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Isolating AGN Using Wide-field VLBI & e-MERLIN Observations

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e-MERLIN and Jodrell Bank Observatory
A radio astronomy facility for the SKA era

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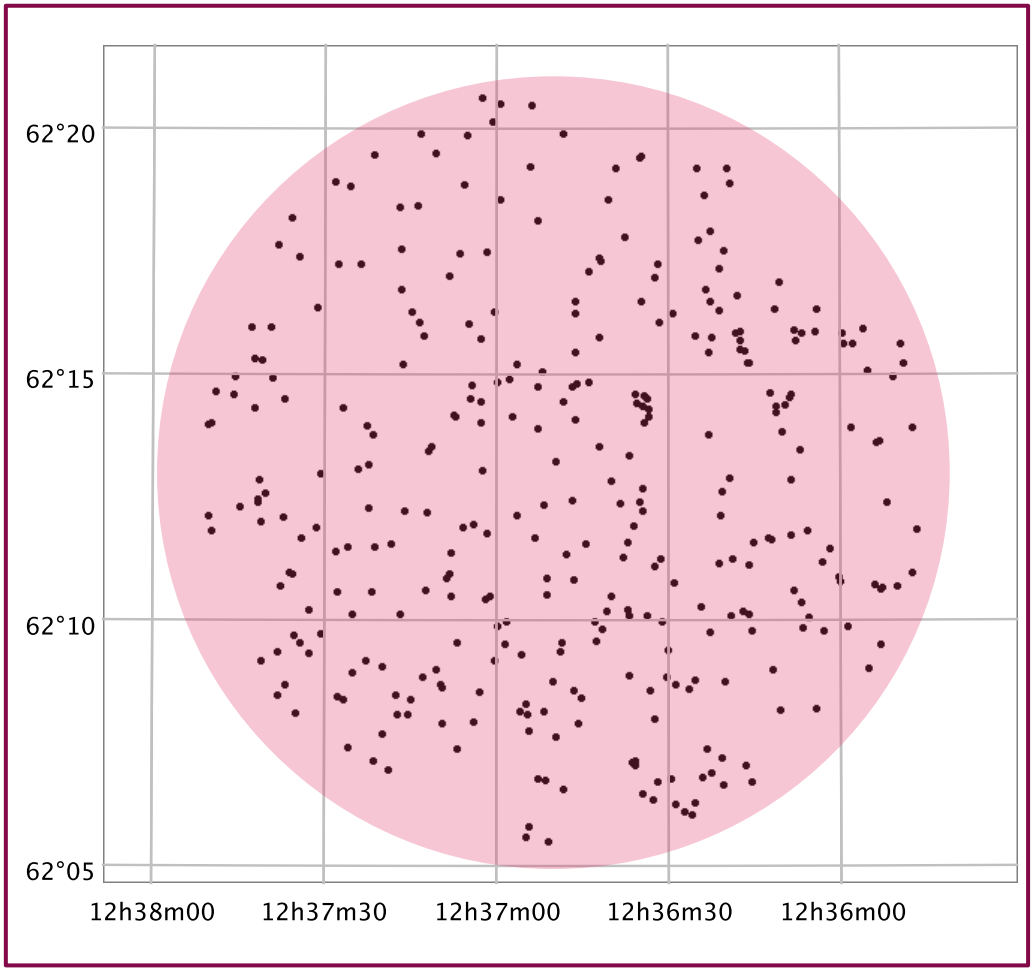
Introduction

1. Wide-field EVN observations of GOODS-N

2. Untangling SF and AGN - first results from the first epoch of data in combination with eMERGE

Conventional Wide-field VLBI

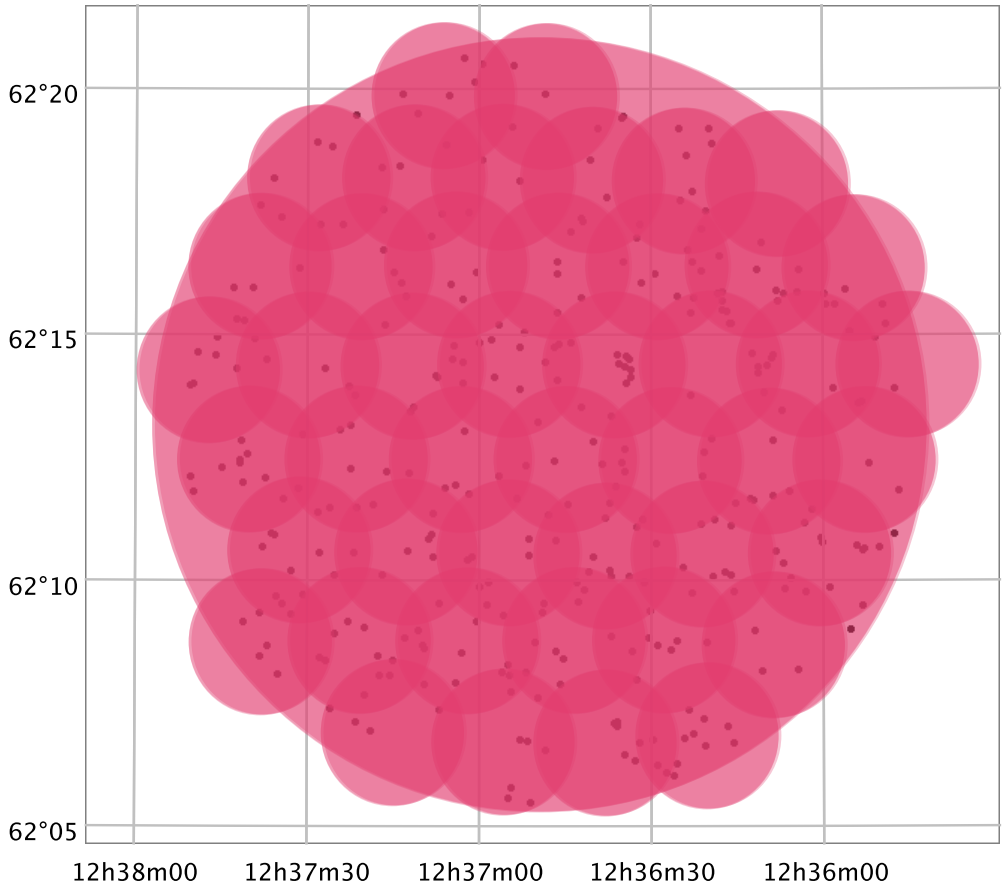


HDF-N eMERGE positions (Wrigley et al. in prep)

