GALAXIES

(particularly nearby ones)

Ian McHardy

University of
Southampton

MAIN SCIENCE AREAS

1. AGN (nucleus)

   - AGN/star formation discrimination
   - accretion, radio/X-ray connection
   - jets

2. Star formation (host galaxy)

   - individual populations, eg SN, PNe, HII regions
   - unresolved large scale emission

3. Neutral gas (host galaxy)

   - the fuel for star formation)

Southampton

NEARBY GALAXIES

Few pc resolution can help distinguish nuclear AGN from star formation (SF) regions, but need other diagnostics, eg spectra.

Reach down almost to Sgr A* luminosities

Can resolve individual SN and measure SF rate using individual sources on few hundred pc scales.

Provide very well defined local galaxy sample on which to base evolutionary studies.

The University of Manchester
Jodrell Bank
Observatory

MANCHESTER 1824

UNIVERSITY OF Southampton
School of Physics and Astronomy

LeMMINGs

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

Rob Beswick (JBCA/e-MERLIN)

Ian McHardy (Southampton)

Plus the LeMMINGs

e-MERLIN Legacy team including

Ranieri Baldi (Southampton)

David Williams (Southampton)

See also LIRGS IR galaxy survey; Jets surveys

e-MERLIN

Southampton

Sample and observing depths

- 'Shallow' = **Palomar bright galaxy sample**
  - Best selected sample of nearby galaxies (Ho et al 1995)
    - Optically selected, B_T < 12.5 mag, no radio bias
    - All galaxy types: Seyfert, liner, transition, starburst (HII region), quiescent
    - All 280 galaxies above Dec +20 [median distance 20Mpc]
    - Strong multi-wavelength coverage
      - Complete HST, Spitzer and (mostly) Herschel imaging
      - Almost complete Chandra imaging (Large Program approved)
      - Complete JVLA imaging just approved.

- 'Deep' survey is a **sub-sample** of shallow picking objects with best multi-λ coverage.

LeMMINGs Sample

Southampton

- Total project allocation is 810hrs
  - **Palomar shallow tier** → ~280 galaxies (on-source time ~48min/band/source); 750 hours total; no Lovell
  - Median distance = 20Mpc
  - **Deep tier** → 6 Targets observed (sub-set of shallow tier) ~5hrs/band/source; 60 hours total; Lovell

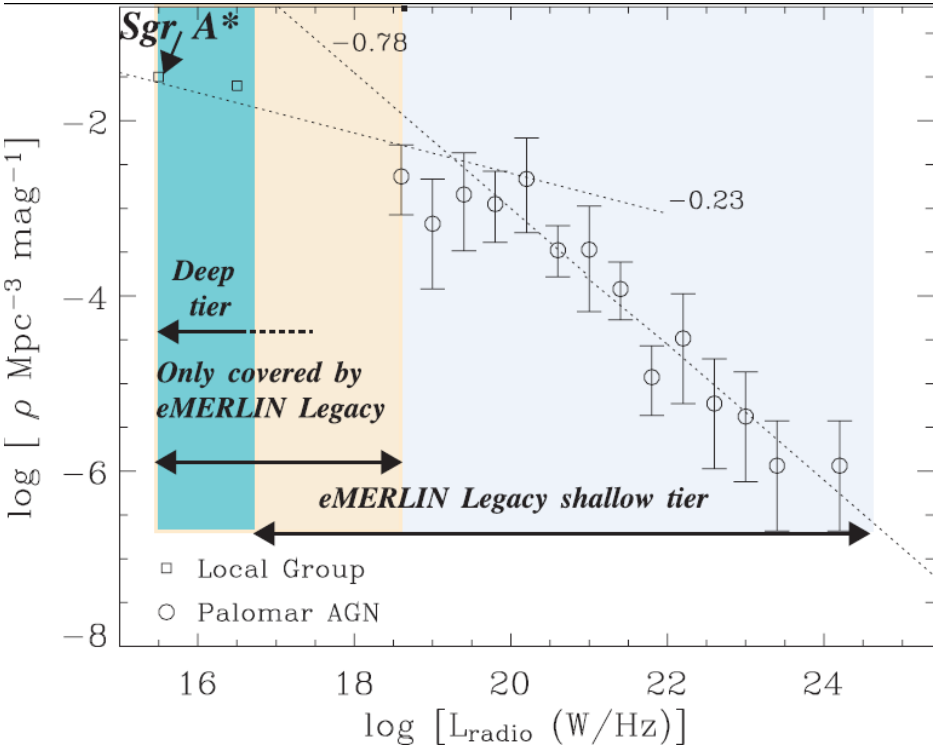
	Number of targets	Sensitivity μJy/bm	Luminosity (at median D)	Approx. On-source time
Shallow (L-band) res ~120mas	290	38	$1.8 * 10^{18}$ W/Hz	48min
Shallow (C-band) Res ~ 35mas	290	15	$7.2 * 10^{17}$ W/Hz	48min
Deep (L-band) with LT	6	8	$7.5 * 10^{16}$ W/Hz	4.8hr
Deep (C-band) with LT	6	3	$2.8 * 10^{16}$ W/Hz	4.8hr

