Filippo Maccagni, Paolo Serra, Mpati Ramatsoku, Dane Kleiner,
Daniel Molnar @ OAC (INAF)
MeerKATHI group & MeerKAT commissioning team @ SKA-SA

First Results from MeerKAT Commissioning Observations

Osservatorio Astronomico di Cagliari

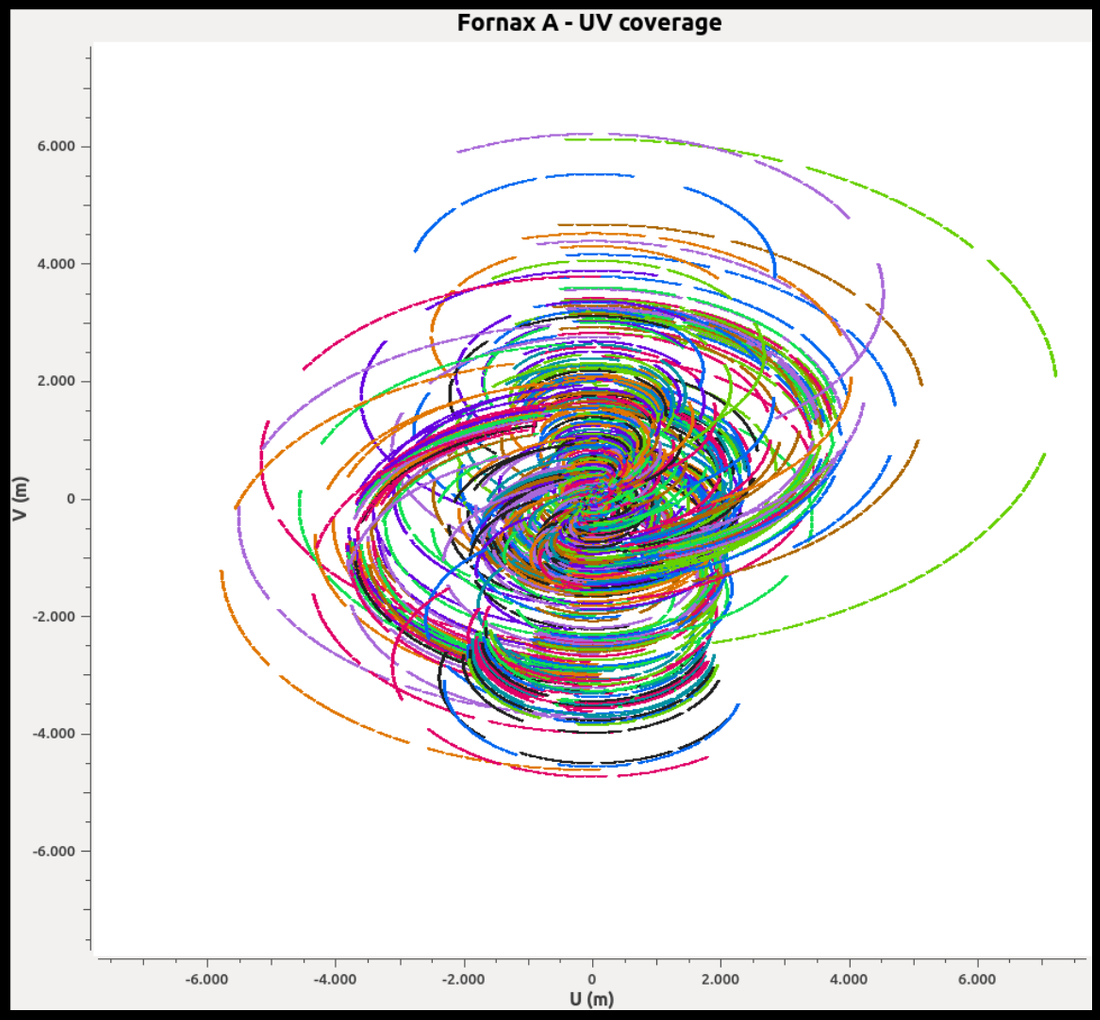
This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement no. 679627).

The MeerKAT telescope

- Antennas & Baselines:
  - 64 antennas, 13.5-m diameter
  - Longest baseline 8000 m. + Dense core of baselines < 50 m.
  - T_{sys}/efficiency = 22 K at 1.4 GHz
- Spectral information:
  - Bandwidth: 0.9–1.67 GHz (HI 0<z<0.58) + UHF + S-band
  - Wideband mode: ~ 20kHz ~ 5 km/s (32K channels)
  - Zoom Mode: 0.1 km/s

Credit: SKA-SA

MeerKAT: the SKA precursor



- MeerKAT has small antennas
  - Large F.O.V.
    - Primary beam sensitivity drops only beyond 1 degree.
    - Great to image Fornax A and HI in nearby galaxies
    - Issues with point source calibrators: other bright sources in the field

- MeerKAT has ~ 2000 baselines
  - Extreme UV-coverage
    - Simultaneous A,B,C,D and E VLA configurations.
    - High sensitivity uniform throughout all angular scales
  - S/N ~ 10^4 → SKA regime.

Image Credit: Disney

The MeerKAT Fornax Survey

- Observe the Fornax Cluster and the group of Fornax A with MeerKAT
  - 900 hours to observe 12 deg^2

- Science goals (see Paolo Serra's Talk)
  - Study the phenomena of gas removal and accretion in galaxies.
    - Sensitivity in neutral hydrogen N(HI) ~10^{19} cm^{-2} at 1 kpc resolution
  - Identify and investigate the neutral hydrogen low column ICM.
    - Sensitivity in neutral hydrogen N(HI)~ 10^{18} cm^{-2} at 10 kpc
  - Determine the HI mass function down to M(HI) ~ 5x10^5 M_{sun}

Credit: ESO, Acknowledgement: Grado & Limatola

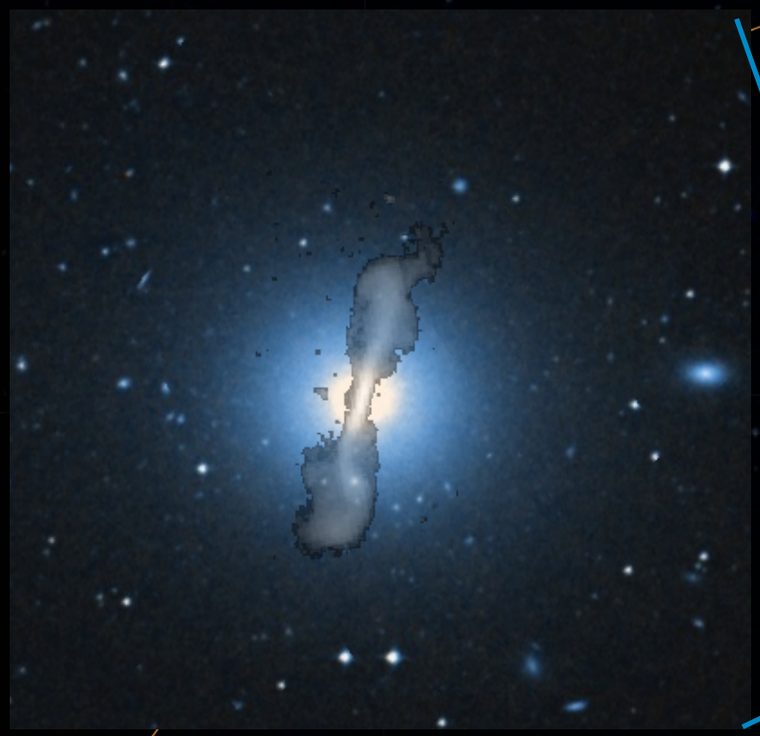
The Meerkat Fornax Survey

PI: P. Serra (OAC - Italy)

E. de Blok (ASTRON, Kapteyn, UCT), G. Bryan (Columbia), R.-J. Dettmar (Bochum), B. Frank (SARAO), **F. Govoni (OAC),** G. Józsa (SARAO, Rhodes, Bonn), **D. Kleiner (OAC),** R. Kraan-Korteweg (UCT), I. Loubser (NWU), **F. Maccagni (OAC), D. Molnar (OAC)**, M. Murgia (OAC), T. Oosterloo (ASTRON, Kapteyn), R. Peletier (Kapteyn), R. Pizzo (ASTRON), **M. Ramatsoku (OAC)**, M. Smith (Cardiff), S. Trager (Kapteyn), van Gorkom (Columbia), M. Verheijen (Kapteyn)

*People present at this workshop

Observations in the Fornax Cluster



NGC 1399 & Fornax A

Chanels: 4096 - SKARAB4K

Channel width: 209 kHz - 45 km/s

Frequency range: 1400 - 1420 GHz

Integration time: ~ 8 hours

Fornax A

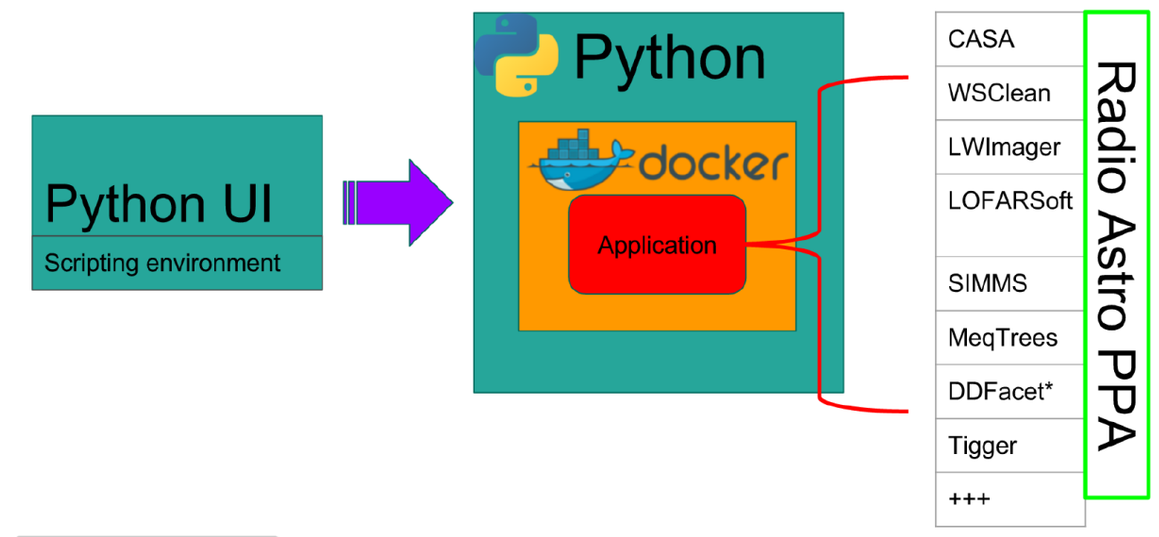
Data reduction — MeerKATHI pipeline

Image Credit: M. Ramatsoku

MeerKATHI

- **MeerKATHI**: end-to-end data reduction pipeline for interferometric observations.
  - Source accessible and easy to change
  - Make use of any best available software, thanks to Stimela [Makhatini et al. 2016]
  - Portable
  - Easy to Install
  - Scalable (working for large data sets in distributed environment)
  - Will be public

```
https://github.com/SpheMakh/Stimela
https://hub.docker.com/u/stimela
https://pypi.org/project/stimela
```