- Correlate on pointing centre (ultra high spectral & temporal resolutions)
- Large (>TB), single data set
- Have to phase shift whole data set to image sources

Multiple simultaneous phase centre observing

(Deller+2011, Keimpema+2015)

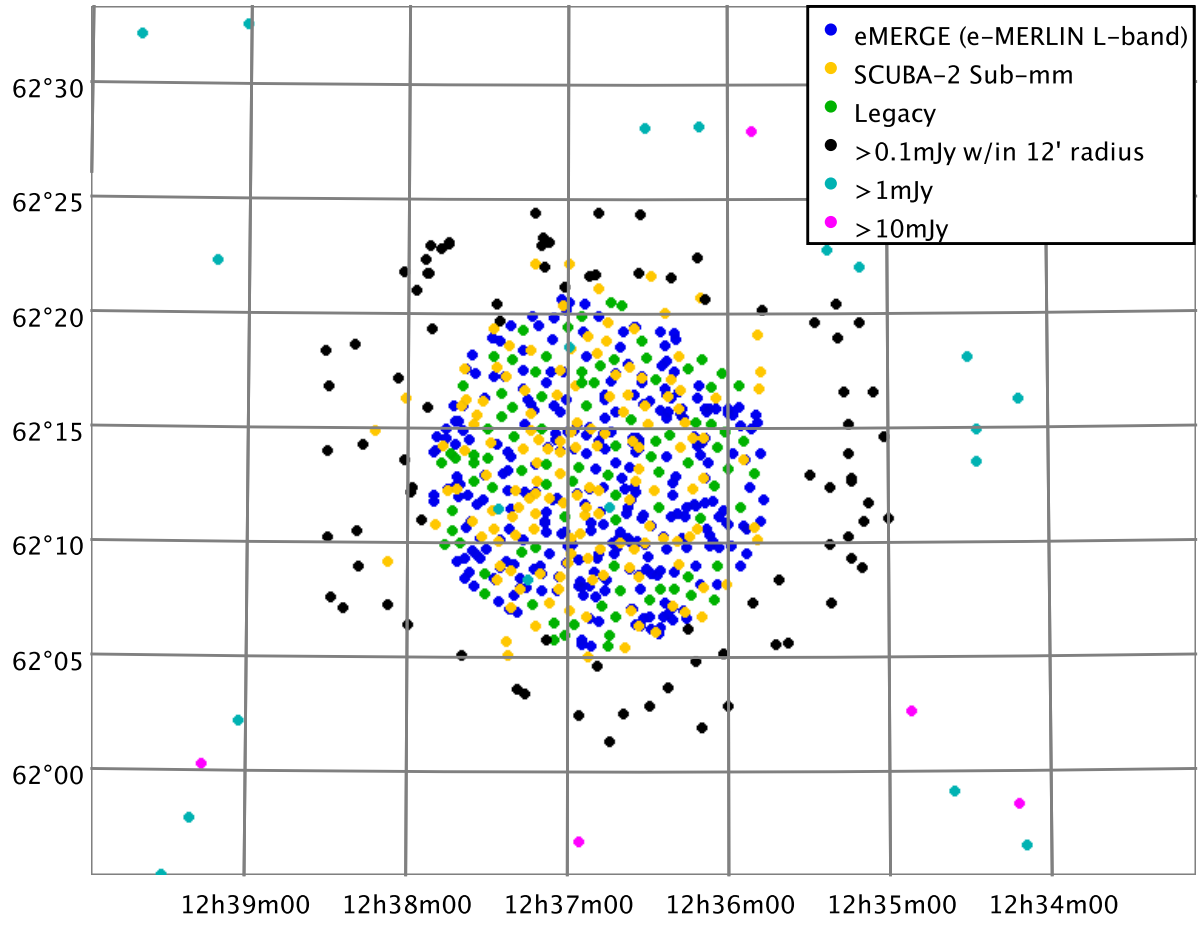


HDF-N eMERGE positions (Wrigley et al. in prep)

- Correlate on pointing centre, shift and re-correlate w/ coarser temporal & spatial averaging.
- Large (>TB) data but comprised of small (~GB) sets
- Same calibration applies to all