LeMMINGs Science
1a: Accretion and Low Luminosity AGN

Southampton

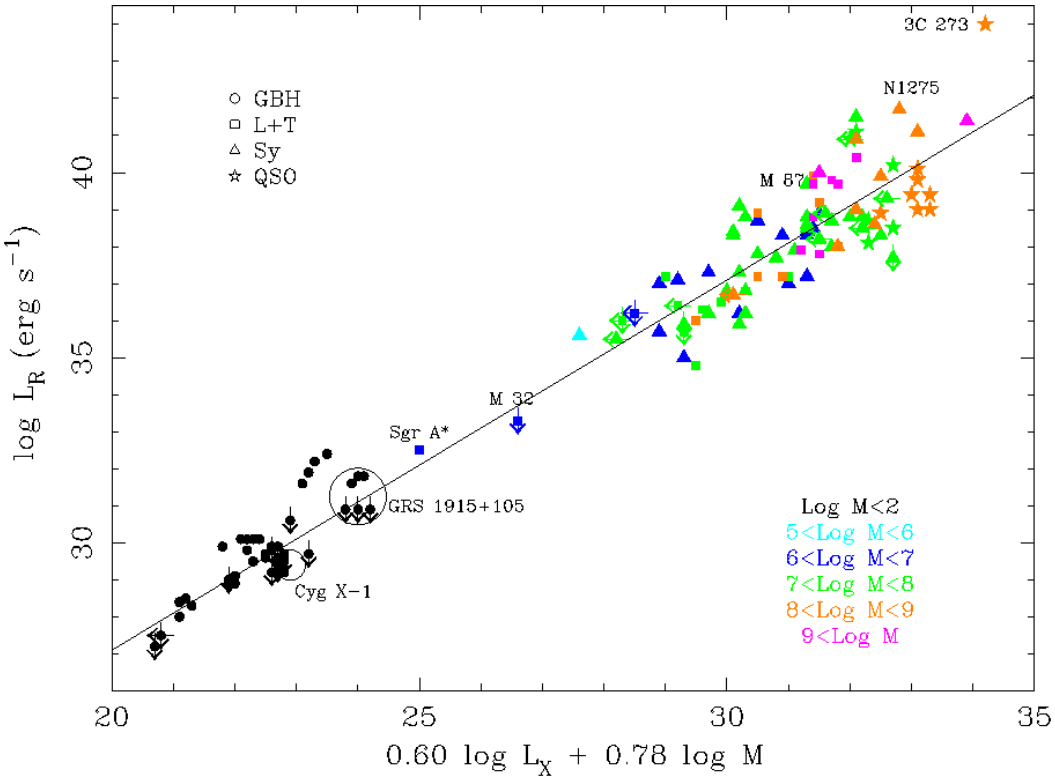
- The Palomar sample will provide a complete census of AGN activity and jet structures in local galaxies of **ALL** types, not just known AGN.
- Radio is best measure of accretion rate at low rates
- We will probe several orders of magnitude lower in radio power than previous surveys with pc resolution, separating AGN/SFR
- Do AGN or SN produce more energy ‘feedback’ to their environment?

Radio luminosity function



LeMMINGS Science
1b: The radio 'Fundamental Plane'

Southampton



(Merloni et al 2003; cf Falcke et al 2004; Koerding et al 2006)

Jet models predict a relationship between L_X, L_R, M.

If well defined, relationship would constrain models.

Observed relationship has great scatter, largely due to poor radio resolution including non-AGN emission. eMERLIN will greatly Improve.

Do LINERS follow same track as Seyferts or non-AGN galaxies?

Chandra large program approved

LeMMINGS Science
1c: The Host Galaxy

Balmaverdi and Capetti (2006) claim that host galaxies with a ‘core’ (flatter) rather than ‘power law’ (steeper) surface brightness profile are more radio loud.