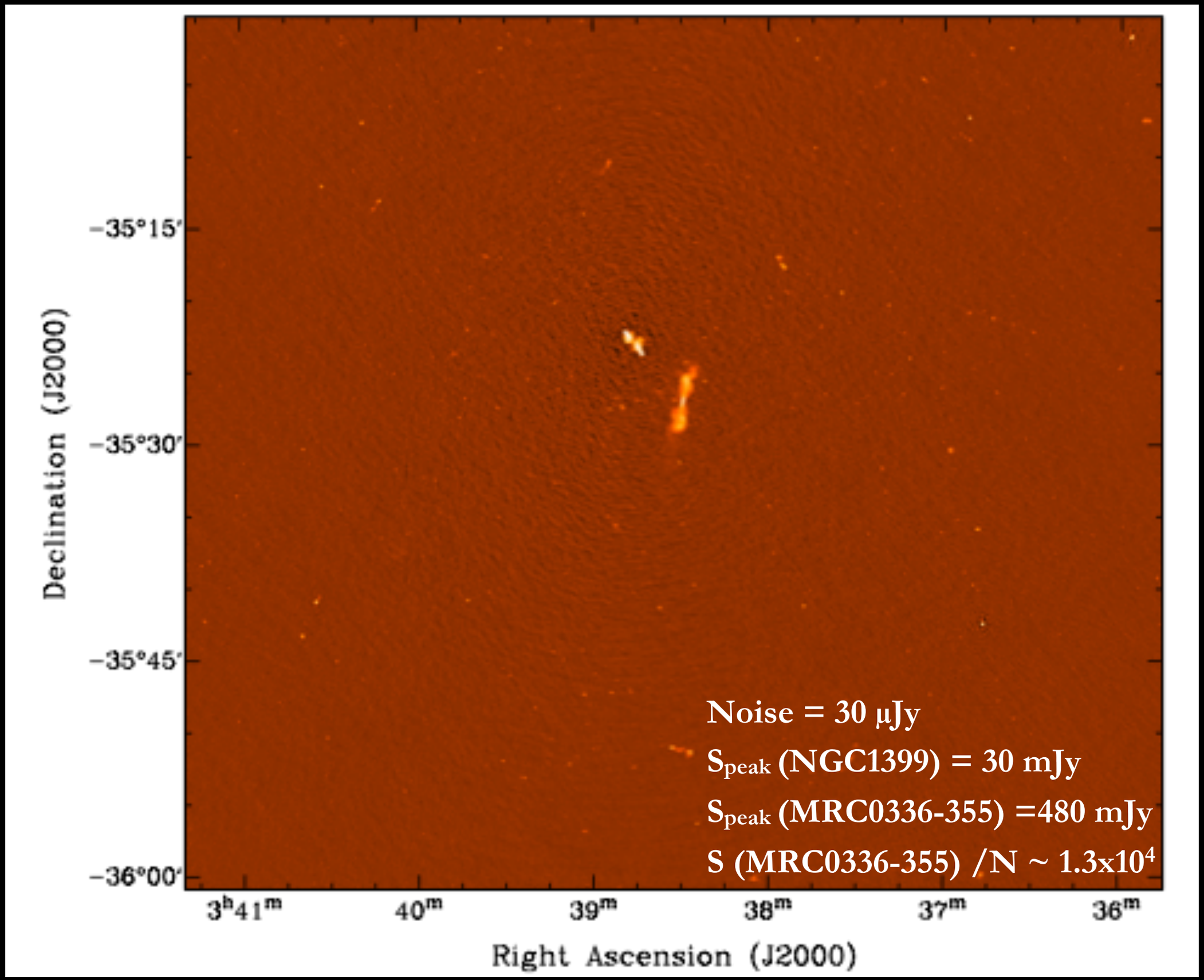


MeerKATHI group:

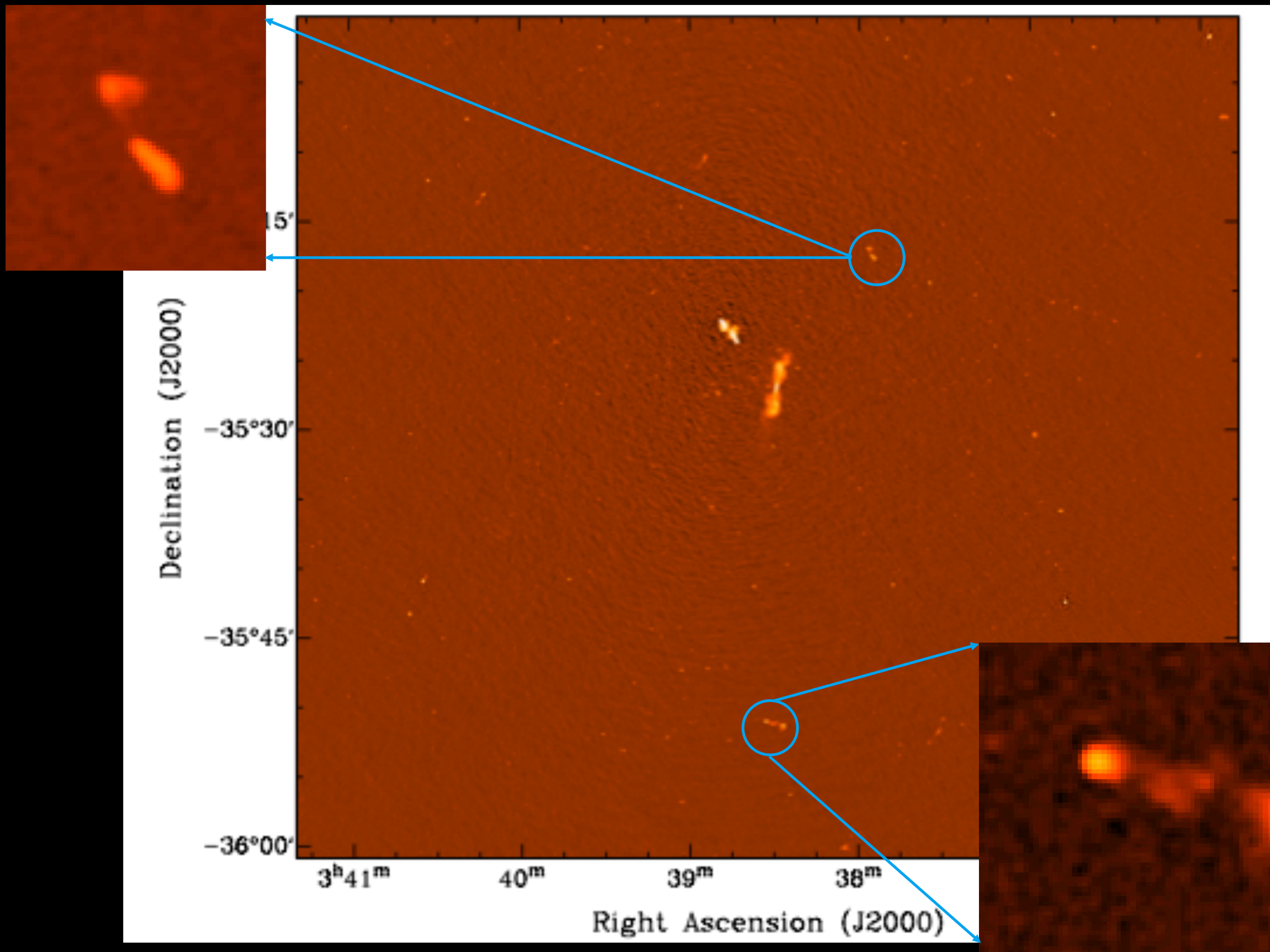
Credit: Disney

S. Makhathini (RATT), B. Hugo (SARAO/RATT), K. Thorat (RATT), **F. Maccagni (OAC)**, E. de Blok (Kapteyn/ASTRON/UCT), **P. Serra (OAC)**, A. Ramaila (SARAO), **M. Ramatsoku (OAC)**, G. Józsa (SARAO, Rhodes, Bonn), P. Kamphuis (Bochum), O. Smirnov (SARAO/RATT), **D. Kleiner (OAC), D. Molnar (OAC)**

