The Legacy e-MERLIN Multi-Band Imaging of Nearby Galaxies Survey - results
Rob Beswick
On behalf of the LeMMINGs e-MERLIN Legacy team.
e-MERLIN

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Outline

e-MERLIN (& LeMMINGs) – background & capabilities

Highlights of results

The future – what next??

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e-MERLIN (SKA-pathfinder) operating at cm-λ with μJy sensitivity and ~10-220km baselines

Key/integral part of the EVN
- providing 'short' spacing baselines
- Now becoming fully integrated

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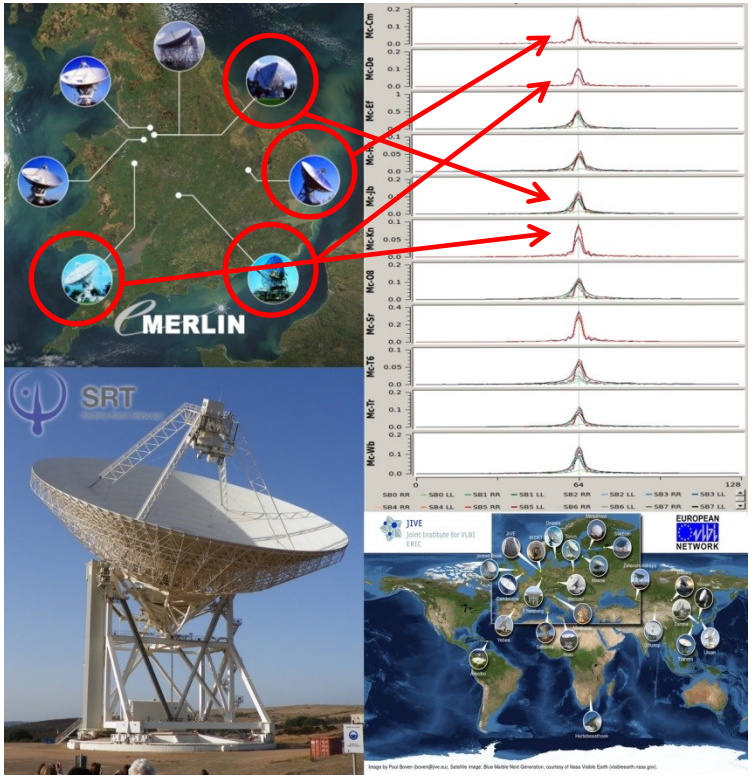
e-MERLIN & EVN

First science eEVN + e-MERLIN + SRT run (18/19th Sept 2018)

- 4 e-MERLIN stations (CM, KN, DE, & MK2)



Key/integral part of the EVN

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e-MERLIN Proposal deadline

PATT proposals (aka PI-led proposals of all sizes)

- 6 monthly call cycle (spring/Autumn) – fully open
- Proposals accepted via Northstar proposals system

See www.e-merlin.man.ac.uk/observe/

- Online Simulator tools and exposure calculators available from e-MERLIN website
- Any use questions : **e-merlin@jb.man.ac.uk**

Typical oversubscription rates are

- 4-3:1 (all proposals)
- 8-5:1 (proposals requesting Lovell telescope inclusion)

NEXT OPEN PATT DEADLINE:
15th November 2018 –
23:59:19 UTC

See call at www.e-merlin.ac.uk – or speak to any e-MERLIN person here this week for info.

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The e-MERLIN Legacy project : LeMMINGs

(a. k. a :
Legacy **e-M**ERLIN **M**ulti-band **I**maging of **N**earby **G**alaxie**s**)

Rob Beswick (JBCA/e-MERLIN)

Ian McHardy (Southampton)

Plus the whole LeMMINGs

e-MERLIN Legacy team

Extra special mention to the key people that have **really** done the work:

Raneri Baldi, David Williams, Jonathan Westcott, Megan Argo, Bil Dullo

Original LeMMINGs Science case

- Basic premise of survey is to
  - Image a complete (representative) sample of nearby galaxies, encompassing all galaxy types, at sub-arcsecond angular resolutions and microJansky sensitivities. Multi-λ follow-up. Provide a public legacy data-set.
- Built around three Core science themes:
  1. Measure star-formation activity and star-formation.
  2. Make a complete census of AGN activity and jet structures in galaxies
  3. A serendipitous parsec-scale imaging survey of the cold ISM via HI absorption and maser emission.
- 2-tiered approach to image ~300 galaxies. Majority via snapshot imaging plus a smaller deep sample.

