LOW FREQUENCY OBSERVATIONS OF S7 SEYFERT GALAXIES

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THE S7 TEAM

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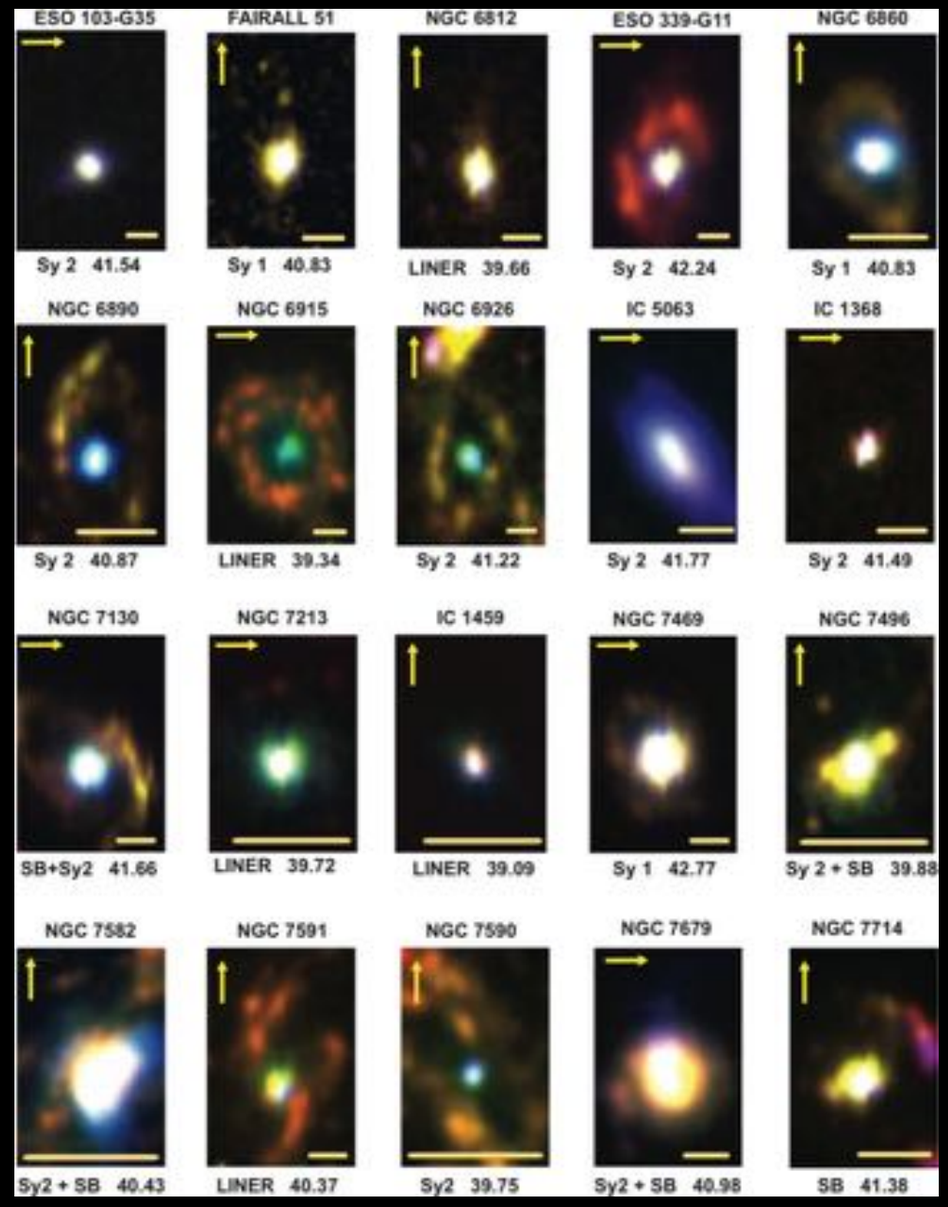
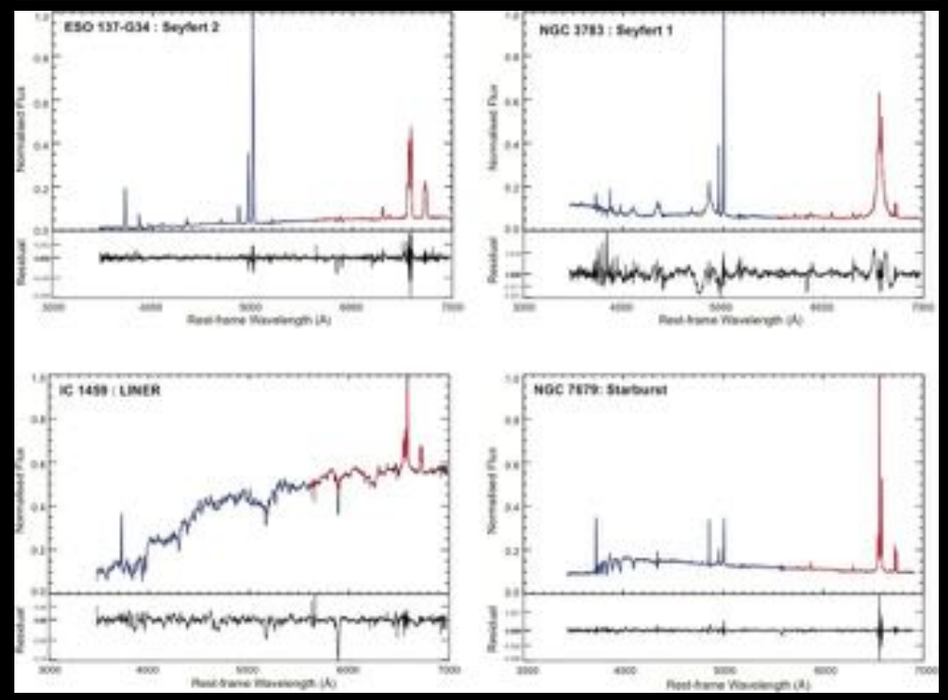
SIDING SPRING SOUTHERN SEYFERT SPECTROSCOPIC SNAPSHOT SURVEY