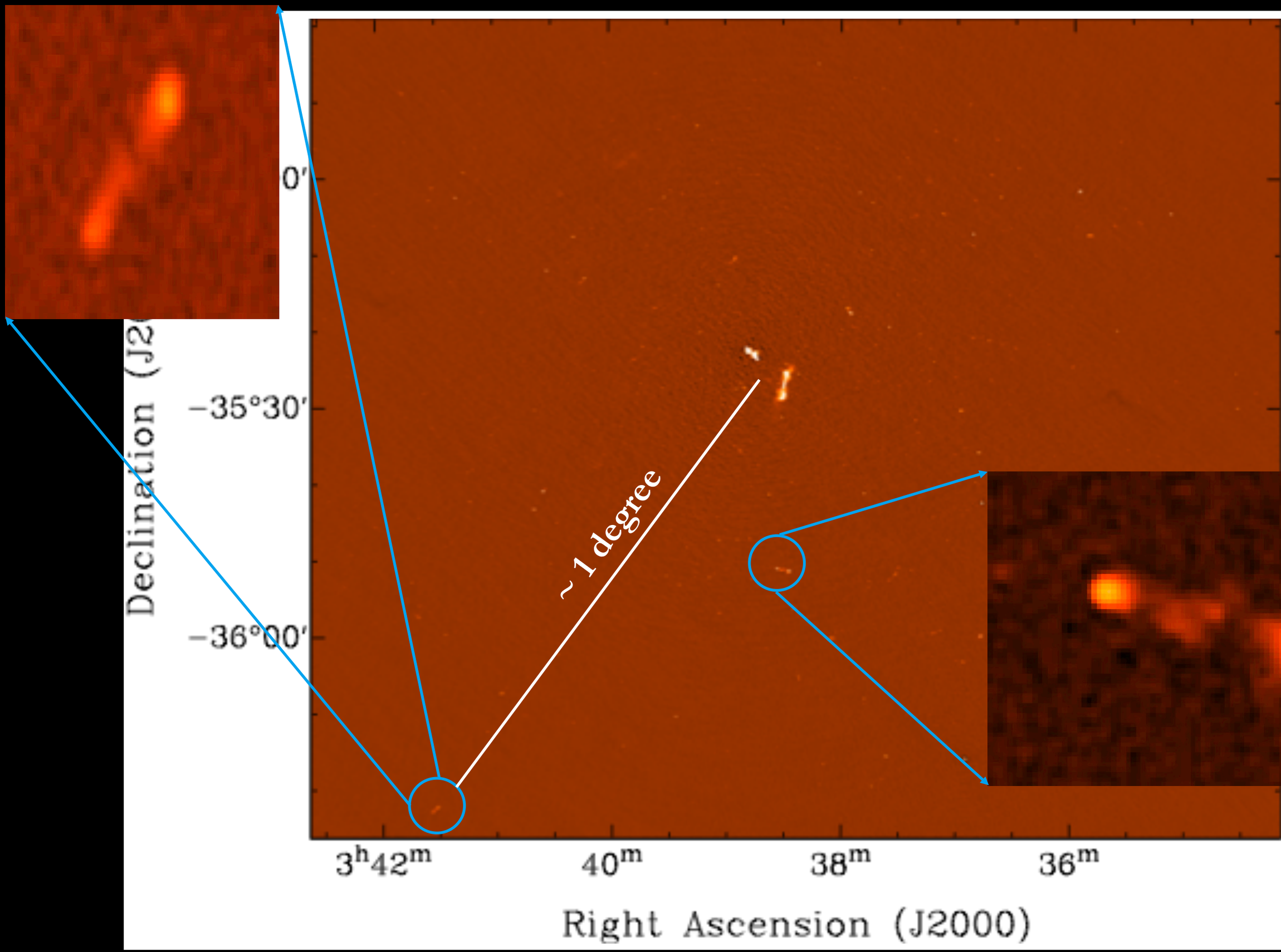
NGC 1399


−35°15′
−35°30′
−35°45′
−36°00′
Declination (J2000)
3h41m
40m
39m
38m
37m
36m
Right Ascension (J2000)
Noise = 30 μJy
Speak (NGC1399) = 30 mJy
Speak (MRC0336-355) =480 mJy
S (MRC0336-355) /N ~ 1.3x10^4

NGC 1399

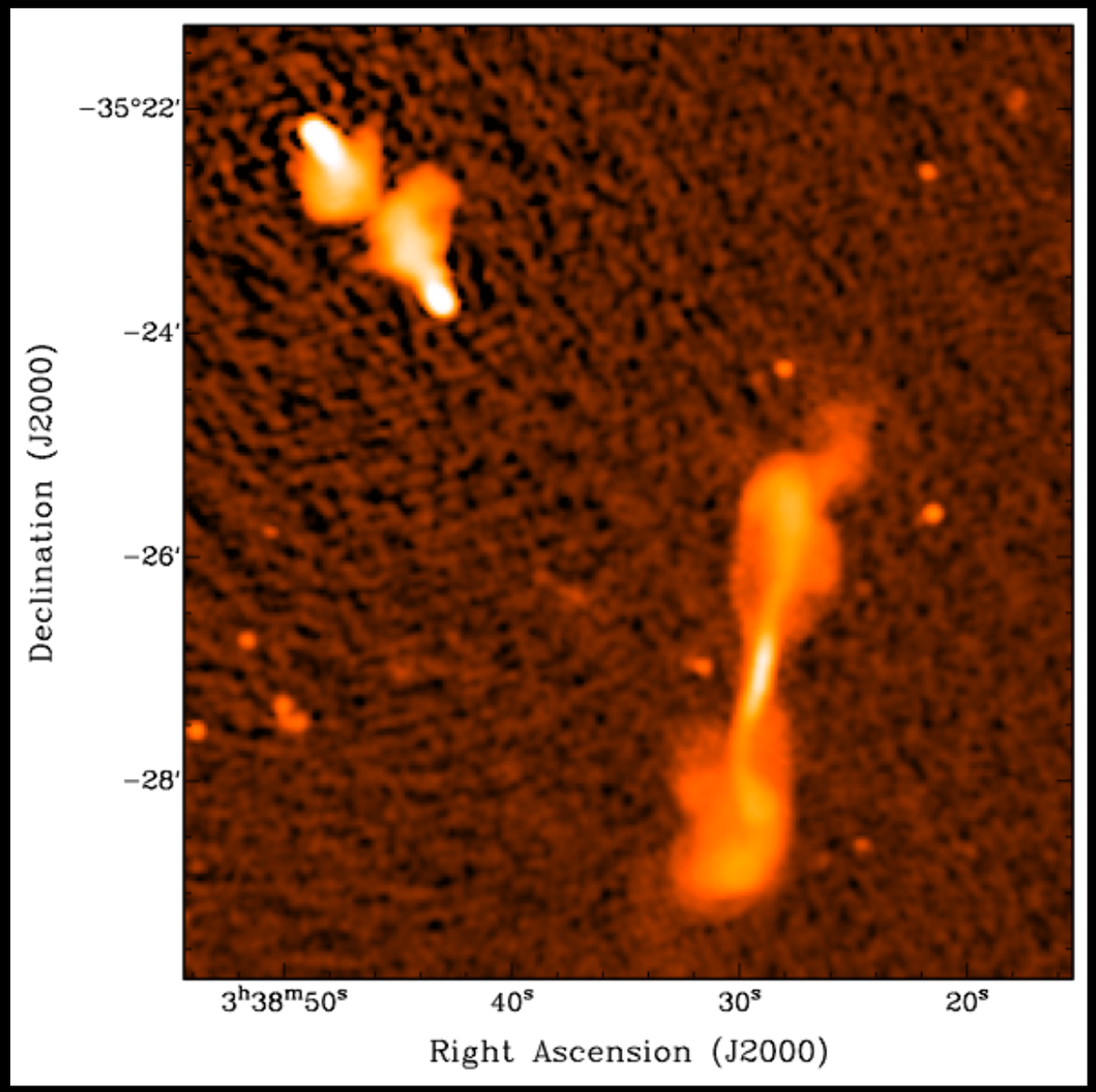

15′
−35°30′
−35°45′
−36°00′
Declination (J2000)
3h41m
40m
39m
38m
Right Ascension (J2000)

NGC 1399

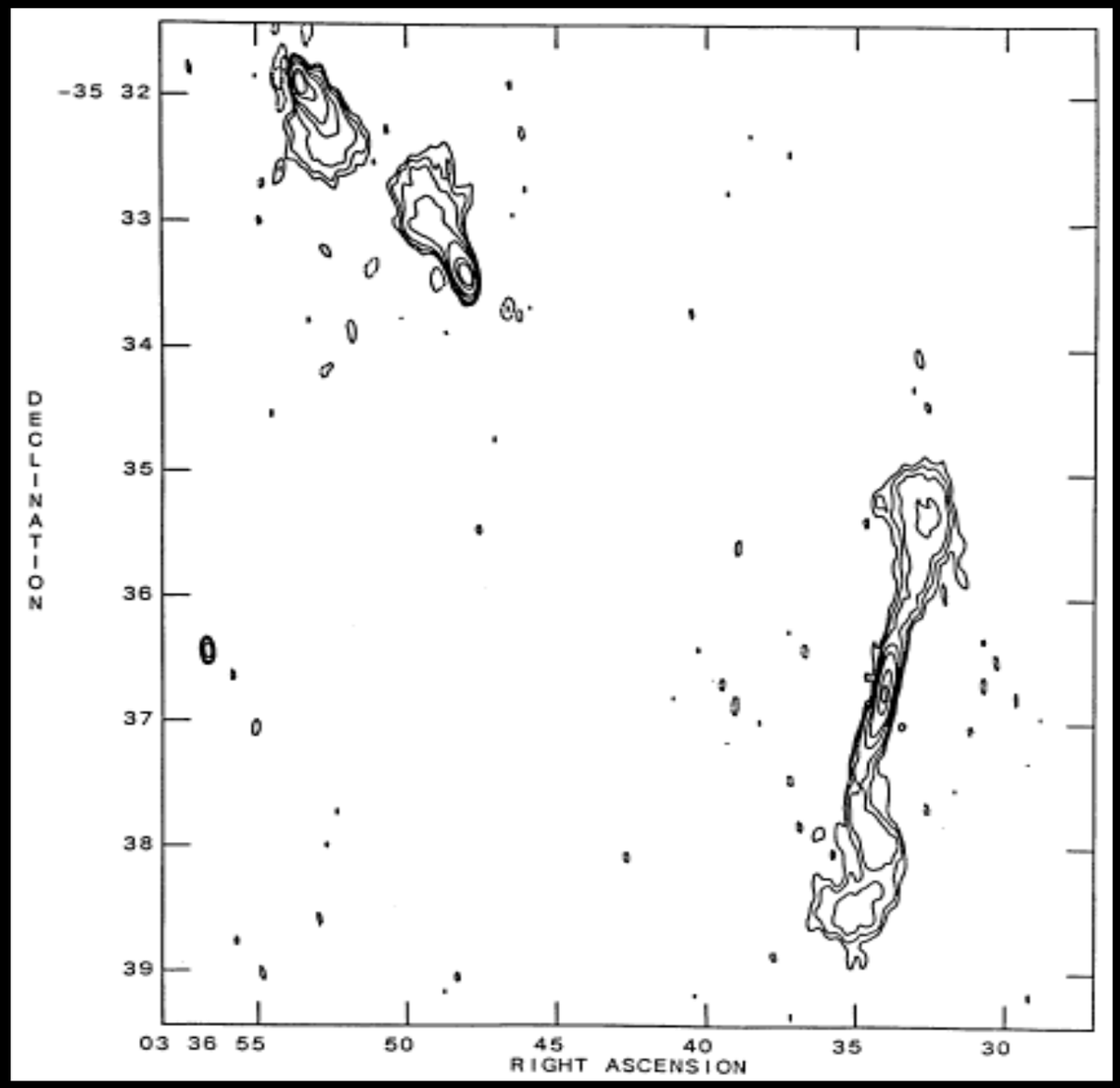

0′
−35°30′
−36°00′
Declination (J2
~ 1 degree
3h42m
40m
38m
36m
Right Ascension (J2000)

NGC 1399: MeerKAT vs VLA

MeerKAT



VLA (Killeen et al 1988)