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Original LeMMINGs Science case

Updated for reality

Basic premise of survey is to

- Image a complete (representative) sample of nearby galaxies, encompassing all galaxy types, at sub-arcsecond angular resolutions and microJansky sensitivities. Multi-λ follow-up. Provide a public legacy data-set.

On-going process working well - lots coming!!!

- Built around three Core science themes:
  - Measure star-formation activity and star-formation.

FIRST results DR1

  - Make a complete census of AGN activity and jet structures in galaxies

FIRST results DR1

  - A serendipitous parsec-scale imaging survey of the cold ISM via HI absorption and maser emission.

- coming soon

- 2-tiered approach to image ~300 galaxies. Majority via snapshot imaging plus a smaller deep sample.

Results DR1 (1/3 statistical sample), lots of single gal. results (Deep tier)!

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Two tier approach – Results thus far..

- Deep 'targeted' tier

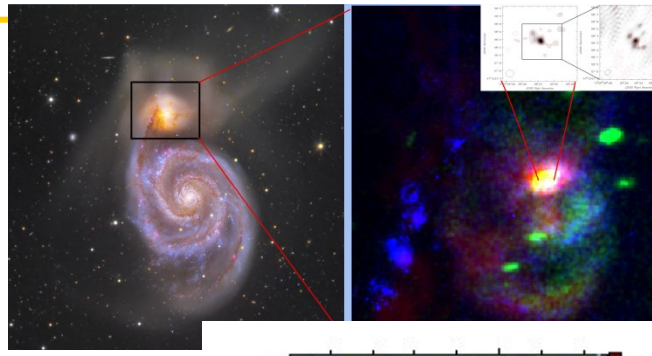
Multiple 'single-source' papers from deep tier programme + usage of data in other projects.. (incomplete selection)

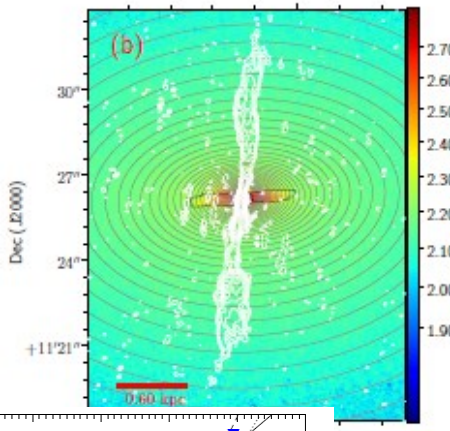
  - Westcott et al 2016 MNRAS, - IC10
  - Dullo et al 2018 MNRAS- NGC5322
  - Williams et al 2017, MNRAS – NGC4151
  - Ramparadarth et al 2018, MNRAS
  - Williams et al, 2018, MNRAS – NGC6217
  - Westcott et al 2018, MNRAS – NGC1569..
  - Plus multiple papers associated or using LeMMINGs data

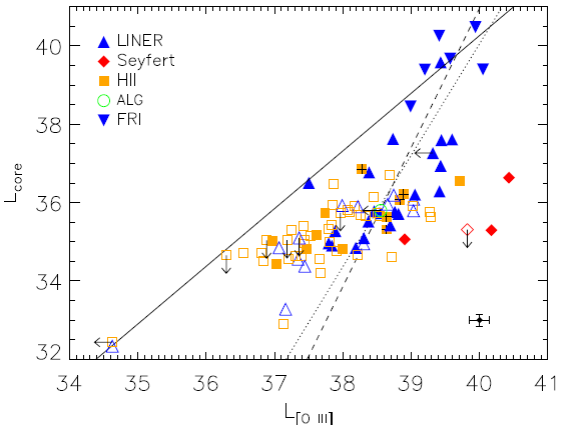
- Shallow 'statistical' tier - 280 gals sample
  - LeMMINGs Shallow paper#1 --

LEM#1 Baldi et al 2018, MNRAS (45pp!).