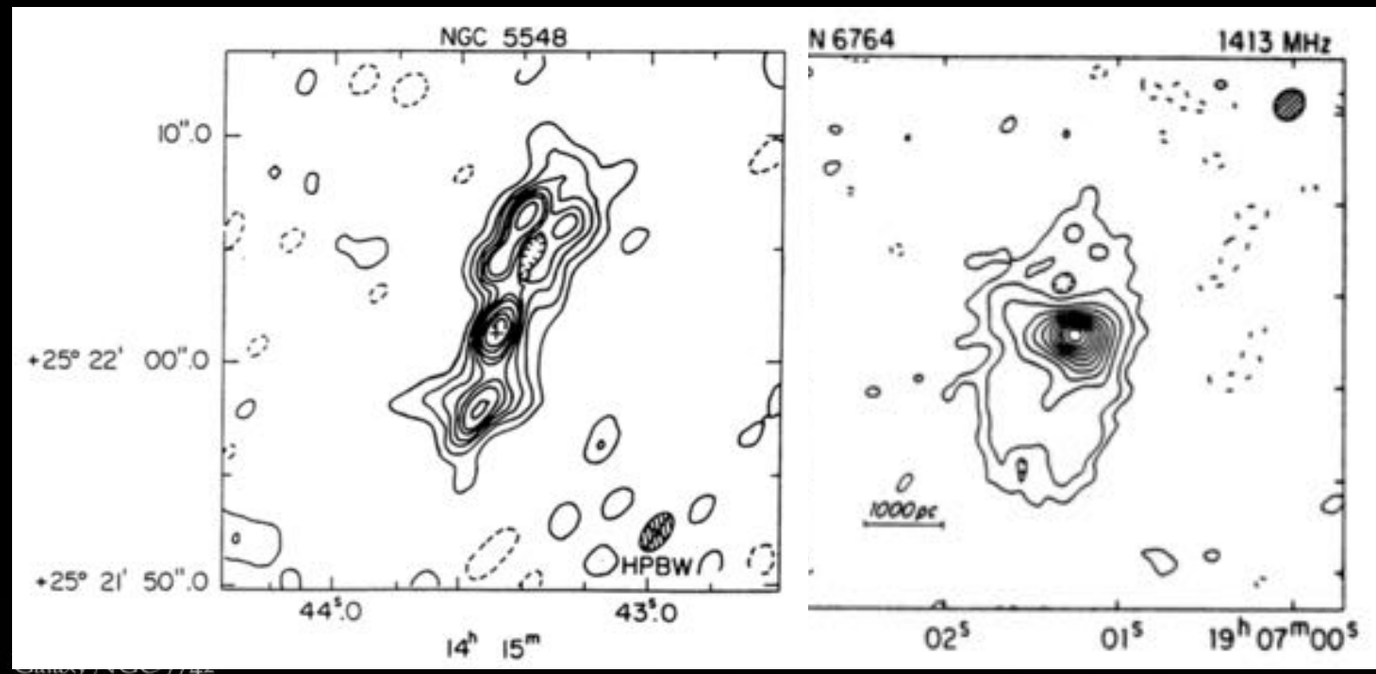
- Wide Field Spectrograph (WiFeS) IFU on ANU 2.3m at Siding Spring Observatory of >100 Seyferts
- Field of view: 38″ × 25″
- Redshift < 0.02 (D < 80 Mpc)
- Spatial resolution better than 400 pc/arcsec, to resolve the Extended Narrow Line Region
- Radio flux density @1.4 GHz > 20 mJy
- Dopita et al. 2014, 2015
- https://miocene.anu.edu.au/S7/





