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e-MERLIN

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 LeMMINGs

e-MERLIN Legacy team

Special Thanks and mentions to Megan Argo (JBCA) and new students Ruth Evans (JBCA), Jonathan Westcott (Herts) & David Williams (Soton)

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…Team LeMMINGs…

The LeMMINGs' Team

Rob Beswick *(University of Manchester)* - Co-PI

Ian McHardy *(University of Southampton)* - Co-PI

Susanne Aalto *(Onsala Space Observatory, Sweden)*, Antxon Alberdi *(IAA, Spain)*, Paul Alexander *(Cambridge)*, **Megan Argo *(JBCA)*,** Willem Baan *(ASTRON)*, Elias Brinks *(Hertfordshire)*, John Conway *(Onsala Space Observatory)*, Stephane Corbel *(CEA Saclay, France)*, Phil Diamond *(SKAO/JBCA, Manchester)*, Tom Dwelly *(Southampton)*, Danielle Fenech *(UCL)*, **Ruth Evans (JBCA),** Jay Gallagher *(Wisconsin, USA)*, Jack Gallimore *(Bucknell, USA)*, Dave Green *(Cambridge)*, Geroge Heald (ASTRON), Melvin Hoare *(Leeds)*, Sebastian Jester *(MPIA Heidelberg, Germany)*, Rob Kennicutt *(Cambridge)*, Hans-Rainer Klockner *(Oxford)* , *Hayden R. (Soton)*, Johan Knapen *(IAC, Tenerife, Spain)*, Christian Knigge *(Southampton)*, Elmar Koerding *(Saclay, France)*, Tom Maccarone *(Texas, USA)*, Jon Marcaide *(Valencia, Spain)*, Sera Markoff *(Amsterdam, The Netherlands)*, Ivan Marti-Vidal *(Onsala)*, Smita Mathur *(Ohio State, USA)*, Carole Mundell *(LJMU)*, Tom Muxlow *(JBCA, Manchester)*, Alison Peck *(ALMA)*, Alan Pedlar *(JBCA, Manchester)*, Miguel Perez-Torres *(IAA, Spain)*, Cristina Romero-Canizales *(Santiago, Chile)*, A. Rushton *(Oxford)* D. J. Saikia *(NCRA, India)*, Eva Schinnerer *(MPIA Heidelberg, Germany)*, Ralph Spencer *(JBCA, Manchester)*, Ian Stevens *(Birmingham)*, Ian Stewart *(Cape Town, SA)*, Michele Thornley *(Bucknell, USA)*, Philip Uttley *(Southampton)*, Fabian Walter *(MPIA Heidelberg, Germany)*, Martin Ward *(Durham)*, **Jonathan Westcott *(Herts)*, David Williams (Soton),** Jeremy Yates (UCL)

LeMMINGs Science

- 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 atomic and molecular absorption/maser emission.
- 2-tiered approach to image ~300 galaxies. Majority via snapshot imaging plus a smaller deep sample.

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LeMMINGs Sample

- Total project allocation is 810hrs of e-MERLIN time split in to 2-tiers
  - **Shallow snapshot tier** → ~300 galaxies (on-source time ~48min/band/source)
  - Median distance = 20Mpc
  - **Deep tier** → 6 Targets observed (sub-set of shallow tier) ~5hrs/band/source

	Number of targets	Sensitivity μJy/bm	Luminosity (at median D)	Approx. On-source time
Shallow (L: 1.2-1.7GHz) res ~120mas	300	38	$1.8 * 10^{18}$ W/Hz	48min
Shallow (C: 4.5-6.5GHz) Res ~ 35mas	300	15	$7.2 * 10^{17}$ W/Hz	48min
Deep (L-band) with LT	6	8	$7.5 * 10^{16}$ W/Hz	4.8hr
Deep (C-band) with LT	6	3	$2.8 * 10^{16}$ W/Hz	4.8hr

Sample and observing depths

- 'Shallow' = Palomar bright galaxy spectroscopic survey with Dec >20deg.
  - Optically selected sample (no radio bias)
  - Sample M_B>12.5, Median Distance = 20Mpc
  - Strong multi-wavelength coverage
    - Overlap with existing major surveys such as, SINGS, KINGFISH, THINGS, Galex etc
    - Ongoing LeMMINGs-led campaign to complete multi-λ coverage.
- 'Deep' survey is a **sub-sample** of shallow picking 'interesting' nearby objects with best multi-λ coverage.

Updates and status

- Selection of initial deep observations now made:
  - Primary initial goals:
    - Initial deep tier observations of few selected targets – (primarily at L-band where full bandwidth is available now)
    - Targets selected with complex morphology and early science potential
    - Technical aim to investigate image fidelity of snapshot survey vs deep survey
- Initial Shallow-tier observations underway. Blocks observed during engineering time to verify strategy

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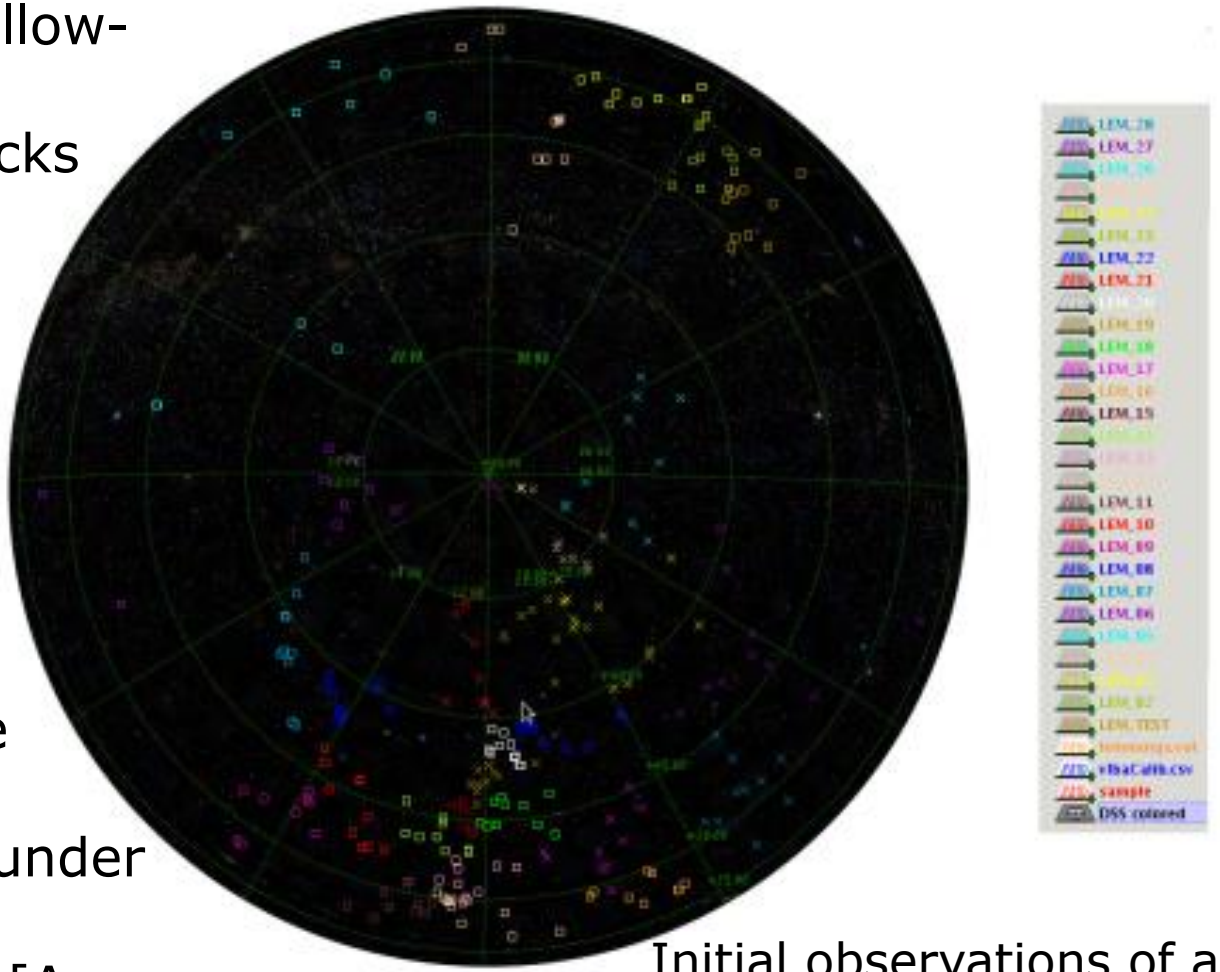
'Shallow' sample