LEM#2 – Williams et al (radio, X-ray)







Samples

1) Shallow(ish) Sample = **Palomar bright galaxy sample**

- Well selected sample of nearby galaxies (Ho ++ 1995)
- Optical selected (NO radio bias), $B_T < 12.5$ mag
- All galaxy types : Active (Seyfert, LINER), non-active (HII, Absorption line gals)
- Total sample 280 galaxies, following applying a declination cut (>+20deg)
  - Median distance = 20Mpc
- Strong multi-wavelength coverage … both pre-existing and being compiled.
  - Complete HST, Spitzer and (near complete) Herschel
  - Almost complete Chandra imaging (with Associated LeMMING large programme approved to fill gaps)
  - Complete JVLA imaging (L + C-band), and selected sub-sample at 15GHz.

Project Core – e-MERLIN *'shallow'* snapshot imaging survey of whole sample. (1.5GHz – complete, 5-7GHz pending)

2) Deep Sample = small number selected targets of interest at L & C-band with observations ~10 times deeper than shallow tier

LeMMINGs #1 – shallow (results Baldi et al 2018)

- Results release 1 (103 targets - snapshot)
  - image rms ~70μJy/bm @ 150mas ang res @ 1.5GHz
  - 'Core region search only' – inner 1arcmin only
  - 47/103 (~46%) detection rate at F>0.2mJy

Fractions by type:

1. LINER: 22/34 → 65%
2. Seyfert: 4/4 → 100%

} **Active**

3. HII: 16/51 → 31%
4. Absorption line gals: 5/14 → 36%

} **Inactive**

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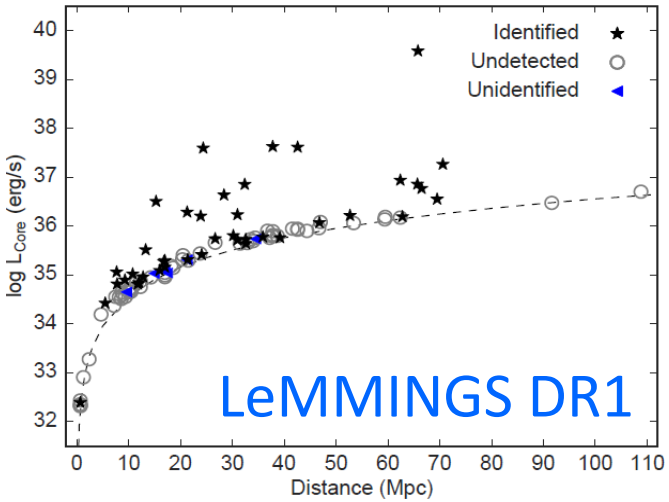
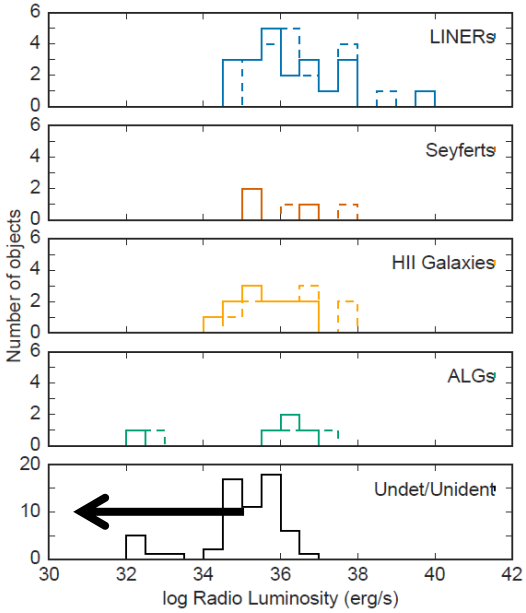
Depth and detection rates

Typical core L_{core}~10^{32}-10^{40} erg/s
(ie. ~100 Sgr A* at L-band
C-band will be ~10× Sgr A*)