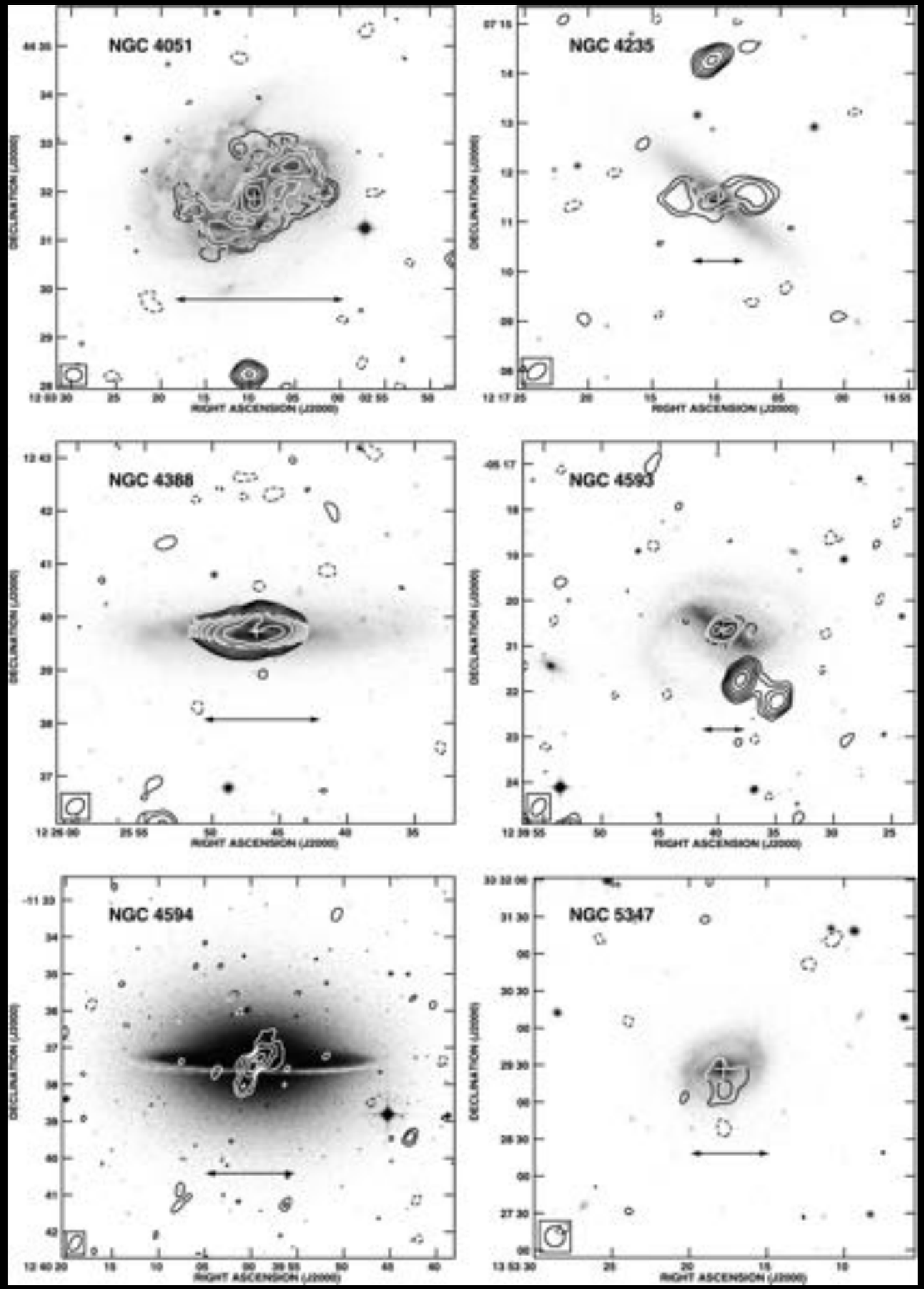
KPC-SCALE RADIO OUTFLOWS IN SEYFERT GALAXIES

- Systematic studies w/ Very Large Array (Ulvestad & Wilson 1984, 1989) and Westerbork telescope (Baum+ 1993) at 5 & 1.4 GHz
- Diffuse radio emission by starburst-driven winds (Wilson 1988; Baum+ 1993)
- Colbert et al. 1996 suggested AGN-driven based on non-spherical morphology and skewed orientations w.r.t. galactic disks

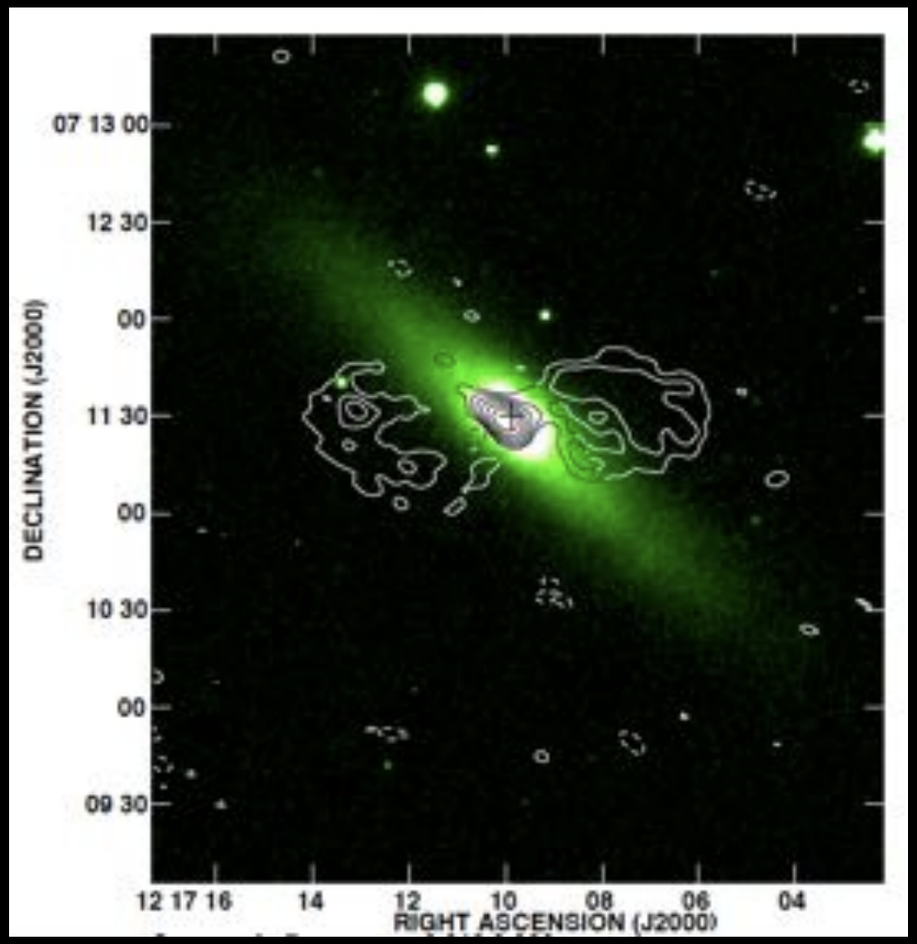


KILOPARSEC RADIO STRUCTURES (KSR)

