

# ORCs: Odd Radio Circles

# EMU: the ASKAP continuum survey

Evolutionary Map of the Universe

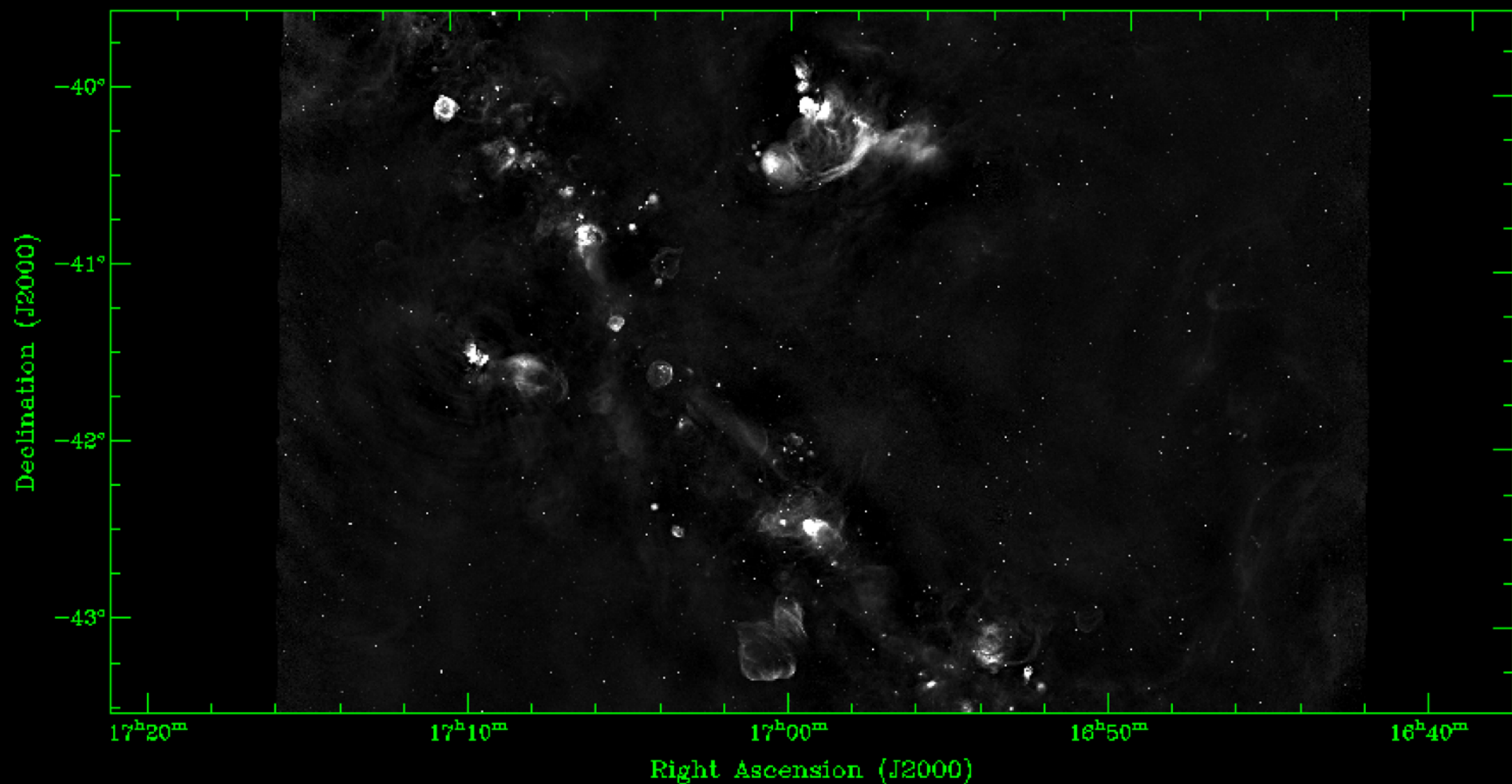
- **Deep radio image of 75% of the sky (to declination  $+30^\circ$  )**
- **Will detect and image ~70 million galaxies at 20cm**
  - c.f. 2.5 million detected over the entire history of radio-astronomy so far
- **Science-driven international project**
  - 300 scientists in 21 countries
- **Will deliver science-ready products, including:**
  - Cross-identification with optical/IR/Xray data
  - Ancillary data (redshifts etc)
  - Algorithms to “discover the unexpected” (WTF?)

EMU will deliver the deepest-ever radio image of the extragalactic sky (image shows part of the EMU pilot survey)