Sky coverage of shallow-sample

- Multiple sched blocks (M. Argo)
- Multi-HA cuts per source to build up uv-coverage.



Data reduction:

- Automatic pipeline (under general e-MERLIN pipeline) under development.

(see e-MERLIN www [Argo et al]

Initial observations of a blocks made – Aug/Sep 2014

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Flavour what's to come: Initial deep observations

- M82 – nearby 'prototypical' starburst galaxy
- IC10 complex nearby dwarf star-forming galaxy (Jonathan Westcott MScR (Herts))
- IC342 nearby dwarf
- NGC2146 – local starburst

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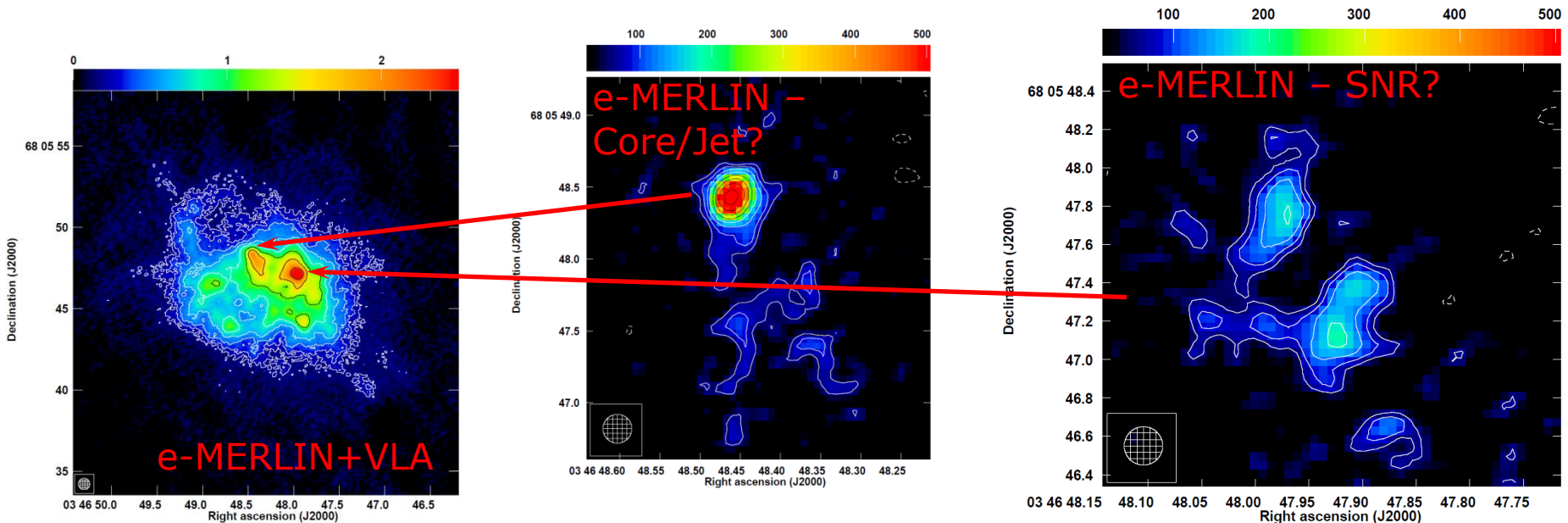
LeMMINGs : Nearby Dwarf galaxies IC10 & IC342

- Part of larger LeMMINGs sample
  - Preliminary results:
  - Two moderately deep observations of nearby irregular dwarf galaxies
  - IC10 (Jonathan Westcott /Elias Brinks (Herts))
    - Post-starburst dwarf irregular galaxy
    - Distance 1Mpc ➔ eMERLIN beam (0.18”) = ~1pc
  - IC342 (below)



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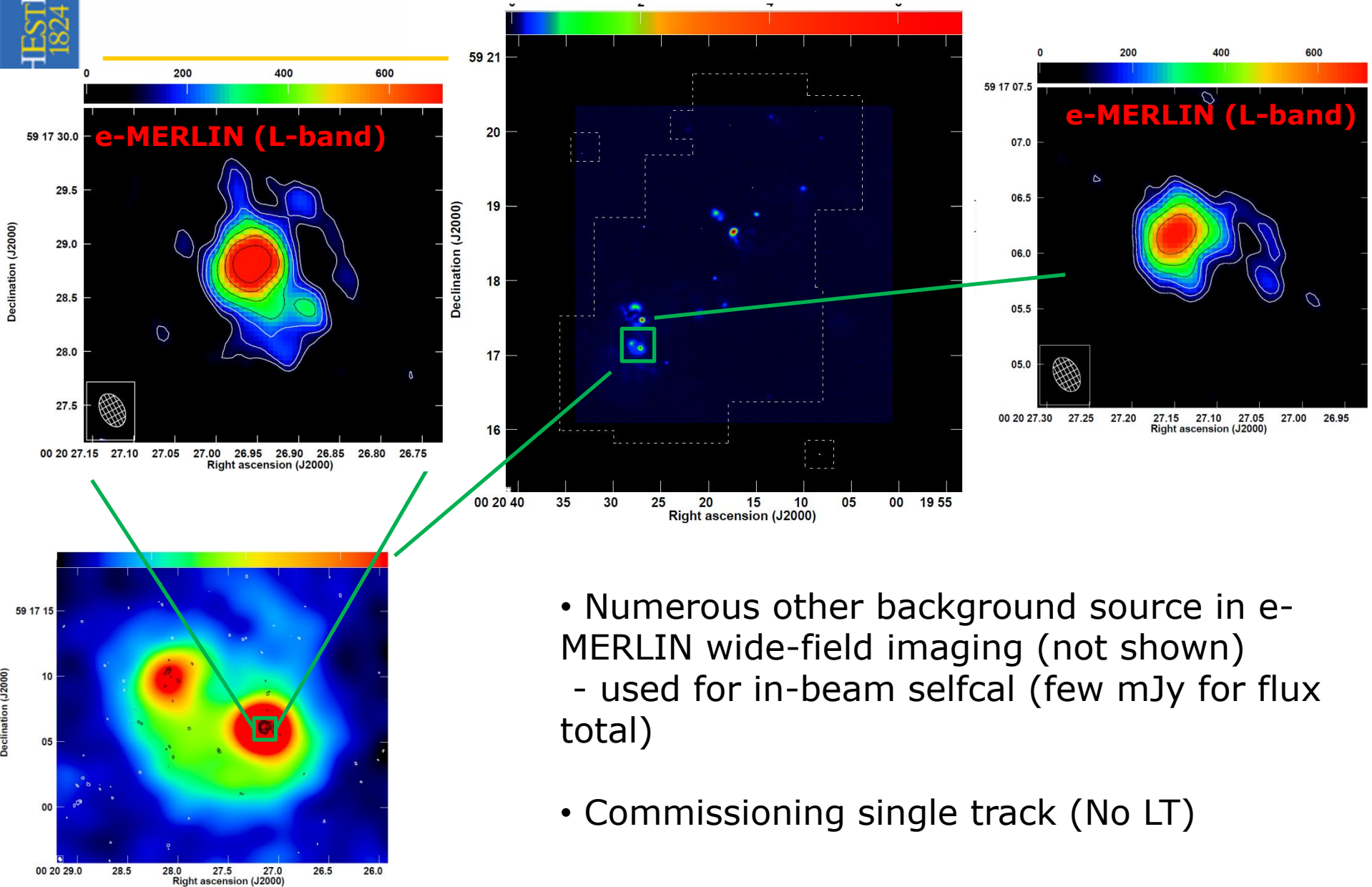
IC10 – local dwarf starburst