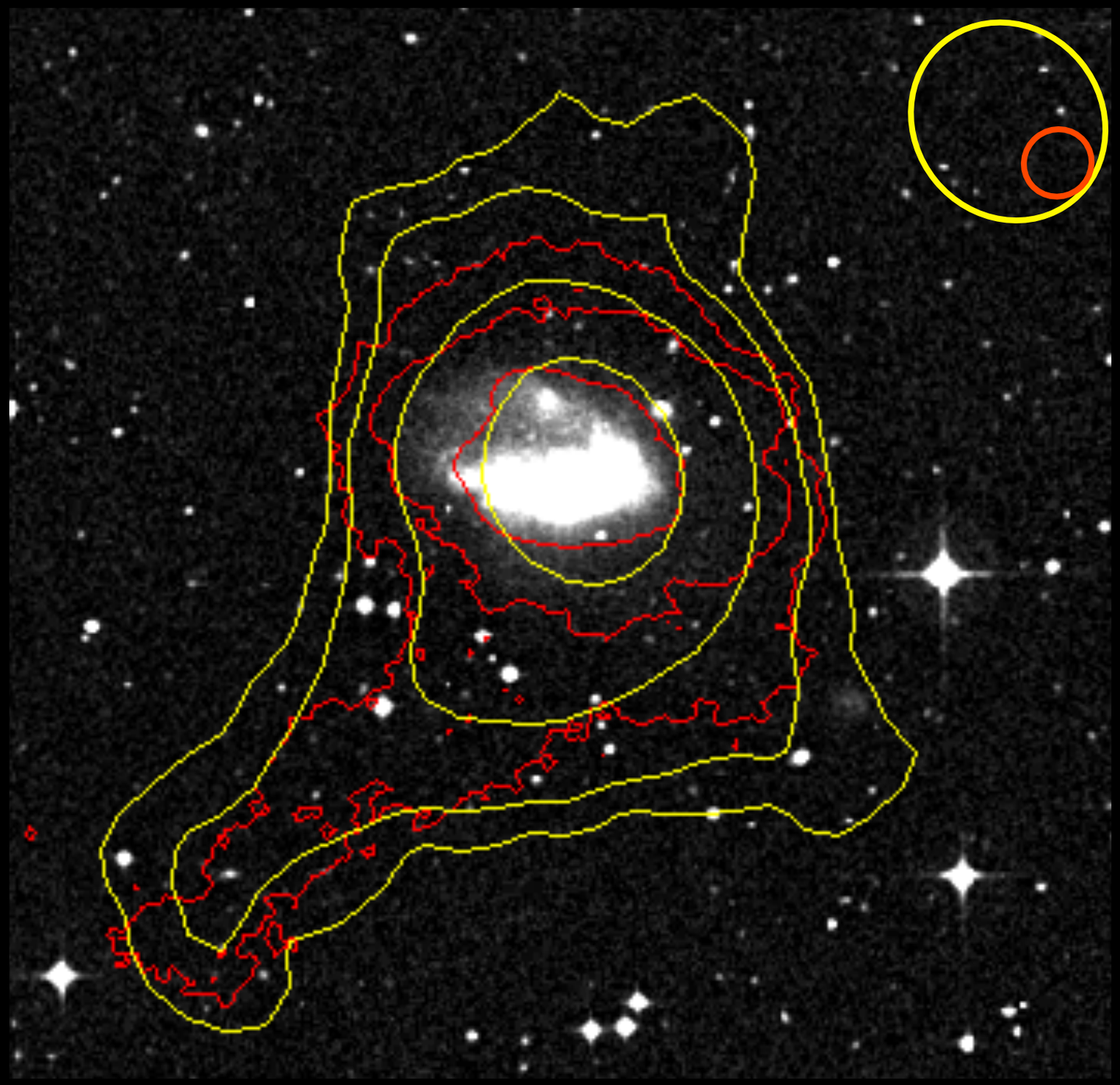
- Diffuse emission easily picked up.
  - New insights about the evolution history of the AGN in NGC1399?
- More point sources detected in the field

MeerKAT spectral line data

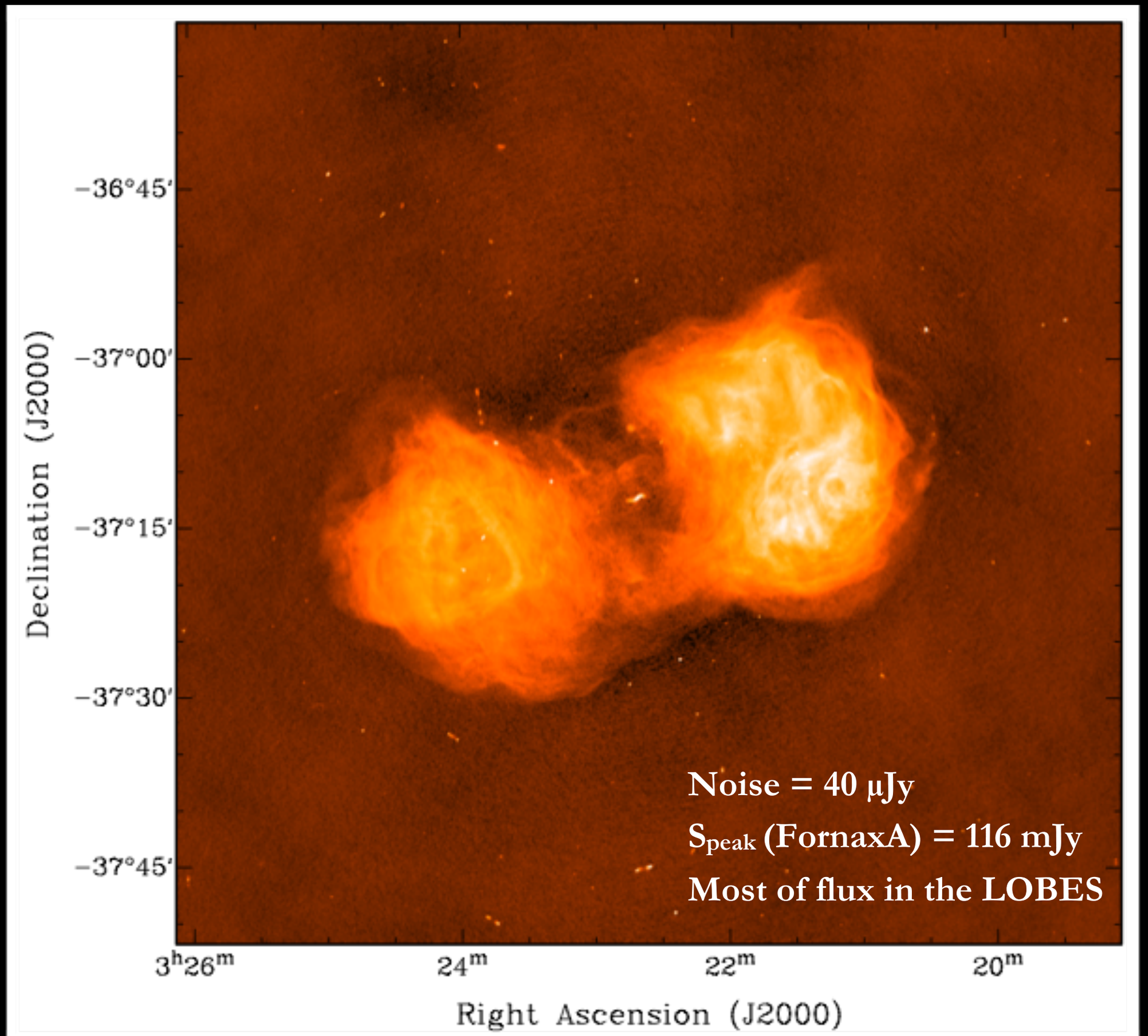
- **NGC 1427A: giant neutral hydrogen (HI) disk in a tidal interaction** [Lee-Waddell et al. 2017]

- Yellow: HI detected by ATCA
  - Beam: 86”x56”
  - Lowest contour: $5x10^{19}$ cm^{-2}
- Red: HI detected by MeerKAT
  - Beam: 32”x 25”
  - Lowest contour: $4x10^{19}$ cm^{-2}

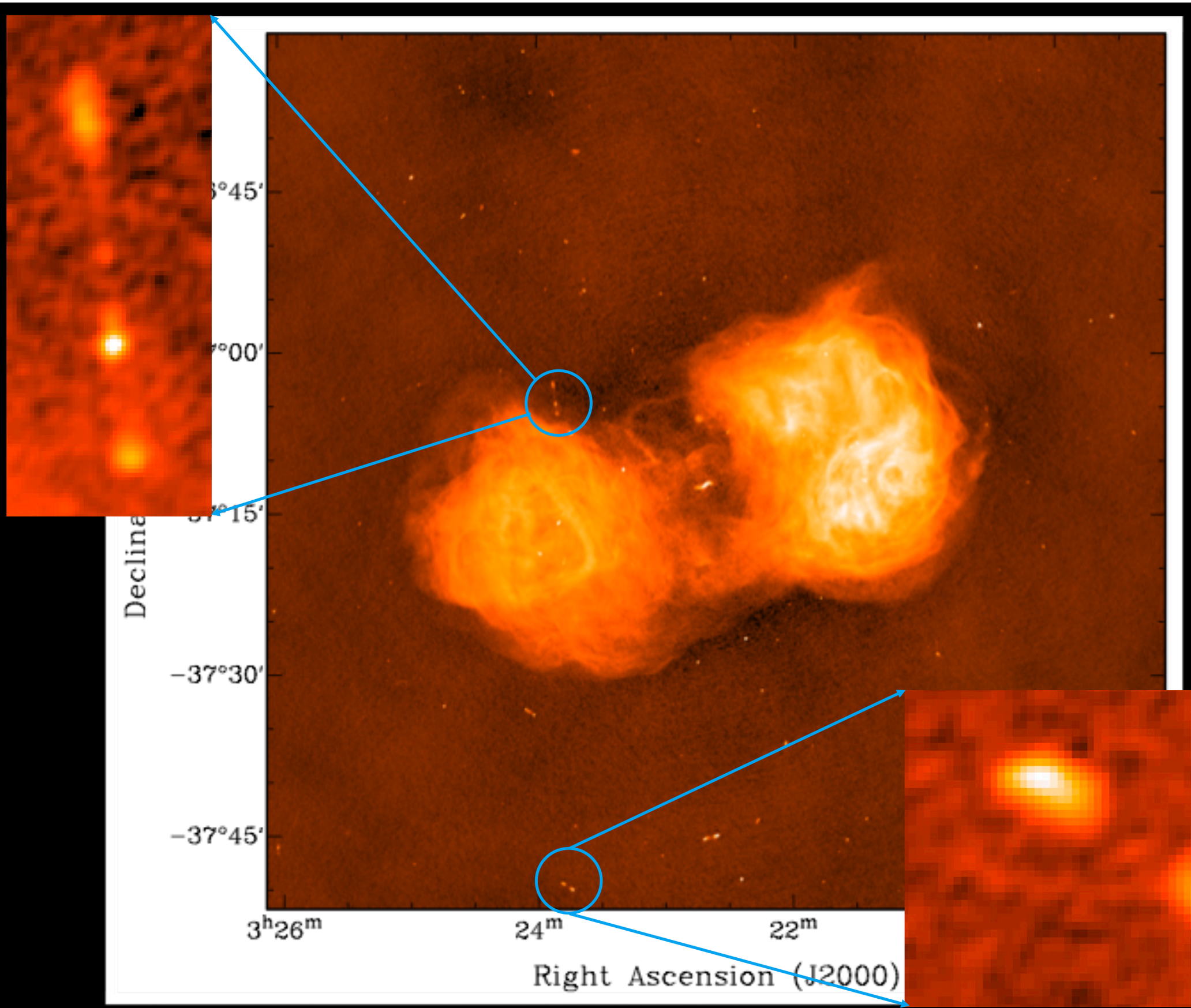
- MeerKAT observation indicate a tidal interaction rather than ram pressure stripping, as previously hinted by ATCA.