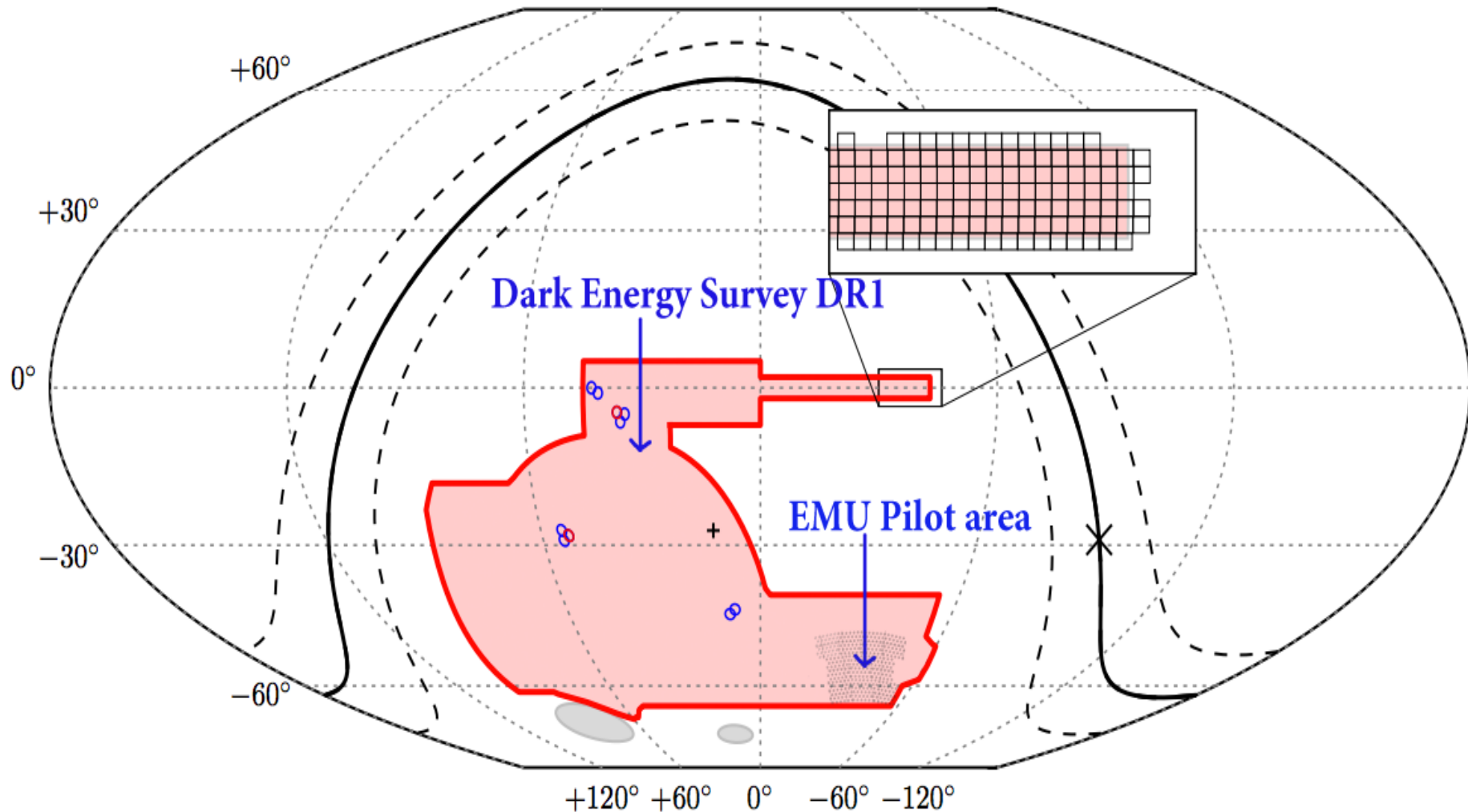


EMU will deliver the deepest-ever survey of the radio continuum in the Galactic Plane  
(image show EMU Early Science data in the SCORPIO field)