→ embarrassingly parallel

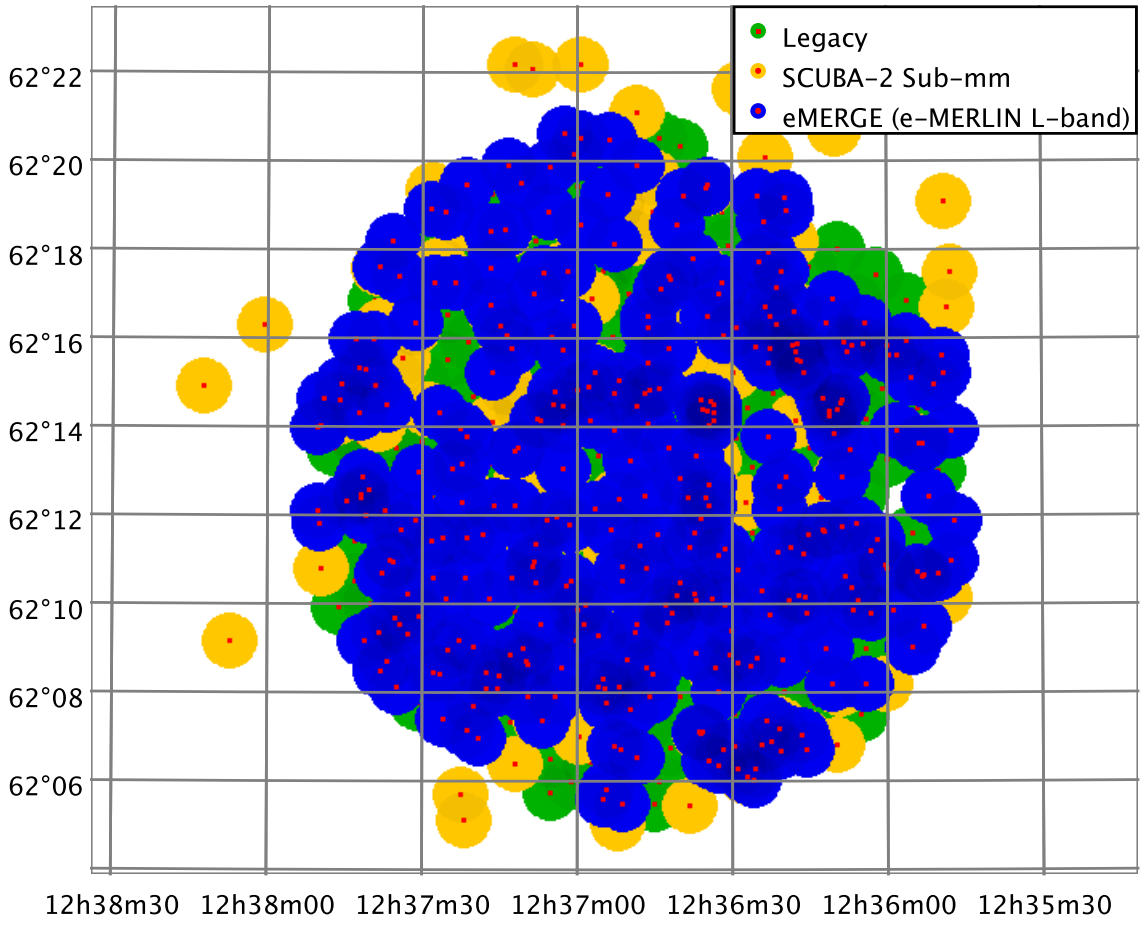
Wide-field EVN observations of GOODS-N



- 699 targeted sources
- EVN 1.6 GHz, 128MHz BW
- Two areas:
  - Central 15’
  - Outer annulus (20’ diameter)
- Science targets
  - Sub-mm
  - eMERGE
  - Transients

Central region

- Covers 15’ diameter area to complement the eMERGE project

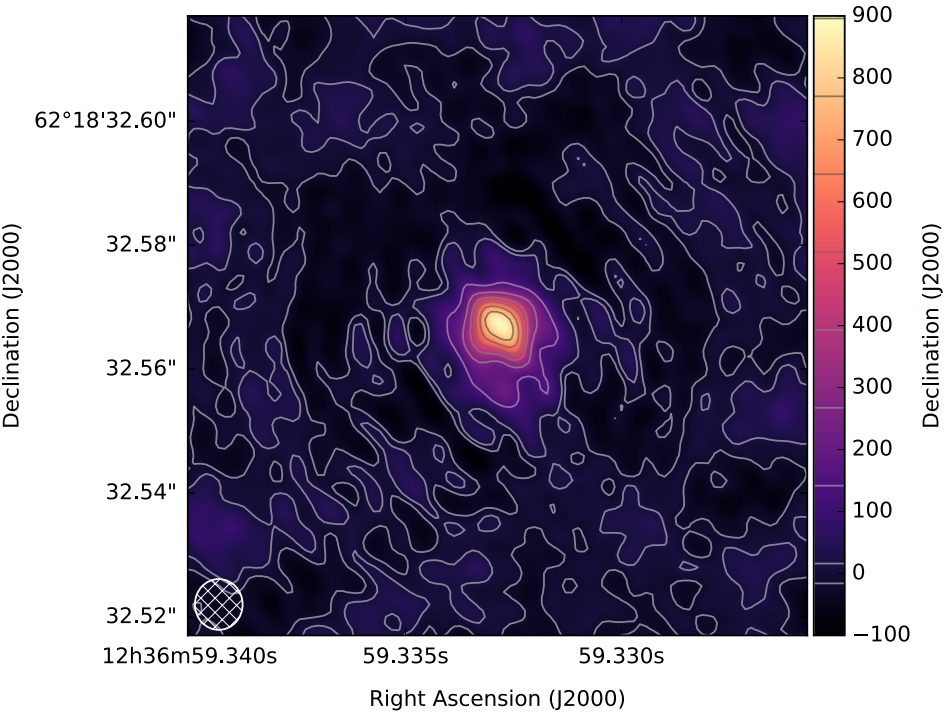


- Ef & Lovell offset to create even sensitivity
- 24/72 hrs taken w/ max. r.m.s of 5μJy/bm
- Expect 1.5-3μJy/bm
- Cover entire area w/in 1% smearing

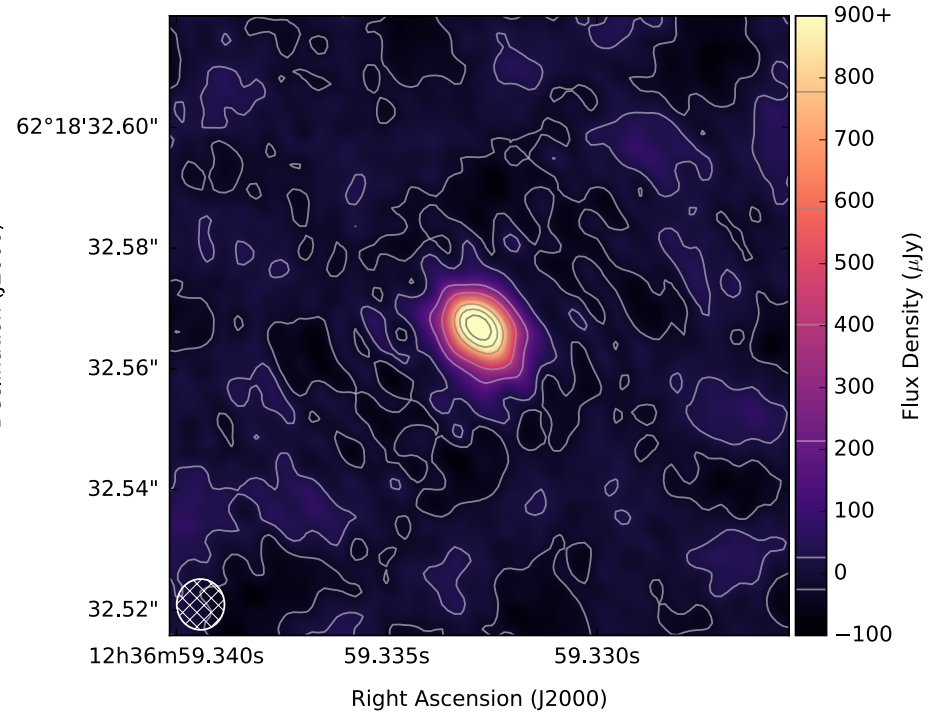
Multi-source Self-calibration (arXiv:1601.04452)

- Uses the combined response of targeted sources to permit self-calibration and reduce phase errors.