Survey depth >10 deeper than previous surveys (e.g. Nagar+, Filho+)
Optical source classification via BPT



Detection fraction follow M_{BH}
Jetted structures in sources >$10^6 M_\odot$

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Typical images

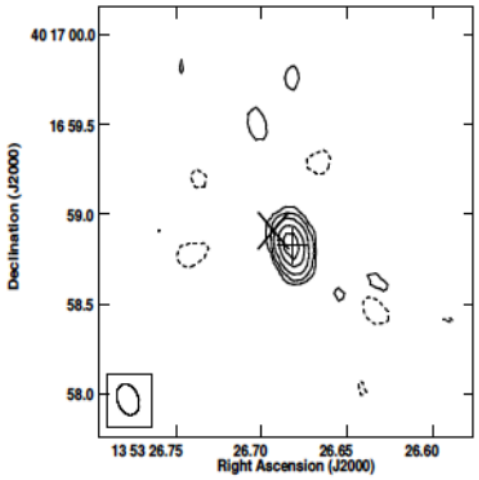
Single core
NGC5353

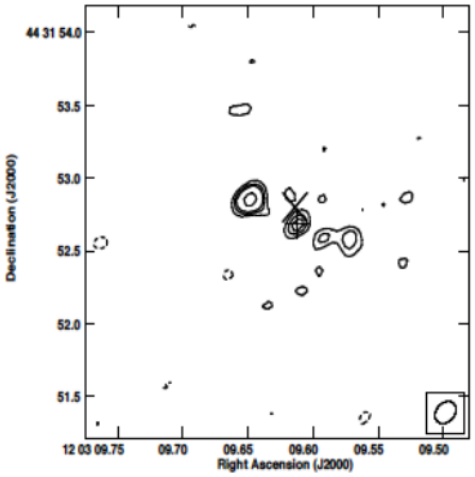
Triple source
NGC4051