Fornax A

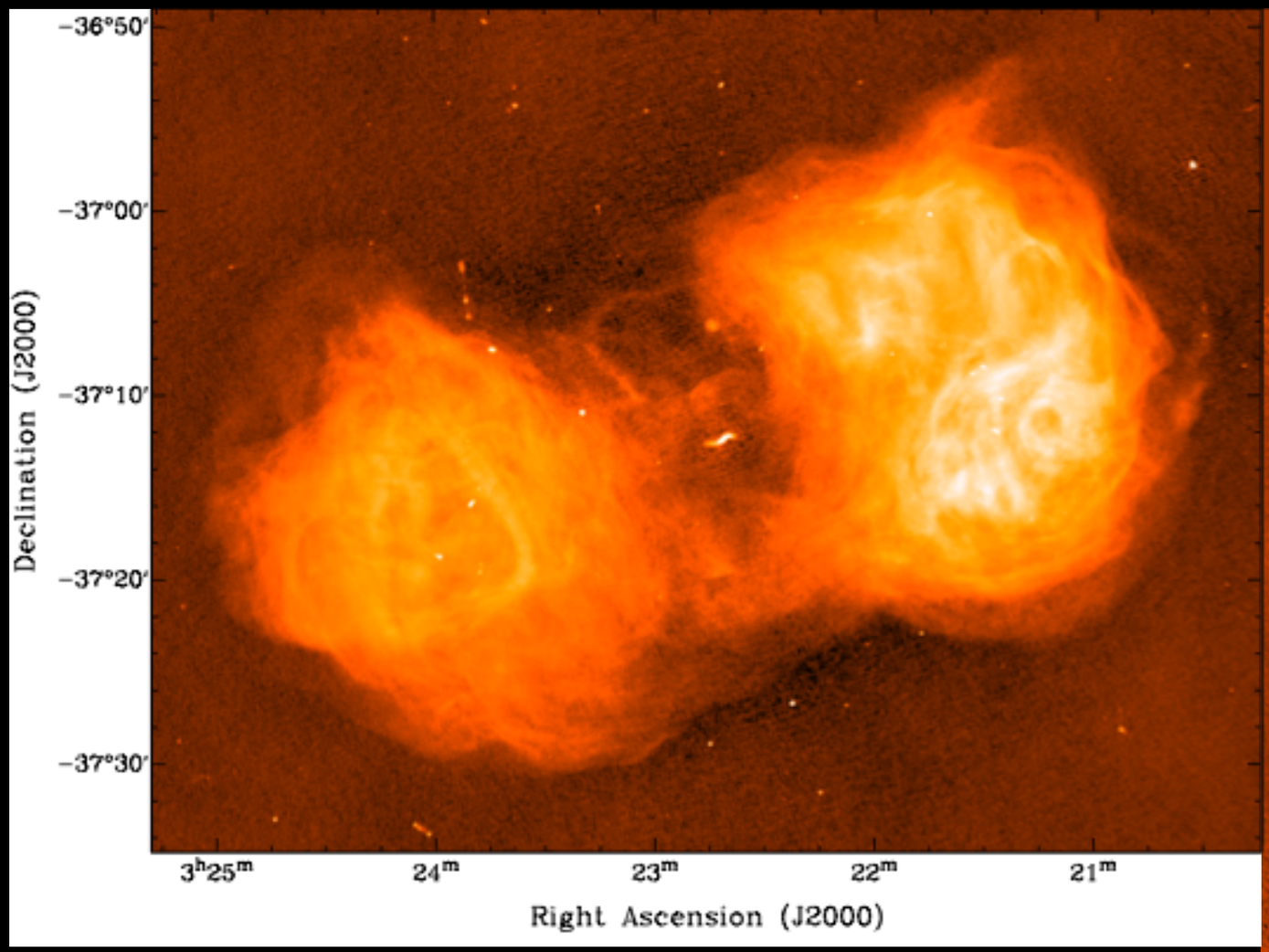

−36°45′
−37°00′
−37°15′
−37°30′
−37°45′
Declination (J2000)
3h26m
24m
22m
20m
Right Ascension (J2000)
Noise = 40 μJy
Speak (FornaxA) = 116 mJy
Most of flux in the LOBES

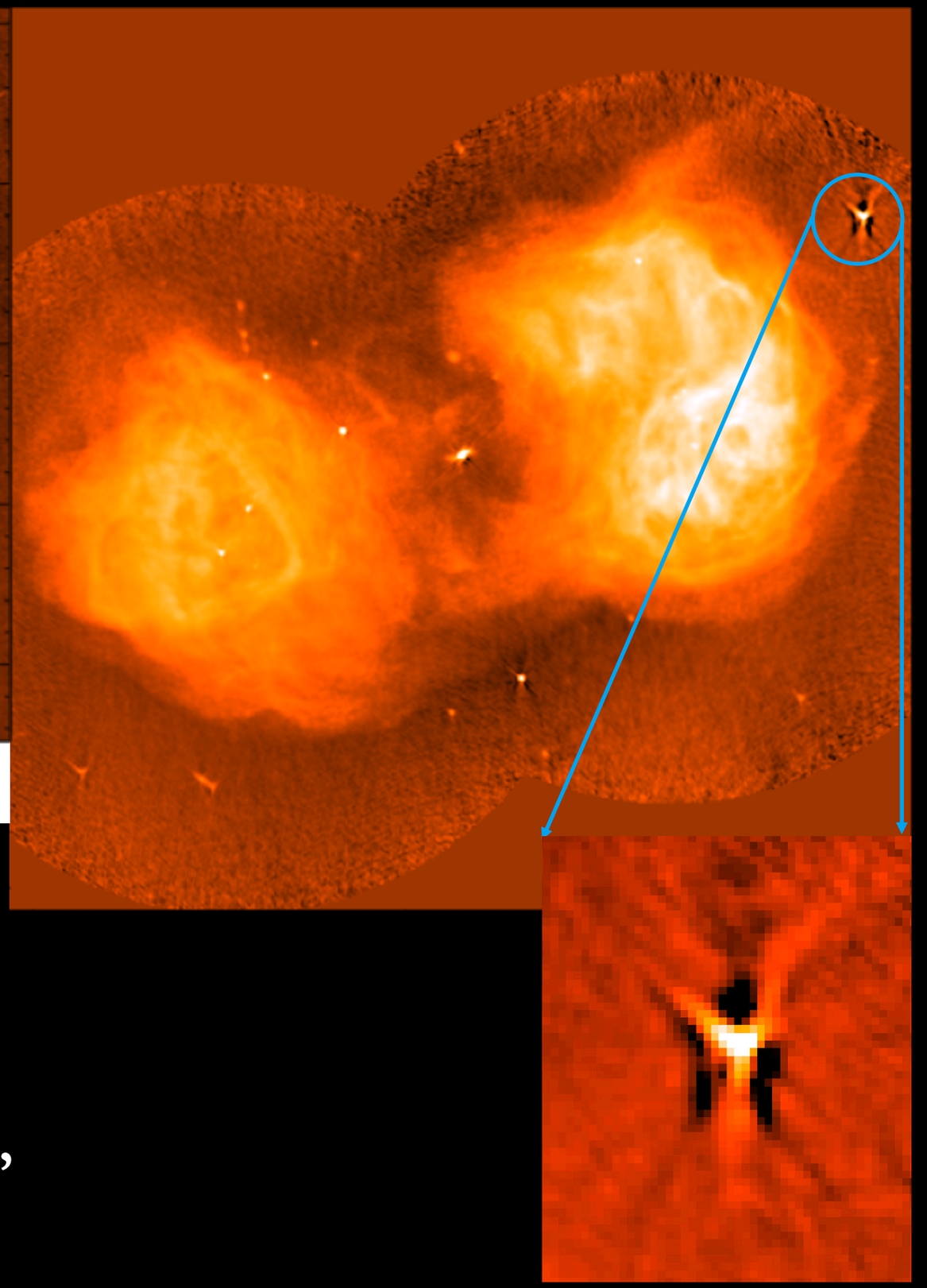
Fornax A



Fornax A: MeerKAT vs VLA

- **MeerKAT** [Maccagni et al. in prep.]
- **VLA** [Fomalont et al. 1989]