- Numerous other background source in e-MERLIN wide-field imaging (not shown)
  - used for in-beam selfcal (few mJy for flux total)

- Commissioning single track (No LT)

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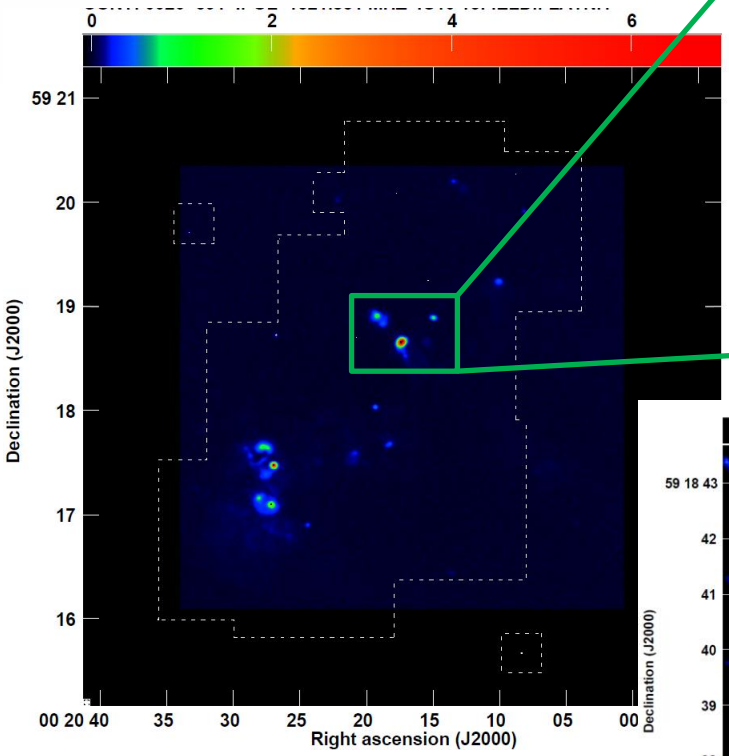
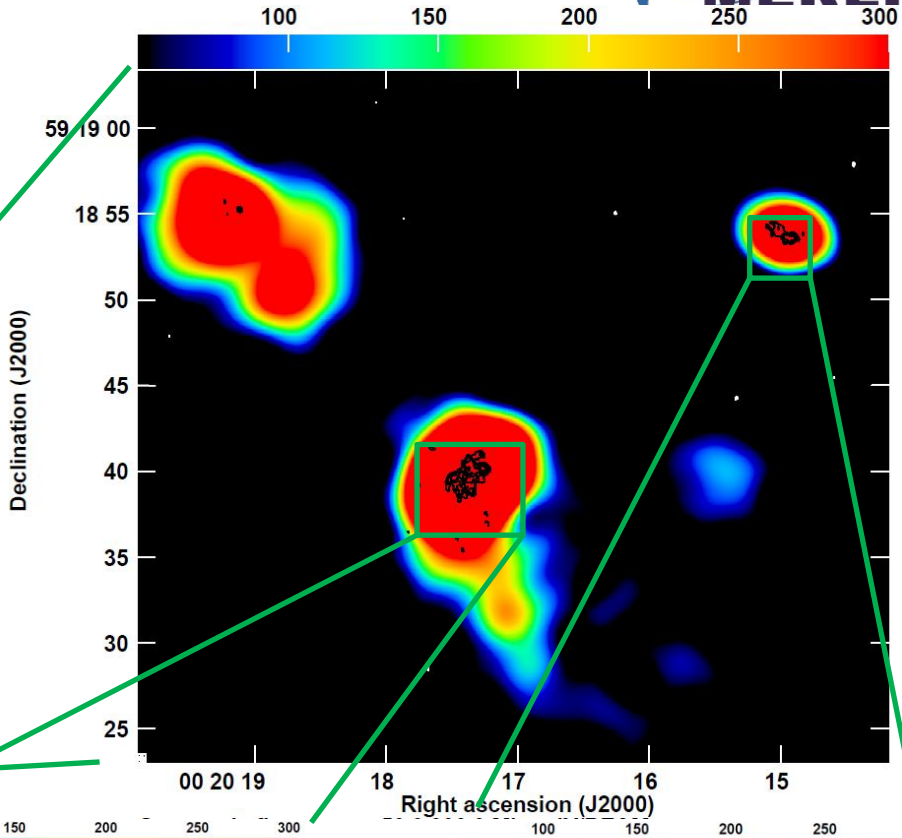
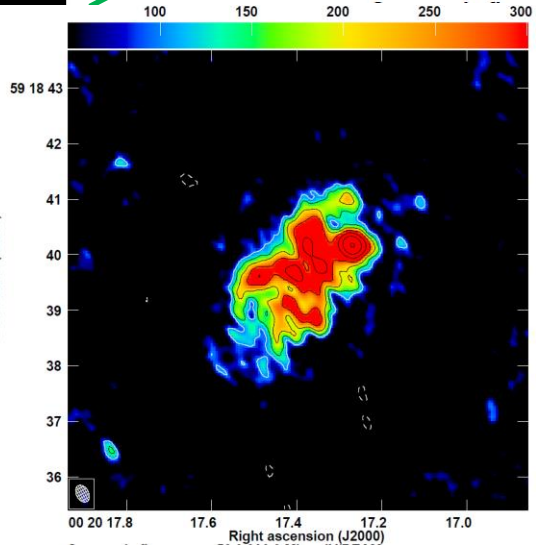
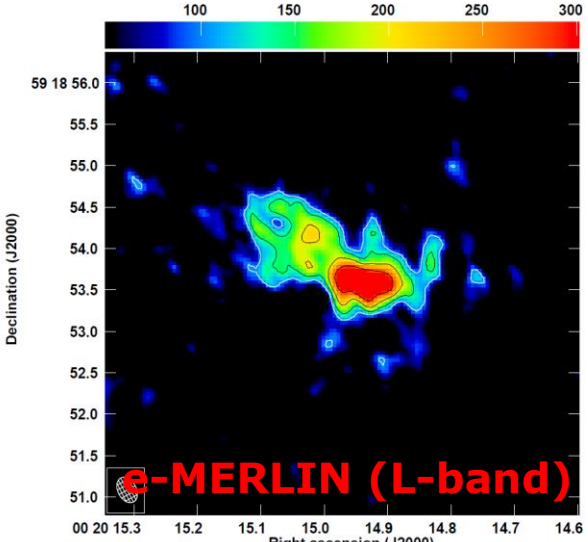
IC10