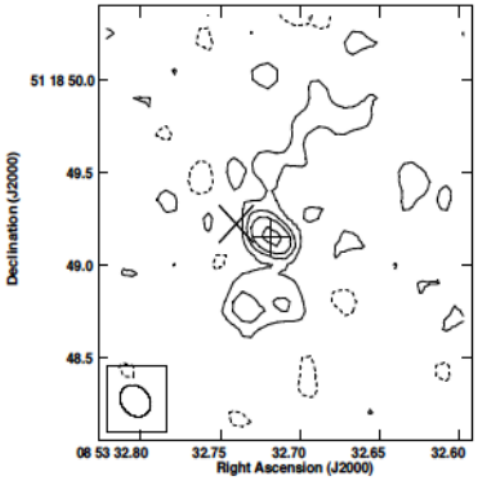
Double jet
NGC2681

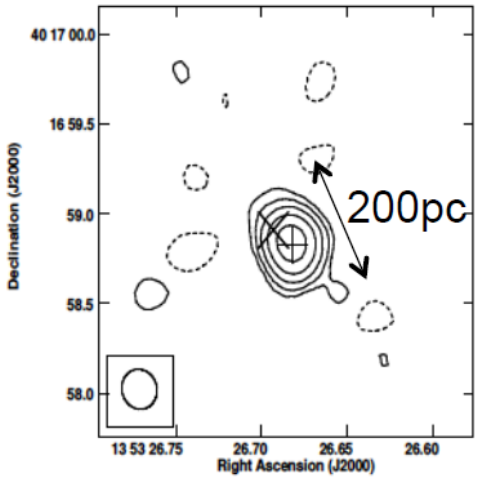
Full resolution

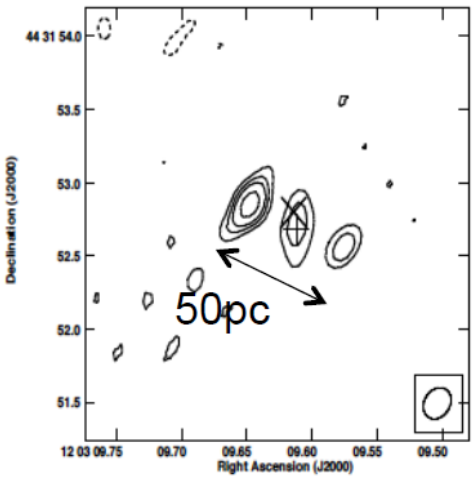
Low resolution

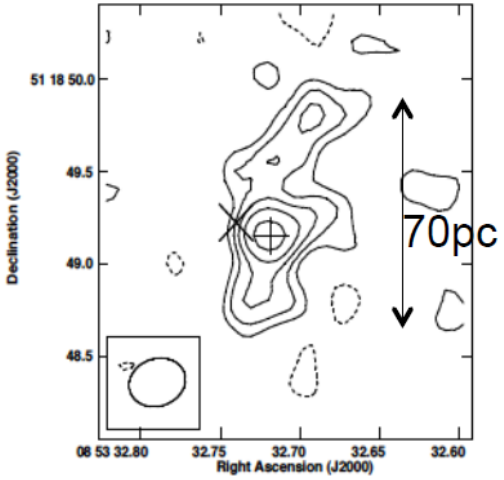












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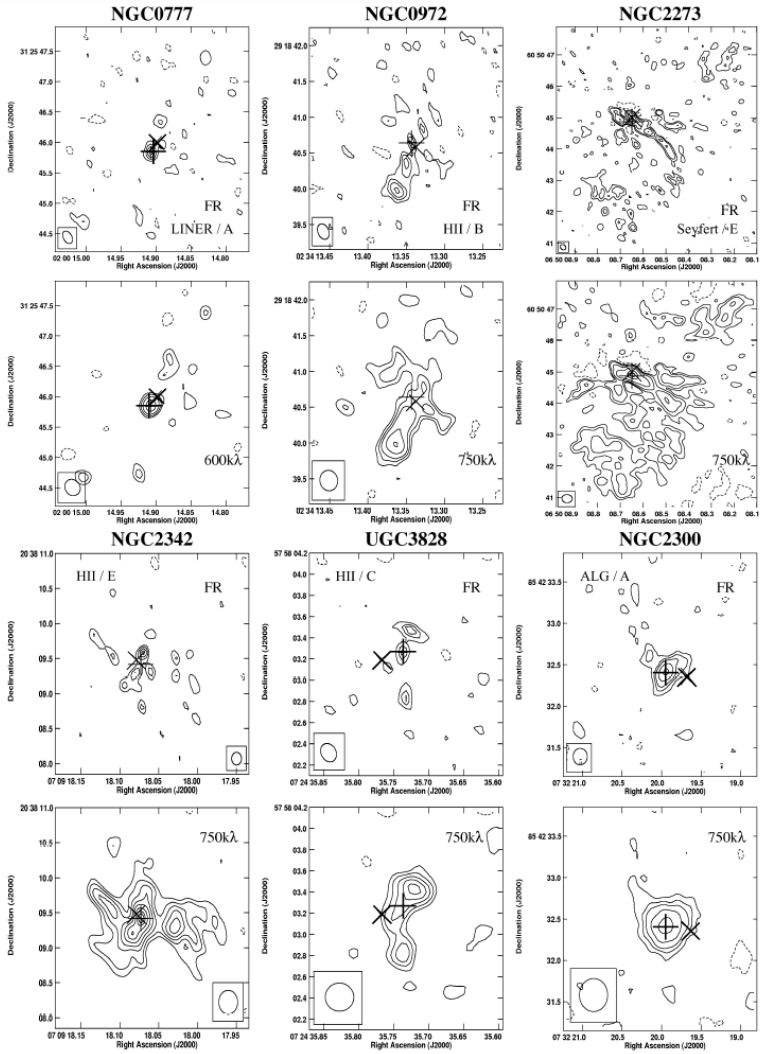
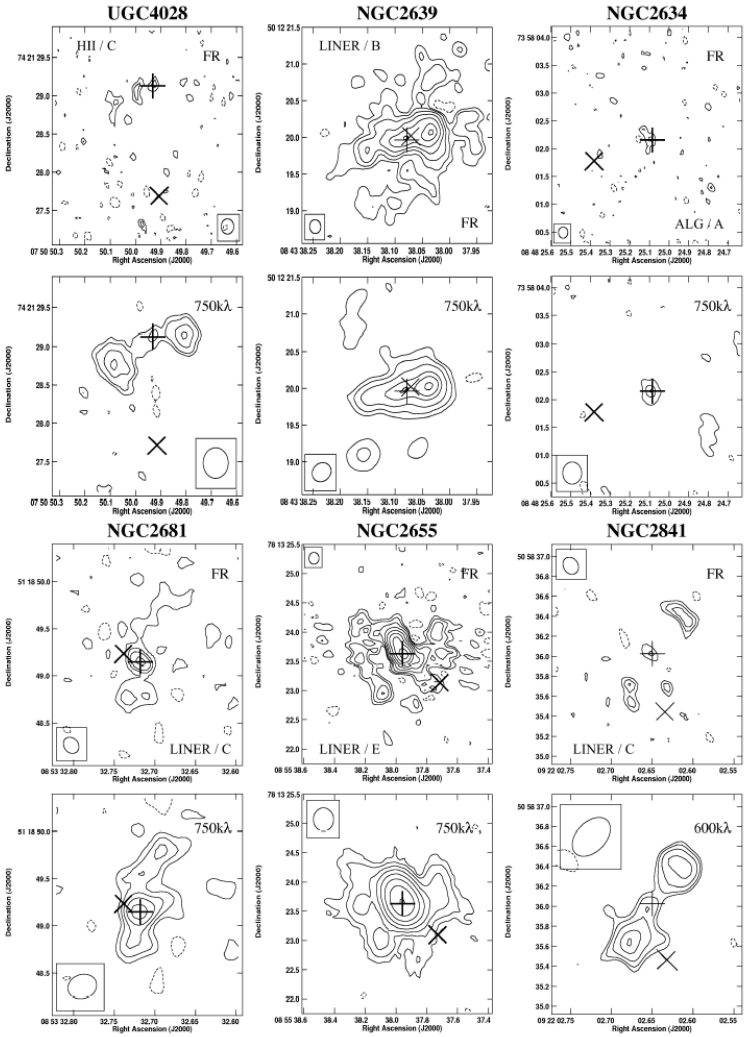
Images