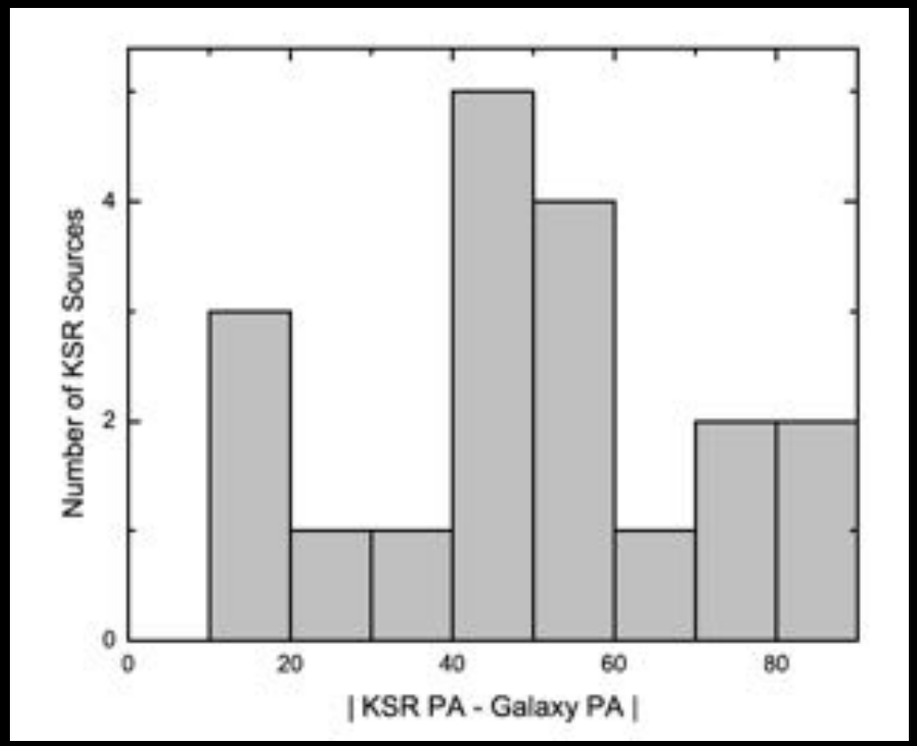
- 44% of a volume-limited Seyfert sample (#43) shows outflows at 5 GHz (Gallimore et al. 2006). Resolution (15” or 5 kpc) + Projection issues remain
- 43% in FIRST-NVSS sample (#>1700) at 1.4 GHz (Singh et al. 2015)
- Test Starburst versus AGN: Evidence in favor of AGN-driven



OUTFLOWS AT SKEWED ANGLES



NGC4235; Kharb et al. 2016



Gallimore et al. 2006

- Outflows at oblique angle (40 - 50 deg) from host galaxy minor axes (Colbert+ 1996; Gallimore+ 2006). Starburst winds aligned with the minor axes due to pressure gradients (Colbert+ 1996)
- Excess radio emission compared to far-IR and VLBI observations that detect pc-scale jets support an AGN origin for KSRs

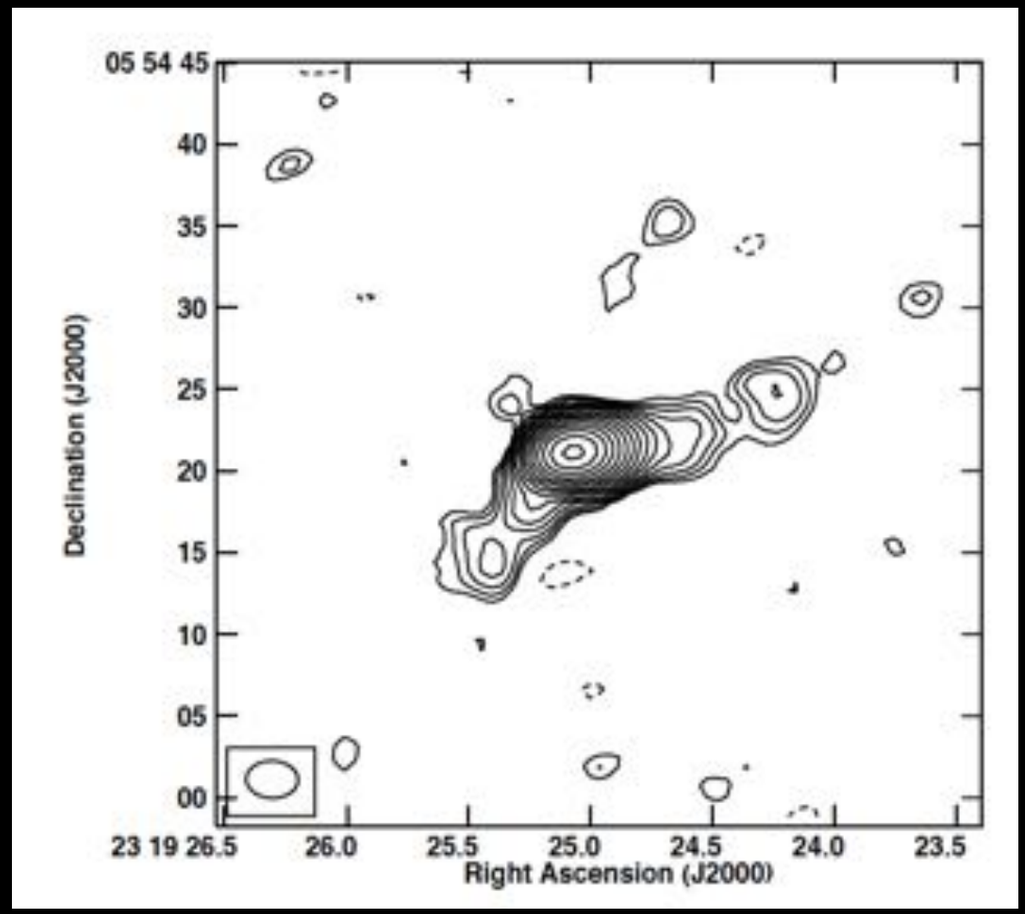
UNDERSTANDING RADIO OUTFLOWS IN SEYFERTS AND THEIR RELATION TO THE ENLR: S7 WITH GMRT