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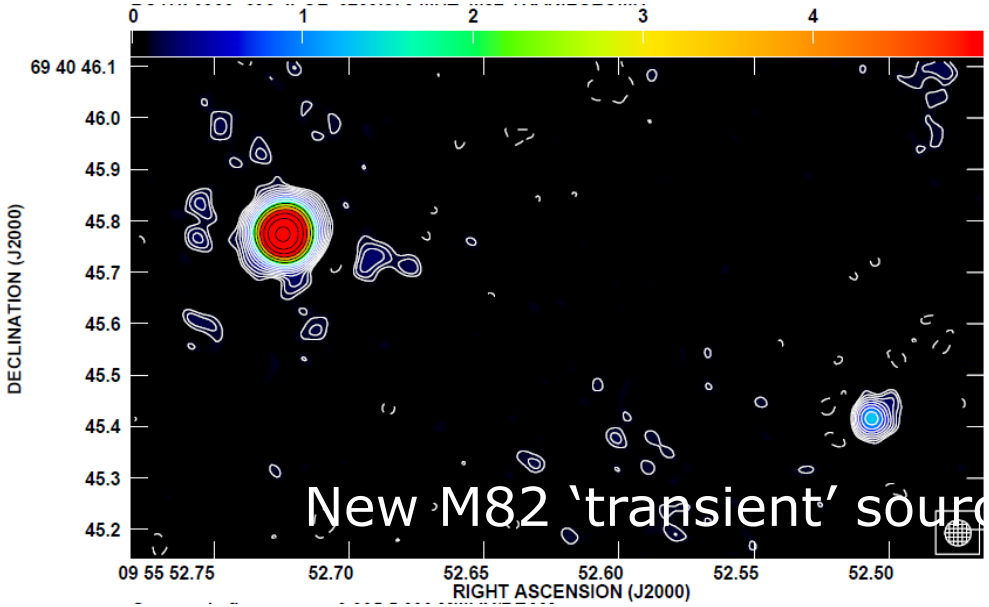
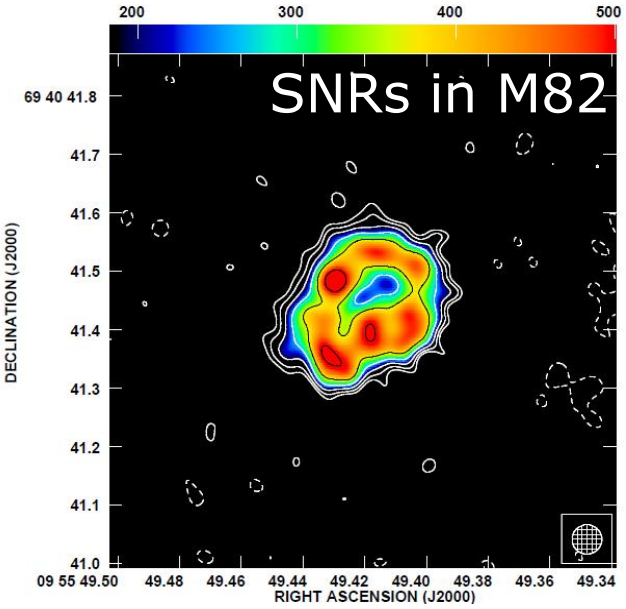
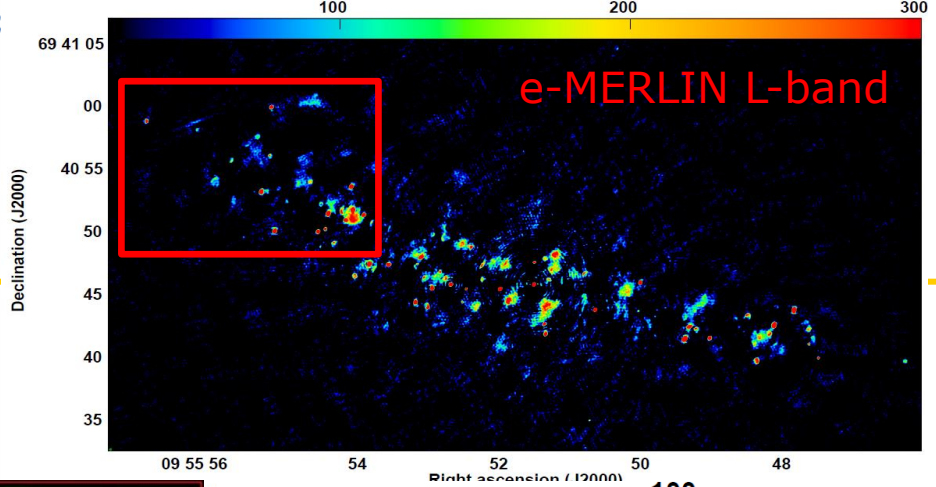
LeMMINGs: M82 – a nearby SNR laboratory

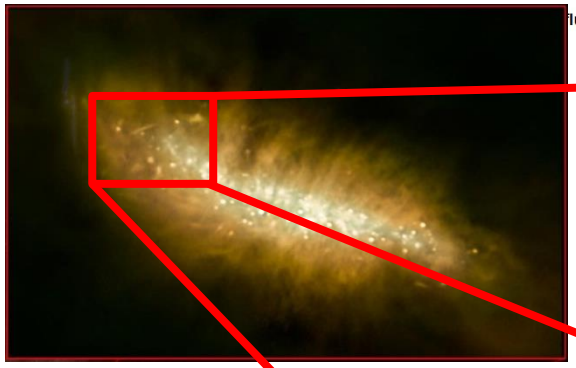
- Part of long term MERLIN+e-MERLIN campaign (Gendre et al 2013 MNRAS) – & LeMMINGs legacy project
- High fidelity e-MERLIN images of individual SNR shells
  - Tracking the evolution of new M82 Transient source (Discovered by Muxlow et al 2010)
- New Deep C and L-band imaging – Coincide with search for radio emission from SN2014J See Perez-Torres talk on Thursday