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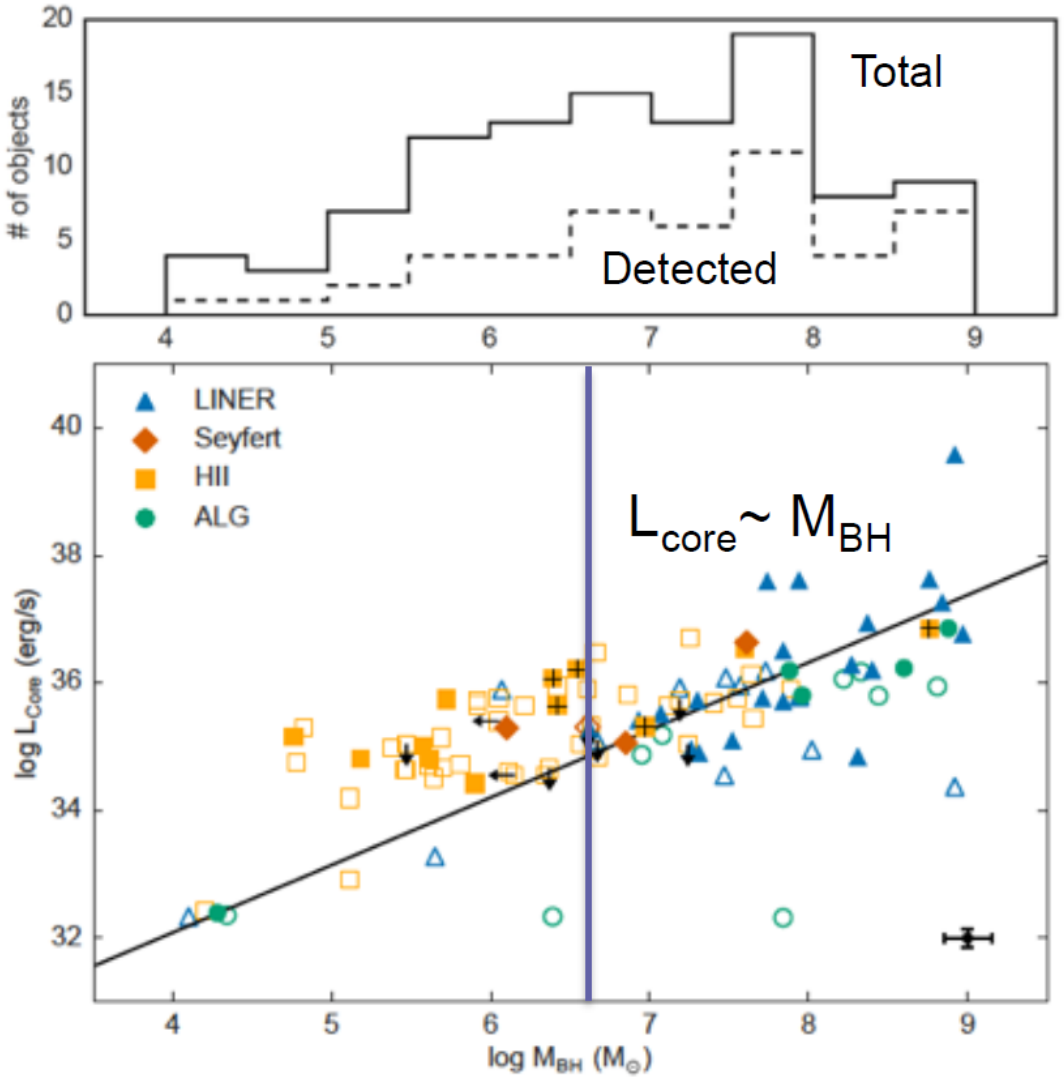
Radio – BH Mass



