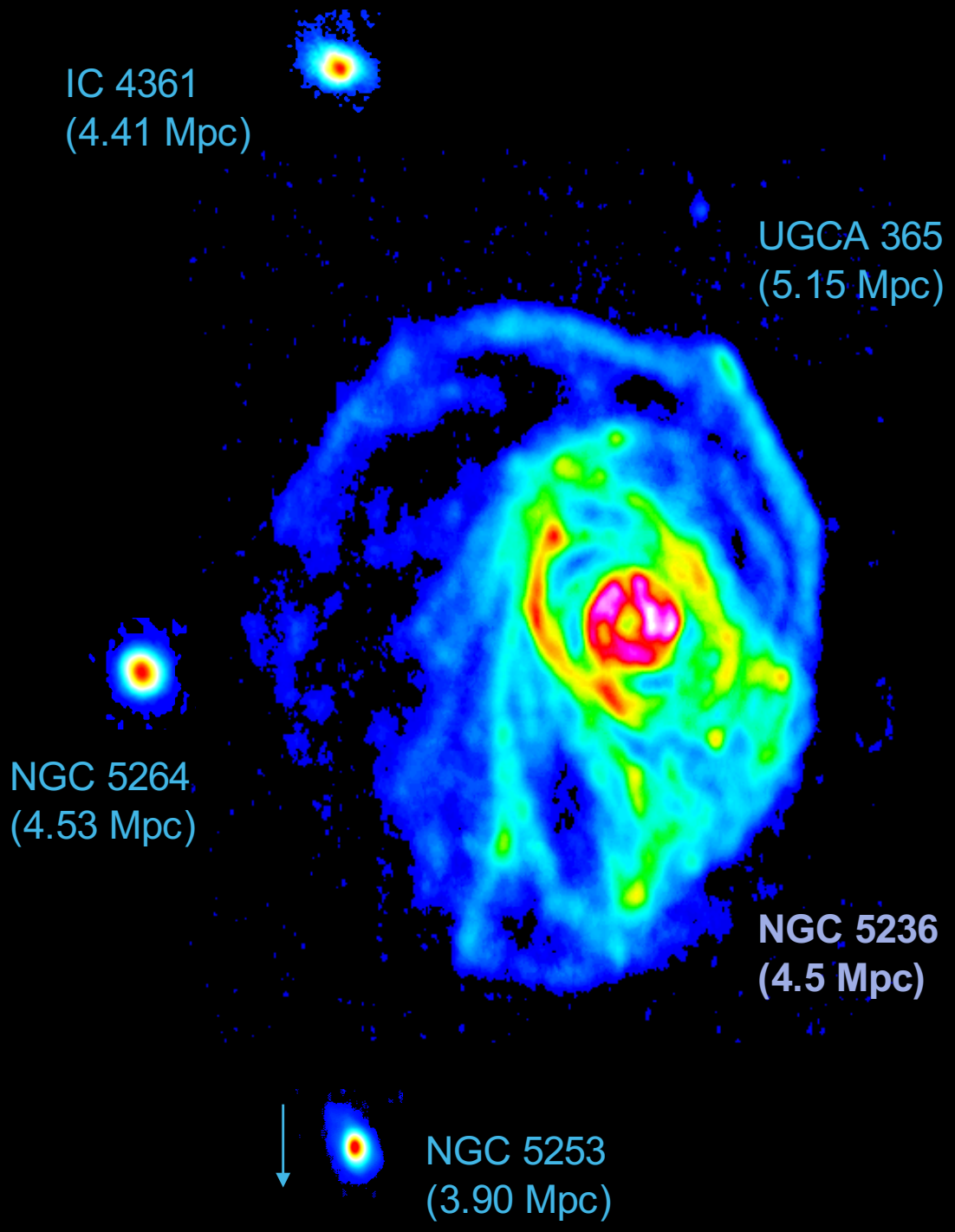

expand to achieve
SKA-survey ?
ASKAP: the Australian SKA Pathfinder


SKA-mid

Why use 3D radio techniques ?


The spiral galaxy M83
2X-HI disk revealed by ATCA HI mosaic (Koribalski et al. 2017)

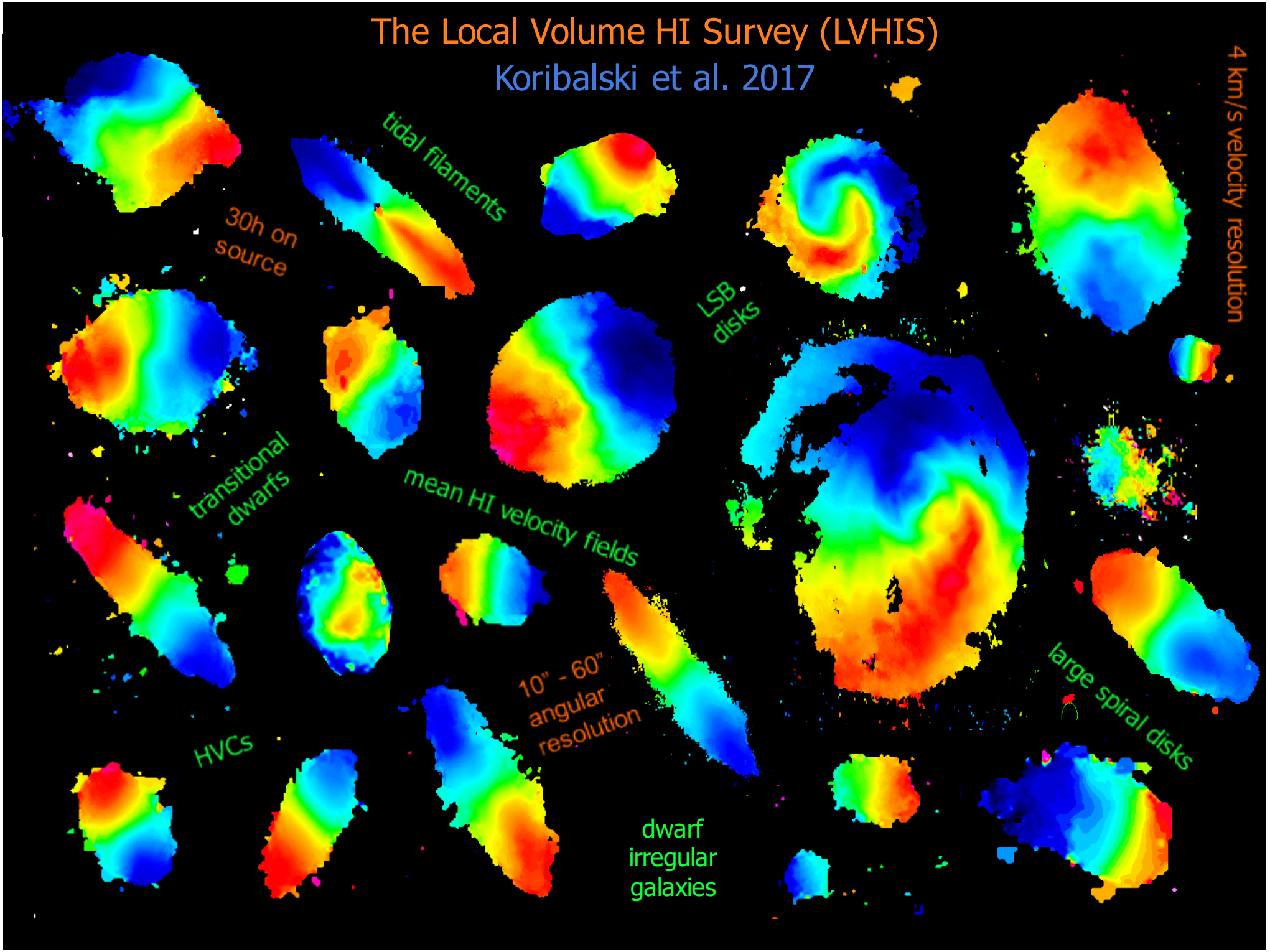
M 83 and its closest neighbours

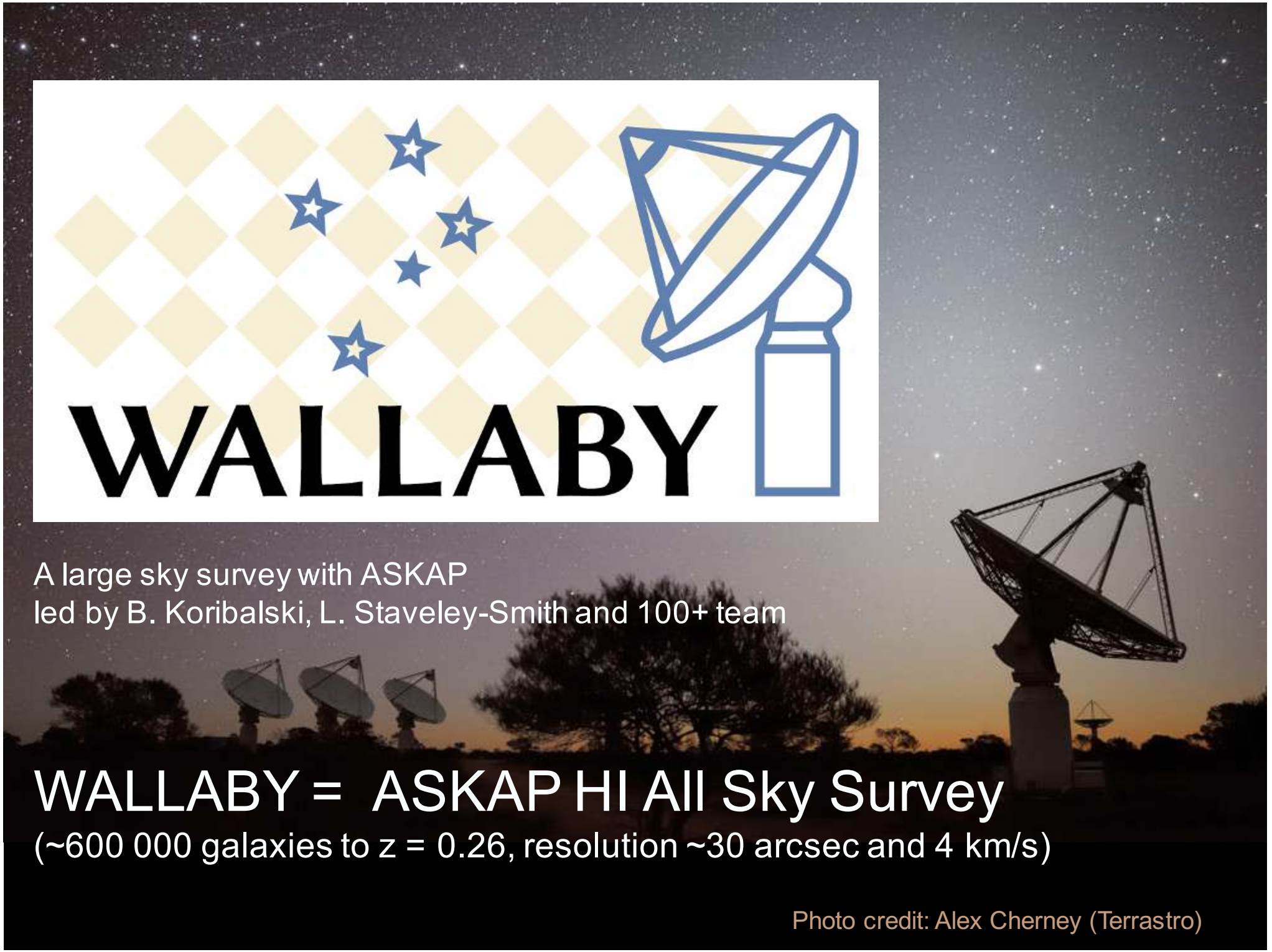


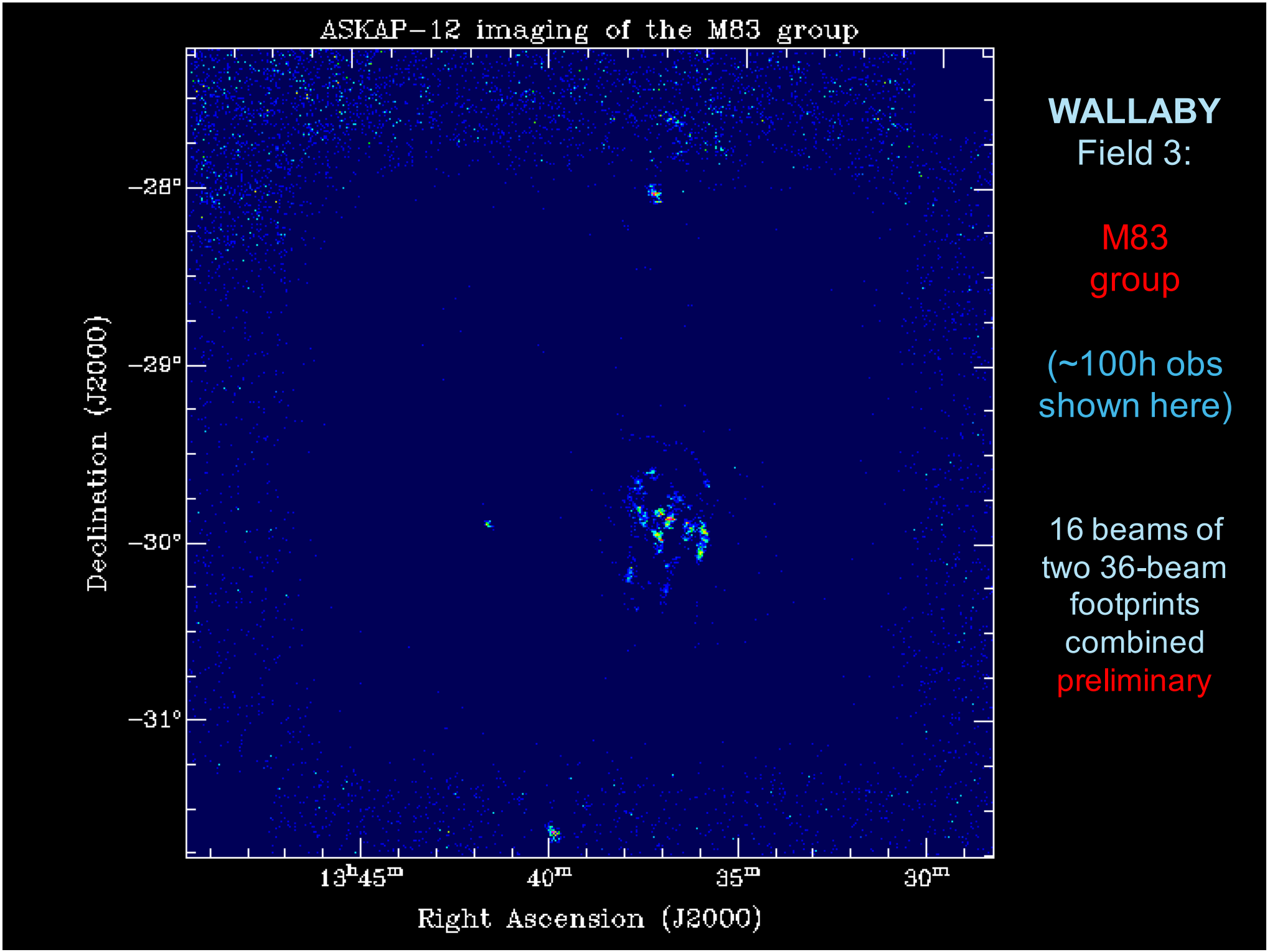
The spiral galaxy M83 appears to grow by regularly accreting neighbouring dwarf galaxies.