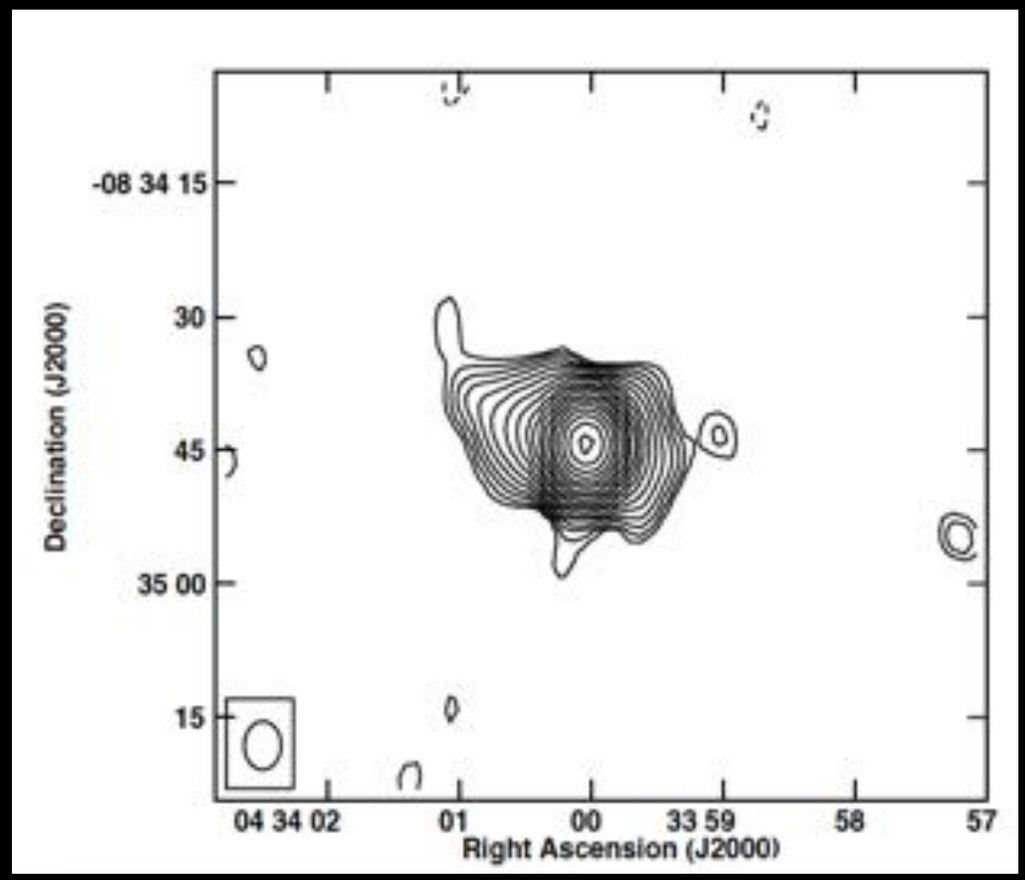
S7 GMRT SEYFERT SAMPLE

- Declination range ±10 degrees, inaccessible to the ATCA
- 1.4 GHz flux density ≧ 25 mJy (single dish or NVSS)
- From 29 Seyferts, excluded those with VLA L-band A-array data of sensitivity of ~0.1 mJy/beam
- 17 Seyferts ≈42 hours with the GMRT, Cycle 27
- Lowered the flux density limit to 20 mJy. Total = 38
- 9 Seyferts ≈36 hours with the GMRT, Cycle 30