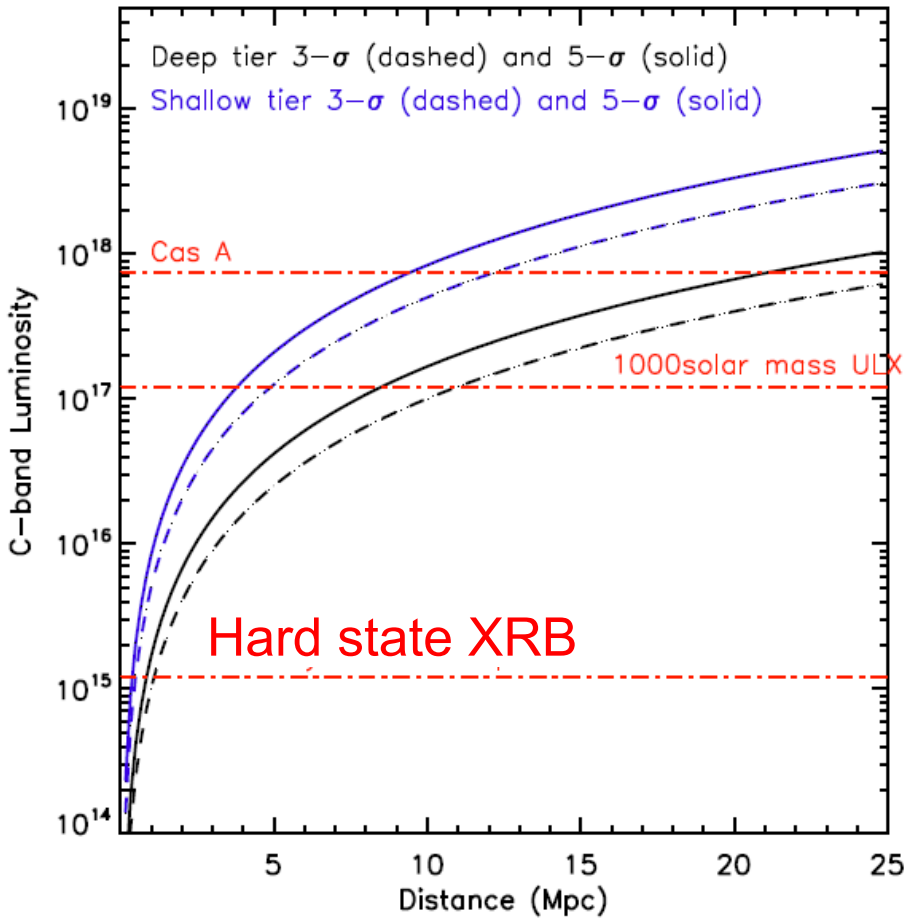
The claim is that the core profile is formed by mergers and the power law by steady accretion. Thus mergers and high spin may power radio emission.

Their data aren’t great. We can do much better.

LeMMINGs Science
2. Star formation

Southampton

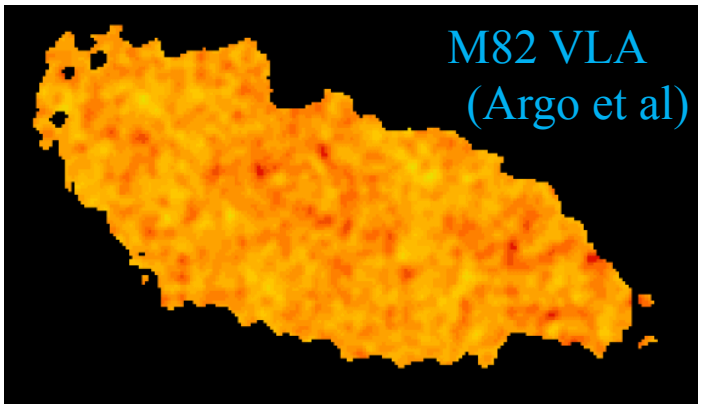
- Shallow-tier will detect and resolve RSNe/SNRs at moderate distance
- Deep tier will also detect radio emission from PNe/HII regions/super star cluster (SSC).
- Hence calibrate SFR in nearby galaxies on the basis of compact radio source populations, independent of obscuration
- Measure LOCAL SFR around SNe Ia with good lightcurves from Palomar Transient Factory. Hence calibrate SN peak luminosity for SFR variation – on few hundred pc scales - important cosmologically
- Search for new populations of radio transients.



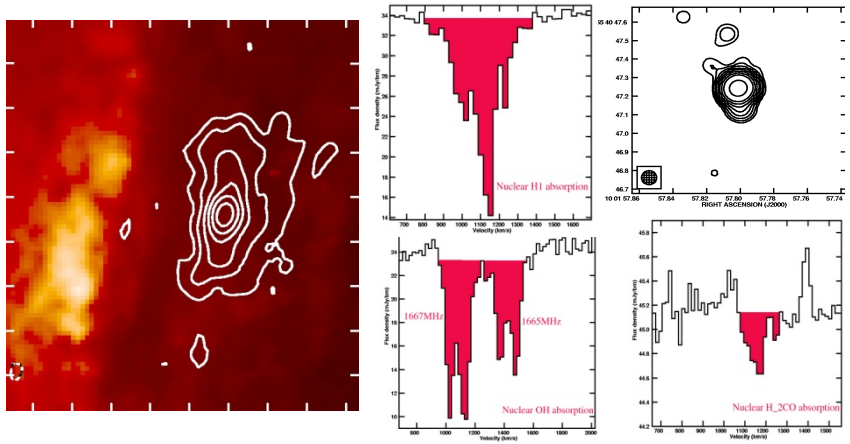
LeMMINGs Science
3. Neutral Gas

Southampton

- For deep tier there is sufficient sensitivity for good spectral line observations (H1, OH (1612,1665, 1667, 1720MHz) + H_2CO, excited OH, HCN?) to search and image absorption and maser emission



- - First sub-arcsecond, simultaneous multi-line survey of its kind.