Gaseous tails and stellar streams tell us about the group evolution.

(Koribalski et al. 2017)


The Local Volume HI Survey (LVHIS)
Koribalski et al. 2017
4 km/s velocity resolution
tidal filaments
30h on source
LSB disks
transitional dwarfs
mean HI velocity fields
10" - 60" angular resolution
HVCs
large spiral disks
dwarf irregular galaxies


WALLABY
A large sky survey with ASKAP
led by B. Koribalski, L. Staveley-Smith and 100+ team
WALLABY = ASKAP HI All Sky Survey
(~600 000 galaxies to z = 0.26, resolution ~30 arcsec and 4 km/s)
Photo credit: Alex Cherney (Terrastro)



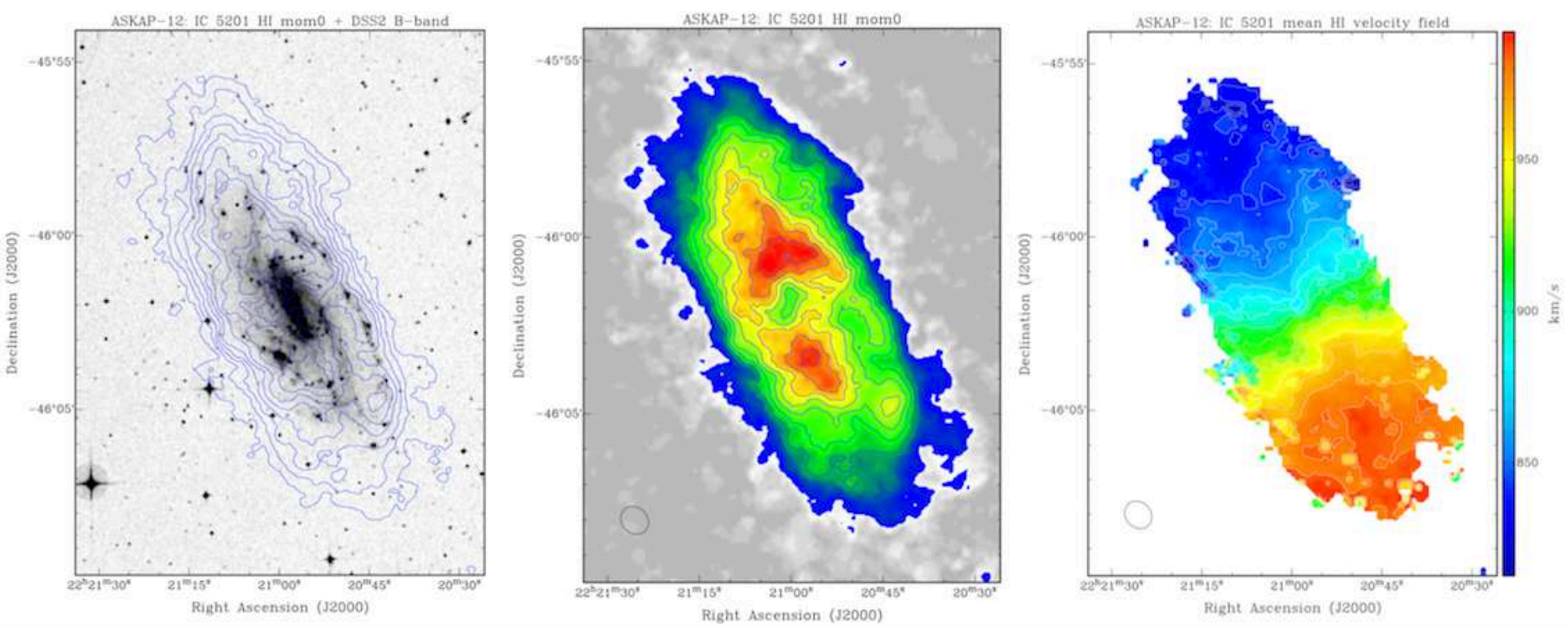
WALLABY
Field 3:

M83
group

(~100h obs
shown here)

16 beams of
two 36-beam
footprints
combined
preliminary

ASKAP-12 Early Science



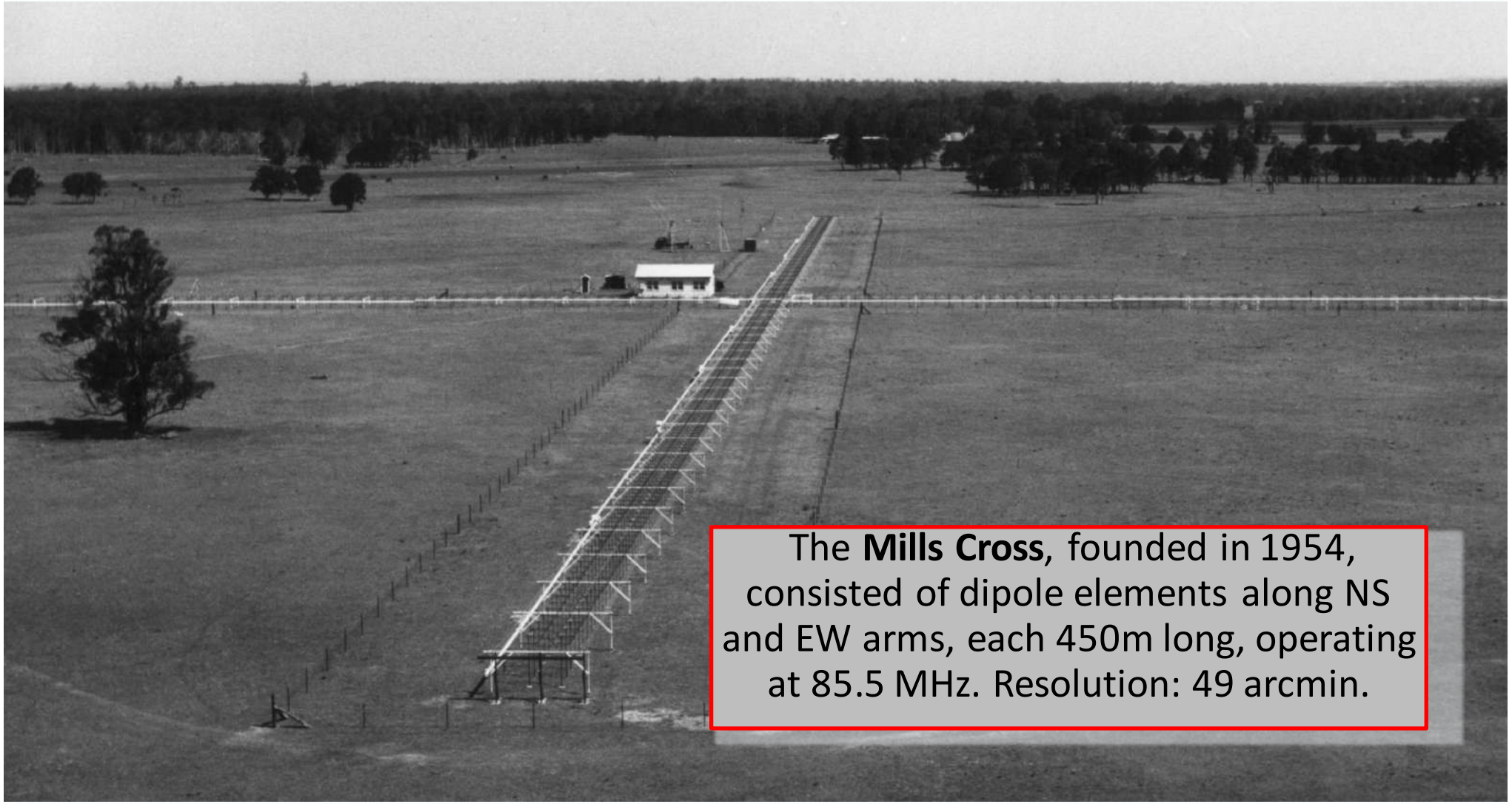
During ASKAP-12 Early Science the WALLABY team is targeting galaxy groups and clusters to study gas and star formation as a function of environment. – Preliminary HI maps of IC5201 above.

(Credit: Lee-Waddell, Madrid, WALLABY data processing team)

Radio interferometers

CSIRO Astronomy and Space Science
www.csiro.au

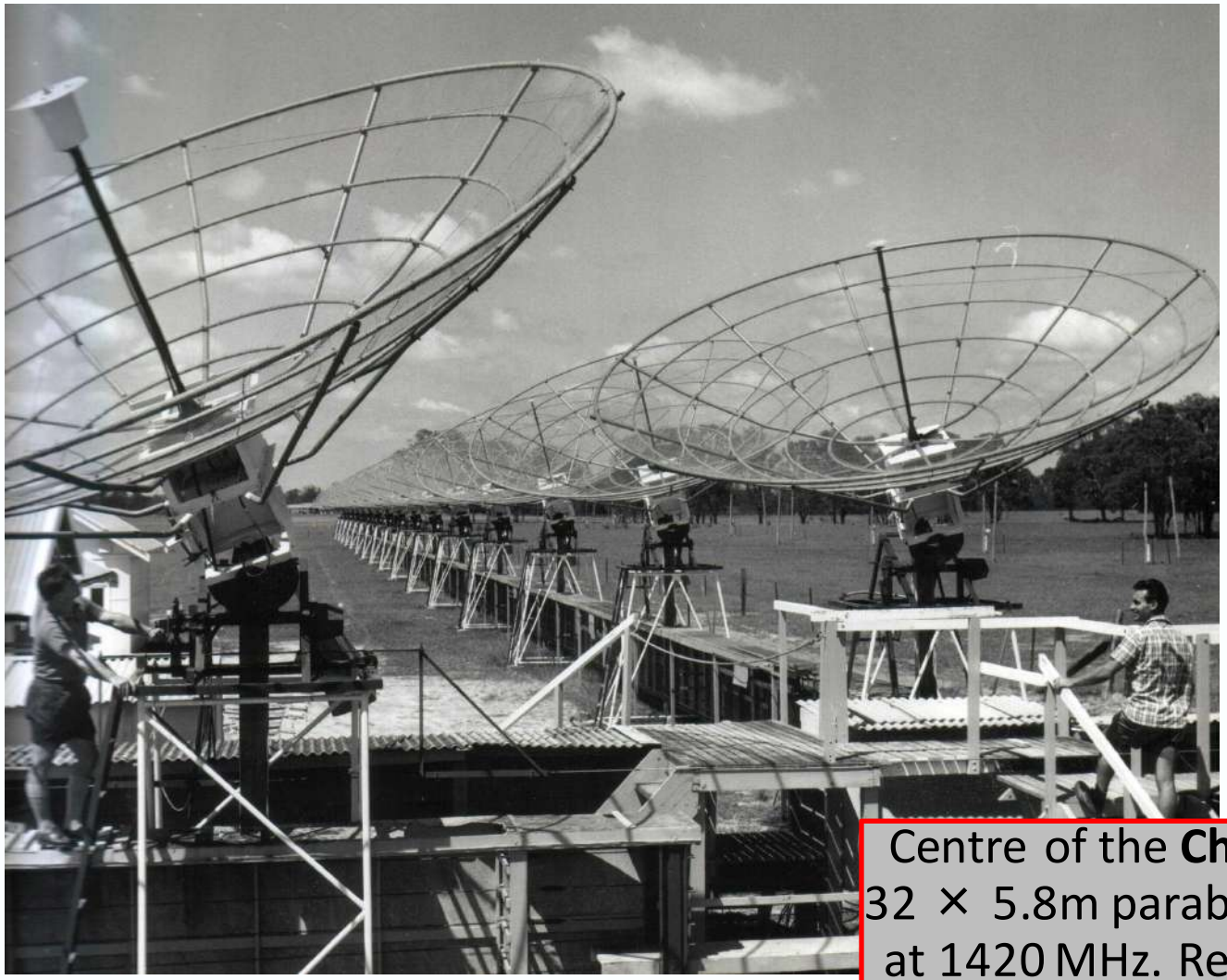
… some early radio interferometers



The **Mills Cross**, founded in 1954, consisted of dipole elements along NS and EW arms, each 450m long, operating at 85.5 MHz. Resolution: 49 arcmin.

http://www.atnf.csiro.au/news/newsletter/jun02/Flowering_of_Fleurs.htm (by *Wayne Orchiston and Bruce Slee)*

… some early radio interferometers



Centre of the **Chris Cross**, an array of 32 × 5.8m parabolic dishes, operating at 1420 MHz. Resolution: 1.5 arcmin.

Westerbork Synthesis Radio Telescope (WSRT)

1970 – 2020?