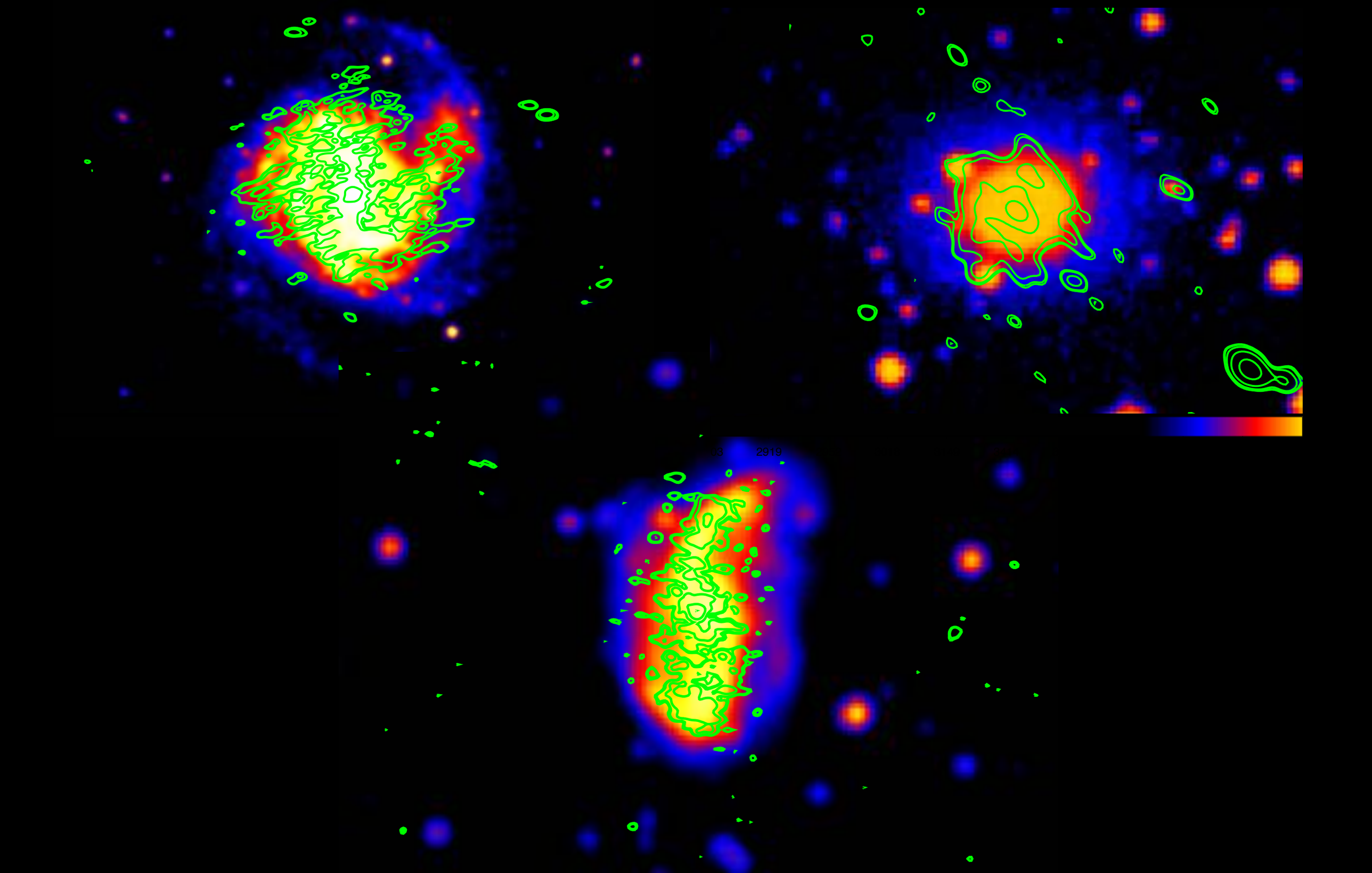
PRELIMINARY RESULTS FOR 29 SEY

- Resolution: 7″ x 4″ at 610 MHz, 3″ x 2″ at 1.4 GHz
- r.m.s. noise ≦ 100 μJy/beam
- Core-Jet structures / Broad outflows not related to the galaxy in ~55% of the sources. eg., IC1481, NGC1614 at 1.4 GHz
- Extents: 11, 10 kpc for IC1481, NGC1614
- Core + galaxy emission in ~25% of sources at 1.4 GHz (e.g., Edelson 1987), but >50% at 610 MHz