Phase referencing
SNR = 43.2



Multi-source self calibration
SNR = 102



Previous VLBI surveys of GOODS-N

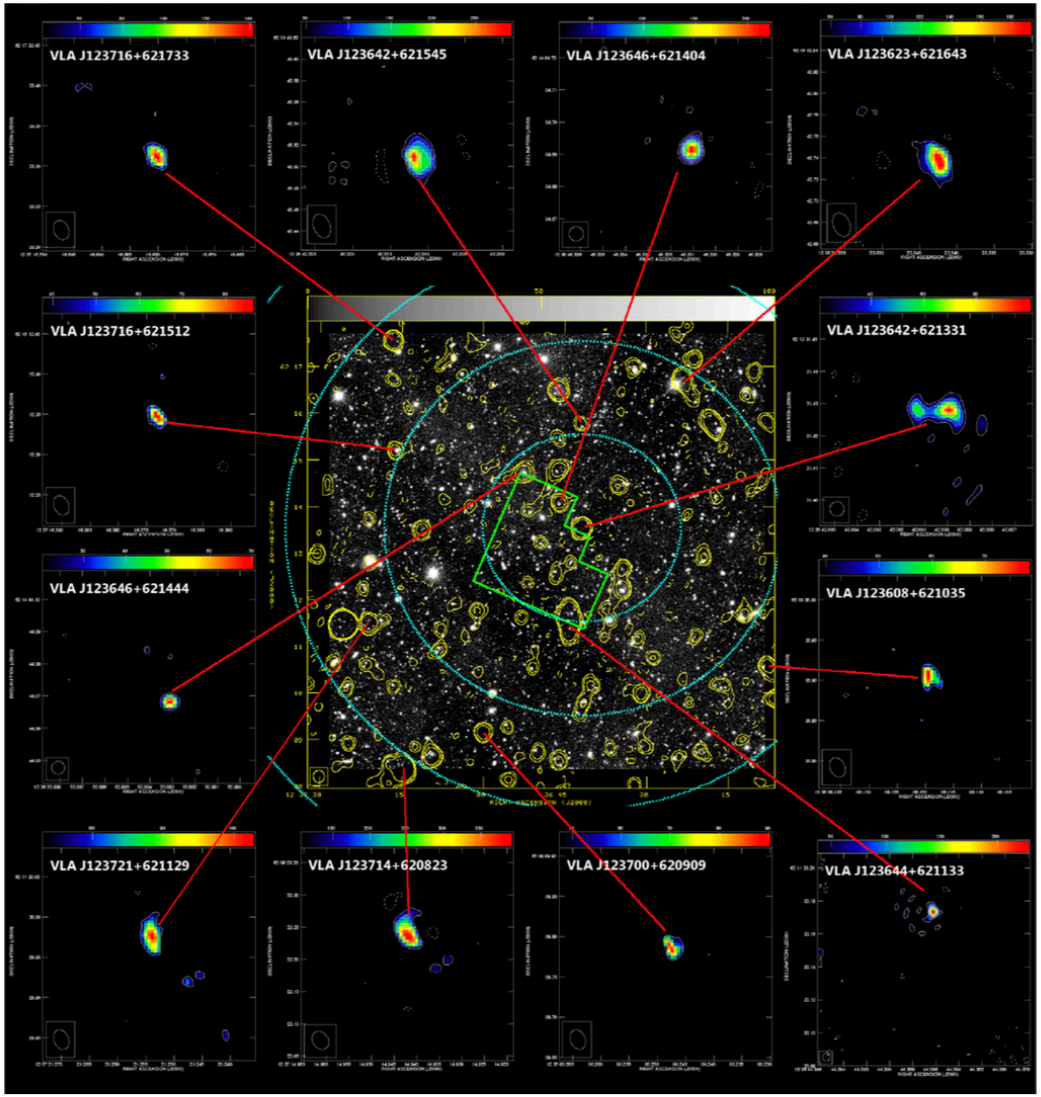
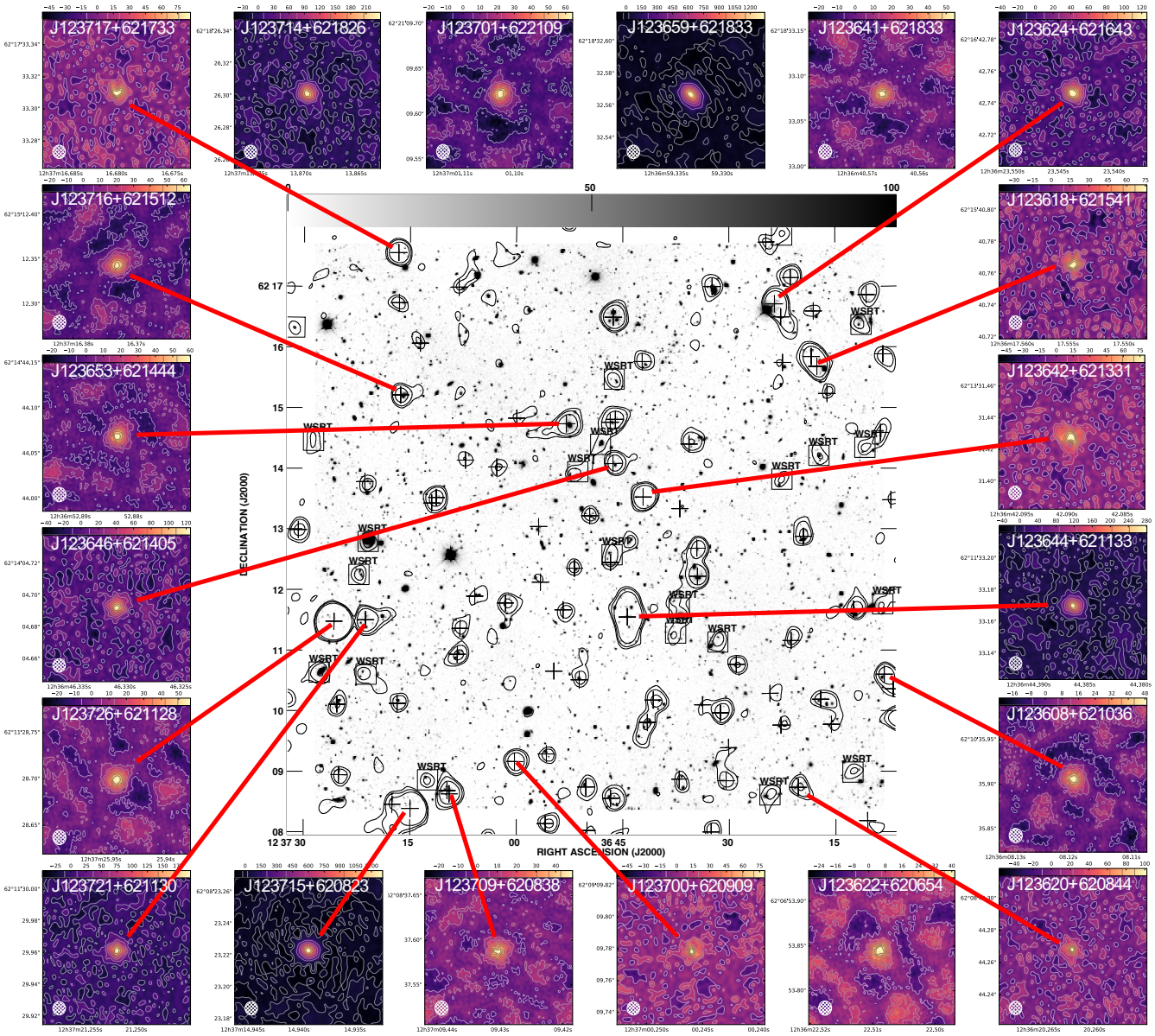