14 × 25-m dishes on a 3 km long East-West track

(frequency range: 0.1 – 8 GHz)

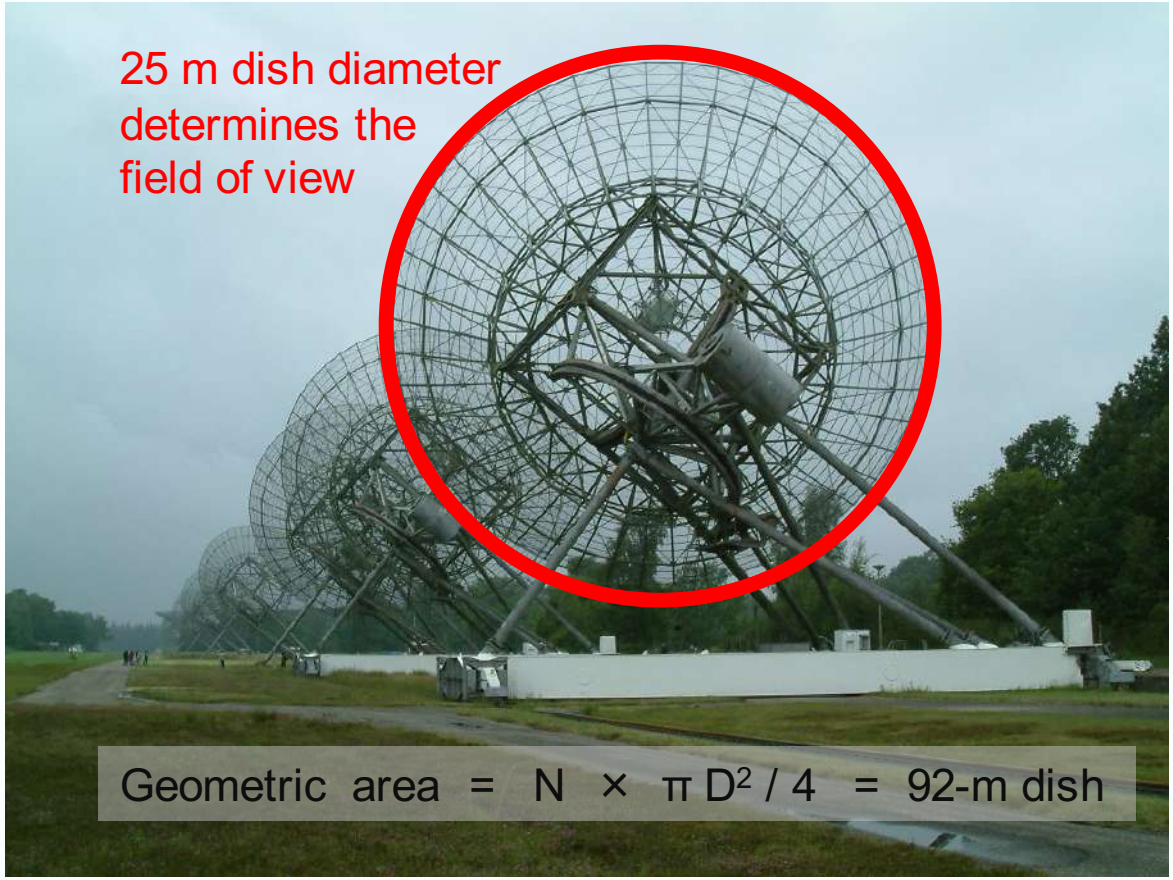


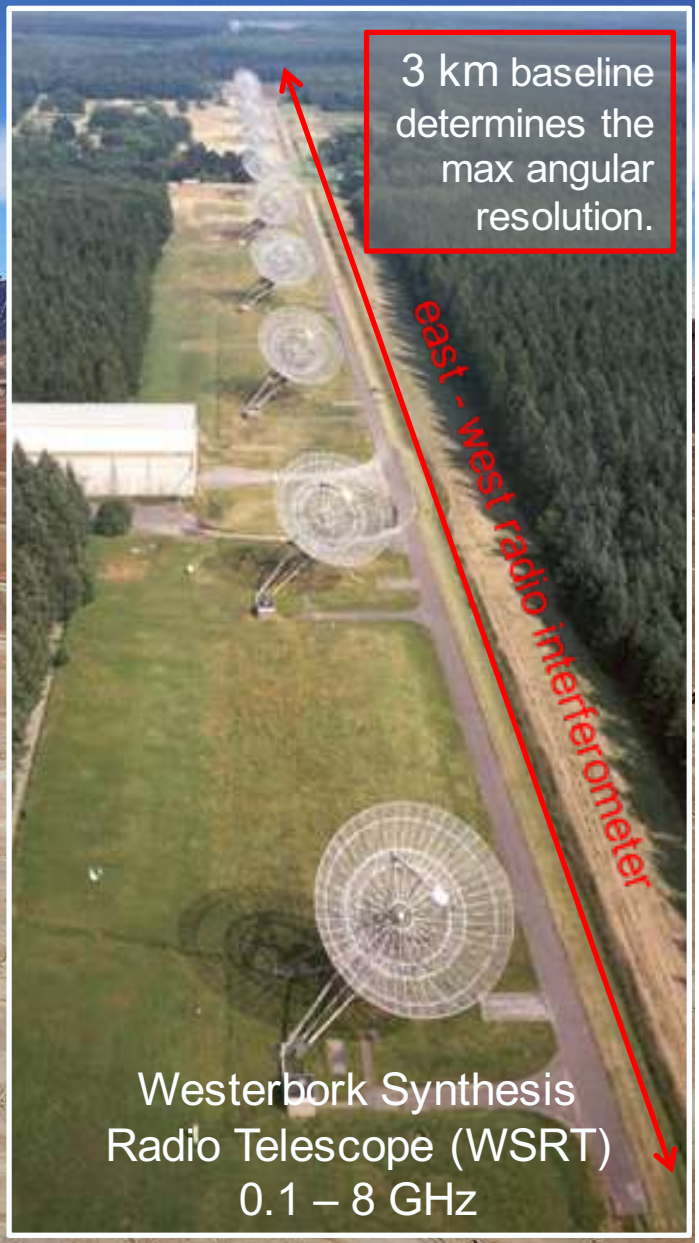
Image credit: ASTRON, The Netherlands.

ALMA @ 5000m altitude

a new radio interferometer:
66 × 12-m dishes

baseline

number of baselines
= N (N−1) / 2



ALMA @ 5000m altitude

a new radio interferometer:
66 × 12-m dishes

baseline

number of baselines
= N (N−1) / 2

Imaging based on Earth rotation aperture synthesis

uv-coverage

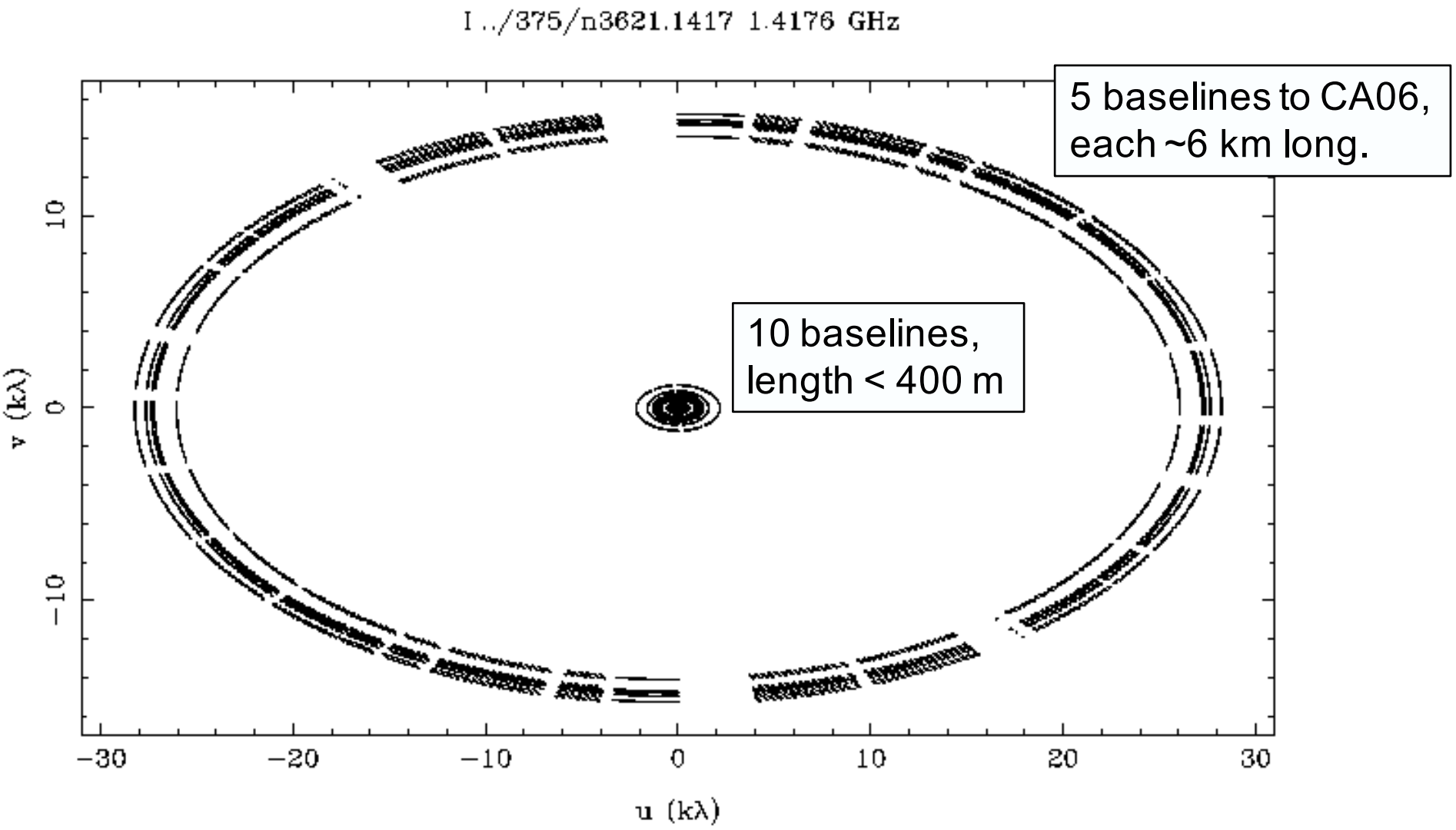
Interferometry uses earth rotation

Full *uv*-coverage achieved in …

- 12 hours for an east-west array (eg WSRT, ATCA)
- 8 hours for a Y-array (eg VLA, GMRT)

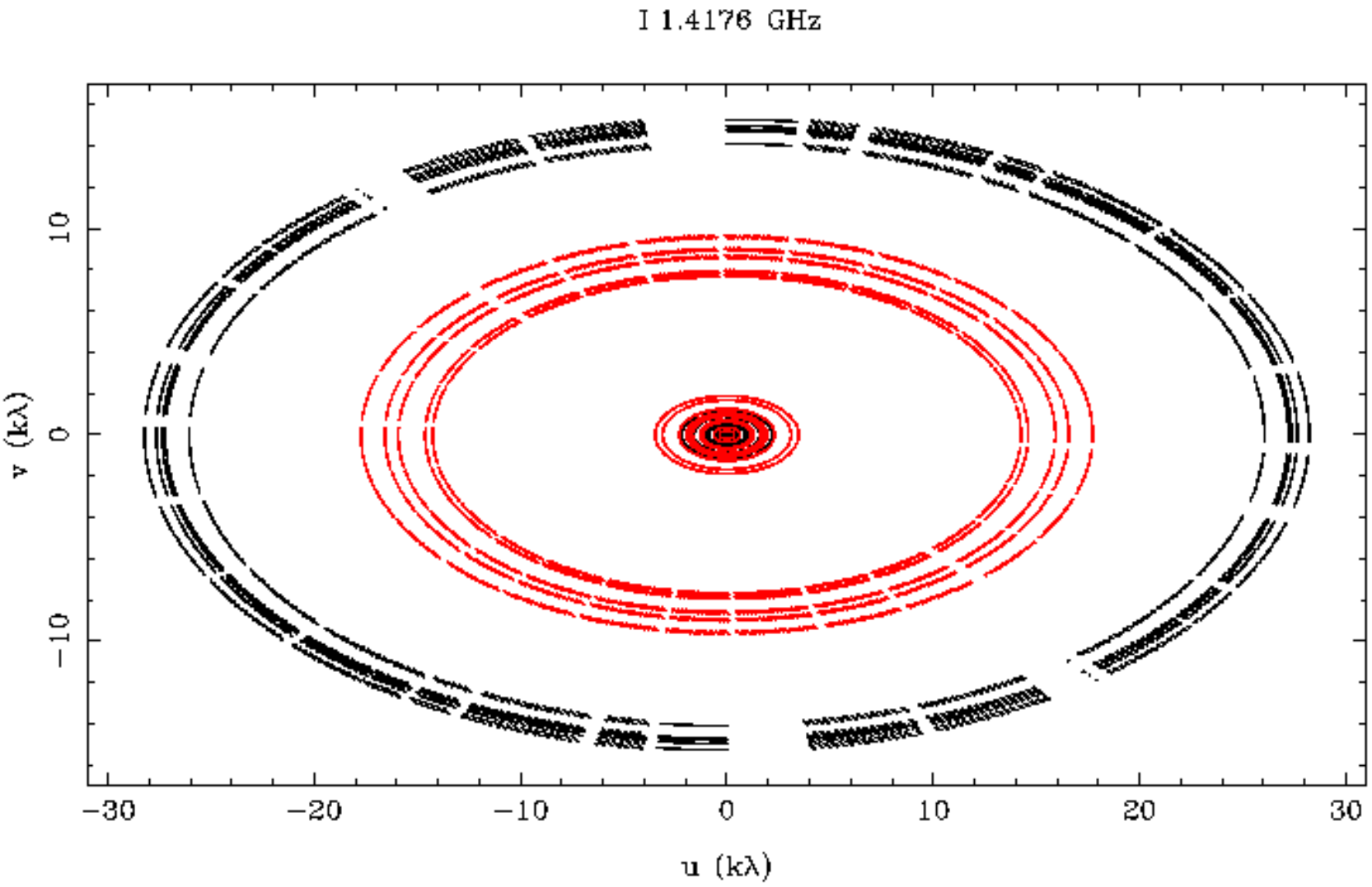
Interferometry & Earth-rotation Aperture Synthesis, eg, see
http://www.cv.nrao.edu/course/astr534/Interferometers1.html

uv-coverage: one configuration (15 baselines)



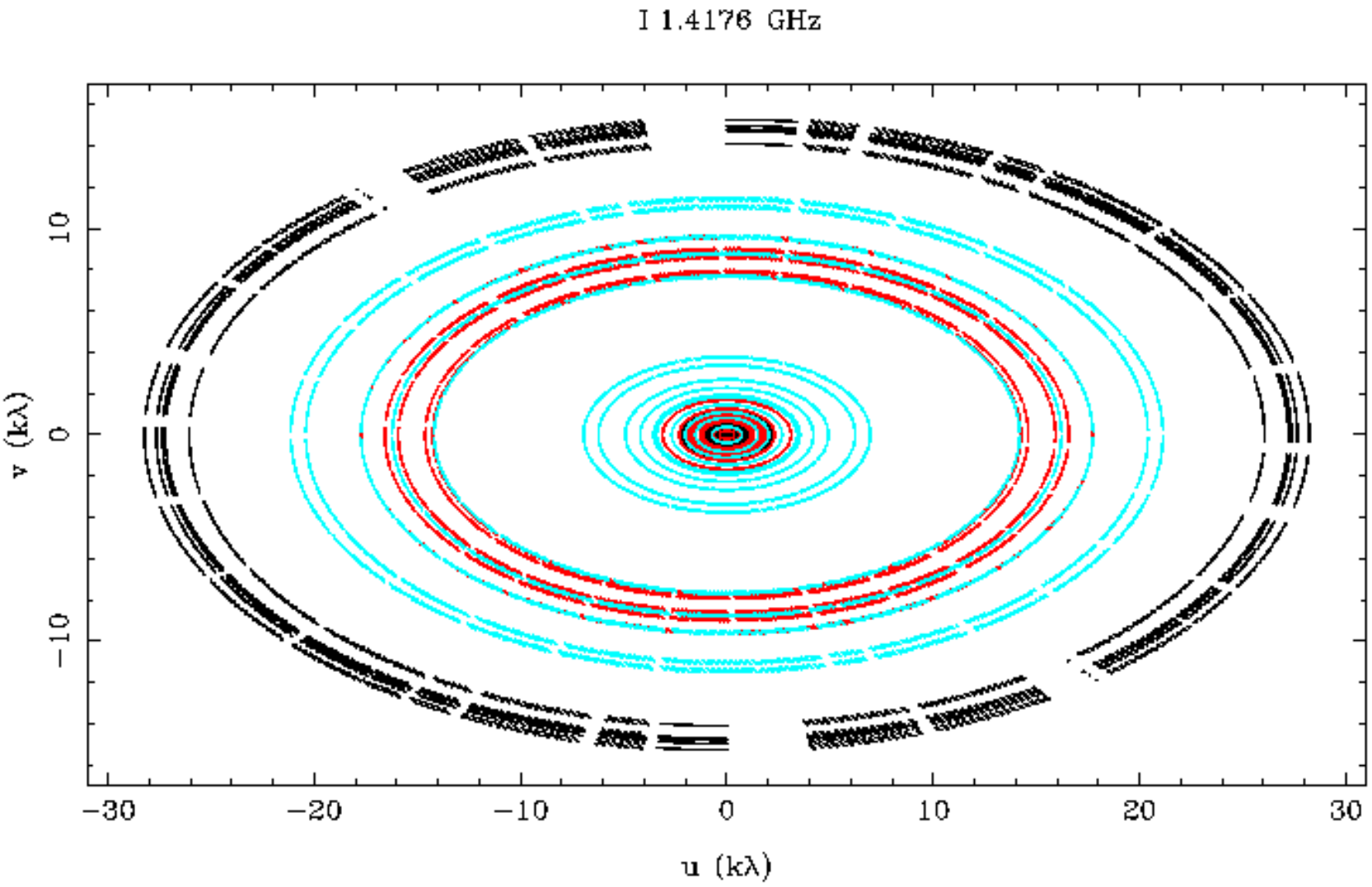
One HI channel at 1.417 GHz, ~12h obs in ATCA 375m array

uv-coverage: two configurations (30 baselines)