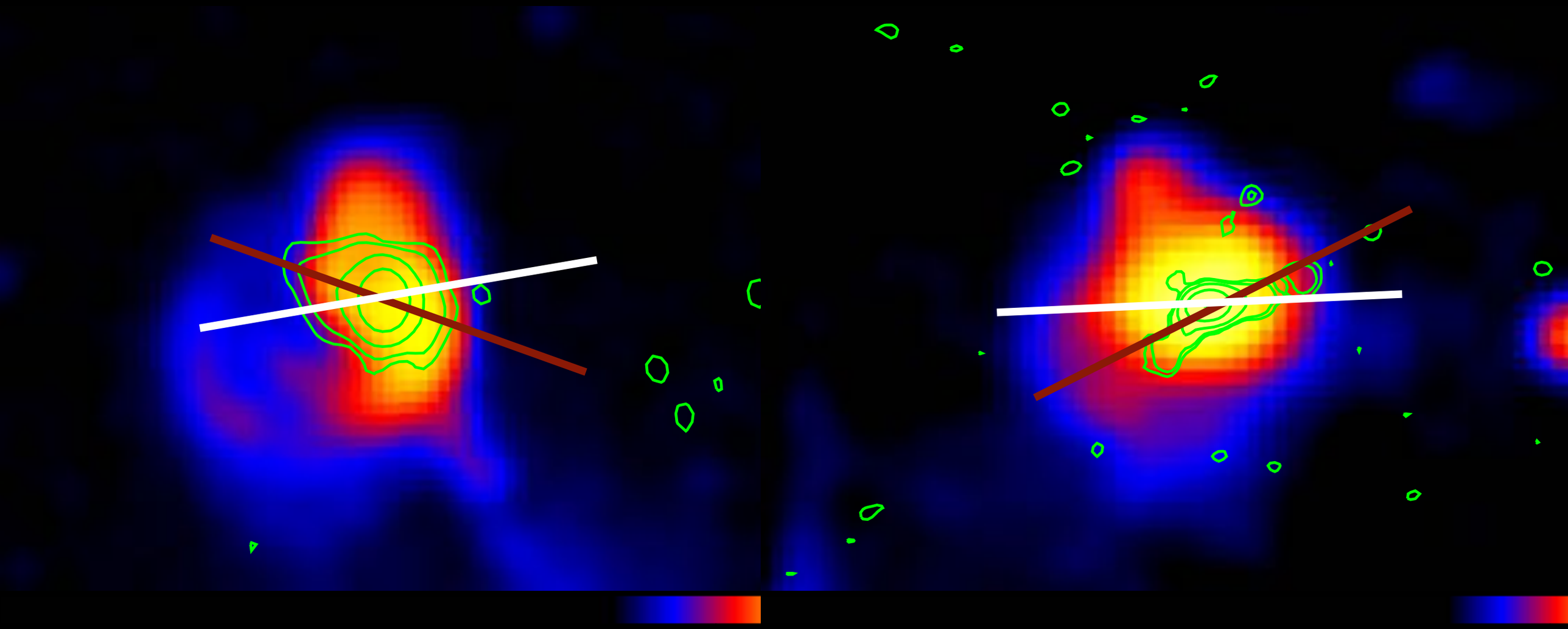




RADIO EMISSION FROM GALAXIES



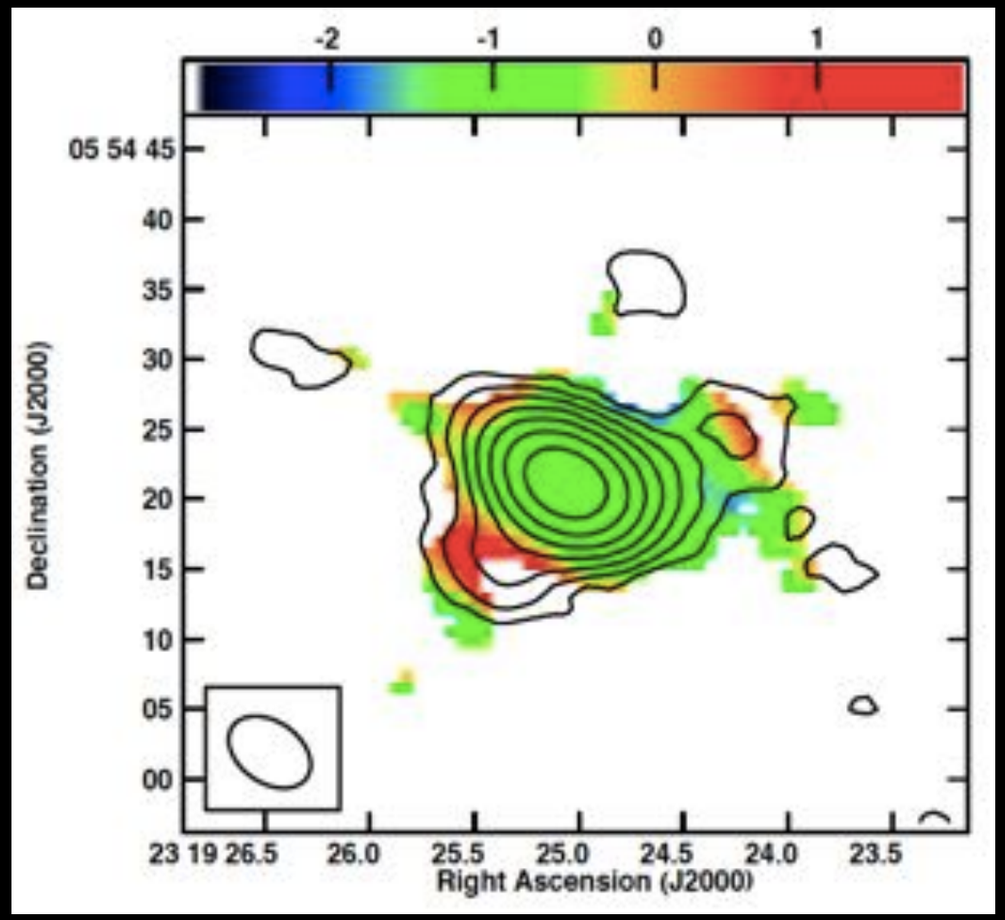
RADIO P.A. NOT WELL ALIGNED WITH GALAXY MINOR AXIS

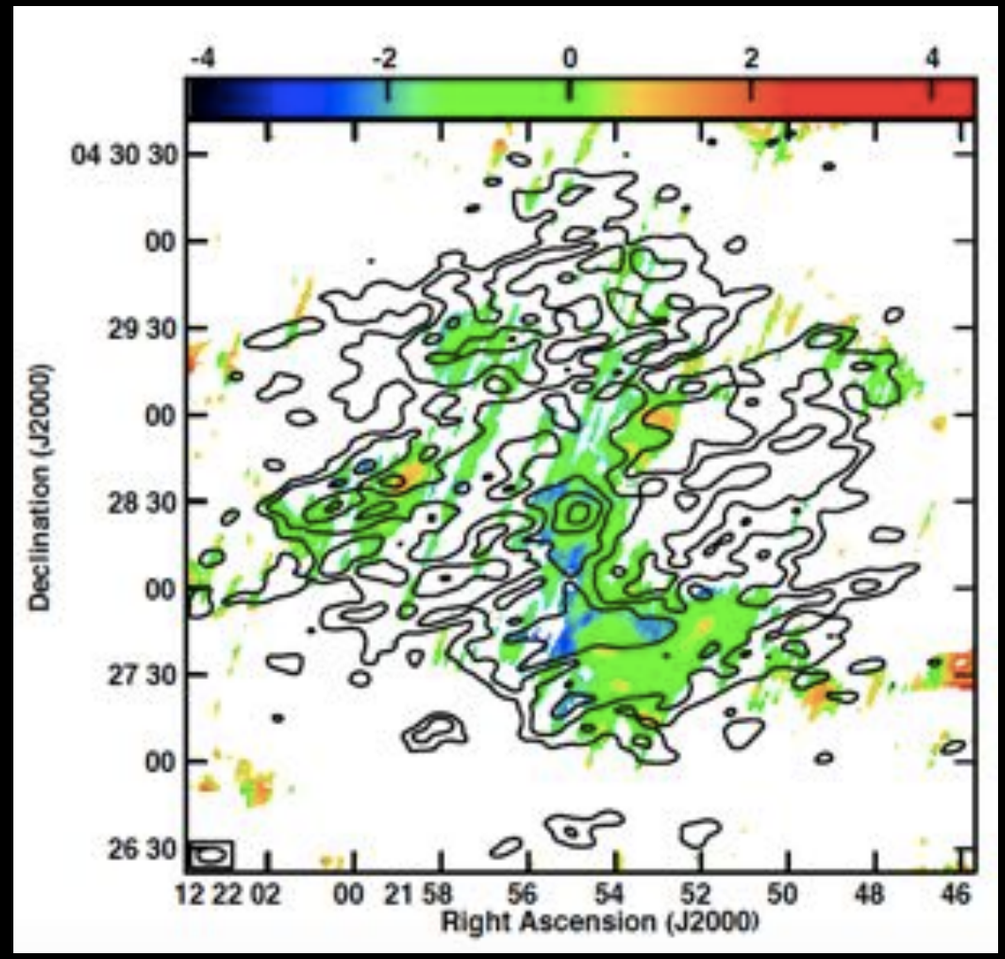


- (host galaxies are disturbed here)

610-1390 MHZ SPECTRAL INDEX

- Steep-spectrum radio cores. e.g., IC1481, $\boldsymbol{\alpha}$ ~ -0.8 ± 0.1
- Compact flat/inverted spectrum core unresolved, contamination from jet
- Galaxy emission, e.g., NGC4303, $\boldsymbol{\alpha}$ ~ -1.3 ± 0.2