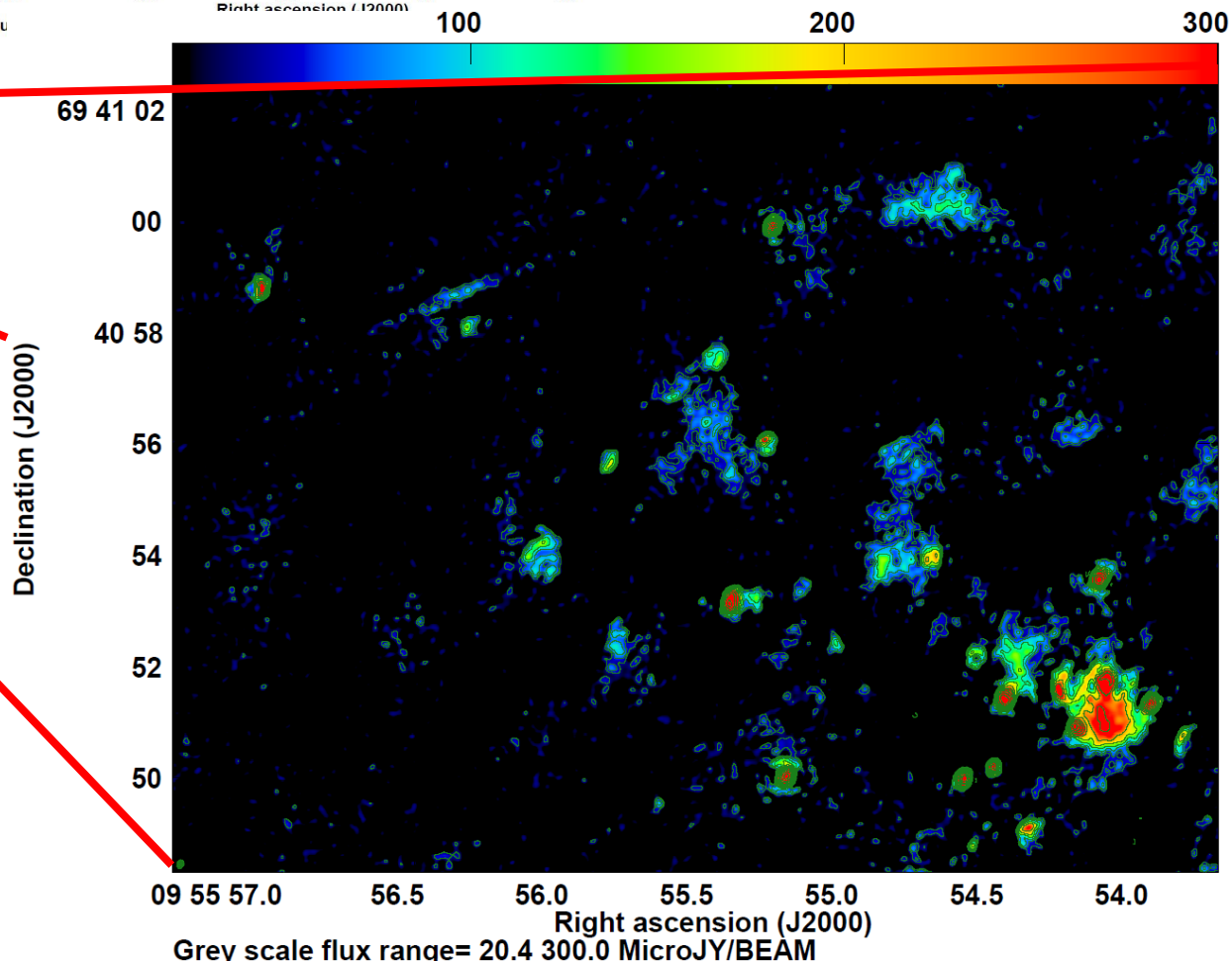


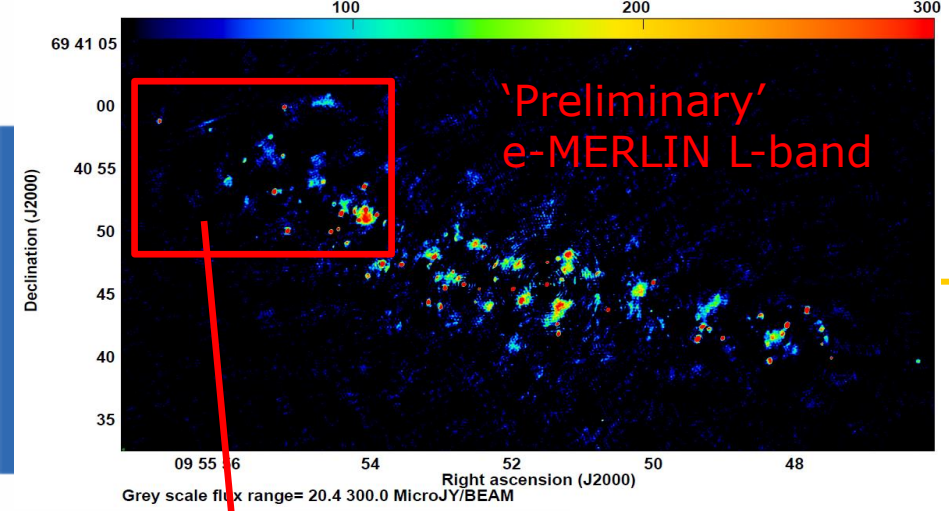


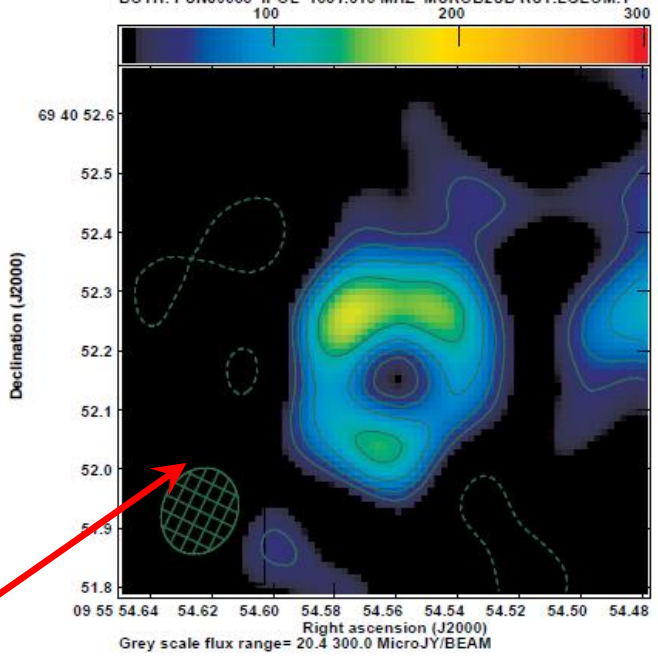

MERLIN


e-MERLIN L-band
100
200
300
69 41 05
00
40 55
50
45
40
35
Declination (J2000)
09 55 56
54
52
50
48