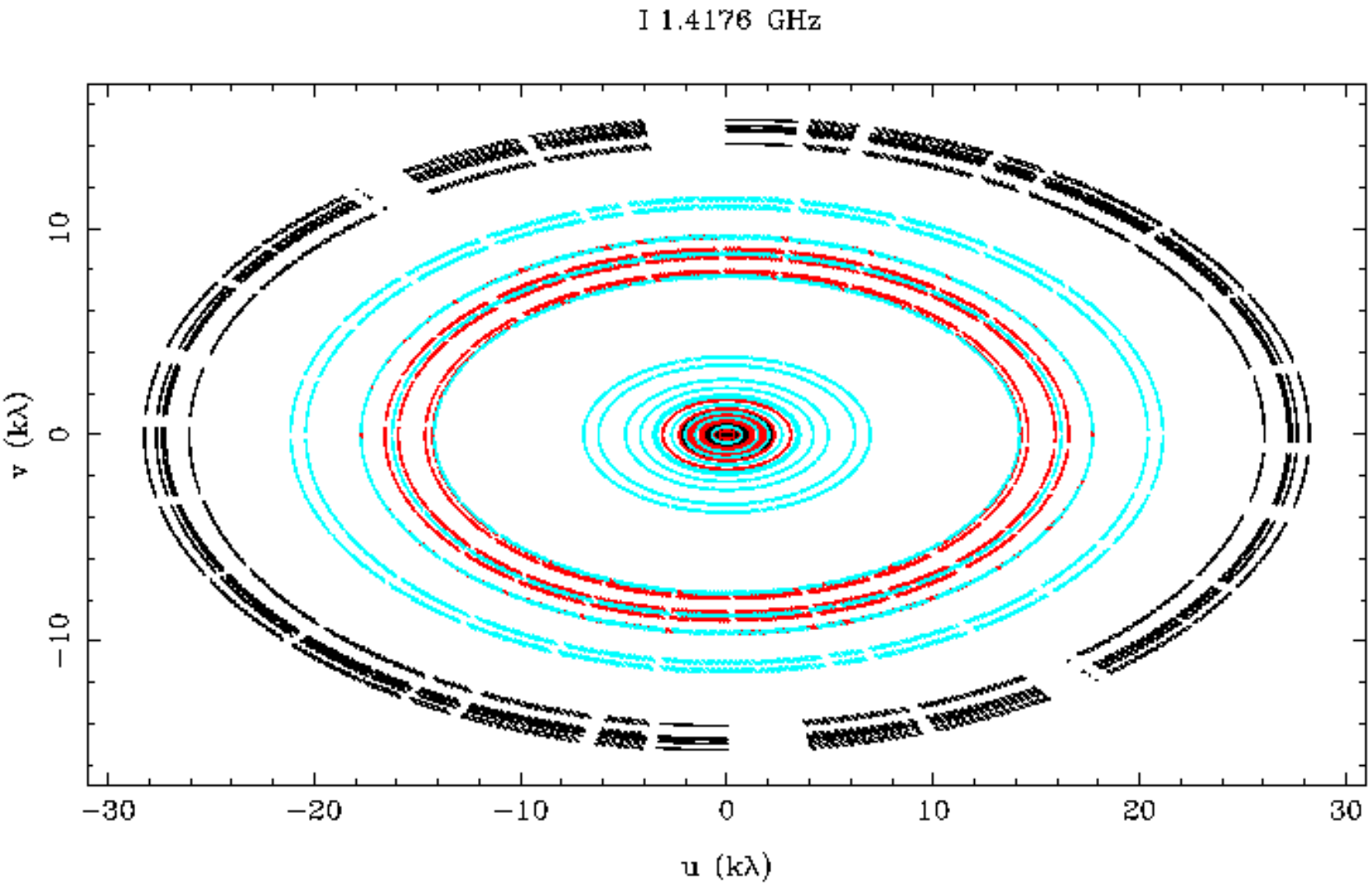
One HI channel at 1.417 GHz, ~24h obs in ATCA 375+750A array

uv-coverage: three configurations (45 baselines)



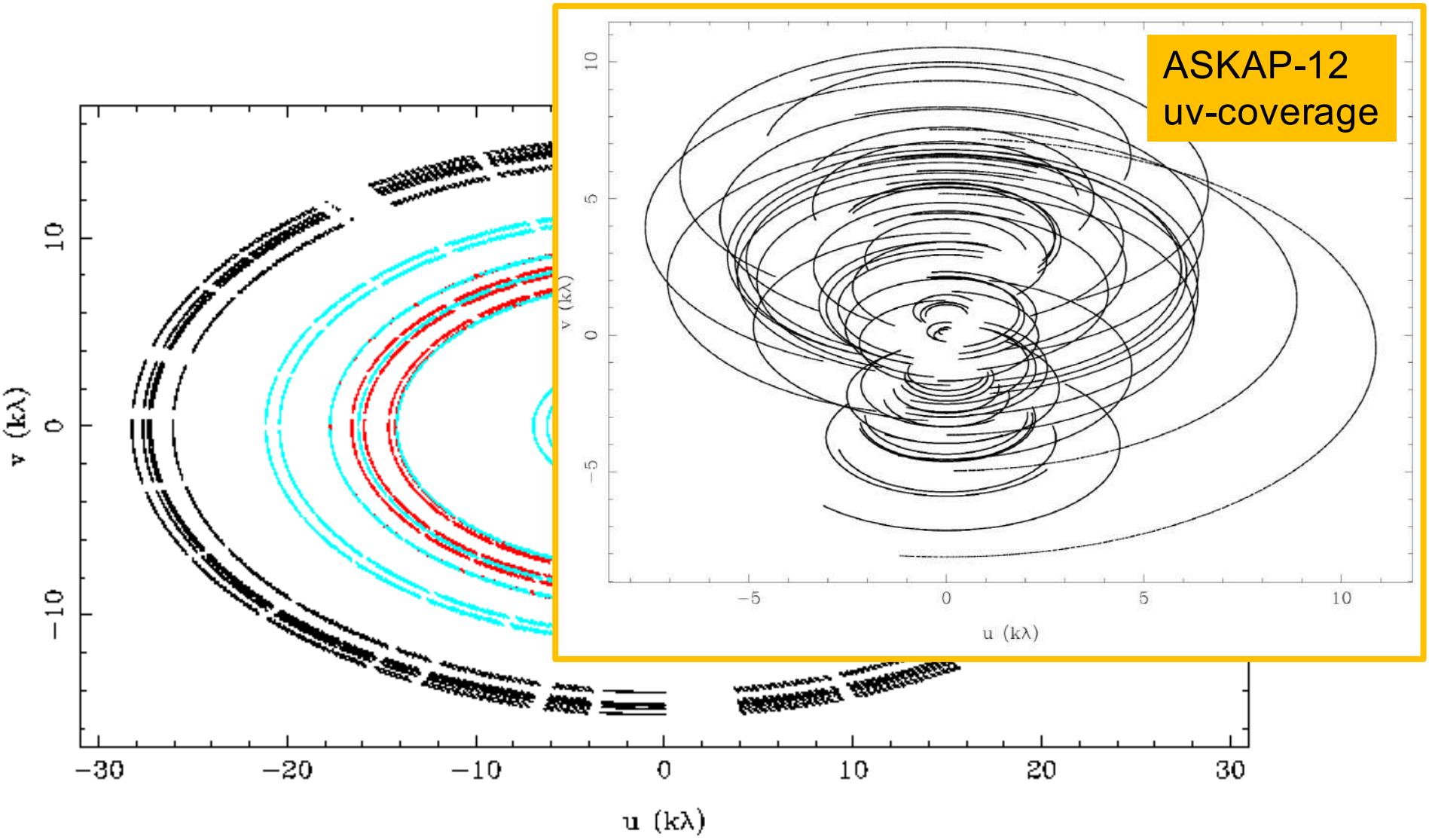
One HI channel at 1.417 GHz, ~36h obs in ATCA 375+750A+1.5A arrays

uv-coverage: three configurations (45 baselines)



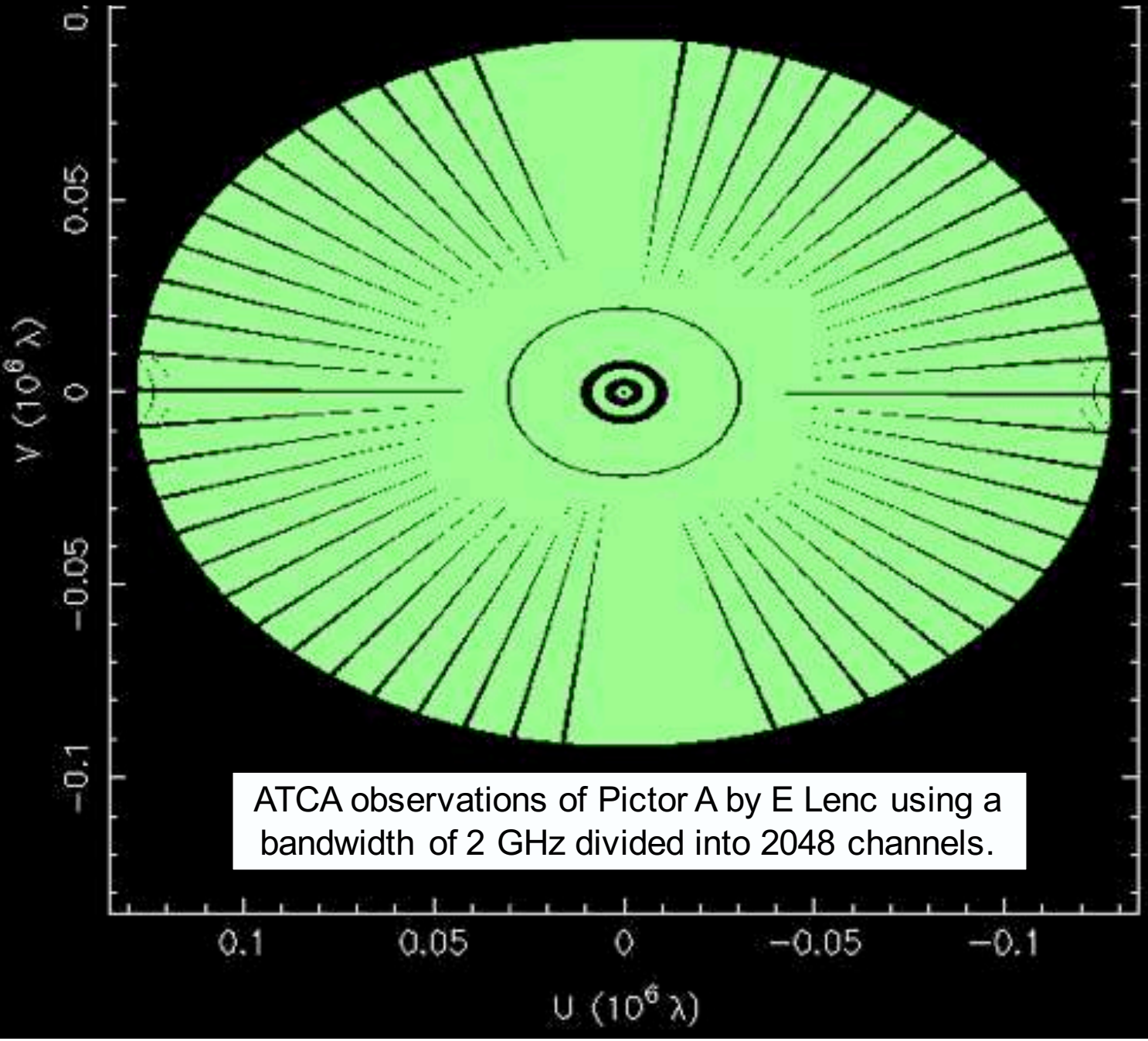
One HI channel at 1.417 GHz, ~36h obs in ATCA 375+750A+1.5A arrays

uv-coverage: three configurations (45 baselines)



One HI channel at 1.417 GHz, ~36h obs in ATCA 375+750A+1.5A arrays

uv-coverage: single configuration (15 baselines)