# The EMU Pilot Survey (1% of EMU)

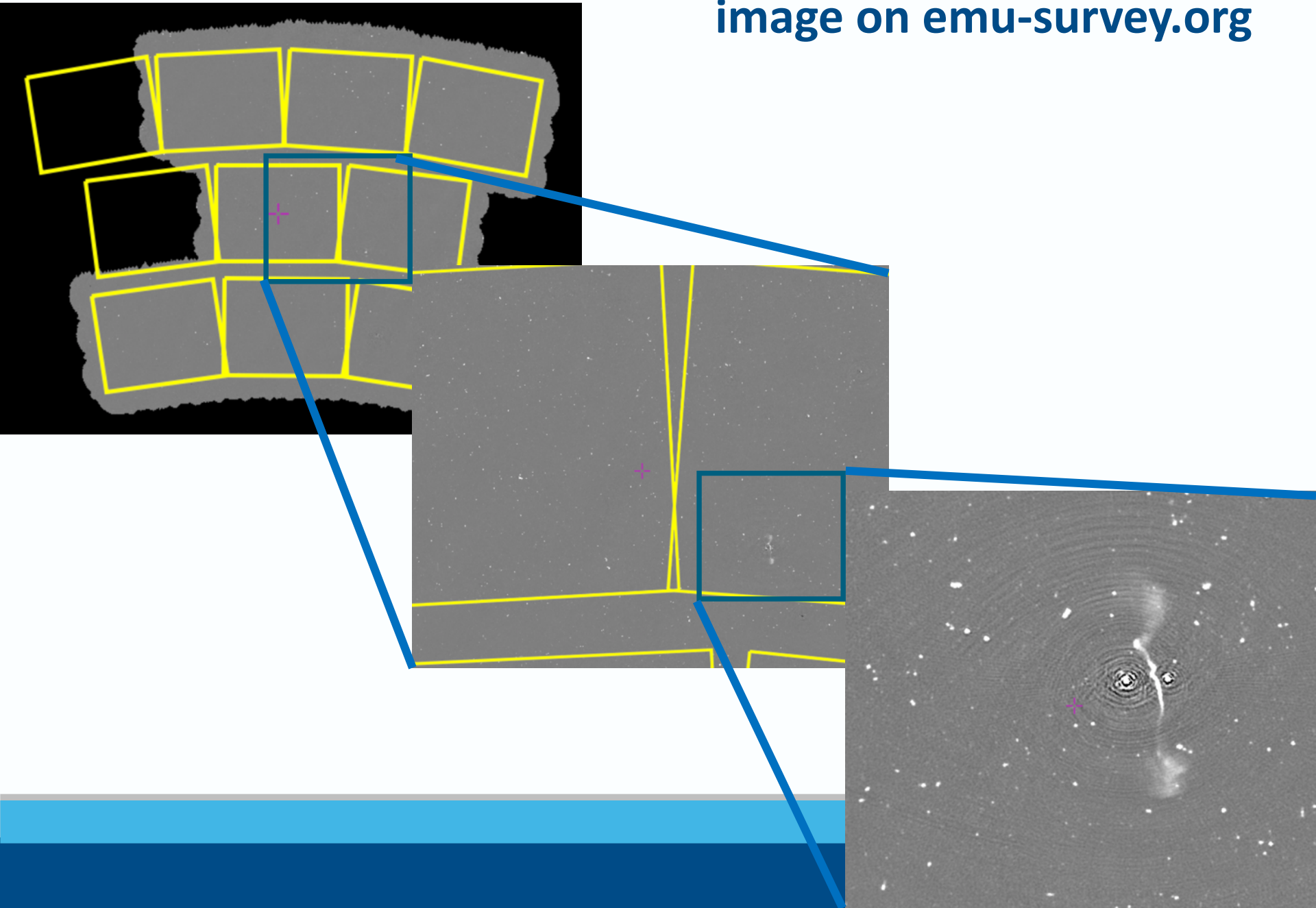


## 2. The EMU Pilot Survey

- **1% of EMU**
- Detected about 250,000 sources
- Unprecedented sensitivity to low-surface-brightness structures
- Sampling a new area of parameter space compared to previous radio surveys
- Several unexpected discoveries
- Multiwavelength data essential to understand science

# The EMU Pilot Survey

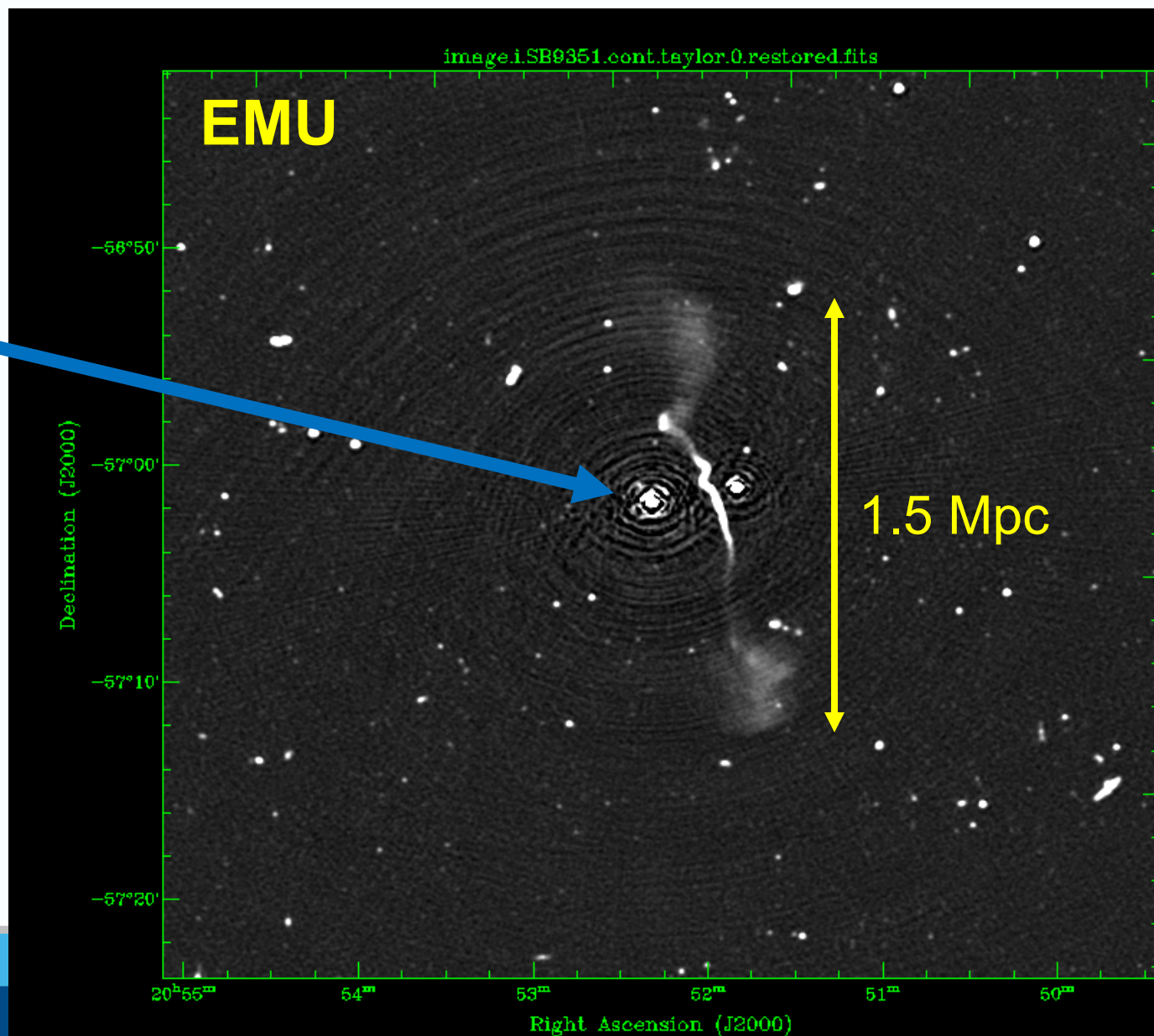
Access this zoomable  
image on [emu-survey.org](http://emu-survey.org)