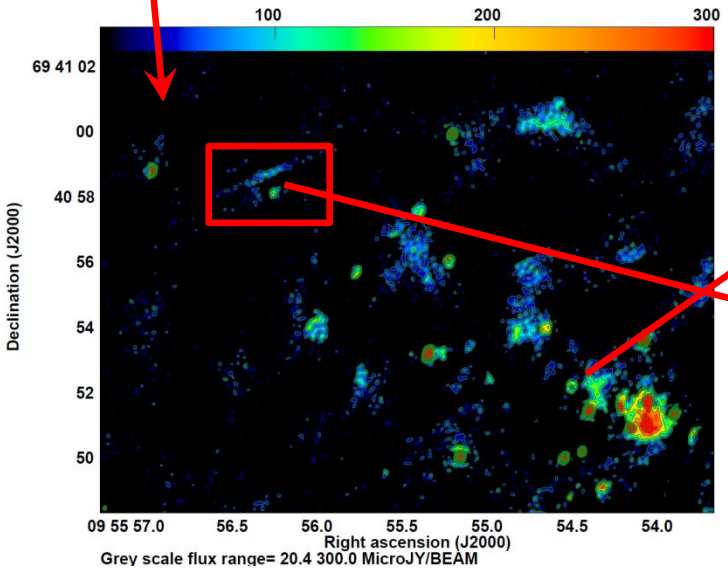


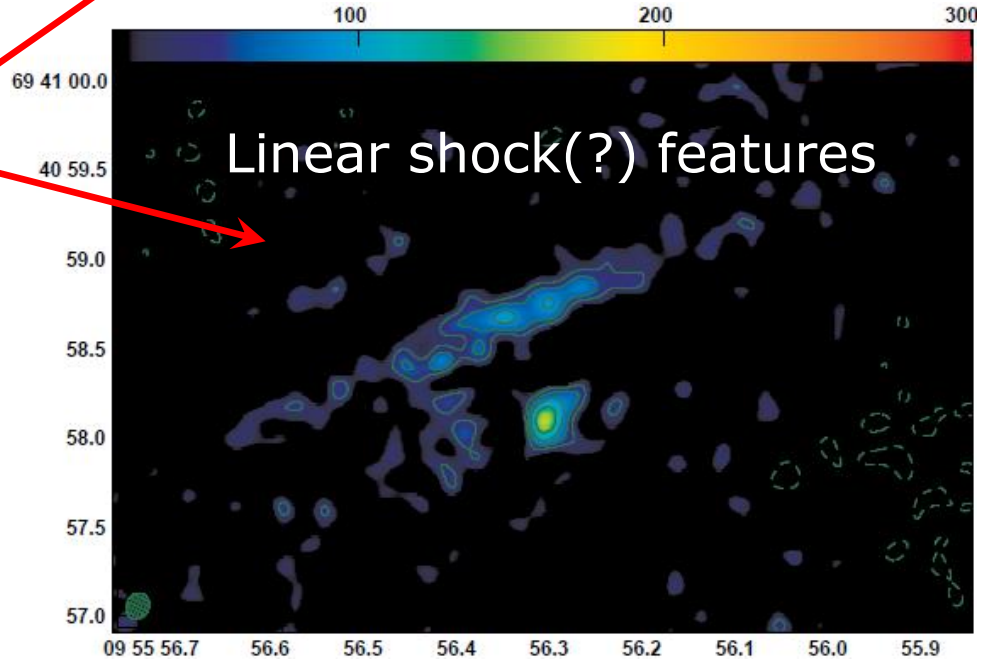

100
200
300
69 41 02
00
40 58
56
54
52
50
Declination (J2000)
09 55 57.0
56.5
56.0
55.5
55.0
54.5
54.0
Right ascension (J2000)
Grey scale flux range= 20.4 300.0 MicroJY/BEAM