Fig. 1. Composite image of the radio (WSRT 1.4 GHz) – optical overlay image of the HDF-N and HFF, surrounded by postage stamp images of the twelve compact VLBI-detected radio sources. The cyan circles represent annuli of decreasing resolution and sensitivity, and are drawn at 2, 4, 6, and 8 arcmin radius w.r.t. the phase center which coincides with radio AGN VLA J123642+621331 (see text Sect. 3).

- Garrett+2001:
  - 2 detections
  - First wide-field observation
- Chi+2013:
  - 12 detections, with r.m.s. 7.3μJy/bm r.m.s

  -> detections of weak AGN in star-forming systems.

And the present:



- 20 detections
- 5.5uJy/bm (expect 1-2uJy in the end)
- Mixture of AGN cores, sub-mm galaxies and SF + AGN hybrids
- Paper is on its way!

1. Wide-field EVN observations of the GOODS-N

2. Untangling SF and AGN - first results from the first epoch of data in combination with eMERGE

eMERGE - e-**MER**lin **G**alaxy **E**volution **S**urvey

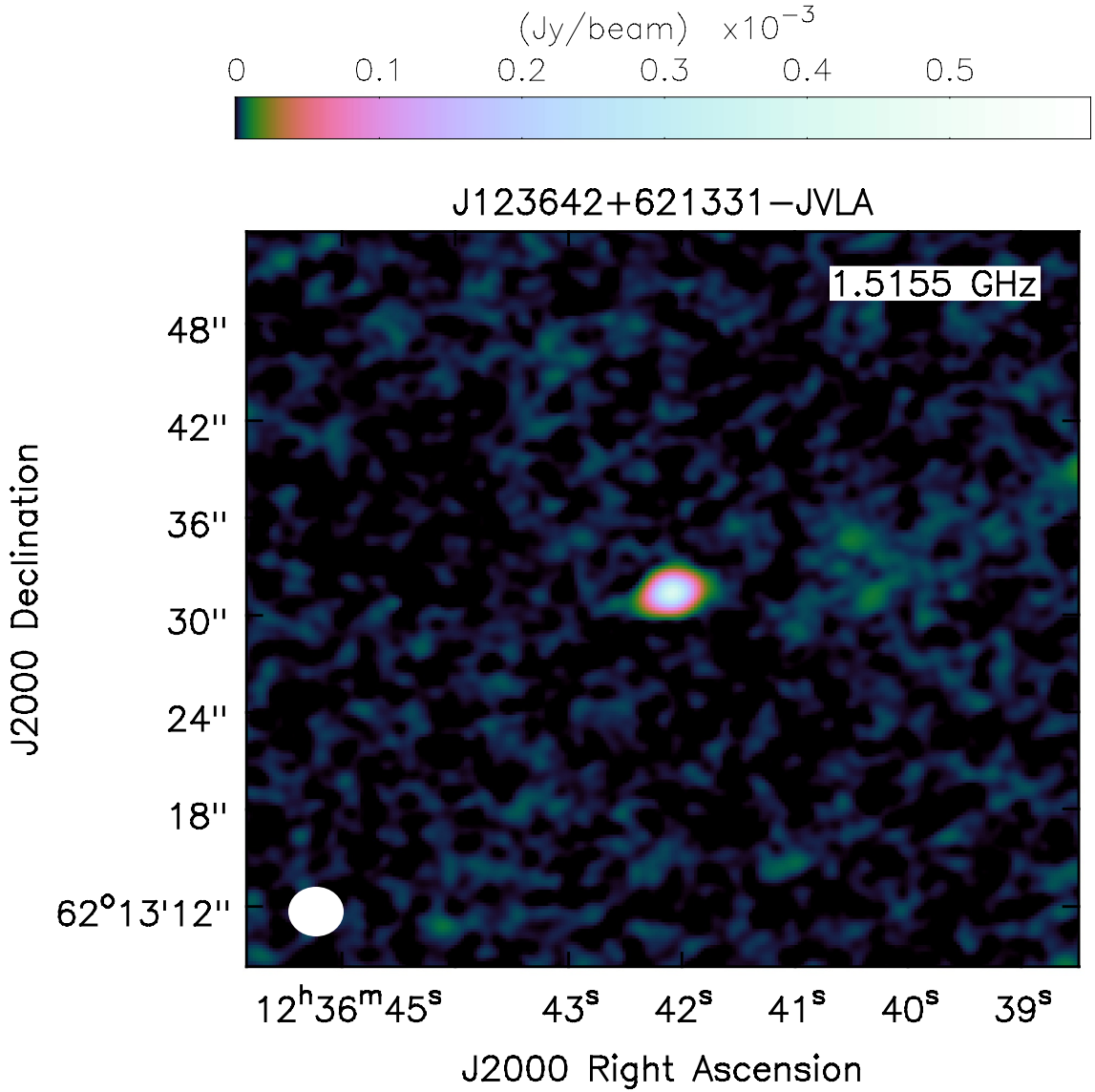
Tier 1

- Allocated 738 hours of e-MERLIN time (360 hr at 1.4GHz & 378 at 5GHz) - sensitivities <1uJy!

