The e-MERGE e-MERLIN/VLA/VLBI Wide-field Deep High-resolution Radio Survey of GOODS-N

Update....

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> EVN Symposium Cork 11th July 2022

e-MERGE Deep High-resolution Radio Survey of GOODS-N

Unique high-resolution imaging with arcsec \rightarrow sub-arcsec \rightarrow mas angular resolution, sub-µJy sensitivity, + full *uv*-coverage at λ^{\sim} cms

Goals:

- Investigate star-formation & AGN co-evolution over cosmic time
 - → Detailed AGN-SF feedback over a variety of physical scales
 - → Matched resolution 1.5GHz & 5.5GHz imaging
 - \rightarrow High-z AGN SMBH growth and jet formation investigations

Complement wide-area studies (LOFAR International surveys +....)

- → Very deep, detailed studies of >4000 individual galaxies
- → Utilize diverse deep multi-wavelength GOODS-N coverage

e-MERGE Delivery

DR-1 Released 2021 – Initial verification imaging of central 15' field

Heterogenous array imaging with complex (33%-50% fractional bandwidth) wide-field PSFs, + associated data weighting, imaging software strategy in WSClean, auto-flagging....

DR-1.5 mas-scale imaging tests(30%) EVN EG078 + e-MERGE DR-1

Initial Science extraction: Work in Progress – but awaiting DR-1 multi-band catalogue paper...

DR-2 Release 2023 – Deep high-resolution imaging of full 30' field x4 DR-1 area + x2 depth in inner 15' field

+ Deep 5.5GHz e-MERLIN+VLA mosaic of central 15 arcmin field

EVN: Jack Radcliffe+ (2018) A&A 619, A48 + MSc student Theo Matespane & Hons student Jayde Bhana VLBA: Ngeri+ In Press

The e-MERGE Survey

Characterizing the nature of the μ Jy radio source population



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Main Release DR-2 – 2023 covering the complete 30 arcmin region involving all the e-MERLIN 1.5GHz data (unaveraged [τ, γ] and being reprocessed)
>25TB 1.5GHz data >10⁹ pixels in 30 arcmin field Seamless transition inner → outer field
VLA + 380hrs e-MERLIN+Lo 5.5GHz combination 7-pointing centre mosaic
500nJy/bm in central region, ~50mas bm.

VLA + e-MERLIN 1.5GHz combination (VLA 42hr + 20 days of e-MERLIN data) 500nJy/bm in central region 1μ Jy/bm in outer annulus



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Properties of the 848 catalogued radio sources in DR-1 Size (kpc) Muxlow+ (2020) MNRAS 495 1188 5 20 0 10 15 SFG ٠ Δ AGN radio-quiet AGN 0.8 radio-loud AGN **R-LAGN** e. ۳. Fraction SFG Sources with catalogue numbers 10²⁶ 156 discussed in description paper **R-Q AGN** 1.0 Sr (1.4GHz) [mJy] Padovani+ (2014) 0^{3} -1.4GHz (W Hz⁻¹ 1024 (M_©yr 0^{2} 180 Population 150 SFR_{radio} dominated by ۱0¹ 120 1022 Ν small (<20kpc)</pre> 90 high-z systems ۱0⁰ 60 32 30 0⁻¹ 10²⁰ A few example DR-1 5 6 0 2 3 radio sources follow.... 0⁻² Zphot 2 3 5 0 4 6 Z_{phot}

Embedded Radio-Quiet AGN Systems



Extended steep-spectrum (α >1.62) starburst + embedded low-luminosity AGN+jet?

e-MERGE:

Deep high angular resolution images of systems containing radio-quiet AGN – little is known about the detailed radio properties for this population at higher redshifts

Radio emission extends across face of massive spheroidal galaxy Bright galaxy core shows BL emission → AGN optical activity AGN or nuclear starburst? – Compact at e-MERLIN resolution EVN non-detection (30% data – catalogue s/n=6 cut-off (54µJy/bm))

Some lower resolution e-MERGE suite images show possible NE-orientated core-jet structure

Nature of the faint µJy R-L AGN Systems - Only 2 'classical' Radio-Loud (mJy) double sources seen in DR-1

Use e-MERGE+EVN combination imaging to investigate jet length & sidedness – constrain models of SMBH jet launching to investigate SMBH mass & spin with redshift

Combination imaging beams from 150 – 5 mas planned to study jet properties close to the AGN core

62 14 08

06

05

03

02

01

12 36 46 8

46.6

464

Declination (J2000)





Wide-Angled Tail J123725+621129

Inner collimated jets disrupted by surrounding cluster gas at hotspots – ISM/ICM interface

Spectral index map from matched resolution L- & C-Band maps.

S_{1.5GHz} 5.5mJy − Brightest object in DR-1 Spectral age calculated from spectral index in the lobes assuming a fiducial magnetic field strength of $5\mu G \rightarrow ~50Myr$



Core overlies nucleus of I=22.9^{mag} z=1.2653 galaxy Massive elliptical galaxy ~1.8 \pm 0.1 x 10¹¹M_{\odot}



Wide-Angled Tail J123725+621129

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Core overlies nucleus of I=22.9^{mag} z=1.2653 galaxy

Massive elliptical galaxy ~1.8 \pm 0.1 x $10^{11} M_{\odot}$



Comparison with a Representative WAT Sample

Very luminous and small

Sample drawn from: Blanton et al. (2000) Image: Provide the state of the state o

The highest redshift Wide-Angled Tail source yet studied in detail. Well above eMERGE sensitivity luminosity cut off.

Sample is not complete

purely representative in luminosity, size, and redshift coverage





Comparison with a Representative WAT Sample

Hardcastle & Sakelliou (2004) showed that

WAT jet termination length is related to

Very luminous and small Tiny jet termination length (Core-hotspot length)



The e-MERGE Update Summary

Targeted deep field to image µJy radio sources in detail from arcsec to mas-scales

Constrain models of star-formation and SMBH co-evolution, and associated feedback interactions across cosmic time from >4000 individual galaxies.

Utilise the extensive multi-band coverage across the e-MERGE field

Complementary to extremely wide field deep surveys of radio sources at lower angular resolution.

DR-1 released and in science exploitation for brighter sources

DR-1.5 initial test combination imaging with VLBI (EVN)

DR-2 delivery expected 2023 with science exploitation in 2024/25