# Wiggly jets and a Giant Radio Galaxy

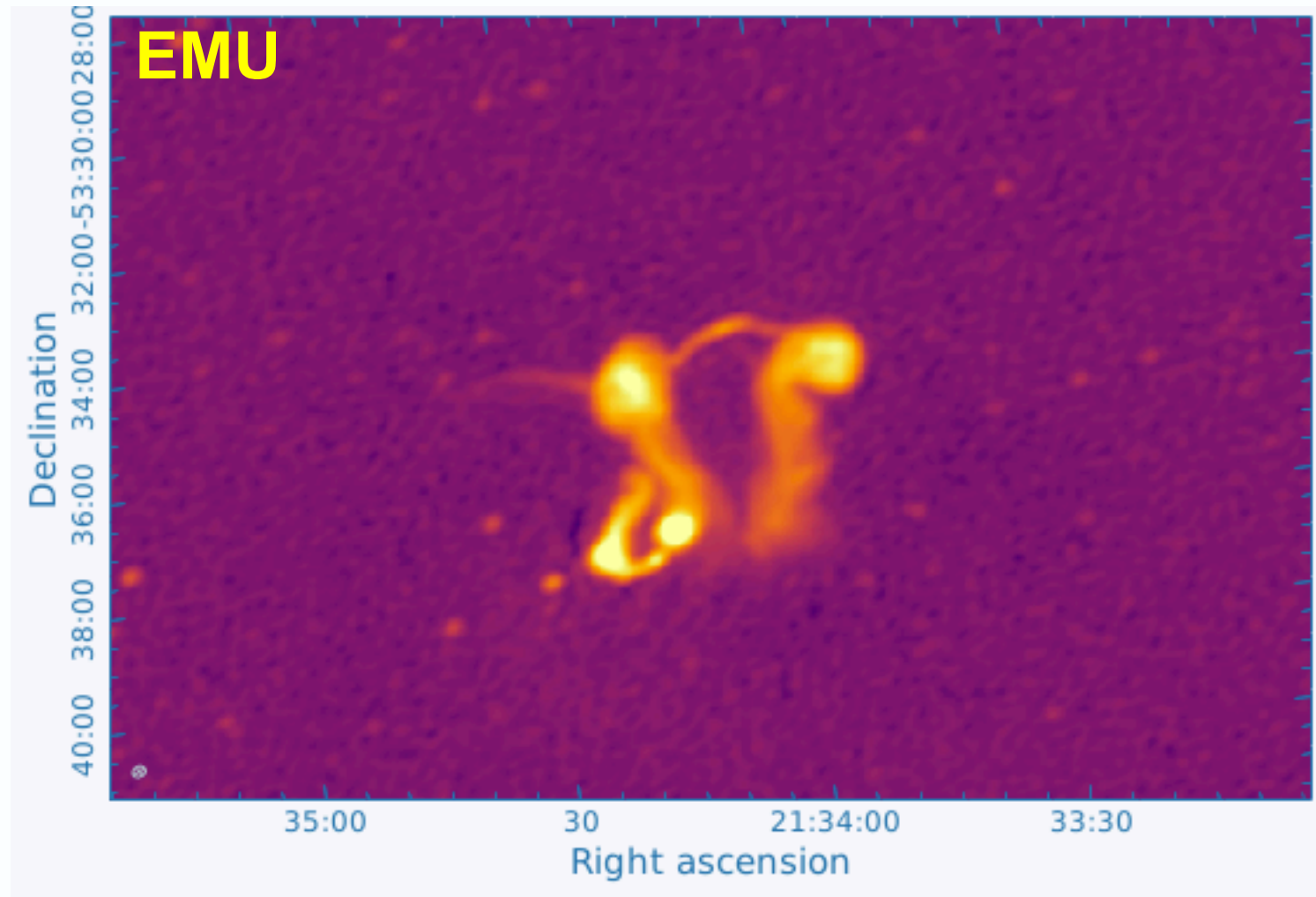
IC5063



# The EMU Pilot Survey

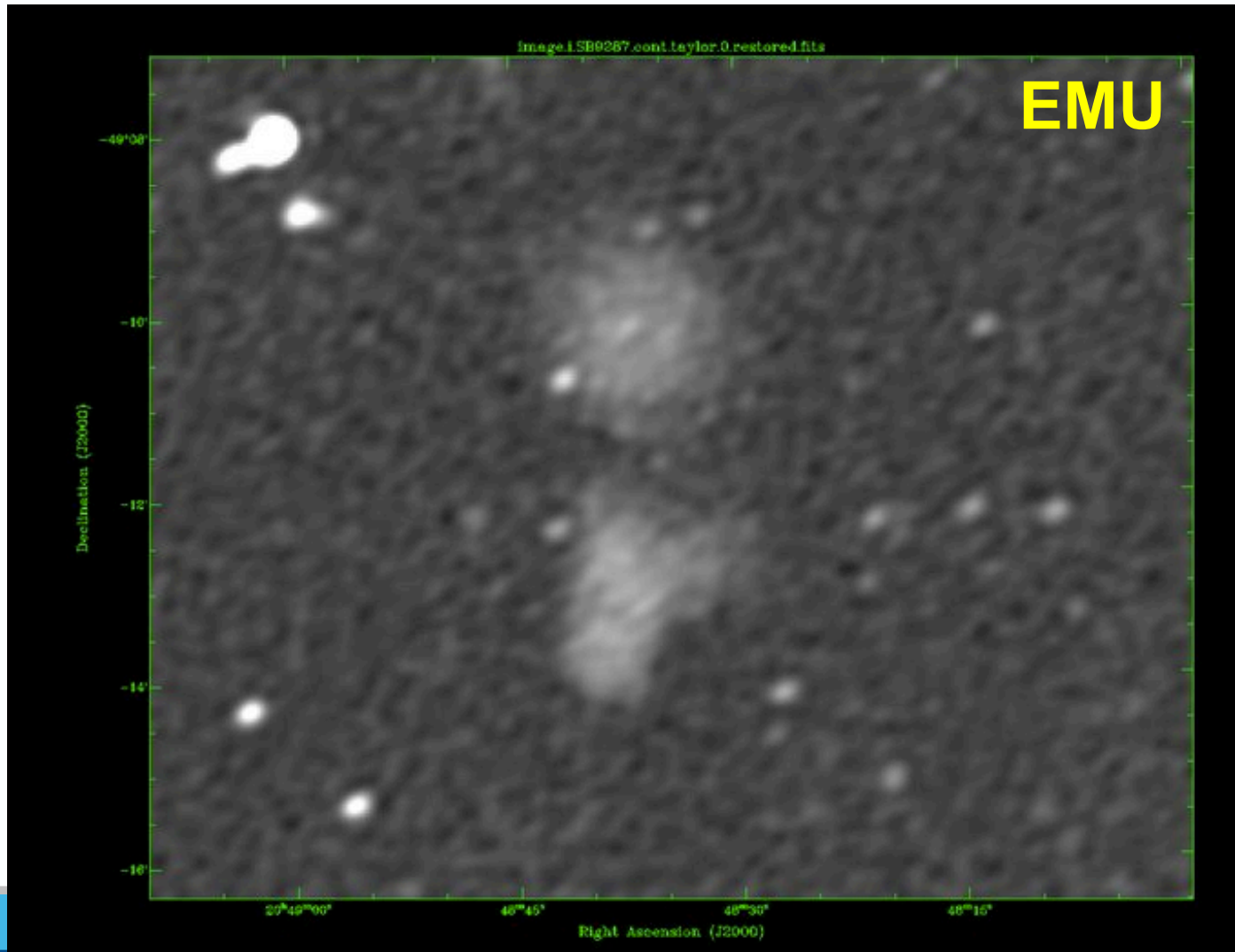
- Survey an area of about 300 sq deg in the Dark Energy Survey field at 800-1088 MHz.
- All observations completed, data reduction 90% complete.
- Rms of 25-35  $\mu\text{Jy}/\text{beam}$ , resolution  $\sim 12$  arcsec
- Detected about 200,000 sources
- Unprecedented sensitivity to low-surface-brightness structures
- Sampling a new area of parameter space compared to previous radio surveys (e.g. sensitivity to diffuse low-surface brightness emission)
- Several unexpected discoveries
- Multiewavelength data essential to understand science