- Complemented with L-Band JVLA-A & EVN + C-Band JVLA-A/B/C + EVN

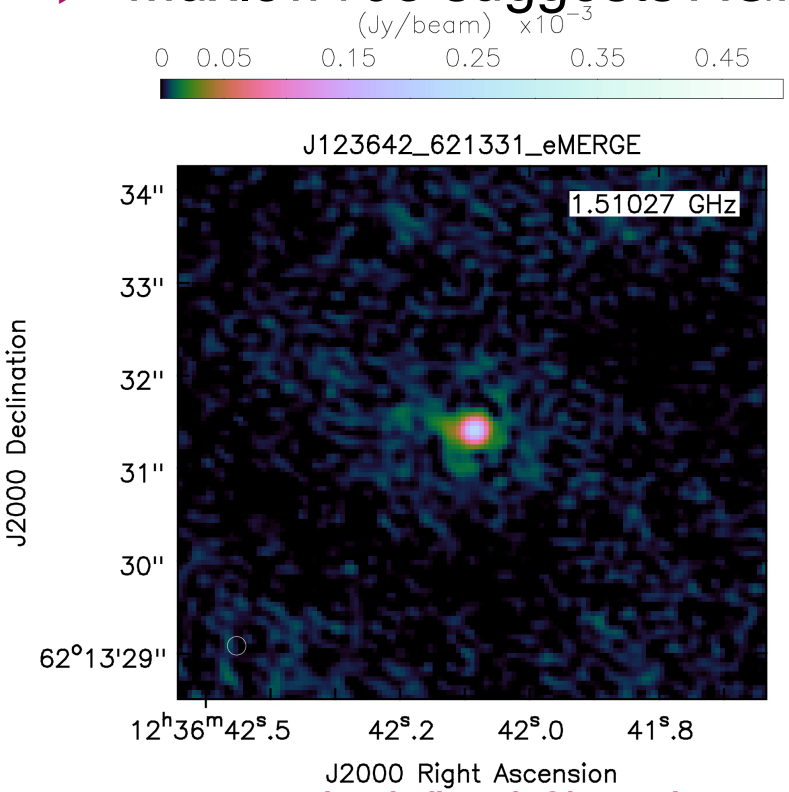
- Compile multi-wavelength, multi-resolution data to:
  - Extend the star formation history to z = 3
  - Allow insights into AGN feedback
  - Separate AGN & star formation

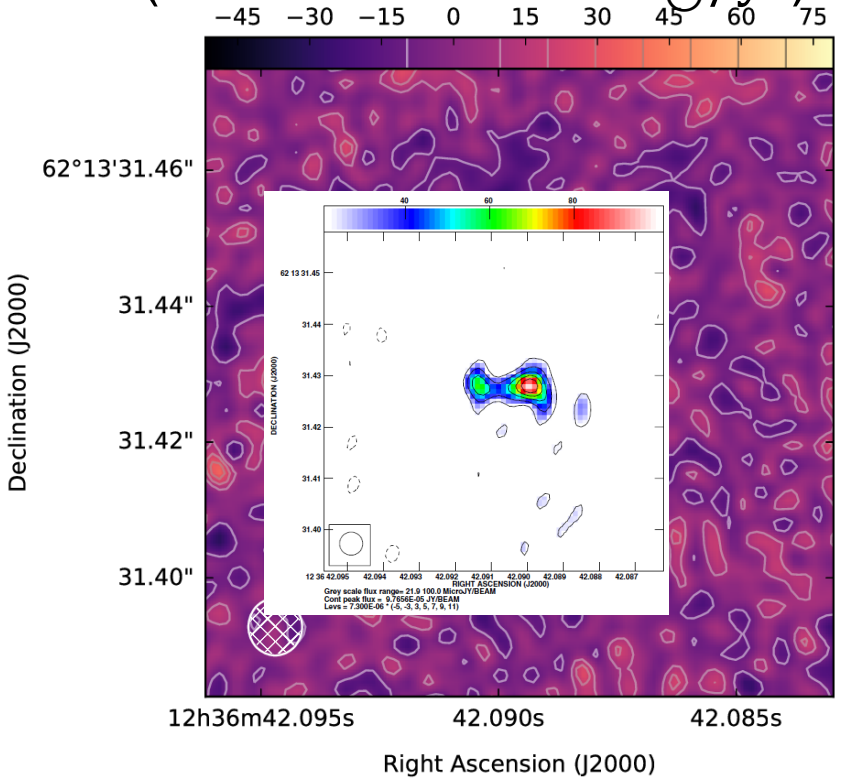
SF+AGN - J123642+621331



J123642+621331– Lo and behold, AGN!

- AGN Confirmed w/ detection by Garrett+01 & Chi+13
- Phot-z suggests z~2 (OIII), originally 4.424 (Lyα) emission (Cowie priv. comm.)
- ISO detection + HST NIR
- Muxlow+05 suggests AGN & SB (SFR now ~ 2000 $M_\odot$/yr)