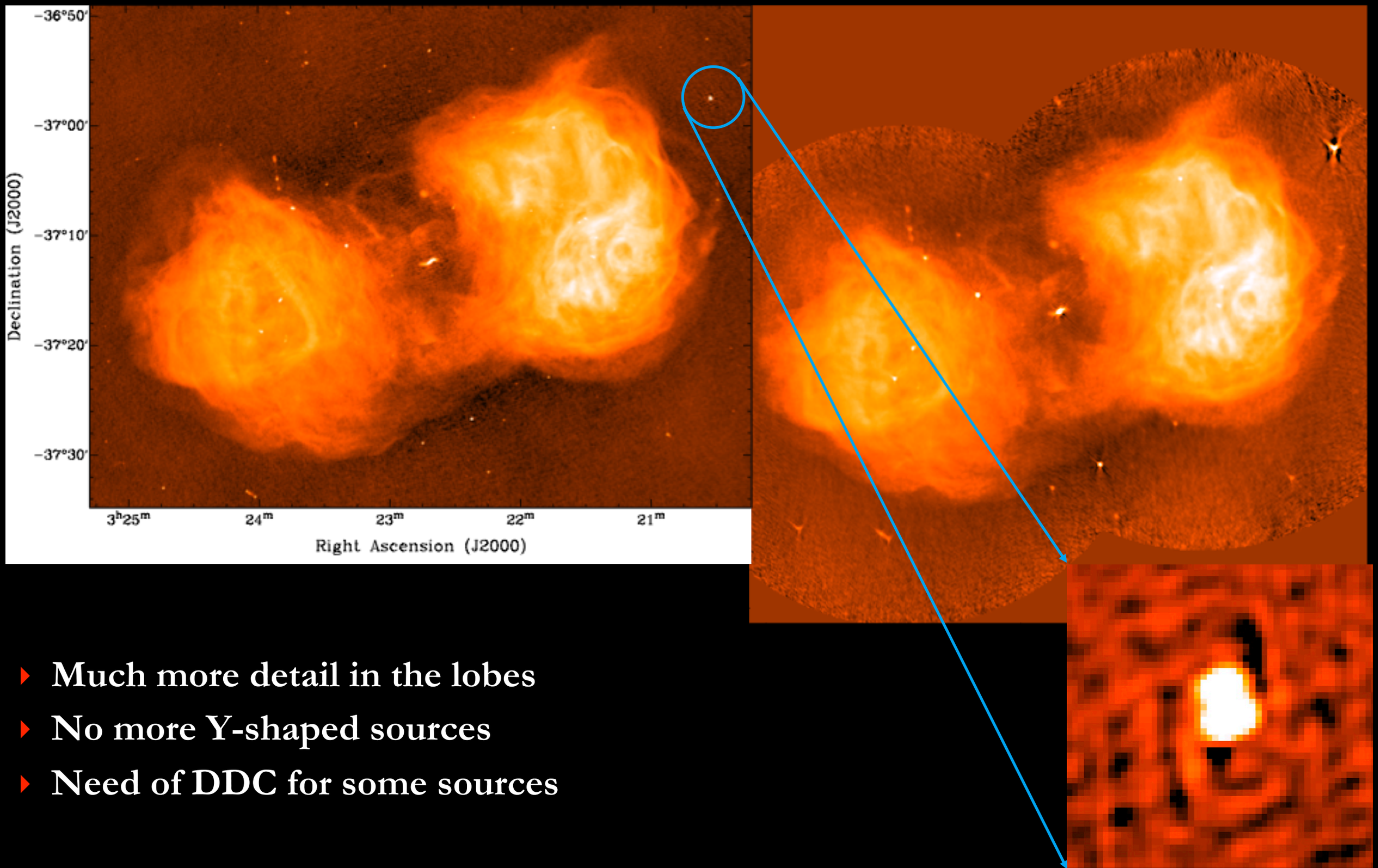




- Much more detail in the lobes
- No more Y-shaped sources
- Good imaging of sources around Fornax A, and behind the lobes.

Fornax A: MeerKAT vs VLA

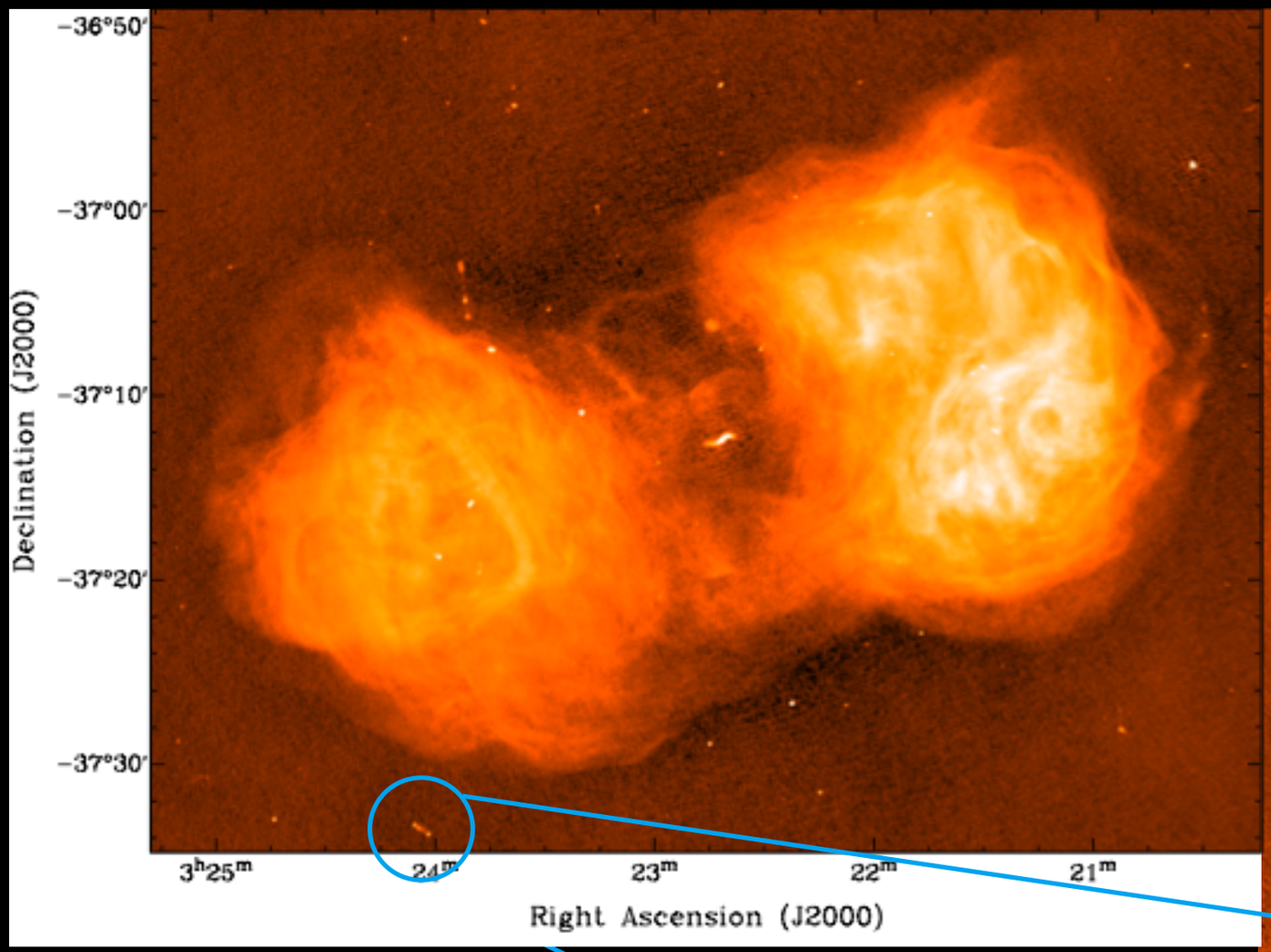
- **MeerKAT** [Maccagni et al. in prep.]
- **VLA** [Fomalont et al. 1989]

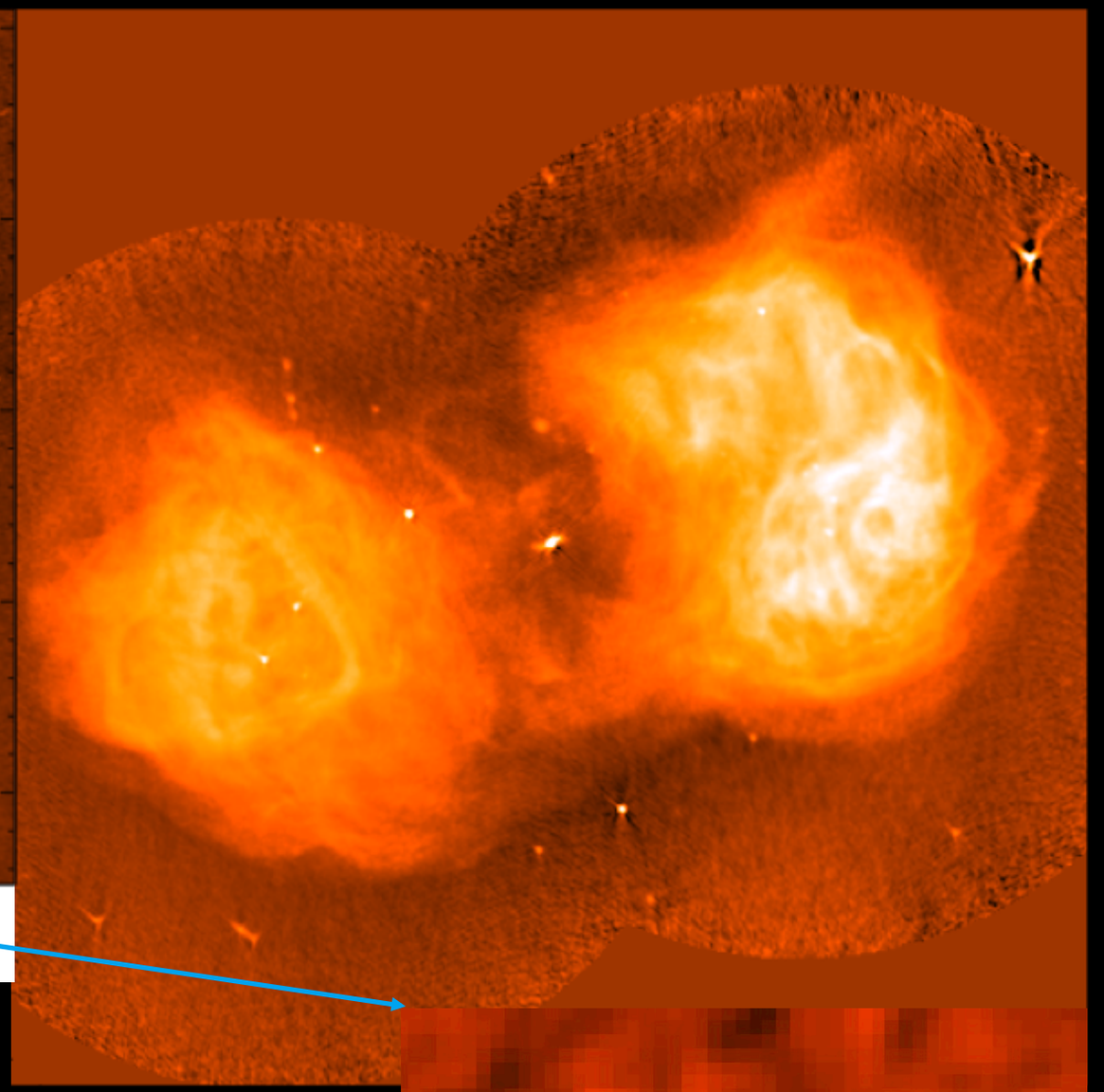


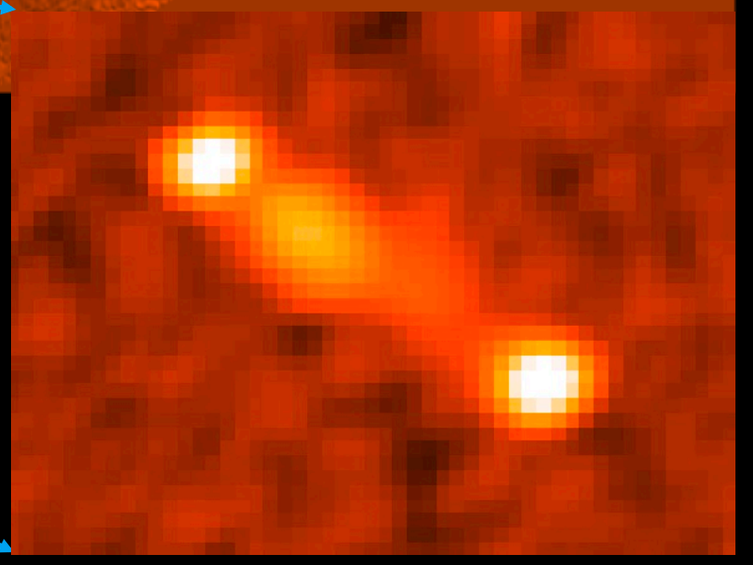
- Much more detail in the lobes
- No more Y-shaped sources
- Need of DDC for some sources