NGC3079

– H1, OH and H_2CO absorption (Beswick et al)

Observations so far: L-band

- Palomar Sample:
  - 12 out of 28 blocks observed
  - 7 blocks calibrated, 40 sources mapped
  - RFI big problem. SERPent (D.Fenech) important
  - Currently only reaching >2 Muxlows sensitivity
  - Seyferts, Liners mostly detected
  - Some extended starbursts detected but starburst galaxies generally detected less.

- Deep Sample:
  - All 6 observed

Deep :
Nearby Dwarf galaxies IC10 & IC342

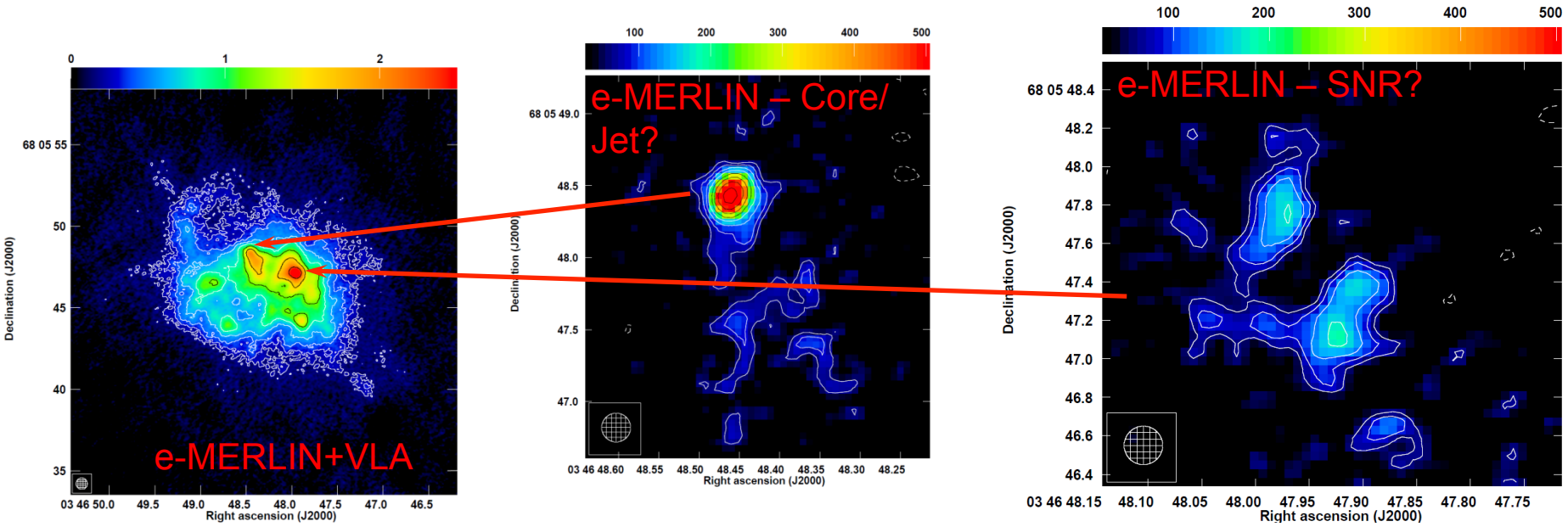
Southampton

Jonathan Westcott /Elias Brinks (Herts)

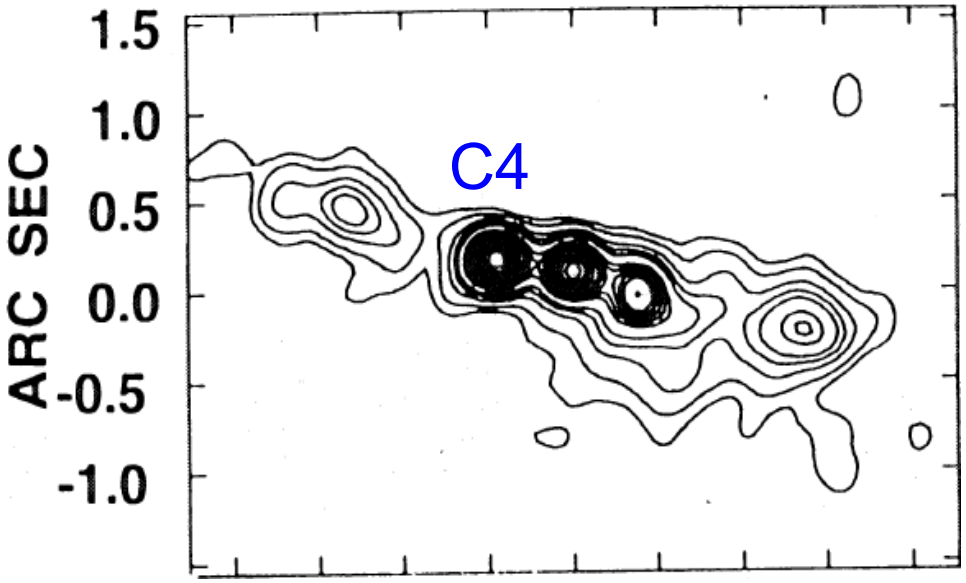
- Post-starburst dwarf irregular galaxies
- Distance 1Mpc ➔ eMERLIN beam (0.18”) = ~1pc