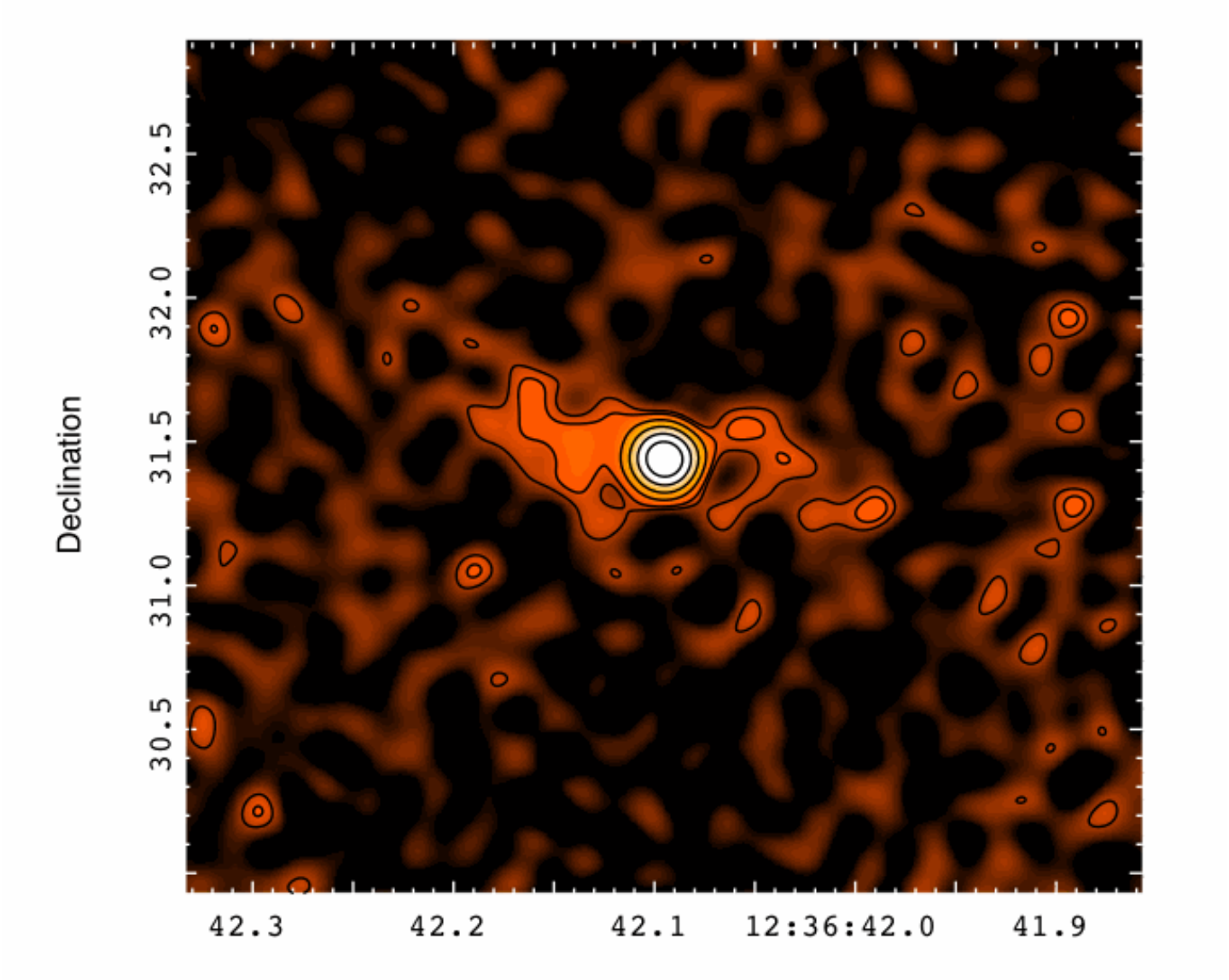




VLBI

8.0 x 7.7mas bm

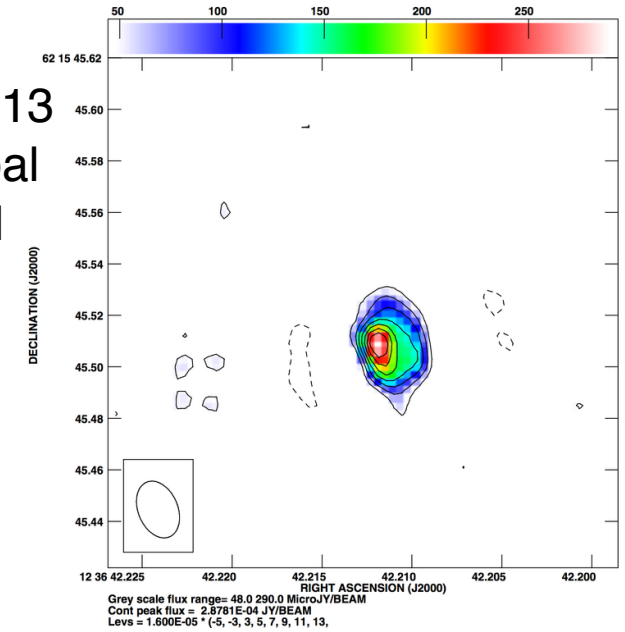
SF+AGN - J123642+621331



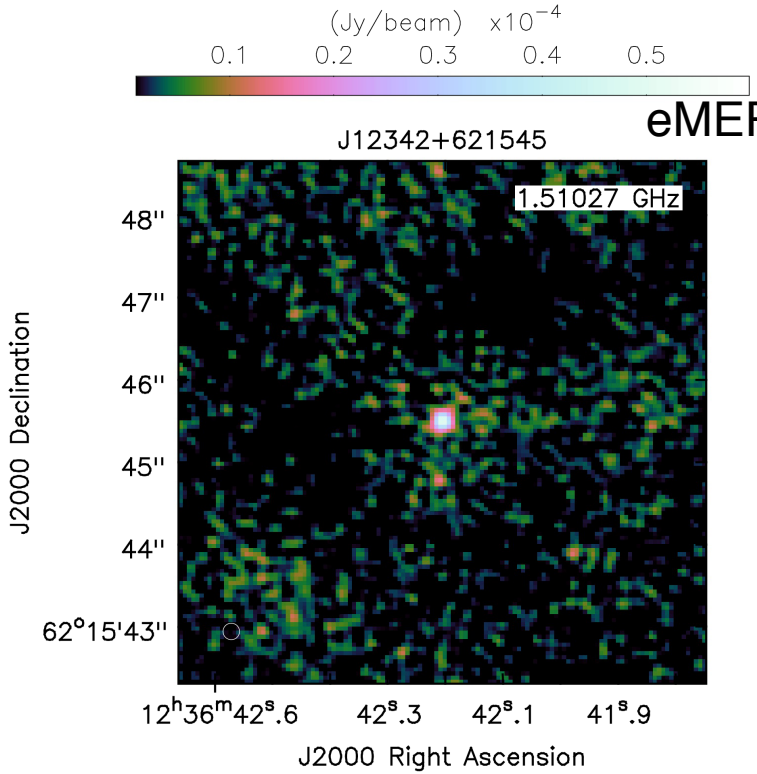
AGN variability - J123642+621545

- Classed as AGN candidate (z = 0.857) detected ISO & Chandra
- Chi+13 (data taken in 2004) detected extremely bright (343μJy) -> brighter than VLA in Morrison+2010 (158μJy)
- Undetected in new VLBI (2014), eMERGE 2013 data supports this. Now only 60μJy.