Fornax A: MeerKAT vs VLA

- **MeerKAT** [Maccagni et al. in prep.]
- **VLA** [Fomalont et al. 1989]





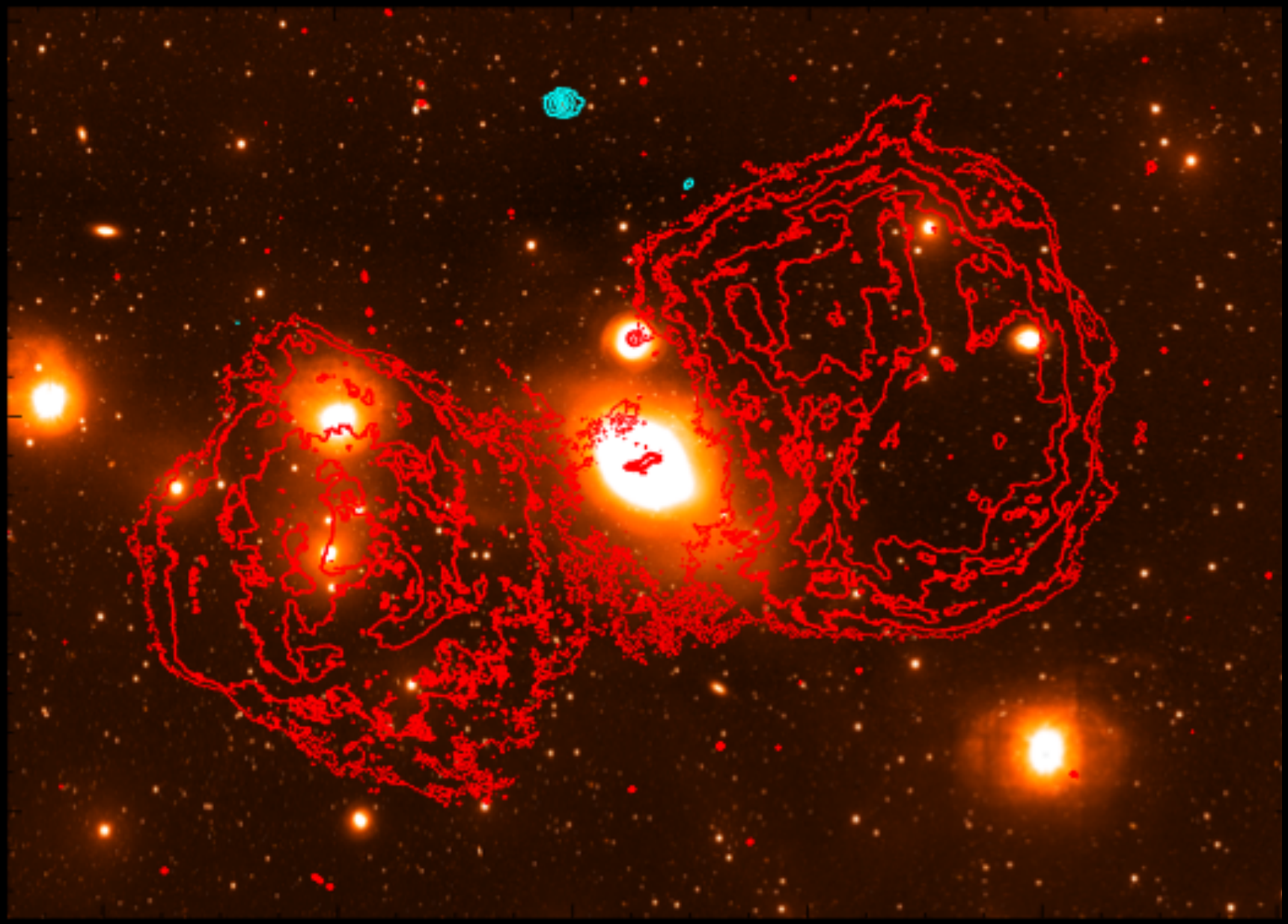


- Good imaging of sources around Fornax A, and behind the lobes.
- The full information is contained in the spectral line data cube

Fornax A: spectral line data

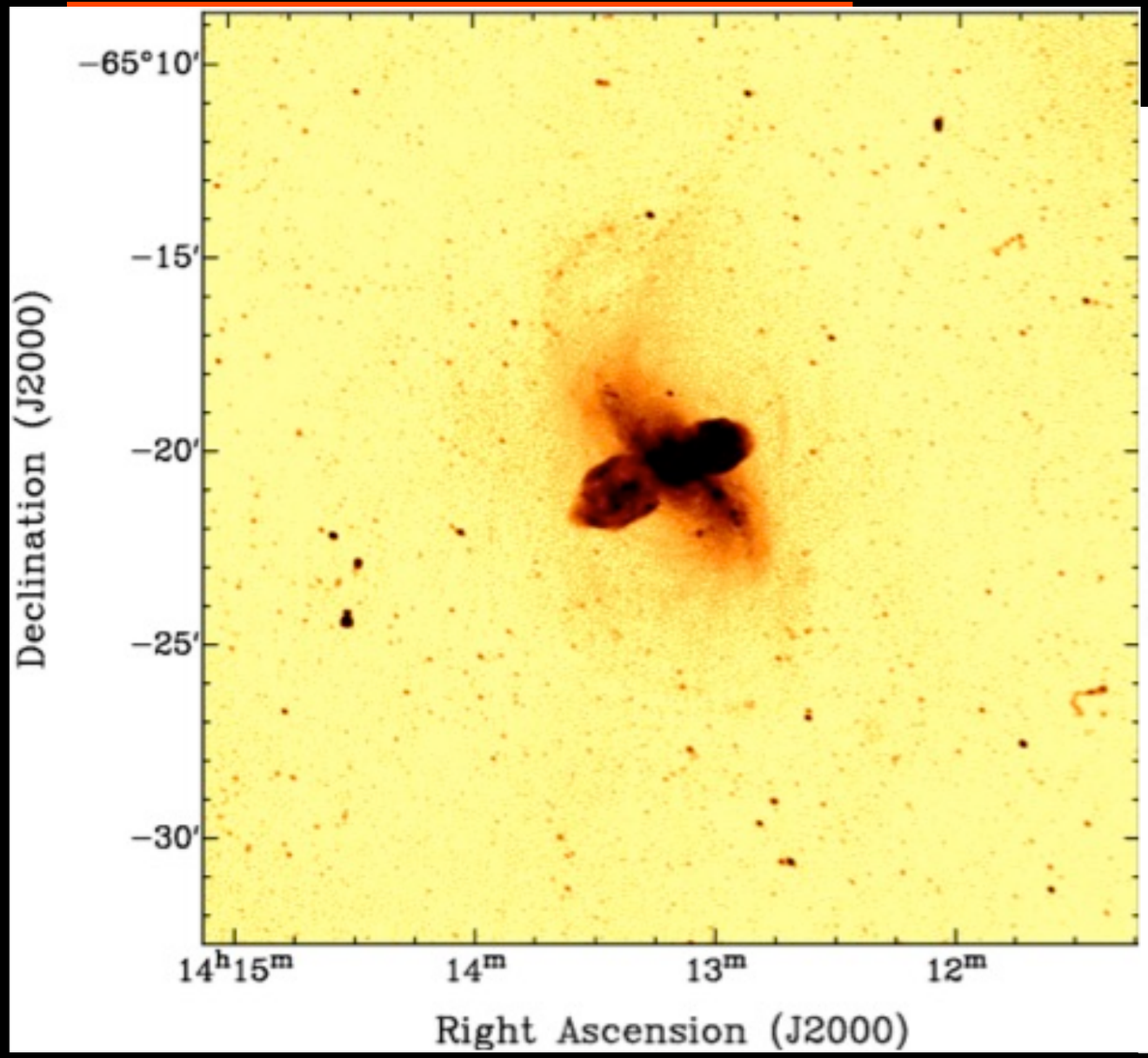
- The goal of the MFS is detect low column density HI in the Fornax cluster.

- Red: 1.4 GHz continuum
- Background: FDS survey, r-filter [Venhola et al. 2017].
- Cyan: HI detections from MeerKAT observation (1.40-1.41 GHz).



Commissioning Observations: Circinus

- Closest (4 Mpc) spiral galaxy with a Seyfert 2 nucleus
- $M_* = 9.5 \times 10^{10}\ M_{sun}$
- $M\ (HI) = 9 \times 10^{9}\ M_{sun}$
- D (HI) = 70”
- MeerKAT 1.4 GHz continuum



- ATCA [Elmouttie et al. 1998]