# Lots of weird things in the EMU Pilot



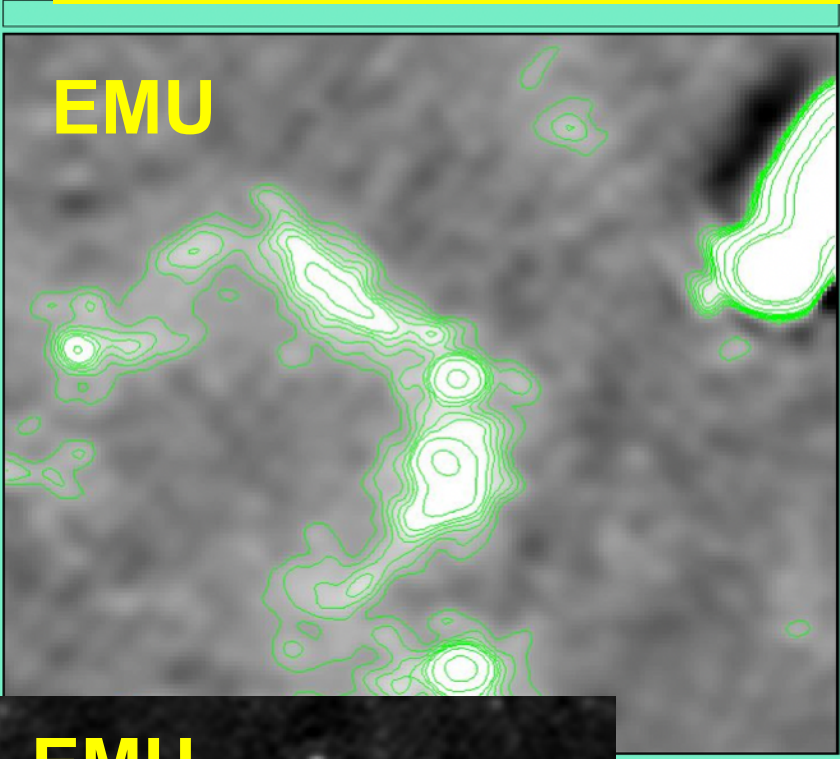


# “Smoking-gun” remnant galaxies (and Giant Radio Galaxies)

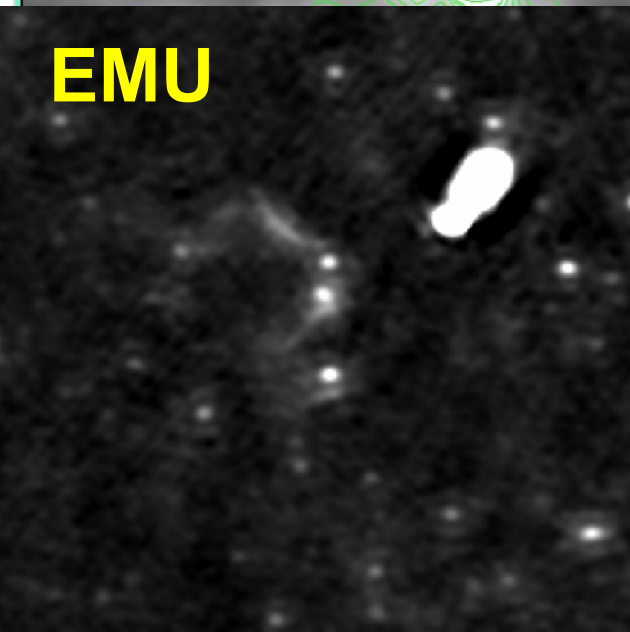


# Wisps and filaments

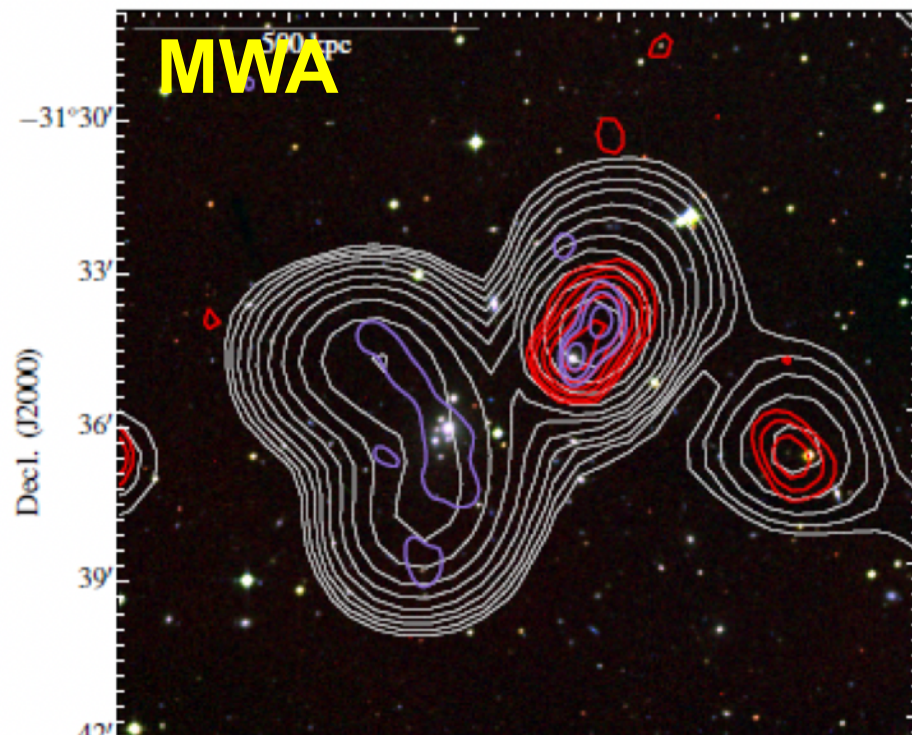
EMU



EMU



MWA

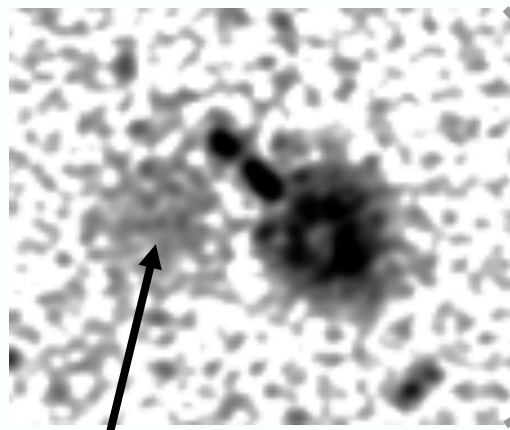


- First seen in the ASKAP Early Science image of Abell S1136
- Appears as a diffuse blob in MWA data
- Now seen in several clusters in the Pilot Survey.
- Similar to, but different morphology from, previously seen “relics”
- Relics? Shock-excited electrons?