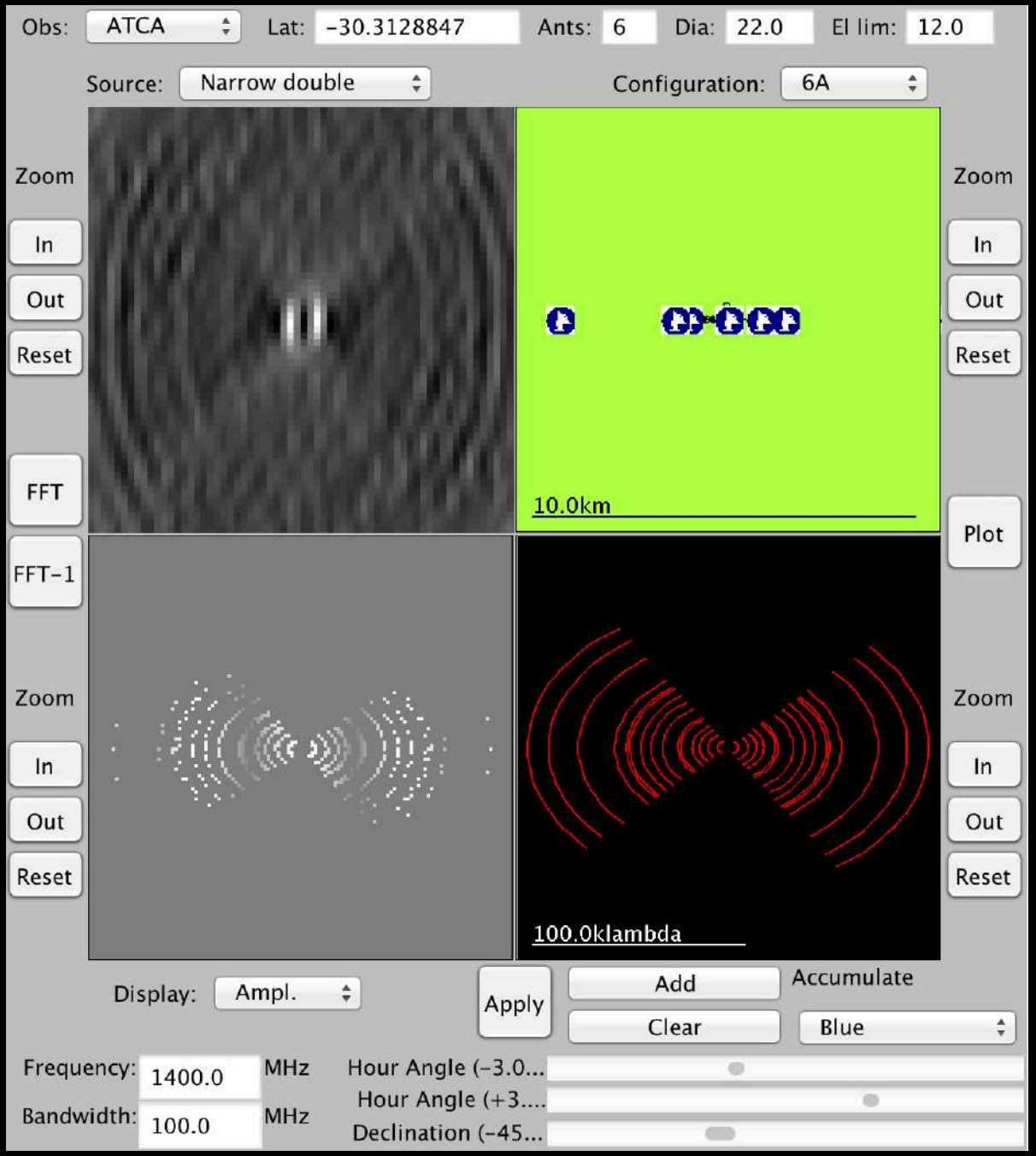


ATCA observations of Pictor A by E Lenc using a bandwidth of 2 GHz divided into 2048 channels.

NOTE:
multi
frequency
synthesis
for
continuum
mapping

V.R.I.

Virtual
Radio
Interferometer



http://www.narrabri.atnf.csiro.au/astronomy/vri.html

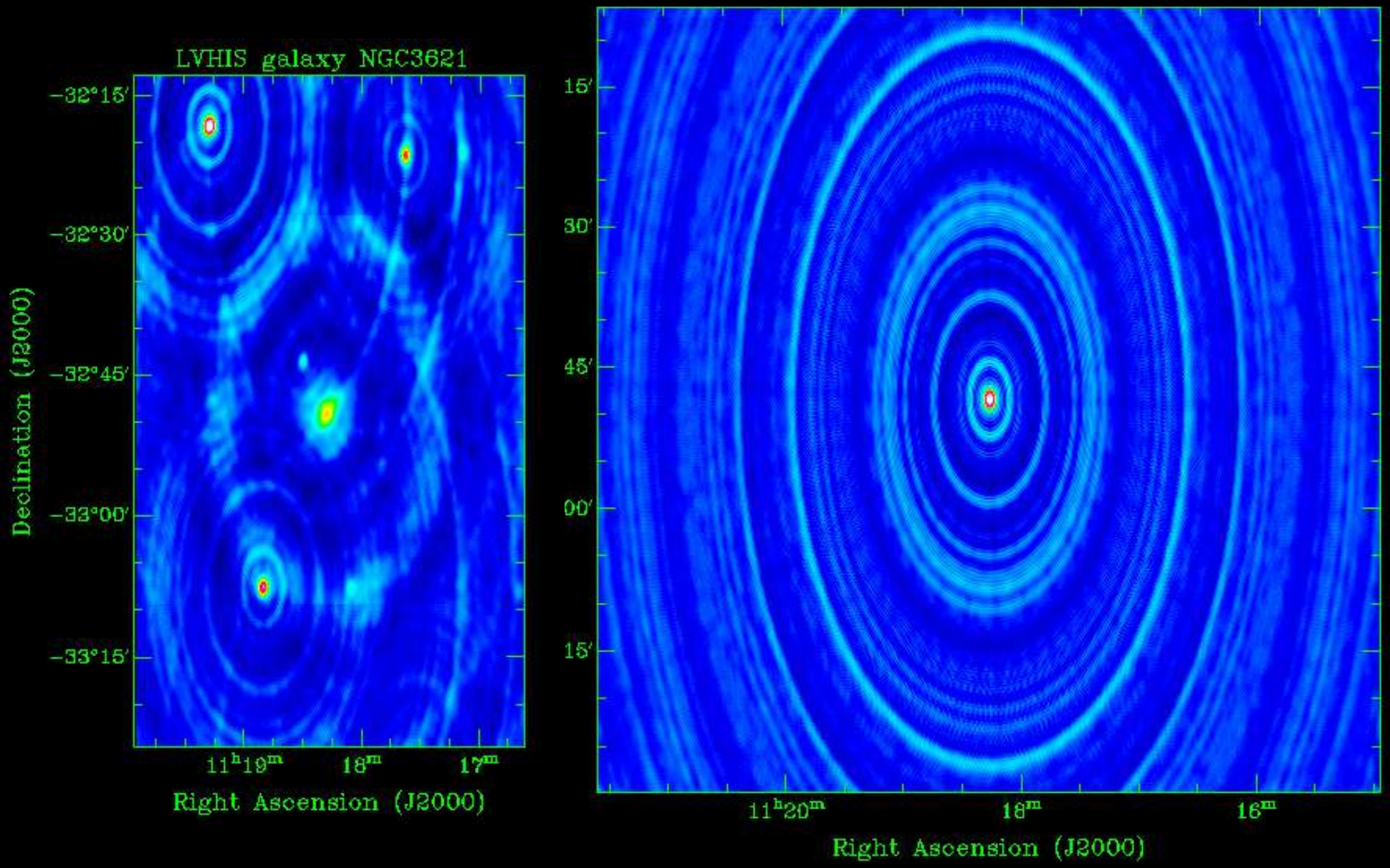
Imaging and cleaning

CSIRO Astronomy and Space Science
www.csiro.au

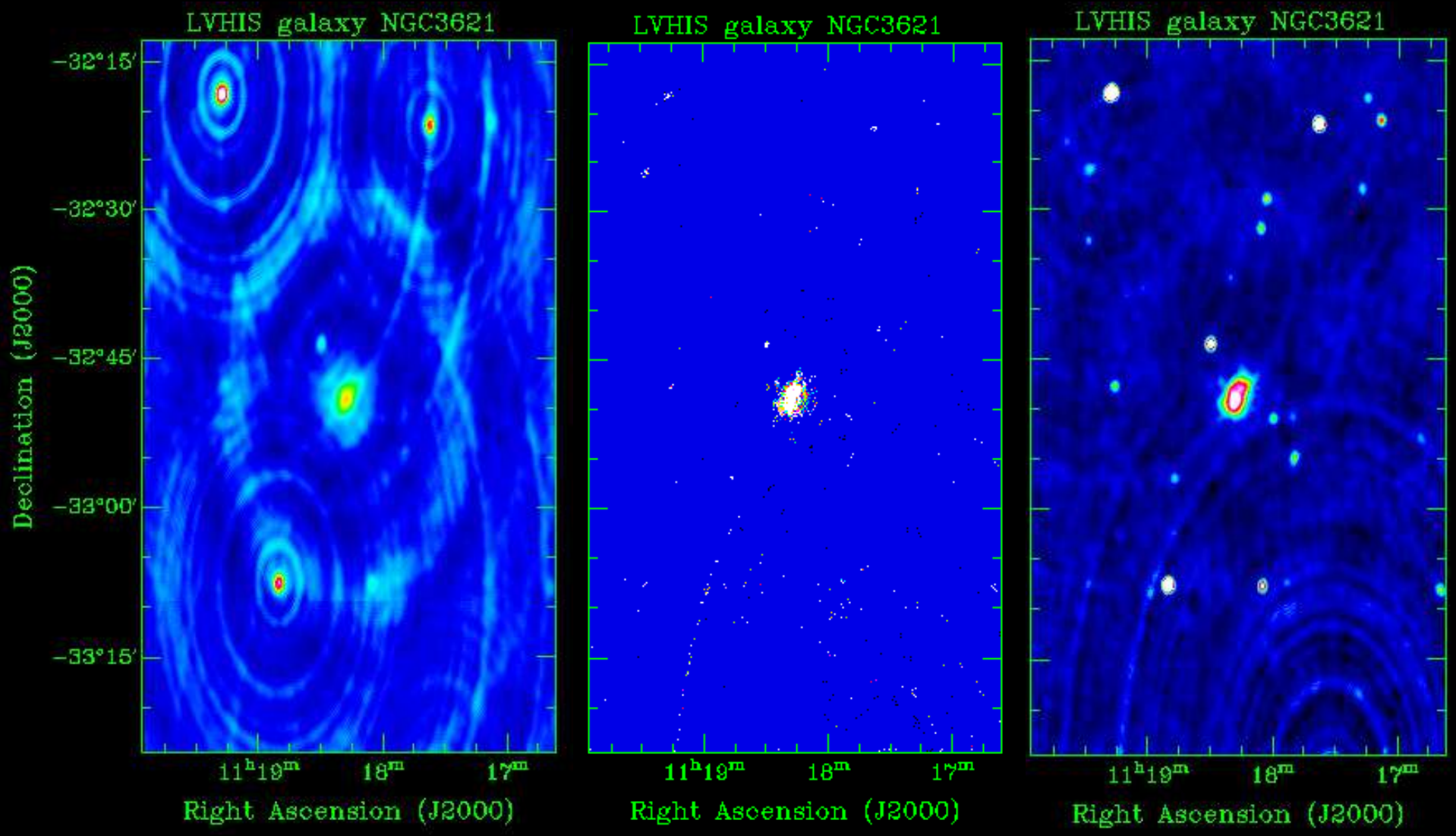
Example: ATCA 20-cm radio continuum image towards the galaxy NGC 3621

“dirty map”

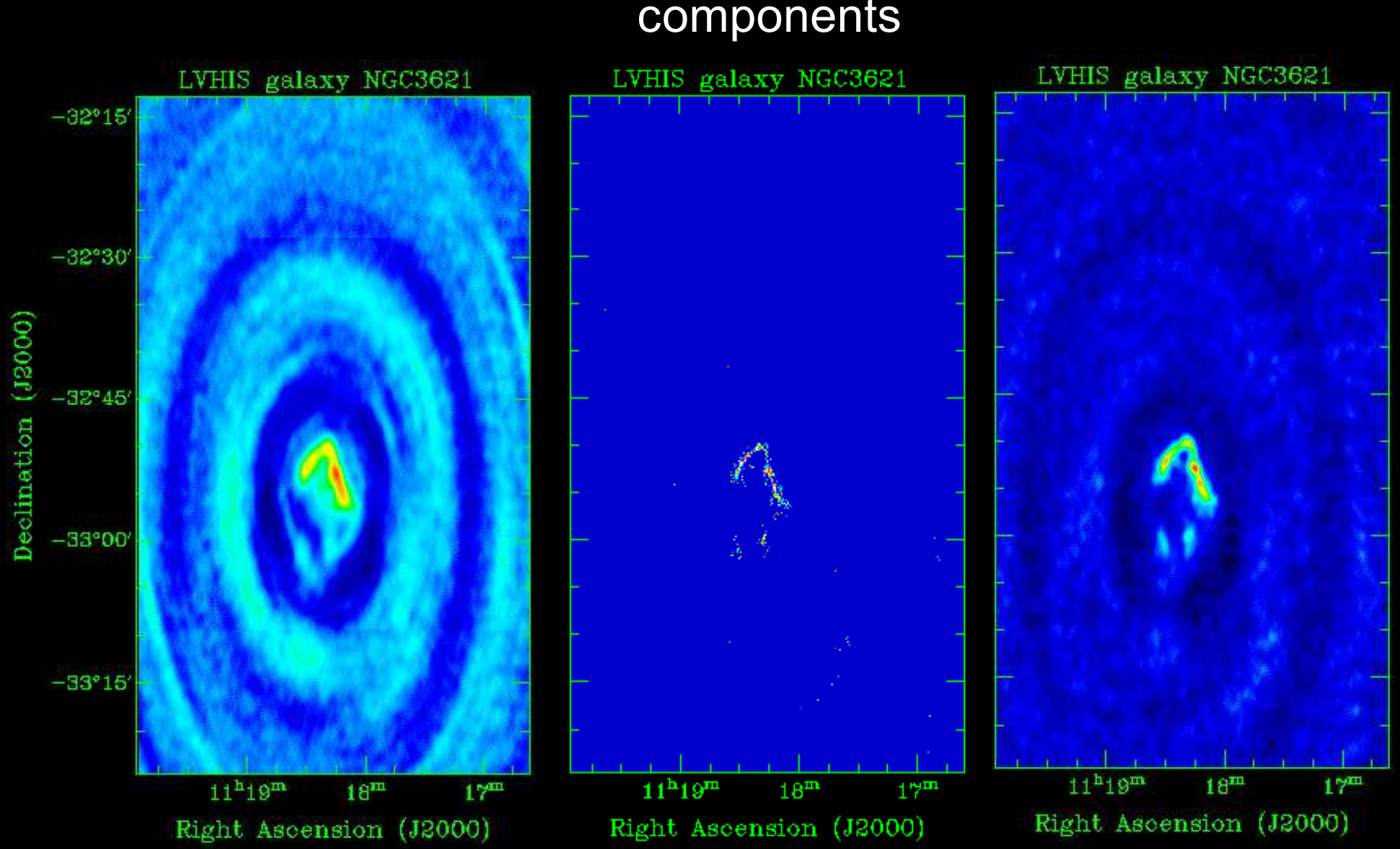
“dirty beam”