– IC342 (below - you’ve already seen M82

Can resolve individual SN



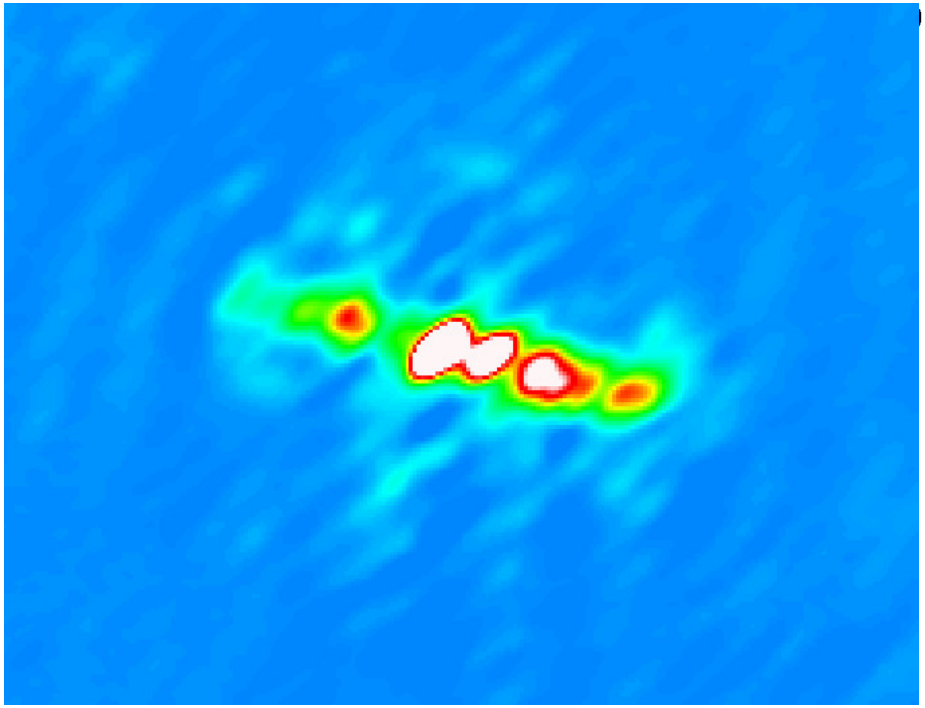
NGC4151 L-band: Deep

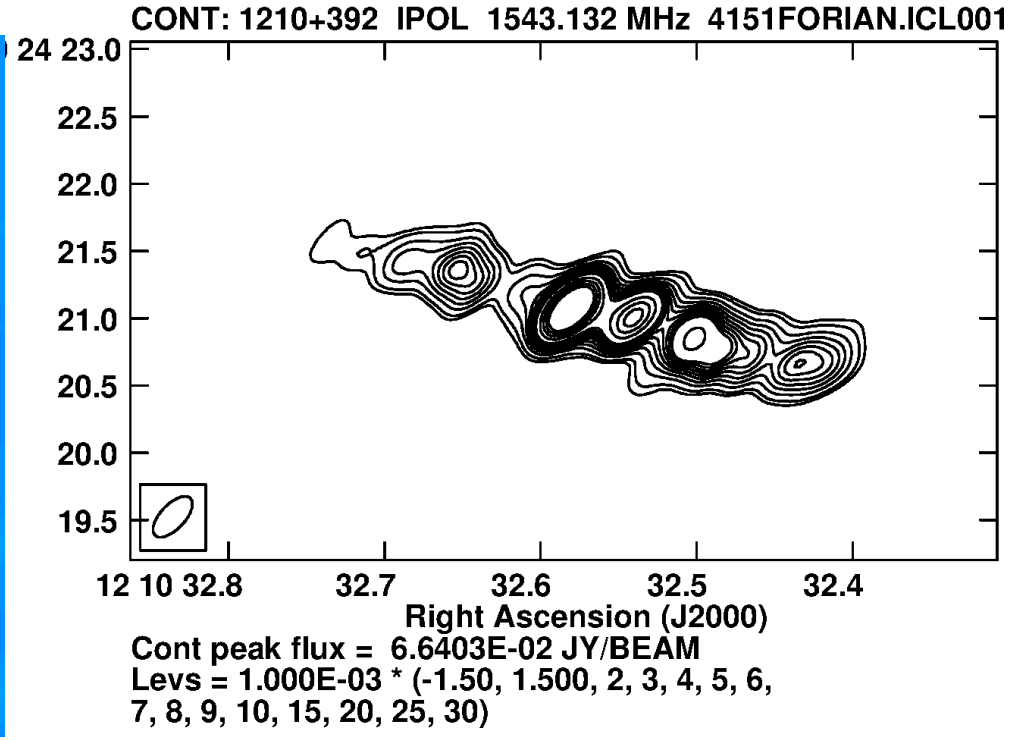


TOP LEFT: MERLIN, MUNDELL et al 1995, **15hr**
BOTTOM LEFT AND RIGHT: eMERLIN, **3.5hr** (Williams et al, in prep). Same contour levels. Both natural weighting.