Chi+13
Global
VLBI



eMERGE 2013-15

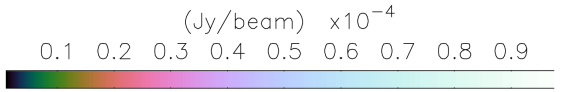


uxlow
5
eMERLIN
Peak
VLA
48 uJy/bm
eak :
50 uJy/bm

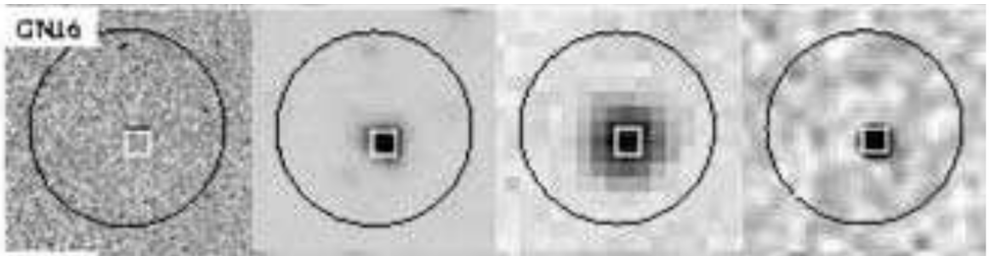
Sub-mm Sources

- Single detection of a sub-mm source J123700+620909 (GN16) ▻ similar properties to J123642+621331
- Detected in Spitzer IRAC + MIPS as well as SCUBA 850um (Pope+06)
- Considering ERO character, considered to be a starburst galaxy at z=1.7, SFR $\sim 1000 \mathrm{M}_{\odot}/\mathrm{yr}$ but there's a weak AGN present.
- AGN detected by Chi et al. + radio excess measurements.

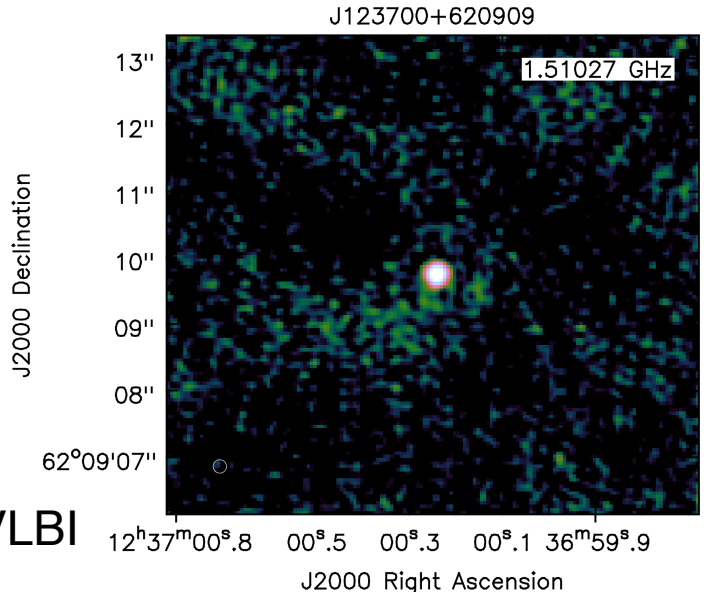
eMERGE L-band



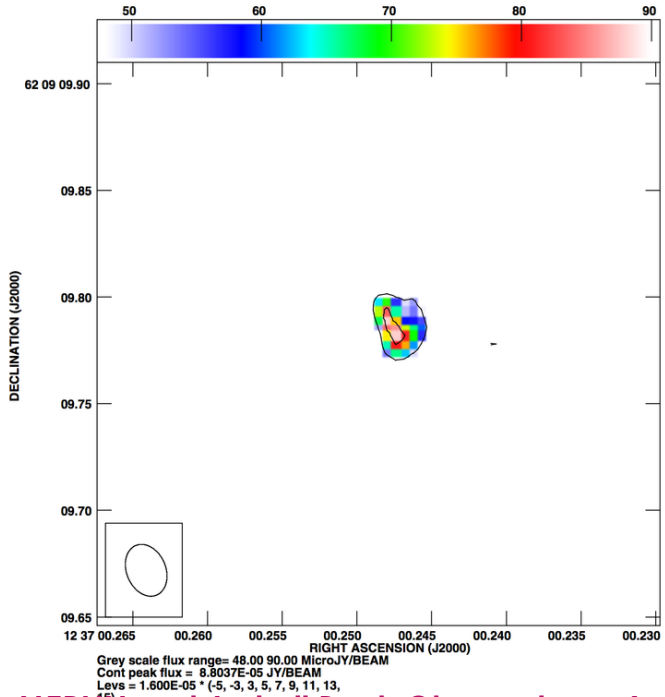
Spitzer



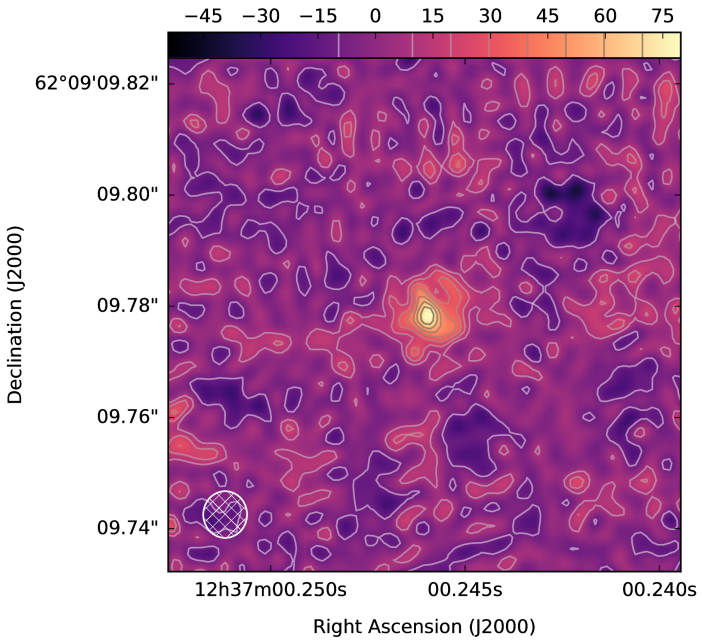
Pope+06



Chi VLBI



EVN VLBI



Conclusions & the future

- Multi-field self calibration makes every field accessible to VLBI.
- GOODS-N EVN observations detect 20 sources (8 more than Chi.) with a population of AGN + SF.
- Sub arcsecond resolution radio surveys can distinguish between SF and AGN permitting a clearer picture on AGN feedback.
- Much more to come! Two more 24hr epochs, uv stacking, eMERGE interim paper release
- Extended e-MERLIN + EVN integration will allow us to resolve structures from arcsecond–milliarcsecond...