Detection fraction Propto M_{BH}

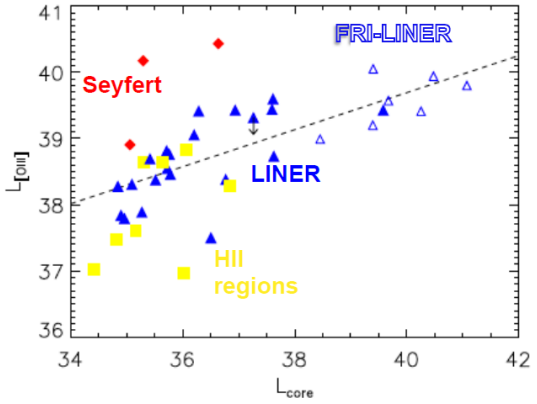
For $M_{BH} > 10^{6.5}$ M_{BH}

$L_{core} \sim M_{BH}$

Break below $10^{6.5} M_{BH}$

(Greater proportion of SF emission)

Hierarchical evolution + SF



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Conclusions

- Nearby galaxy surveys with e-MERLIN are well suited to LLAGN, jets and SF on small scales.
- LeMMINGs survey first DR1 (103 gals) now available
  - Deepest survey high-res survey
  - Pc-scale radio emission to BH ~$10^6 M_\odot$
  - Lots more to come – Deep LeMMINGs survey producing wealth of results.
  - More shallow survey (~180 more galaxies) C/L-band imaging
- Deep tier programme continues on smaller sample but at uJy/bm sensitivities

Next stages of data releases

– Full sample (280 gals) including Ancillary data :

HST imaging, Spitzer, Herschel, new Chandra imaging, new JVLA (1.5, 5 and 15GHz) ++ etc

All to be released with the complete DR1 data set from e-MERLIN..

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Special thanks

All credit to: Wider LeMMINGs team how have done all the hard work.

But especially

- David Williams (Soton, PhD -> Now PDRA Oxford)
- Jonathan Westcott (Herts, PhD → Soon PDRA at Herts)
- Raneri Baldi, Megan Argo, Bil Dullo

- Plus all of the other LeMMINGs core team members!

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