New observations show jet is well collimated. Possible extended surrounding emission in earlier map may not not real; dynamic range issue.

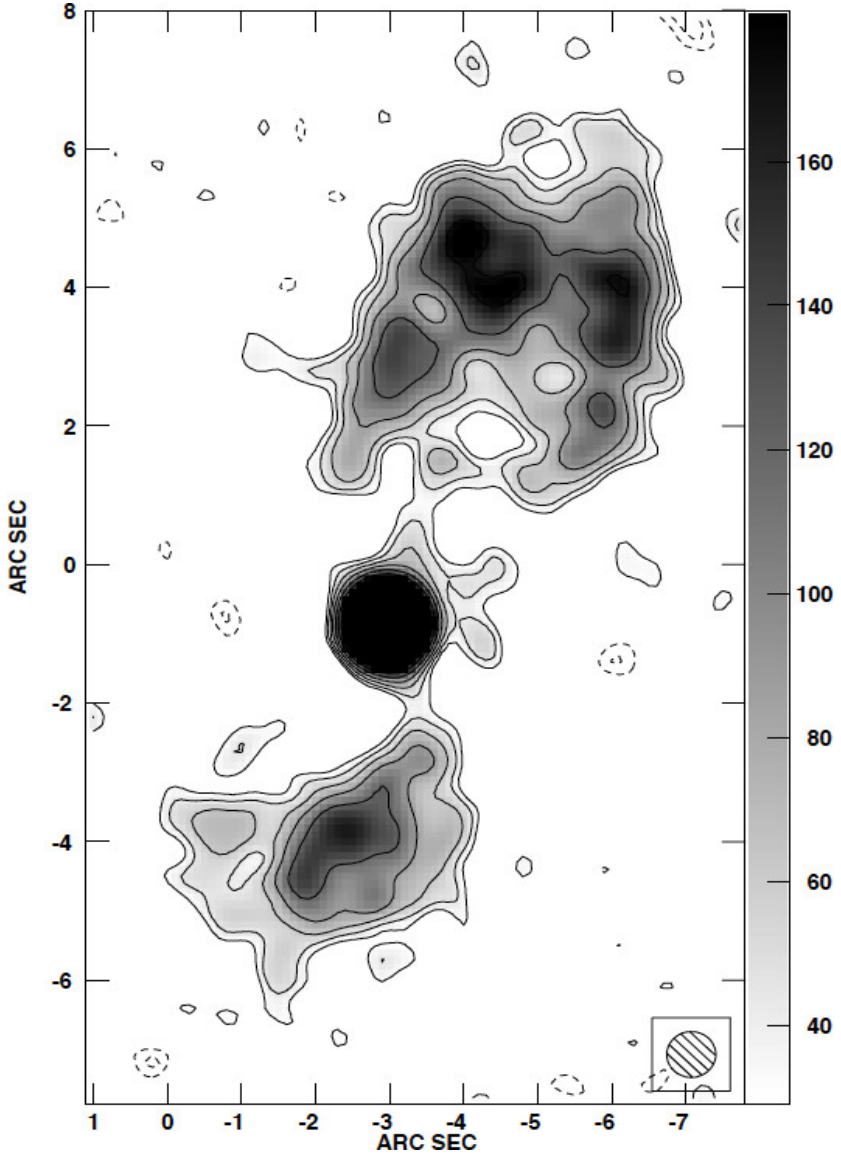
Core (C4 of Mundell 95) has flat spectrum $(\alpha = 0)$ in L-band and has varied by x2.