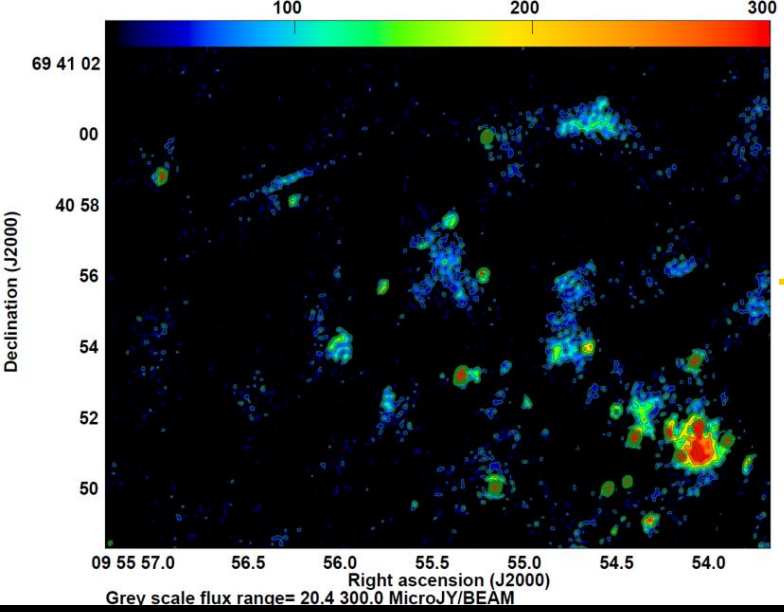


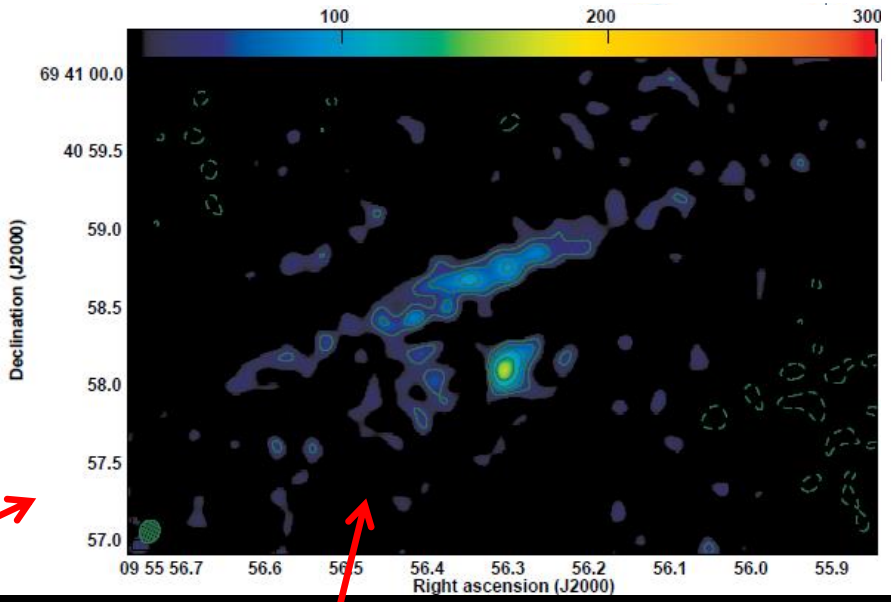
Multiple New faint 'old' RSNe

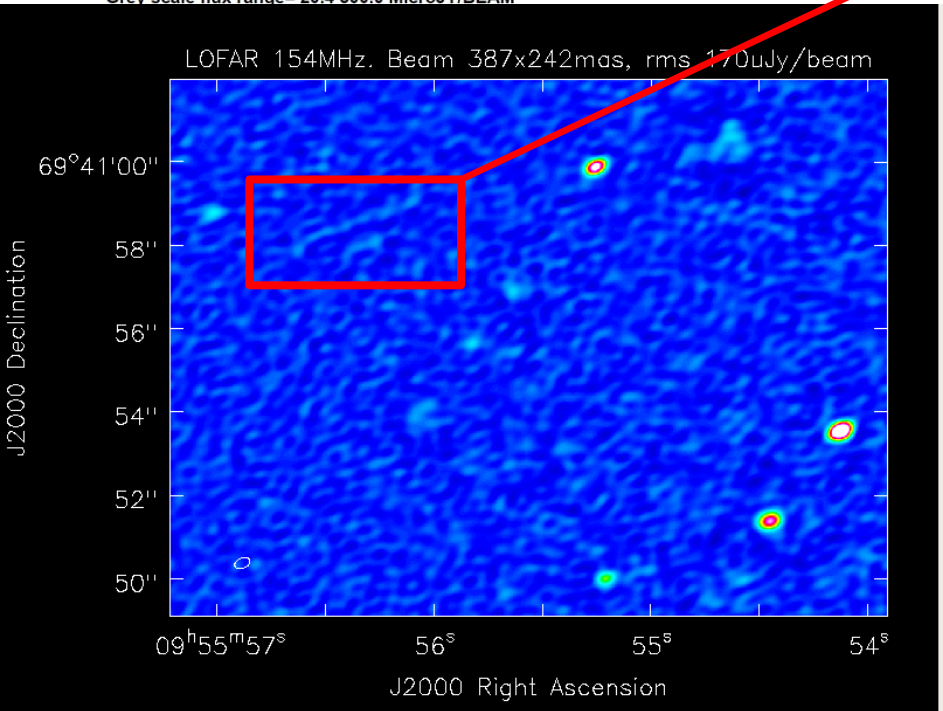




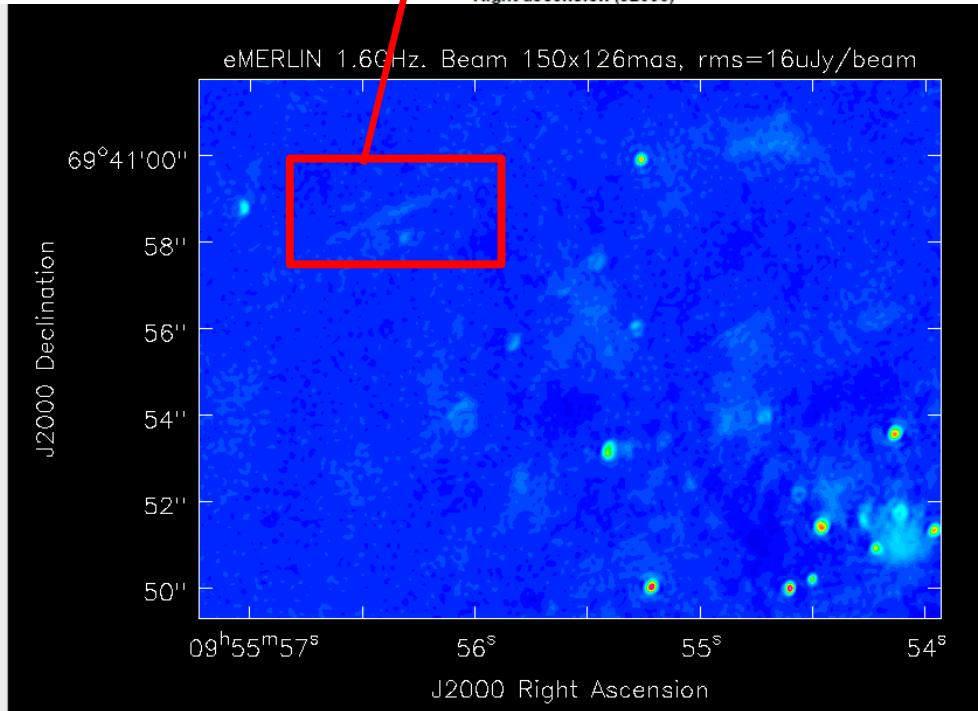
1.25-1.7GHz
rms ~ 16μJy/bm (imaging limited by ill-constrained extended flux)
150mas resolution







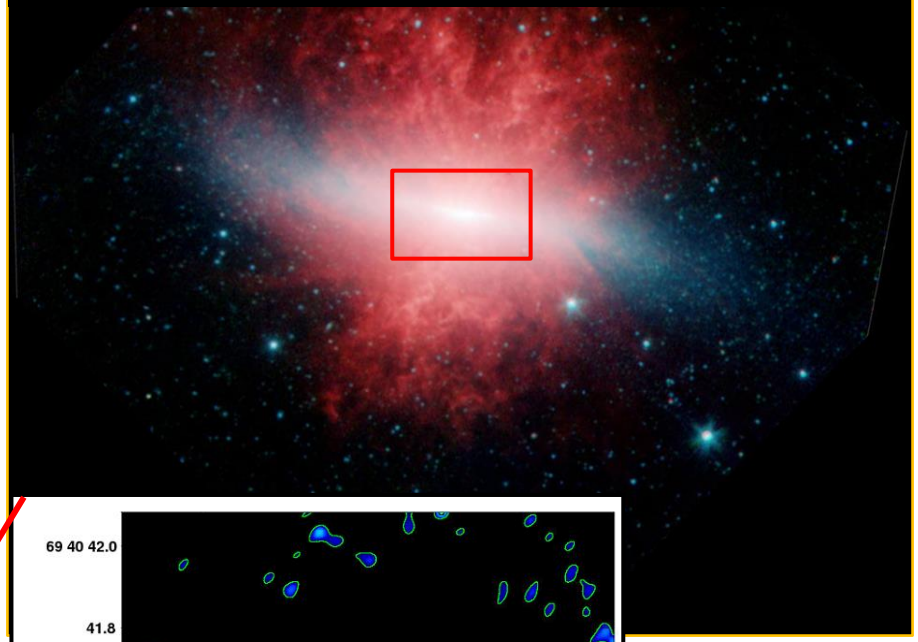
European LOFAR @ 151MHz
Varenus et al 2014, Submitted