Example: ATCA 20-cm radio continuum image towards the galaxy NGC 3621

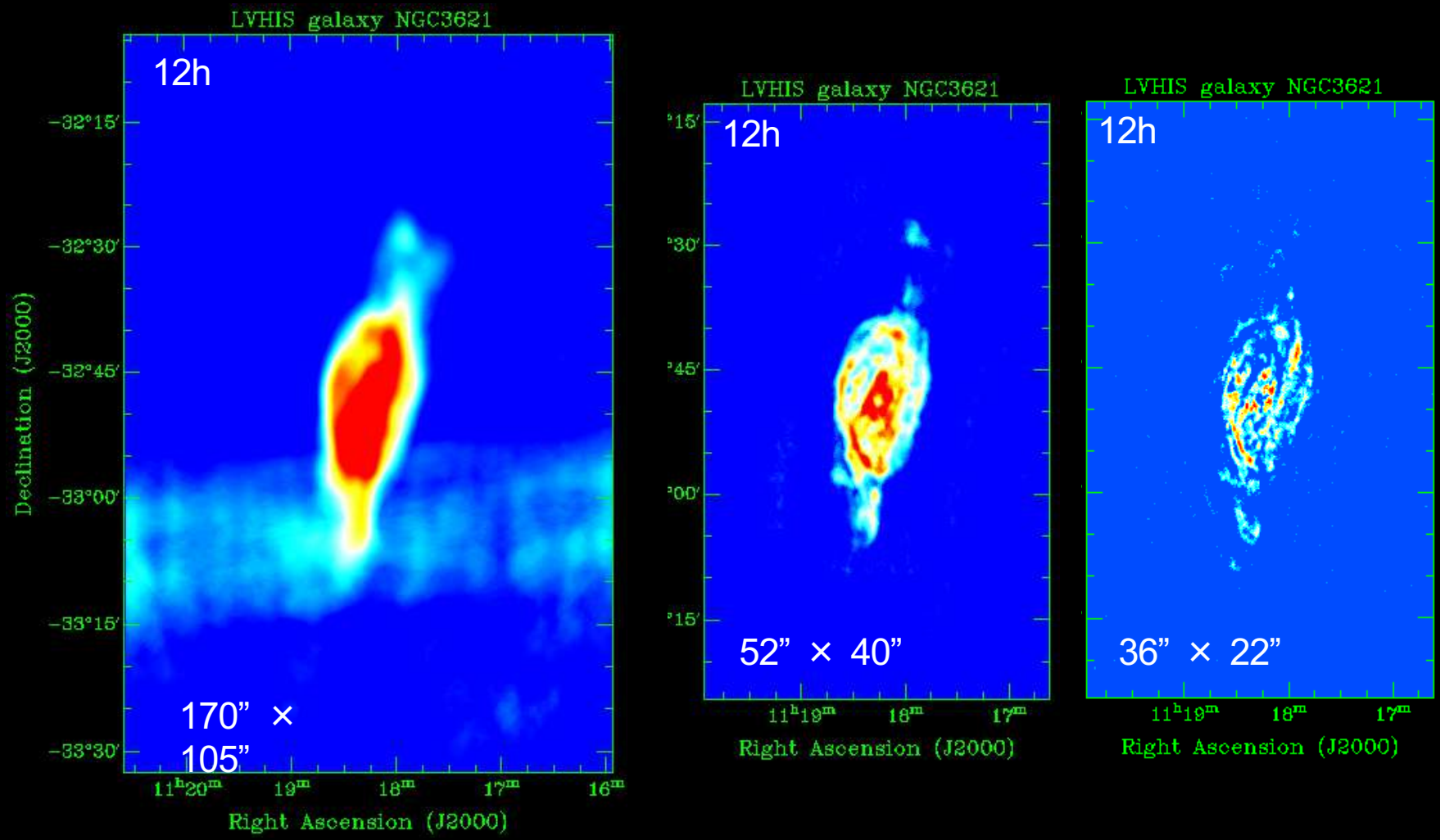


Example: ATCA HI channel map of the galaxy NGC 3621

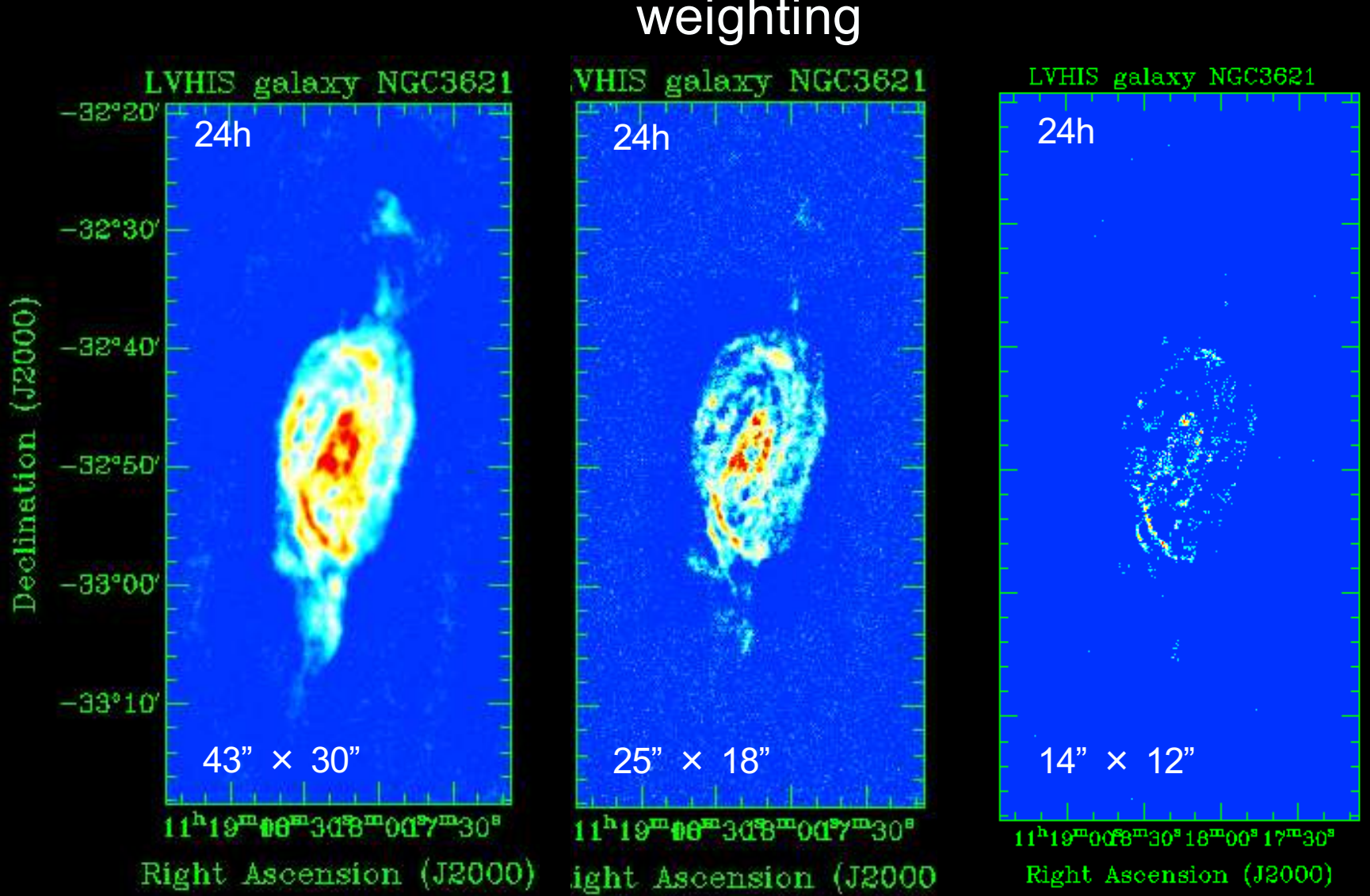


Example: ATCA HI moment maps of the galaxy NGC 3621 (Koribalski et al. 2017)

baselines < 400 m < 800 m < 1500 m

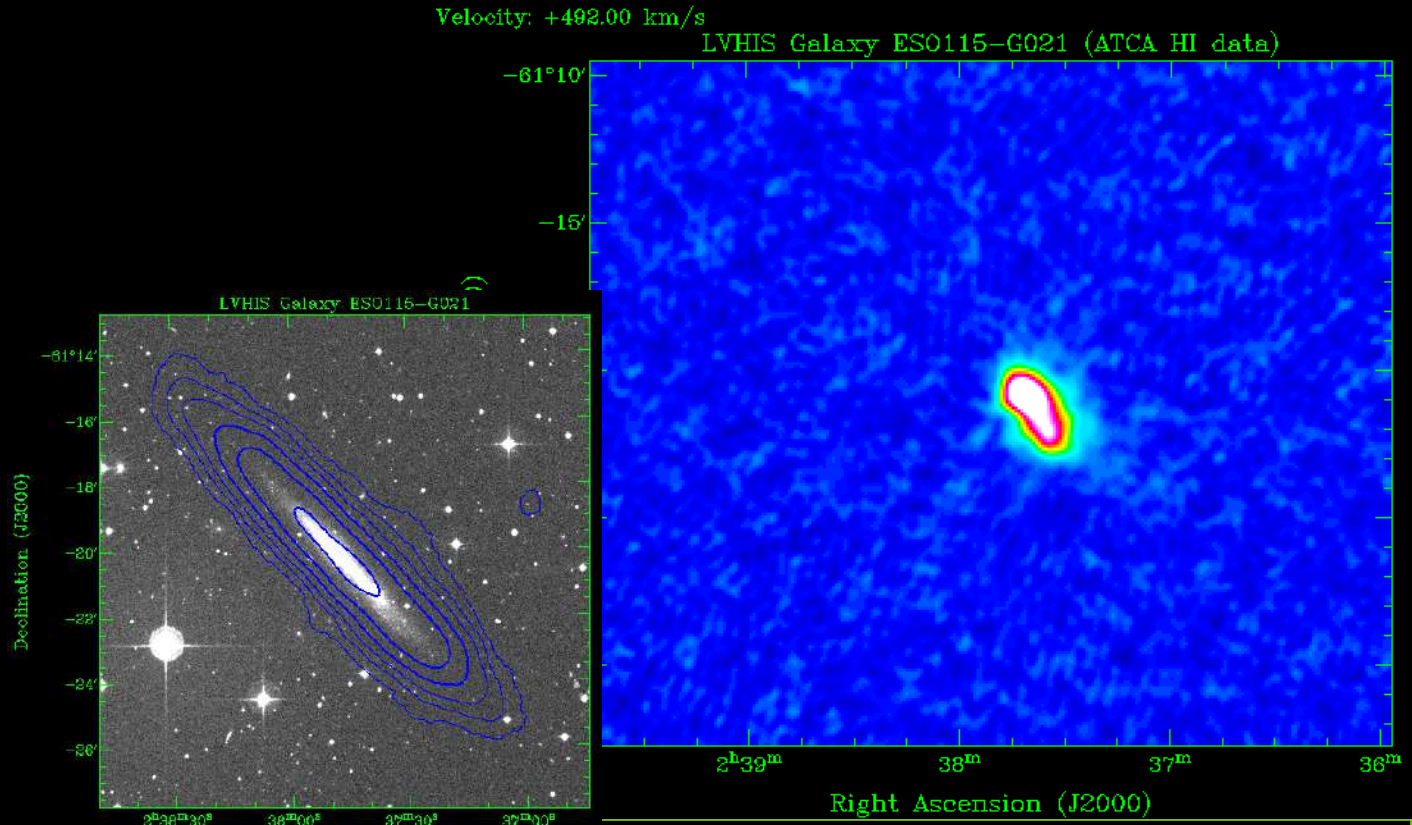


Example: ATCA HI moment maps of the galaxy NGC 3621 (Koribalski et al. 2017)



Channel maps and moment maps

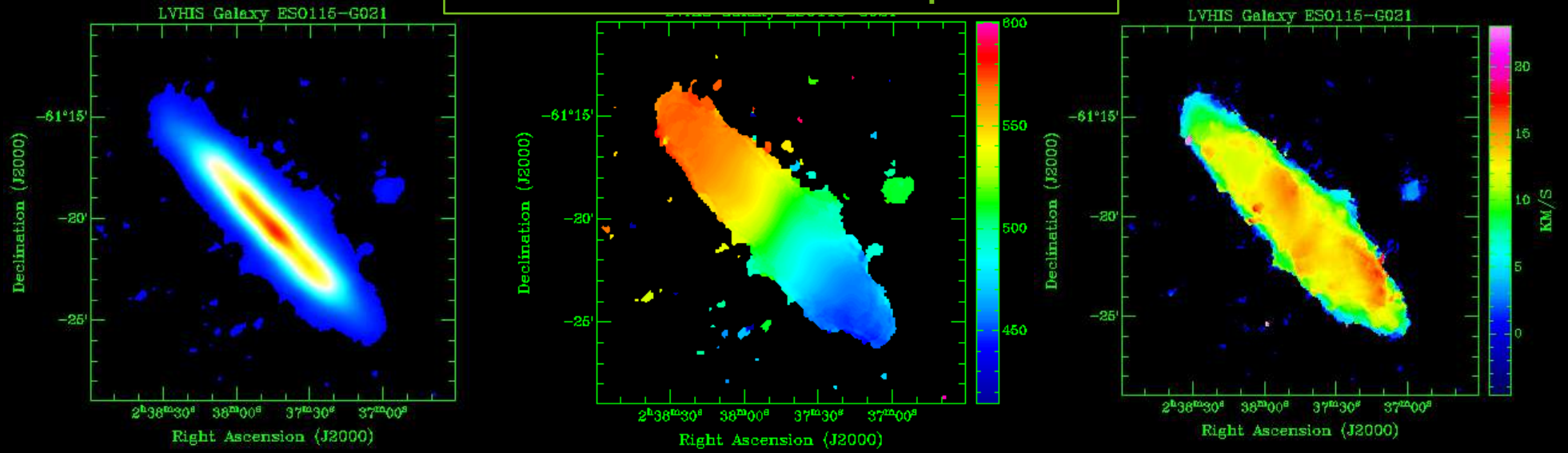
CSIRO Astronomy and Space Science
www.csiro.au