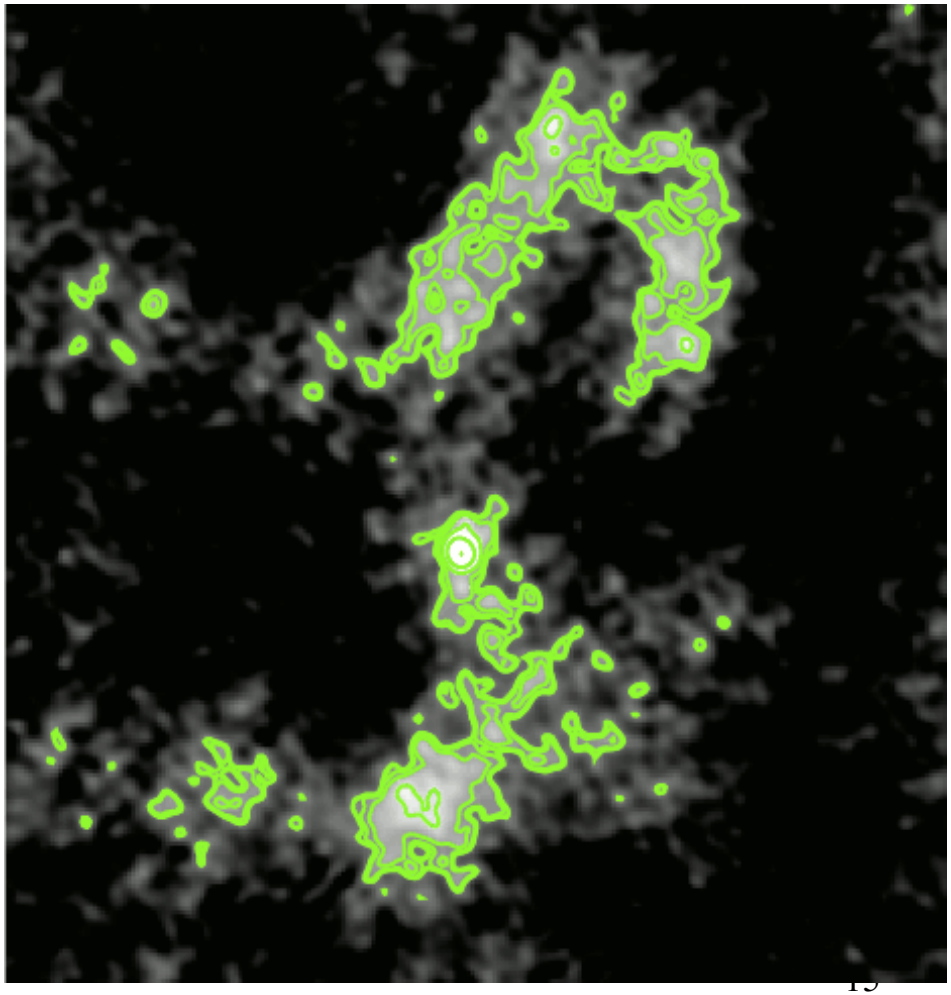




NGC5548: (mid-depth)

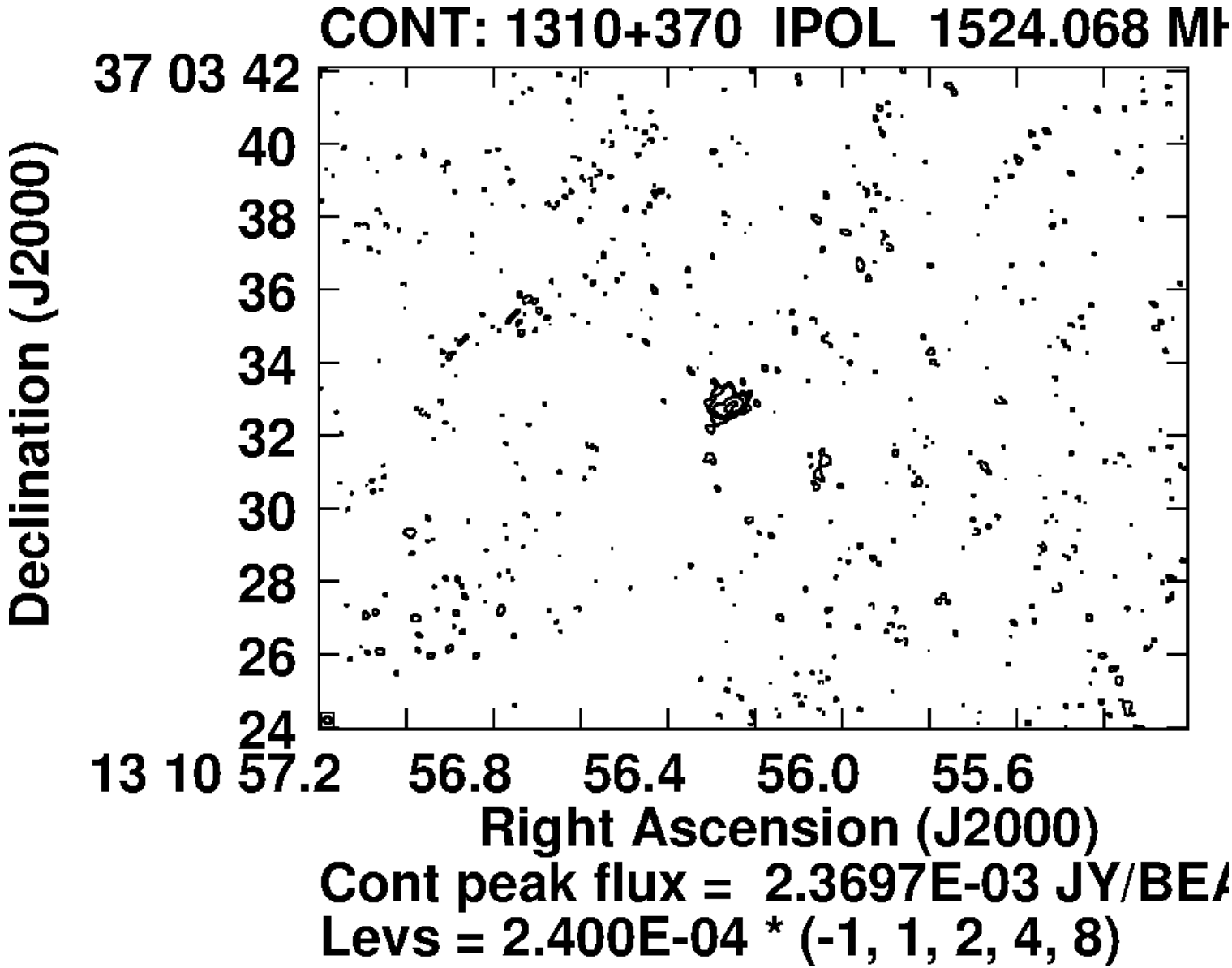
LEFT: Wrobel 2000 VLA 8GHz
BELOW: eMERLIN L-BAND
Curving tracks clearly shown.
(Williams et al)