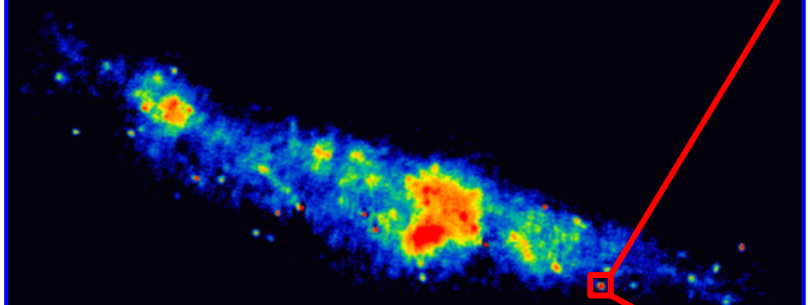
e-MERLIN @ 1.6GHz
Perez-Torres et al 2014,Beswick et al. in prep

e-MERLIN radio telescope - size 220 kms

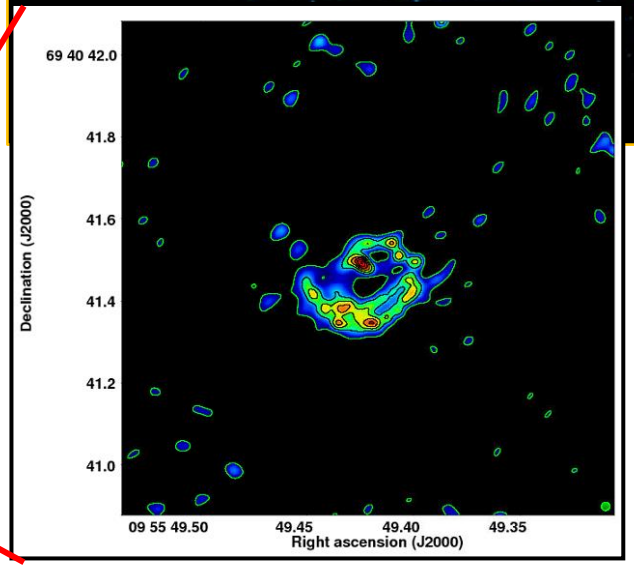
e-MERLIN monitoring of individual expanding Super-Nova remnants.
Expansion speeds ~10,000 km/sec
SNR 40.67+55.1
– size~10ly
– age~150 years



Ultra-high resolution imaging *e*-MERLIN



– Measure expansion and deceleration



C-band,
13 μJy/bm
rms,
20mas res.

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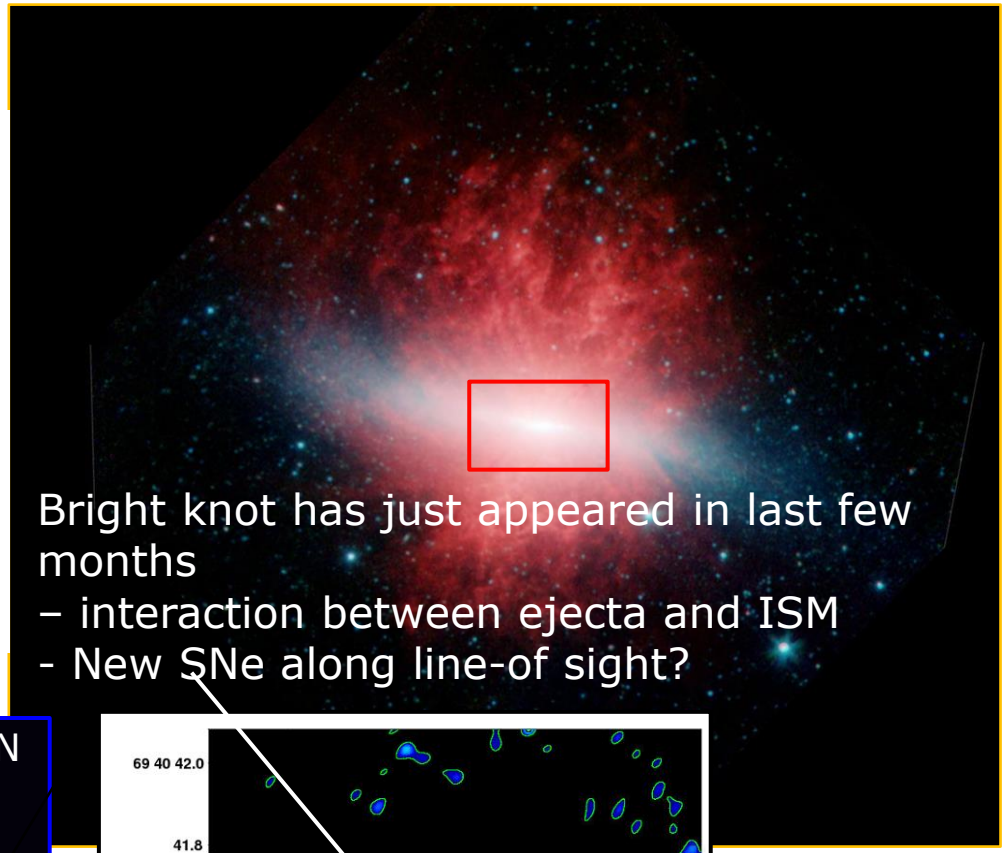
e-MERLIN ultra-high resolution imaging used to calibrate models of star-formation in nearby starburst galaxies like M82

→Directly measure SN (0.05/yr) & star-formation rate



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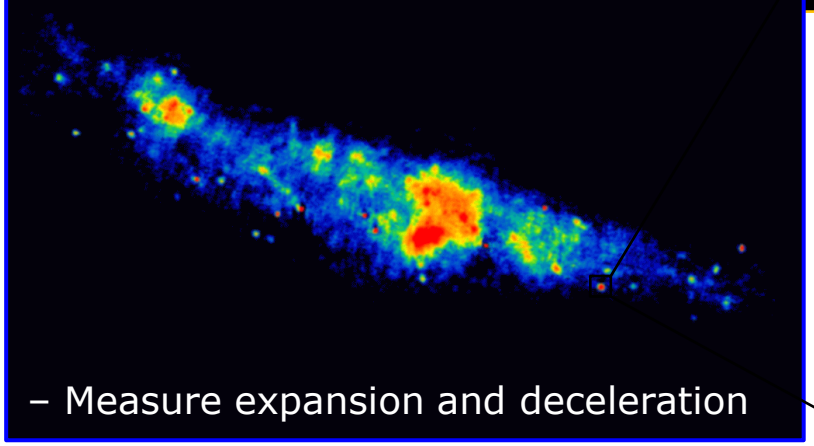

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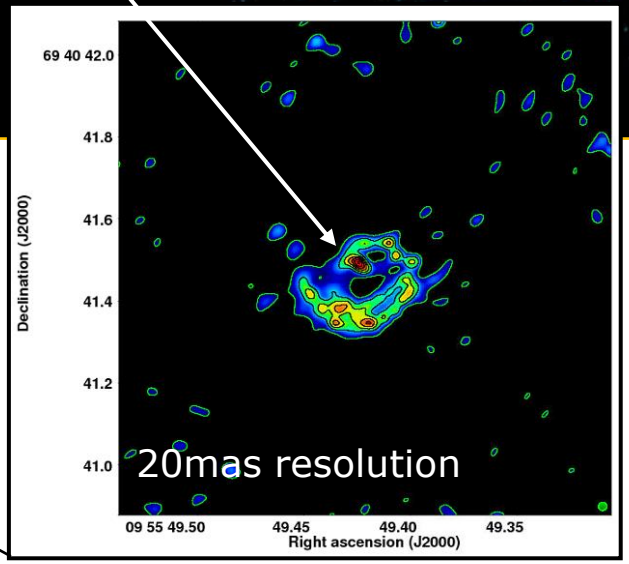

Summary

- Initial observations underway
  - First deep studies, evaluating imaging fidelity
  - Snapshot imaging survey starting now
    - Image testing/scheduling and pipeline preparations ongoing.
  - first science starting to flow..
  - Demonstration of huge science potential already
  - Initial postgrad projects underway with various team members
  - Wide range of ancillary multi-wavelength data in-hand