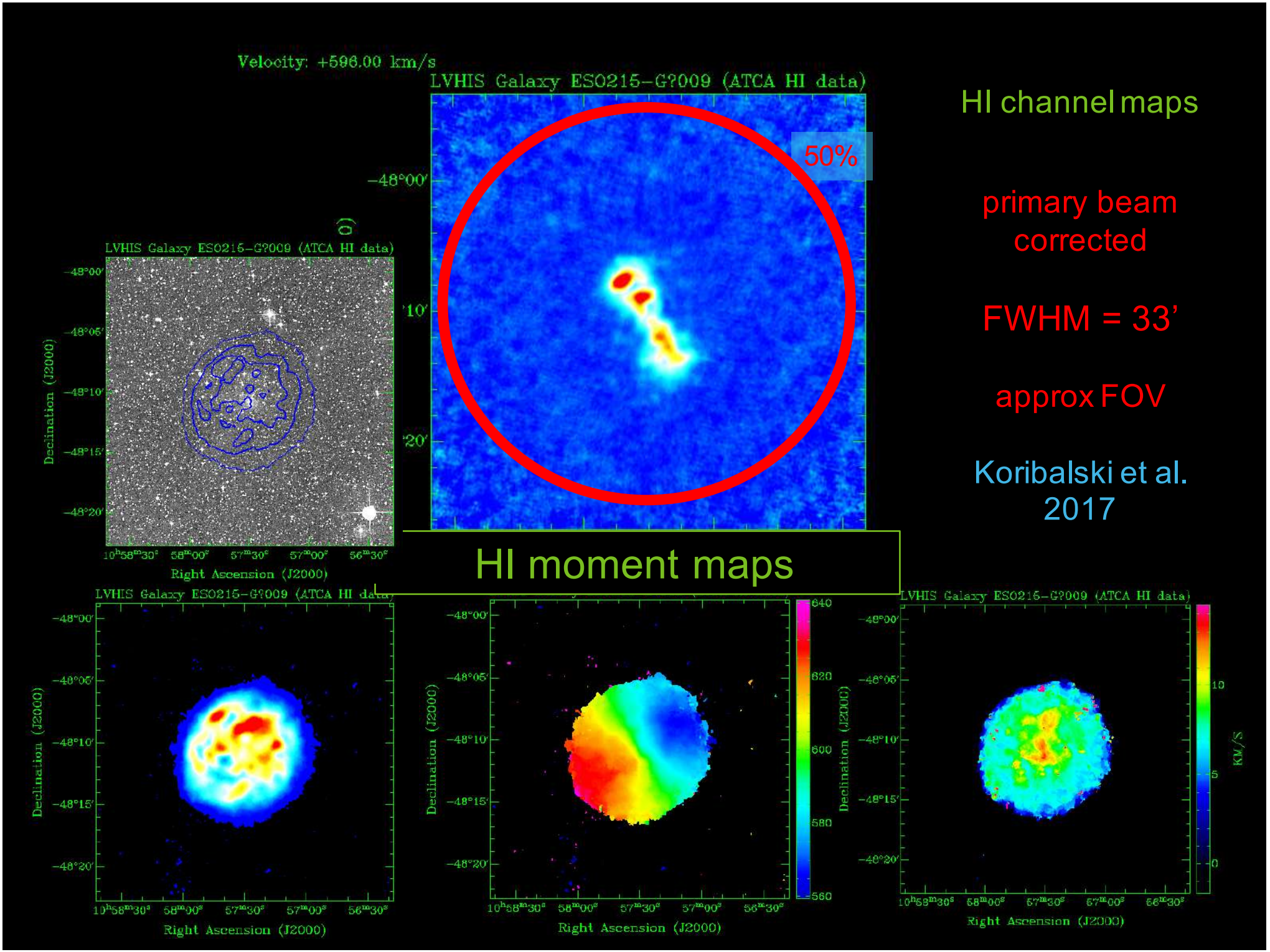


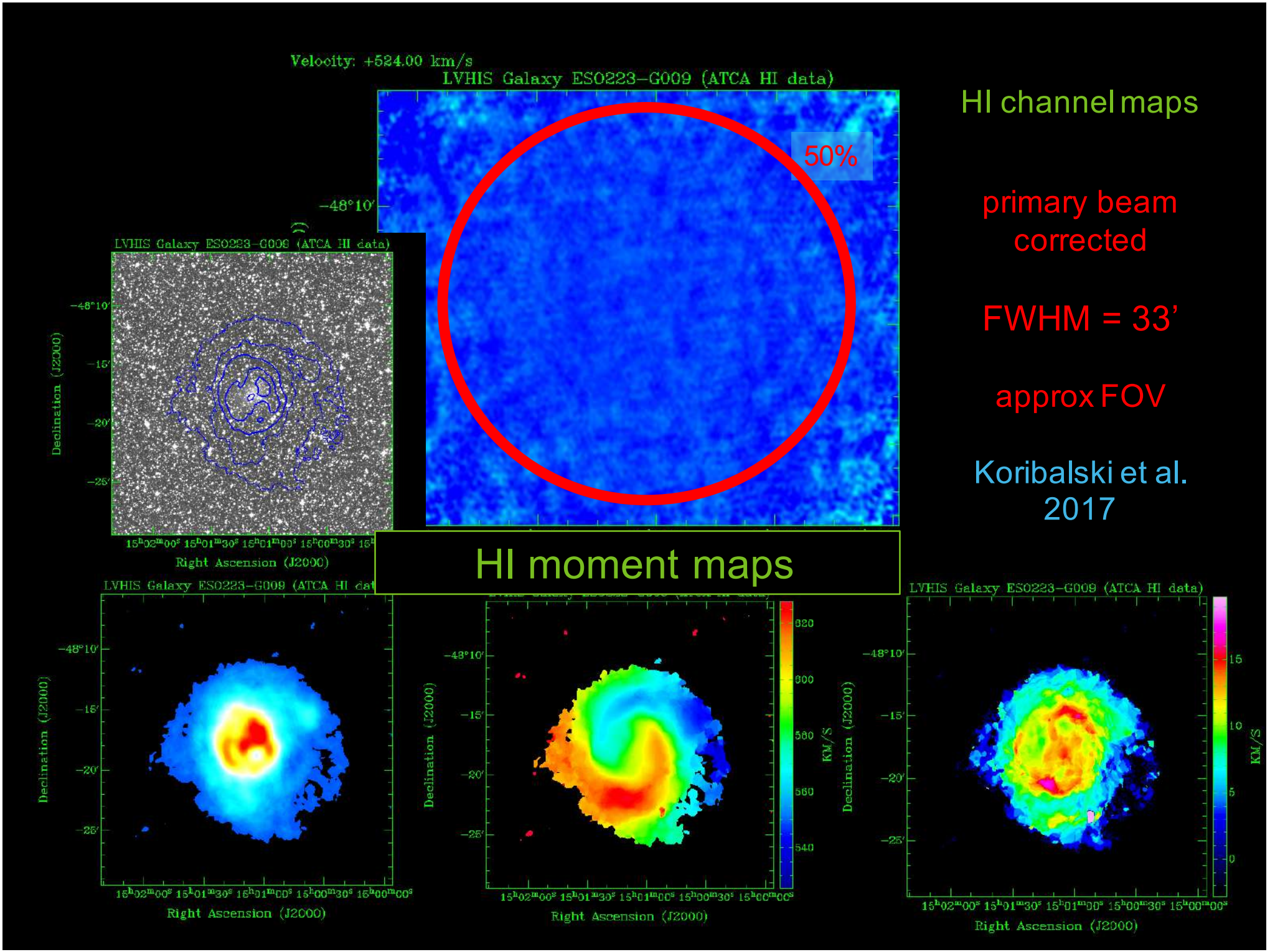
HI channel maps

Koribalski et al. 2017

HI moment maps




Velocity: +596.00 km/s
LVHIS Galaxy ESO215-G?009 (ATCA HI data)
50%
HI channel maps
primary beam corrected
FWHM = 33'
approx FOV
Koribalski et al. 2017
HI moment maps
Declination (J2000)
Right Ascension (J2000)
KM/S


Velocity: +524.00 km/s
LVHIS Galaxy ESO223-G009 (ATCA HI data)
50%
HI channel maps
primary beam corrected
FWHM = 33'
approx FOV
Koribalski et al. 2017
HI moment maps
Declination (J2000)
Right Ascension (J2000)
KM/S

SoFiA - our new **So**urce **Fi**nding **A**pplication

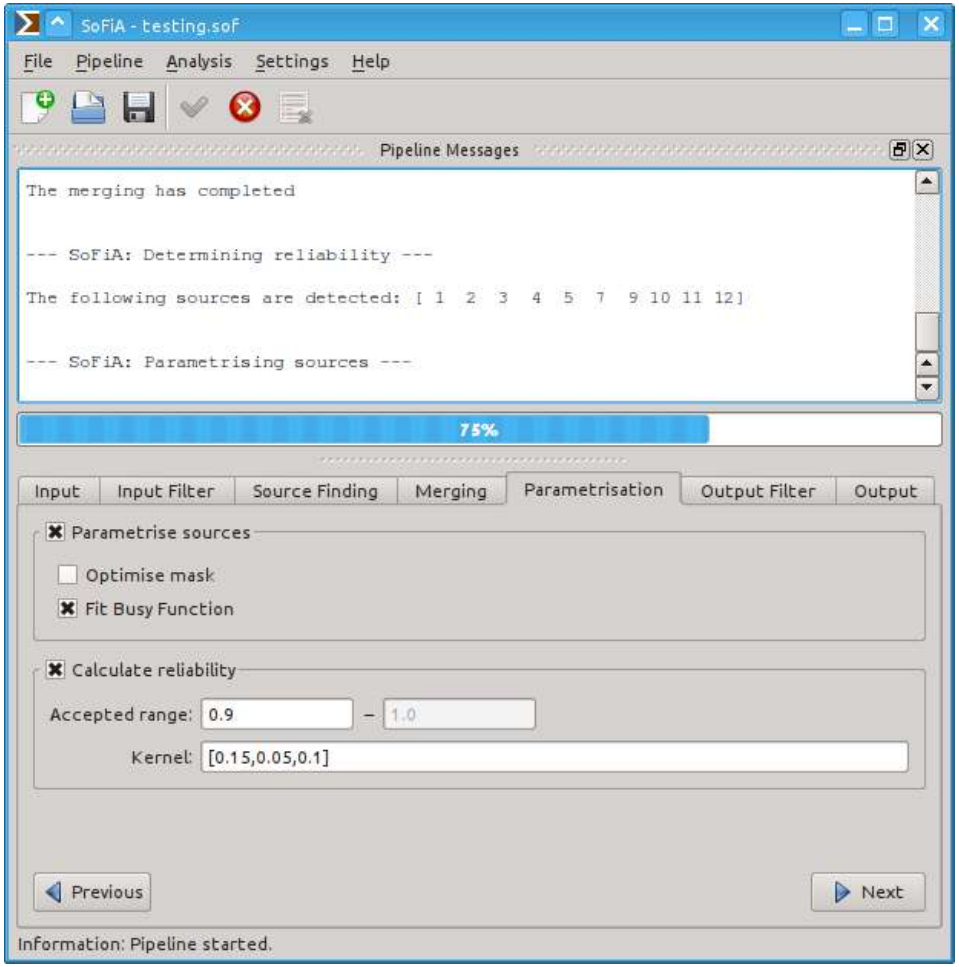
SoFiA

Source Finding Application

developed by members of the **WALLABY source finding working group (TWG4)**

Serra, Westmeier, Giese, Jurek, Flöer, Popping, Winkel, van der Hulst, Meyer, Koribalski 2015, MNRAS 448, 1922

* SoFiA Handbook (on-line)