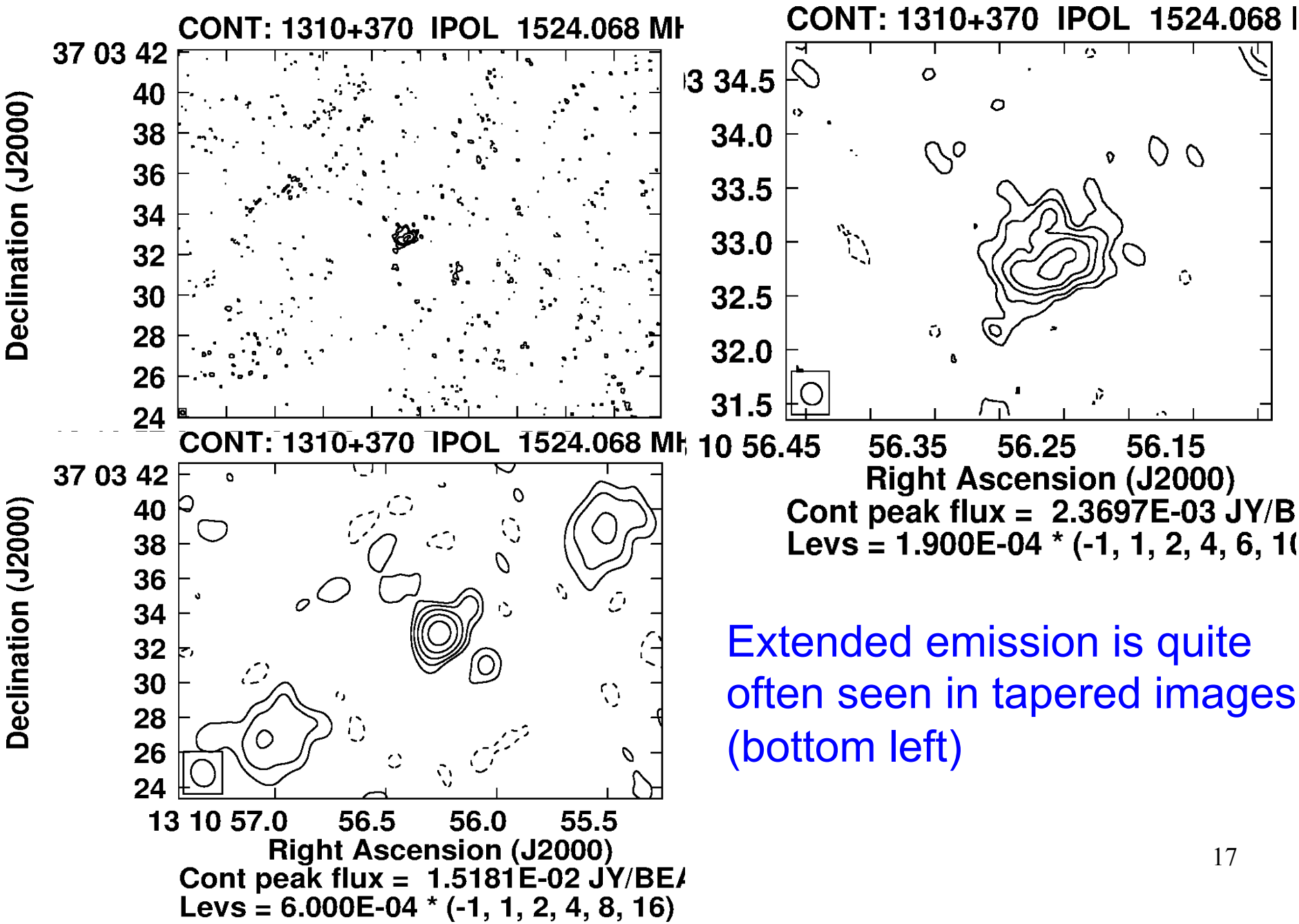


Typical shallow L-band LeMMINGS image

NGC5005; Baldi et al



NGC5005 continued..



Extended emission is quite often seen in tapered images (bottom left)

CONCLUSIONS

Nearby galaxy surveys with eMERLIN have great potential for study of LLAGN, accretion physics, radio/X-ray relationship, jets and star formation on crucial small scales

Current L-band LeMMINGs observations are going well but suffer from RFI. C-band will be less affected.

eMERLIN **resolution** is well matched to nearby galaxy studies but **need improved low frequency sensitivity and uv coverage**

If funding were available, more sensitivity on scales in between current eMERLIN and VLA (ie baselines of 80-100km) would help.