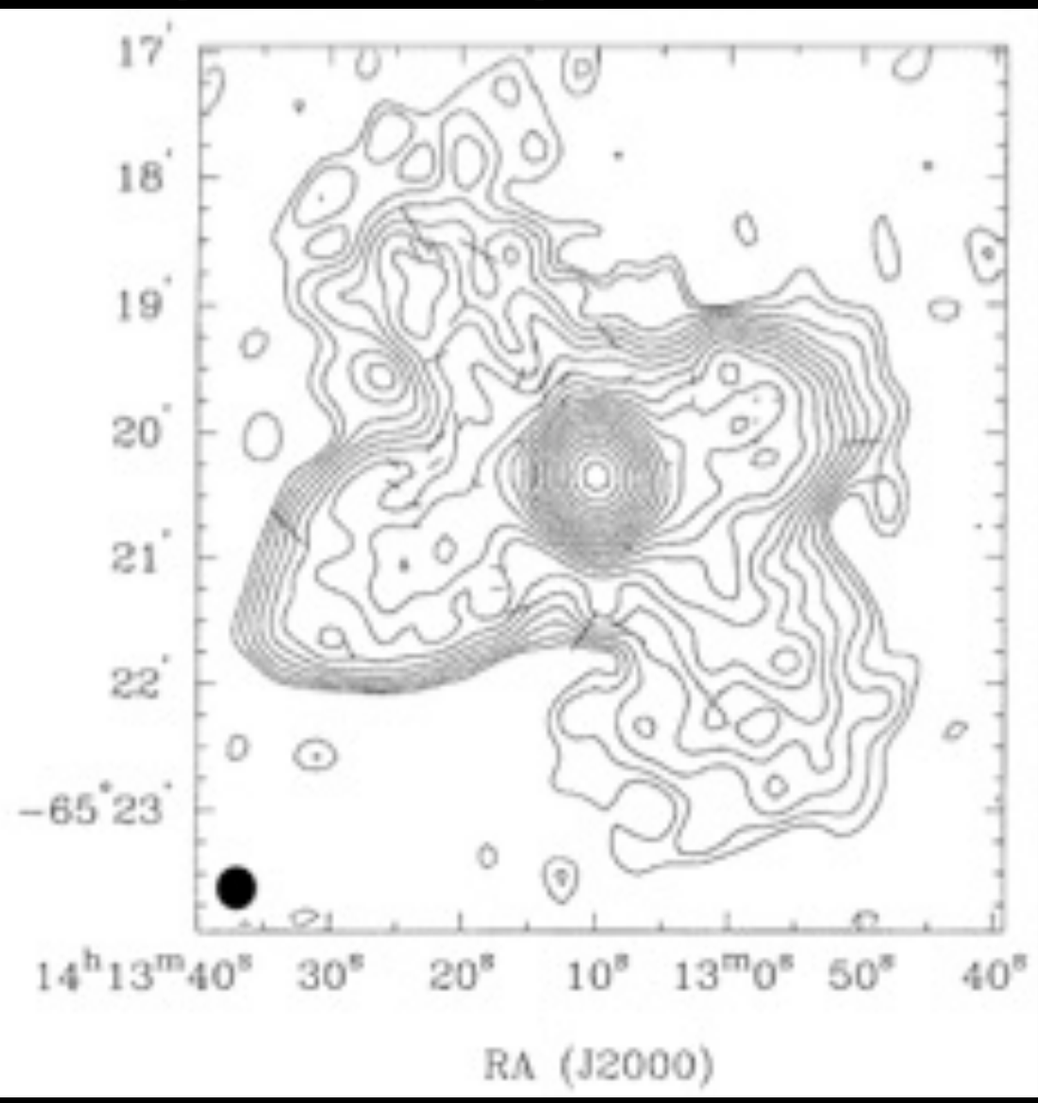
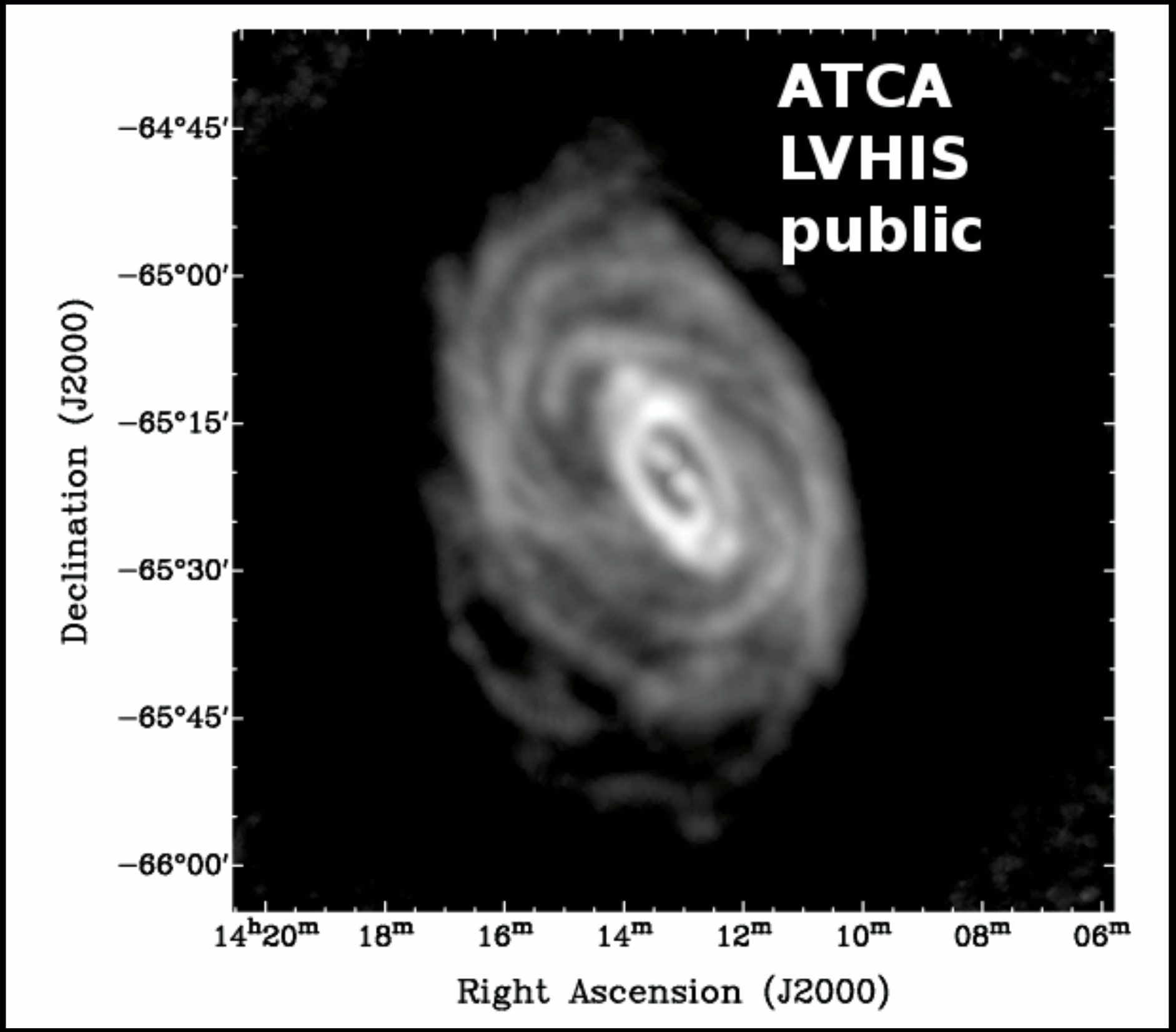


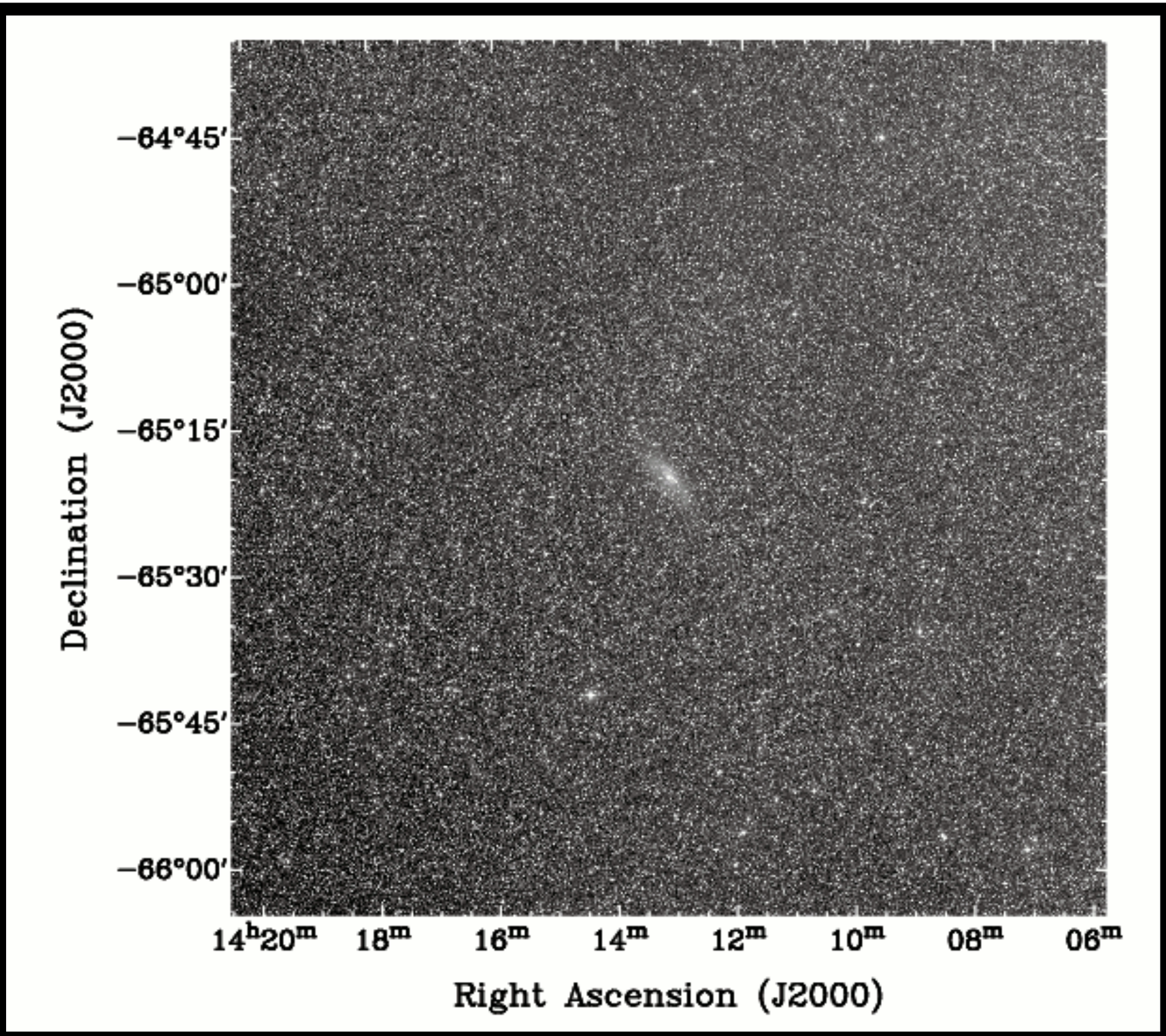
Image Credit: J. Josza

Circinus: spectral line data



Credit: Thorat, Josza

Commissioning Observations: Circinus



Credit: Thorat, Josza

Conclusions

- MeerKAT observations can be reduced via an automated pipeline.
- MeerKAT commissioning observations show promising results:
  - Radio continuum imaging.
    - Wide f.o.v. at high resolution and dynamic range (LOFAR at 1.4 GHz)
  - Spectral line observations.
    - High resolution (10”) observations of nearby HI rich radio galaxies.
- MeerKAT will change our view of the radio sky.