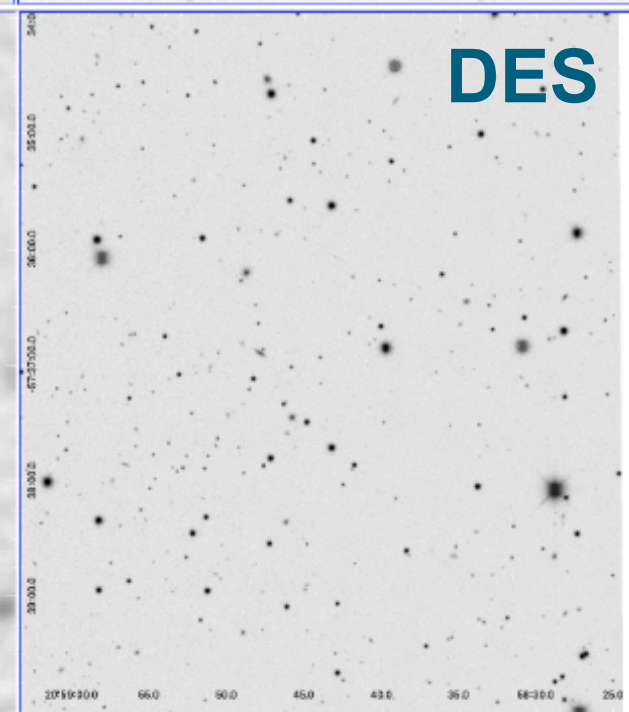
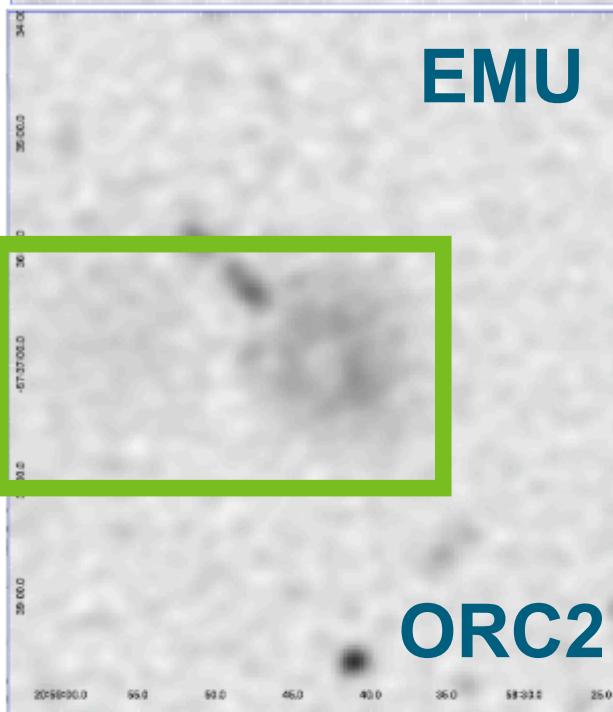
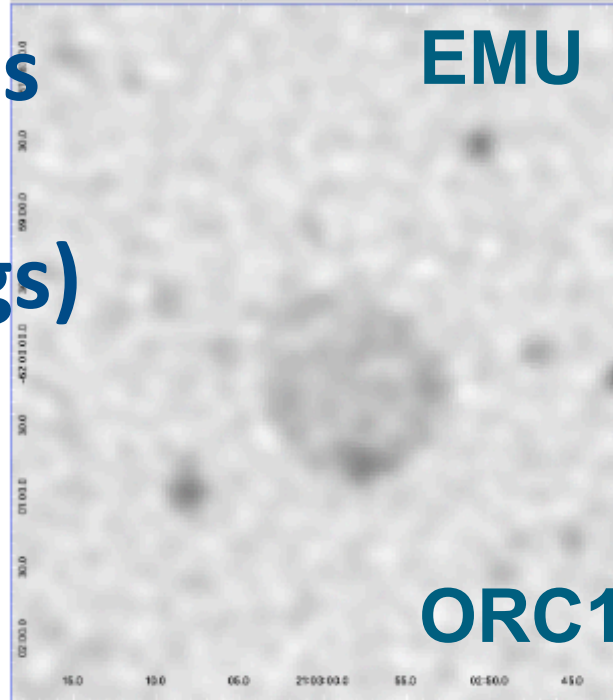
*P. Macgregor et al., in preparation*

# Odd Radio Circles (aka ORCs, or Lords of the Rings)

No obvious optical  
counterpart –  
candidates are  
mainly SF galaxies



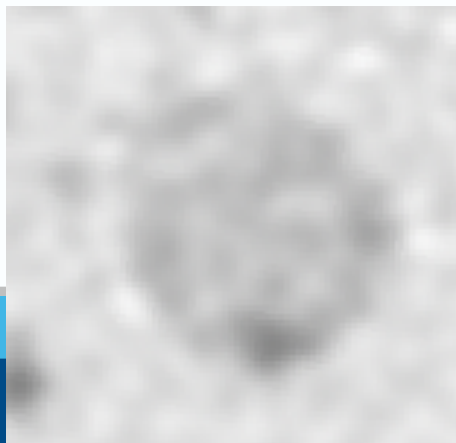
ORC3





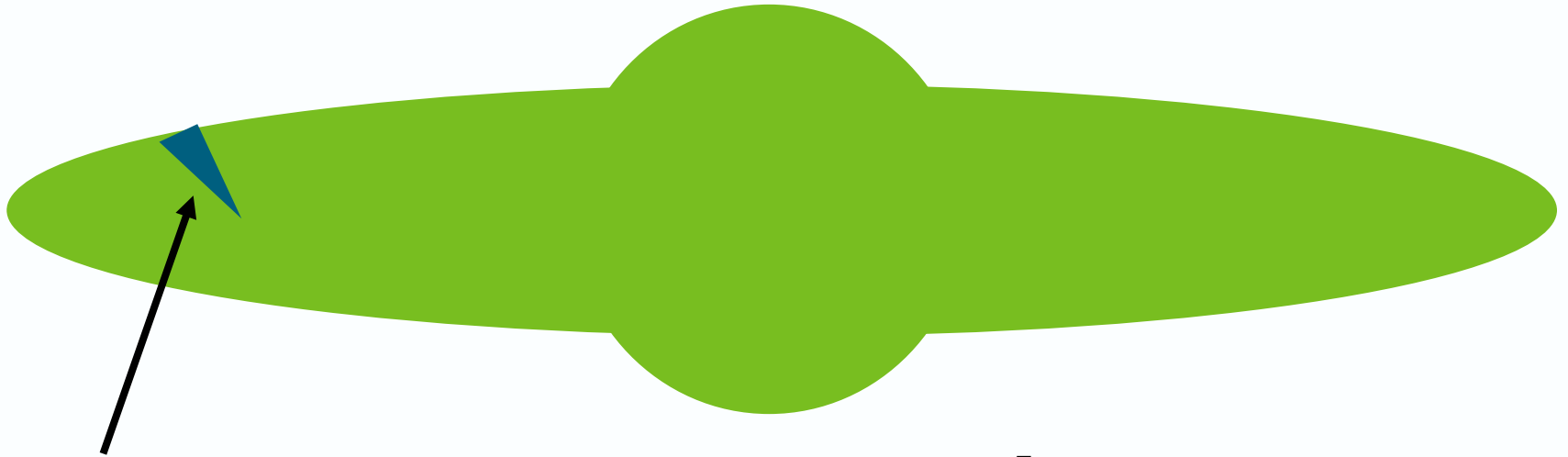
# ORCs

- Not artefacts –seen in 2 separate ASKAP observations
- Also detected by MWA in GLEAM-X
  - courtesy Natasha Hurley-Walker & Stefan Duchesne)
- Surprisingly circular
- Surprisingly uniform – all 3 are about 80 - arcsec diameter
- ORC1 & ORC2 are edge-brightened, but ORC3 isn't
- Extended emission is steep spectrum ( $\sim -1.3$ )
- Nearby radio sources are probably chance background sources
- Not seen before in radio surveys because (a) rare, (b) low-surface brightness