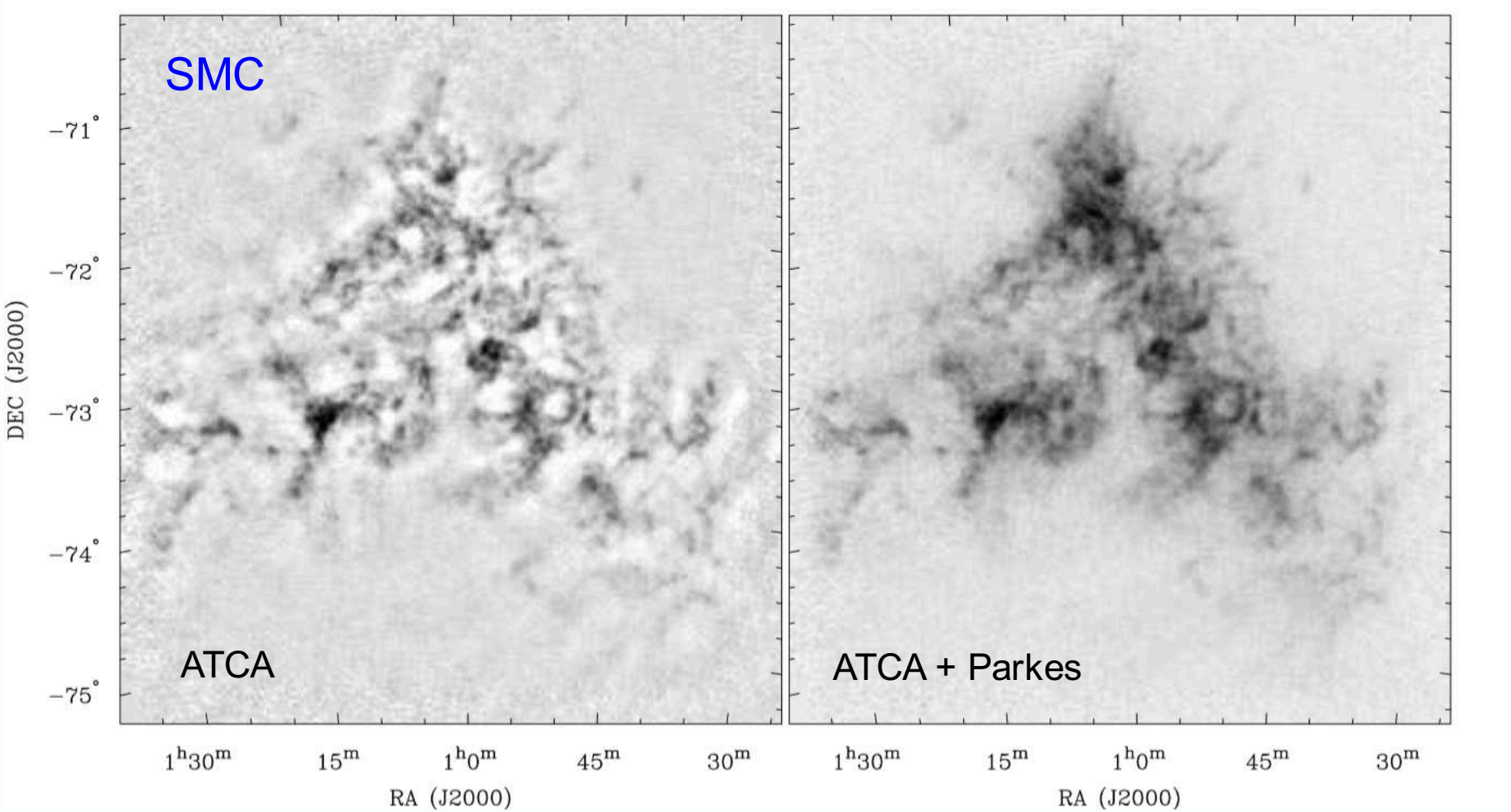


*http://www.atnf.csiro.au/people/Tobias.Westmeier/**tools_software_sofia.php***

CSIRO

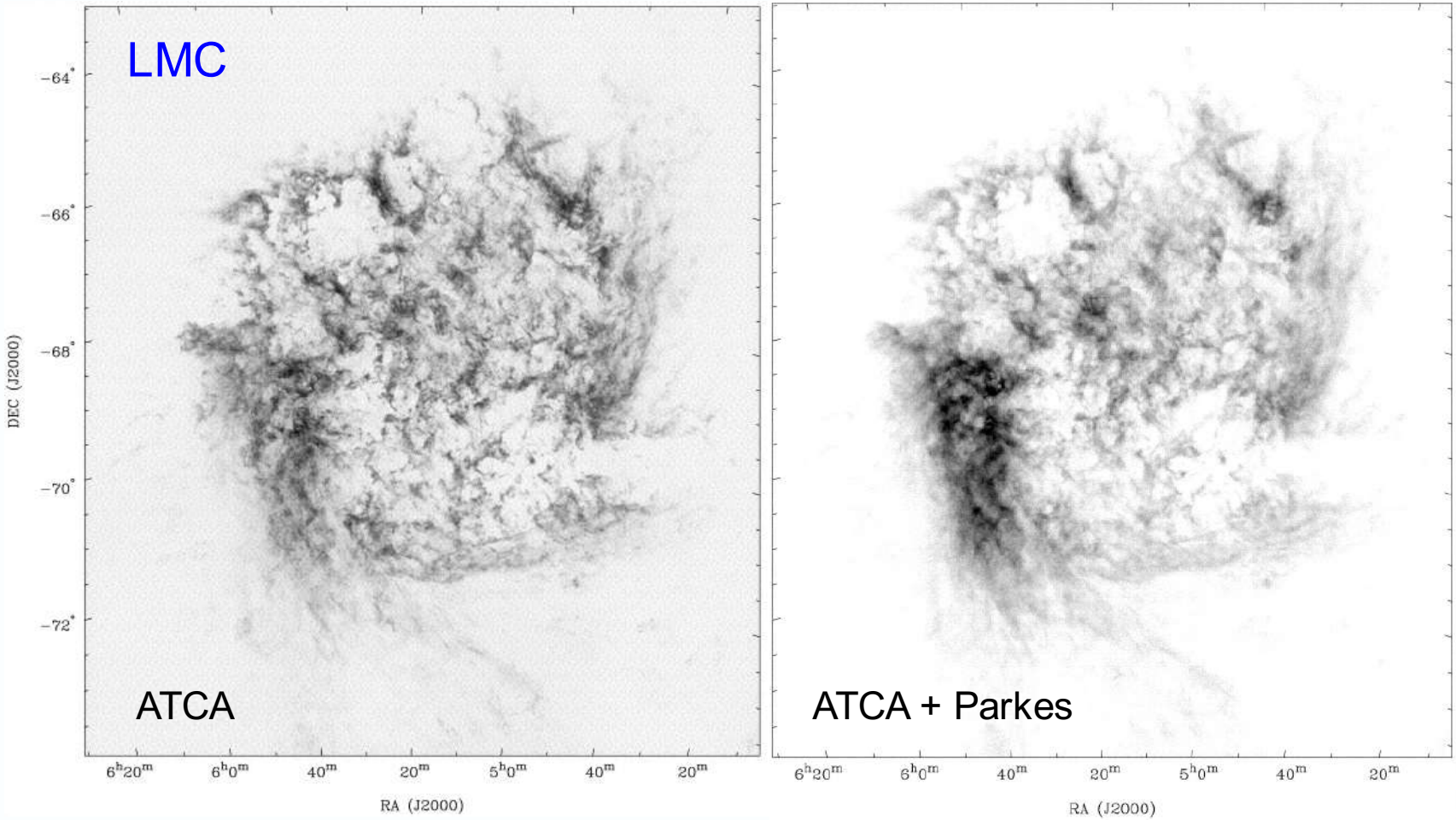
Single dish + interferometer data

Combining single dish and interferometer data



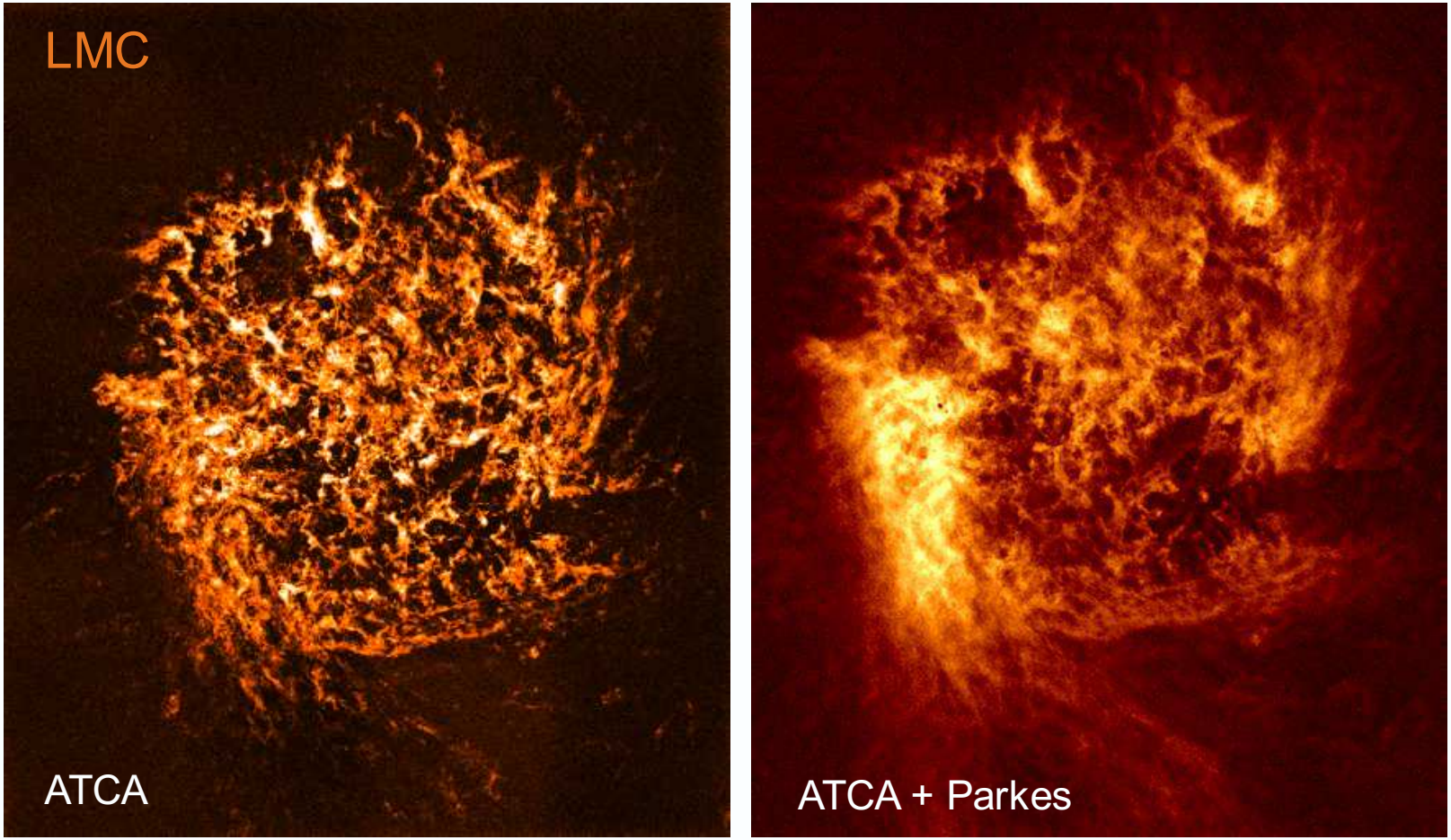
HI mosaic (144 pointings) of the Small Magellanic Cloud by Stanimirovic et al. (1999).

Combining single dish and interferometer data



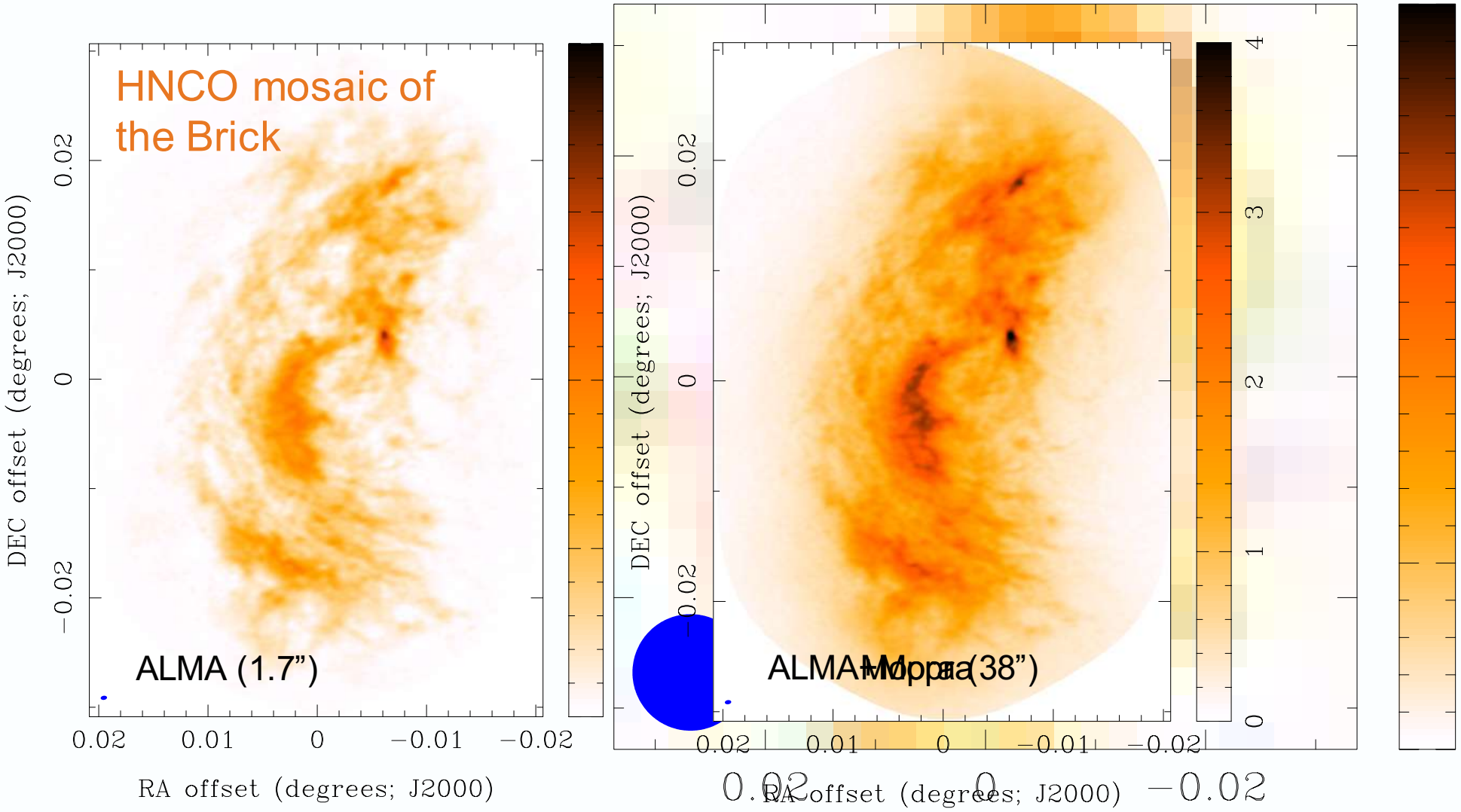
HI mosaic (1344 pointings) of the Large Magellanic Cloud by Kim et al. (1998, 2003).

Combining single dish and interferometer data

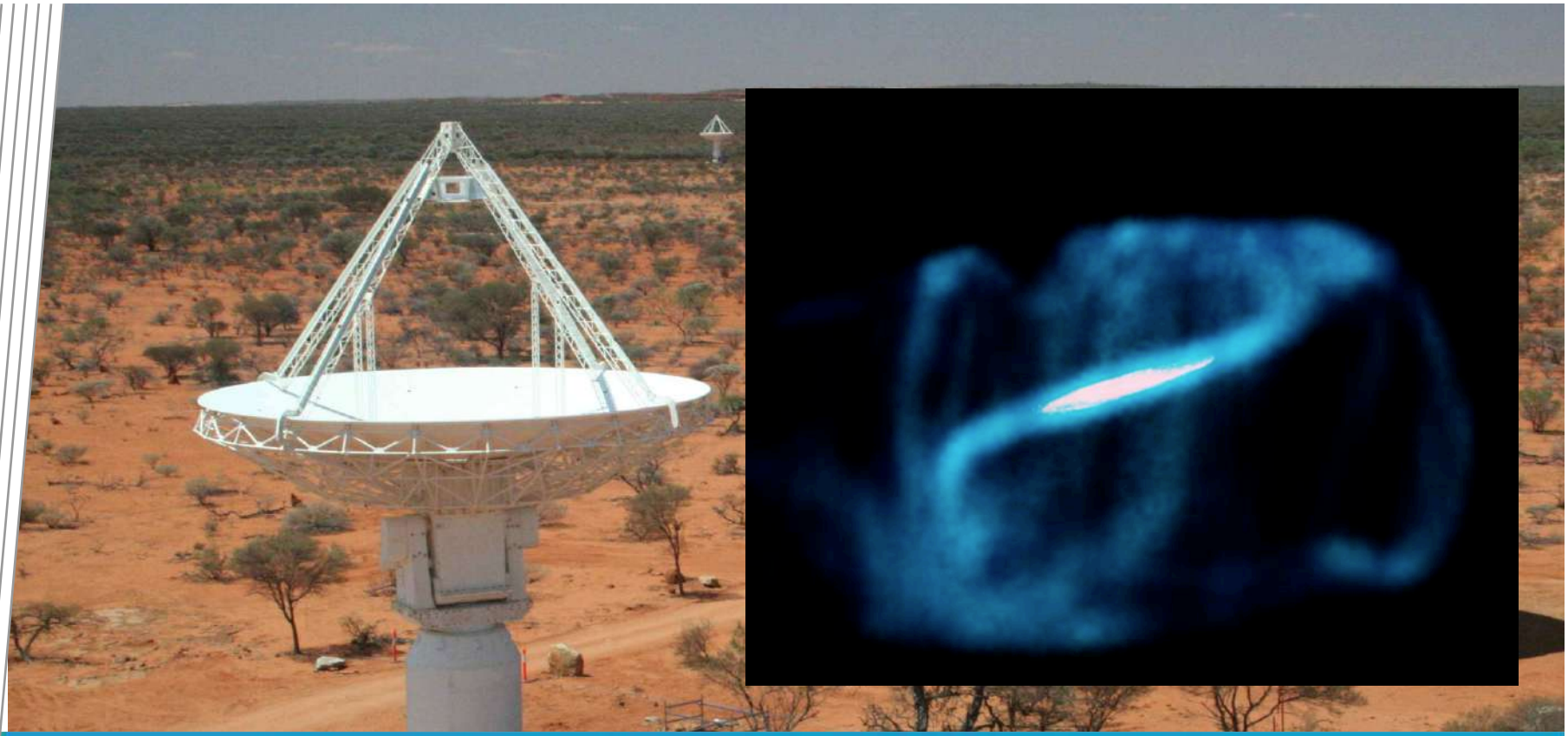


HI mosaic (1344 pointings) of the Large Magellanic Cloud by Kim et al. (1998, 2003).

Combining ALMA and Mopra mm-data



Rathborne et al. (2015) – ALMA 13-point mosaic (5h, 25 antennas); field 3' × 1.5'.



Overview of 3D Radio Techniques

Thank you

Dr. Bärbel Koribalski
CSIRO Astronomy and Space Science
Australia Telescope National Facility
2017 Radio School @ ATCA Narrabri

CSIRO

www.csiro.au