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The University of Manchester

SPARCS-North Survey: Exploring the resolved µJy extra-galactic radio source population with EVN+eMERLIN

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Motivation

□ Wide-Field VLBI

□SPARCS-North with EVN+eMERLIN

Other wide-field VLBI Surveys + results

□ Conclusions

Motivation

One Main goal for astrophysics: study the SFR and galaxy evolution across cosmic time

SFR peaks at $z \sim 1-2$, with AGN accretion showing a similar trend: implying coevolution = host-SMBH feedback



To investigate this co-evolution, we need to find all the AGN in our fields! MULTIWAVELENGTH APPROACH



- □ Radio measurements require no dust corrections
- **\Box** Radio: Upsurge of sources at sub-milliJansky (at z > 0.1)
- Composed of AGNs & SFGs
- Interferometric (+VLBI) radio continuum surveys: High Angular Resolution and High Sensitivity = Detect synchrotron emission
- □ VLBI T_B > 10^{5} K: clear cut AGN indicator (AGN vs SF)

Interferometric vs. VLBI

- VLA, MeerKAT (~arcsec scale resolution) insufficient to spatially resolve AGN & SF activity in distant galaxies
- eMERLIN (~sub-arcsec) partially resolving these galaxies
- VLBI provide ultra-high milliarcsecond (mas) angular resolutions ~parcsec scales
- VLBI only detects compact emission with high brightness temperatures TB > 10⁵K: AGN at z > 0.1
- VLBI provides a powerful extinctionfree tool to hunt for 'elusive' AGN and spatially resolve AGN & SF



Muxlow+2020

Wide-Field VLBI

- VLBI historically limited by small FoV (~ few central arcsecs), time & bandwidth smearing
- Software Correlators Development [Deller et al. 2007, 2011, Keimpema et al. 2015], widening bandwidths & super-computers: extremely high spectral & temporal resolution

Allows imaging of the entire primary beam of a VLBI array <u>Advantages:</u> Imaging entire FoV increase sample size & see multiple science targets in a single observation

- > Wide-field VLBI made possible by:
- Multiple phase-centre Correlation
- Multiple-source self-calibration (MSSC)

* Wide-Field VLBI Survey of the SPARCS-North



□ Square Kilometre Array Pathfinder Radio Continuum Surveys (SPARCS): centered on SDSS North @ *R.A.* 15 / 33m27s, Dec. 29d12m40s

□ EVN+eMERLIN (first VLBI) survey: 52 Phase Centres based on e-MERLIN survey

□ r.m.s = ~6 µJy/beam

- □ Multi-resolution = 10-100 mas
- **11 VLBI Candidates**



Increase in rms/Imaging fidelity

(~sub-kpc scales)

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Serendipitous discovery?

Njeri et al. *nearly submitted*



28×22 mas

Other Wide-Field VLBI Surveys:

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HDF field Chi et al. 2013

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WSRT-Bootes field Garrett et al. 2005



VLBA-GOODS North, Deane et al. In prep

EVN-GOODS-North Radcliffe et al. 2018





VLBA-COSMOS Herrera-Ruiz et al. 2017, 2018

Some science results..binary SMBHs

Herrera-Ruiz+17



Deane+14





- □ Z ~ 1.224 T_B ~ 8.6x 10⁶ K L_{1.5GHz} ~ 6.7 x 10²7 W/Hz
- □ VLBA S/N ~5.7: (source detected in ancillary data)
- □ VLBA position does not coincide with peaks in JVLA & eMERLIN
- □ Merging galaxy system: SF & AGN co-evolving system
- □ Merging galaxy systems: require VLBI

*** Conclusions:**

- 'Wide-field VLBI' technique has facilitated observational & computational demands of large surveys that would otherwise be impossible (e.g. Garrett+00, Middelberg+10,13, Chi+13, Herrera-Ruiz+17, Radcliffe+18,20, Deane+prep, Njeri+).
- > Wide-field VLBI opens possibilities for new/important astrophysical discoveries at mas scales over wide areas
- Directly probe the missing population of dual-AGN & binary SMBH = Crucial for SKA surveys
- Expected that occurrence of such sources is common: limited by sensitivity and FoV.