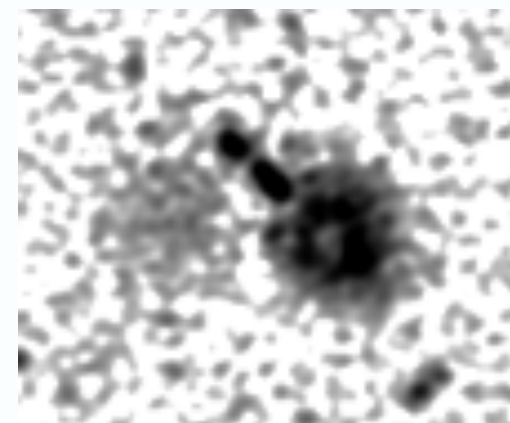
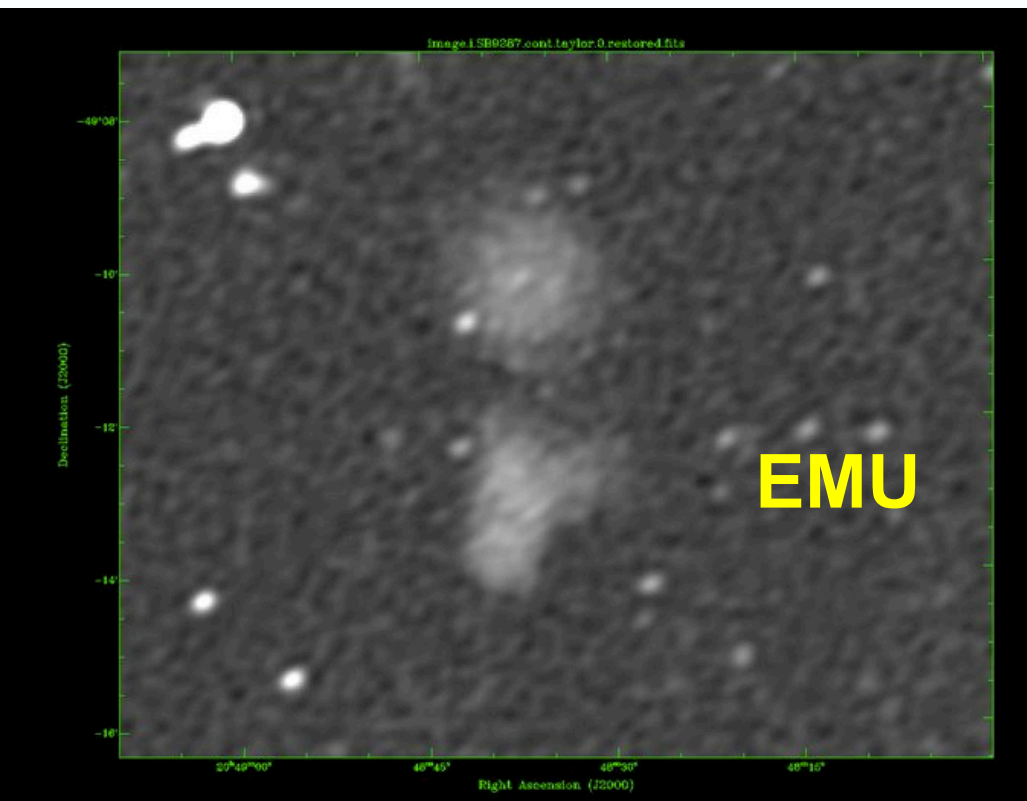
# Obvious explanation: SNR's

Problem with the SNR explanation:



- Volume of the EMU-Pilot is about  $3 \cdot 10^{-5}$  of the Galaxy
- There are ~300 known SNR's in the Galaxy
- So you expect ~ 0.1 SNR in EMU-PS
- Probability of finding 2 is ~ 0.4%
- So very unlikely to be SNRs

# Could they be half of a dead RLAGN



Con:

- only one lobe in ORC1
- ORC1 and ORC2 are edge-brightened
- No obvious optical counterpart

# Why are they so uniform?

- Could it be a selection effect?
- Maybe there are bigger and smaller ones but bigger ones may be too faint, and smaller ones are not obviously extended sources
- But ORC1-3 are  $\sim 6$ -7 beams across – we would still expect to see ones about 4 beams across
- I have searched the EMU-PS and found 44 candidates (most will be SB galaxies, FR II lobes, or cluster halos), but no good candidates are much smaller or bigger.



# Other possible explanations


## - Each has good counter-arguments

- Starburst ring/Ring galaxy (no optical counterpart)
- Einstein ring (too big)
- Planetary nebula/Pulsar wind nebula/WR star (too many)
- Cluster halo (edge-brightened)
- Shock around bubble from SF outflow (no optical counterpart)
- More than one explanation (but size is so uniform)

My favourite explanations:

- Shock wave from central (unknown) transient event such as BH merger – but why do we see two together in ORC2+ORC3?
- Double lobe radio source with a dead host – but why are they edge-brightened?

*We acknowledge the Wajarri Yamaji people as  
the traditional owners of the ASKAP site*



YOU ARE NOW LEAVING THE  
MURCHISON RADIO-ASTRONOMY  
OBSERVATORY  
THANK YOU FOR BEING RADIO QUIET