- Steep spectrum rules out free-free emission, supports synchrotron origin
- Galaxy contamination to core spectra & Image registration difficult for sources with weak radio AGN





DISENTANGLING AGN & STELLAR CONTRIBUTIONS

- S7 Seyfert galaxy NGC613: AGN + starburst ring
- ATCA at 5 & 8 GHz
- Radio $\boldsymbol{\alpha}$: -0.1 ± 0.2, consistent with free-free emission from HII regions. Radio jet $\boldsymbol{\alpha}$ ~-0.9 ± 0.1
- R. Davies et al. 2017, MNRAS submitted

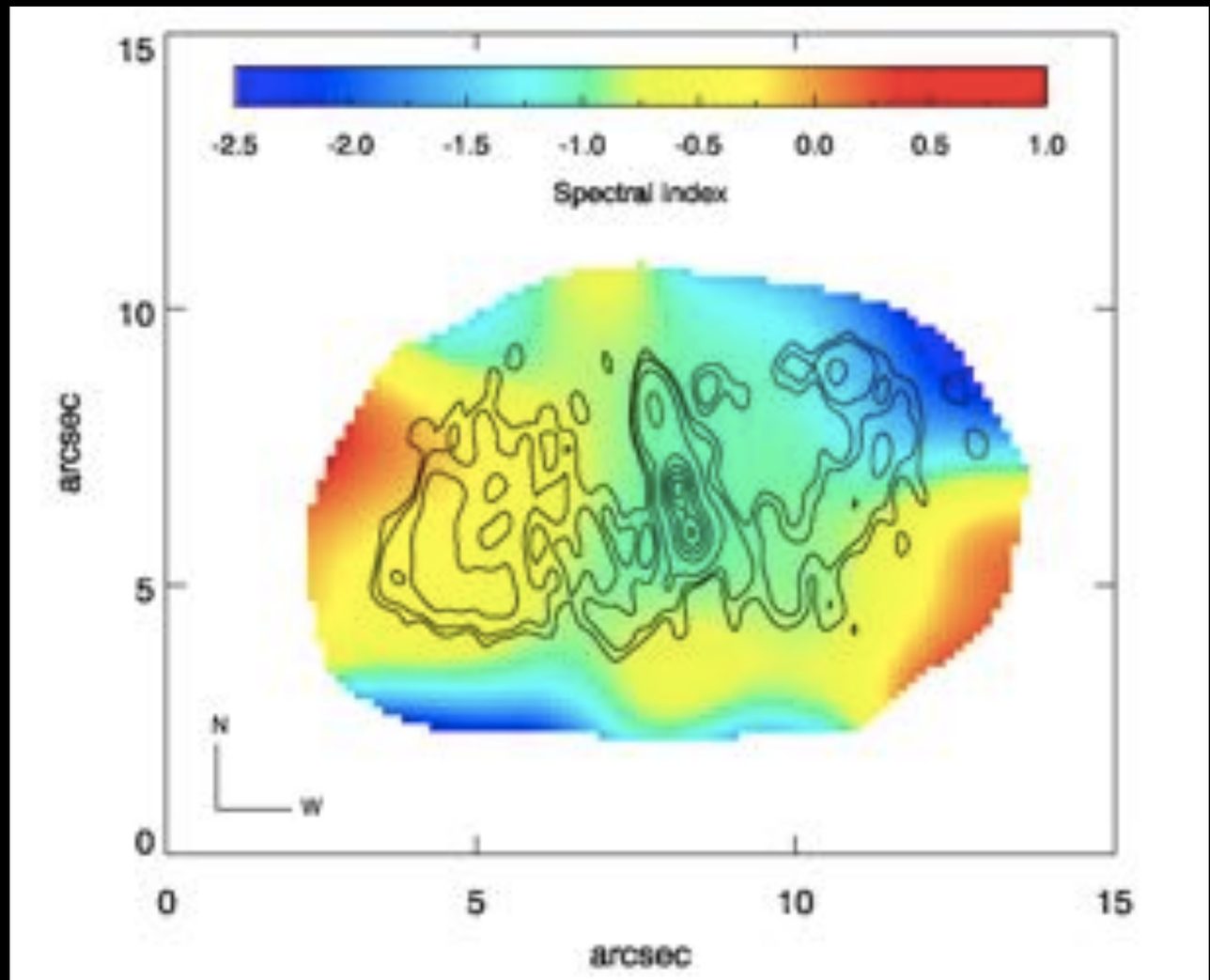
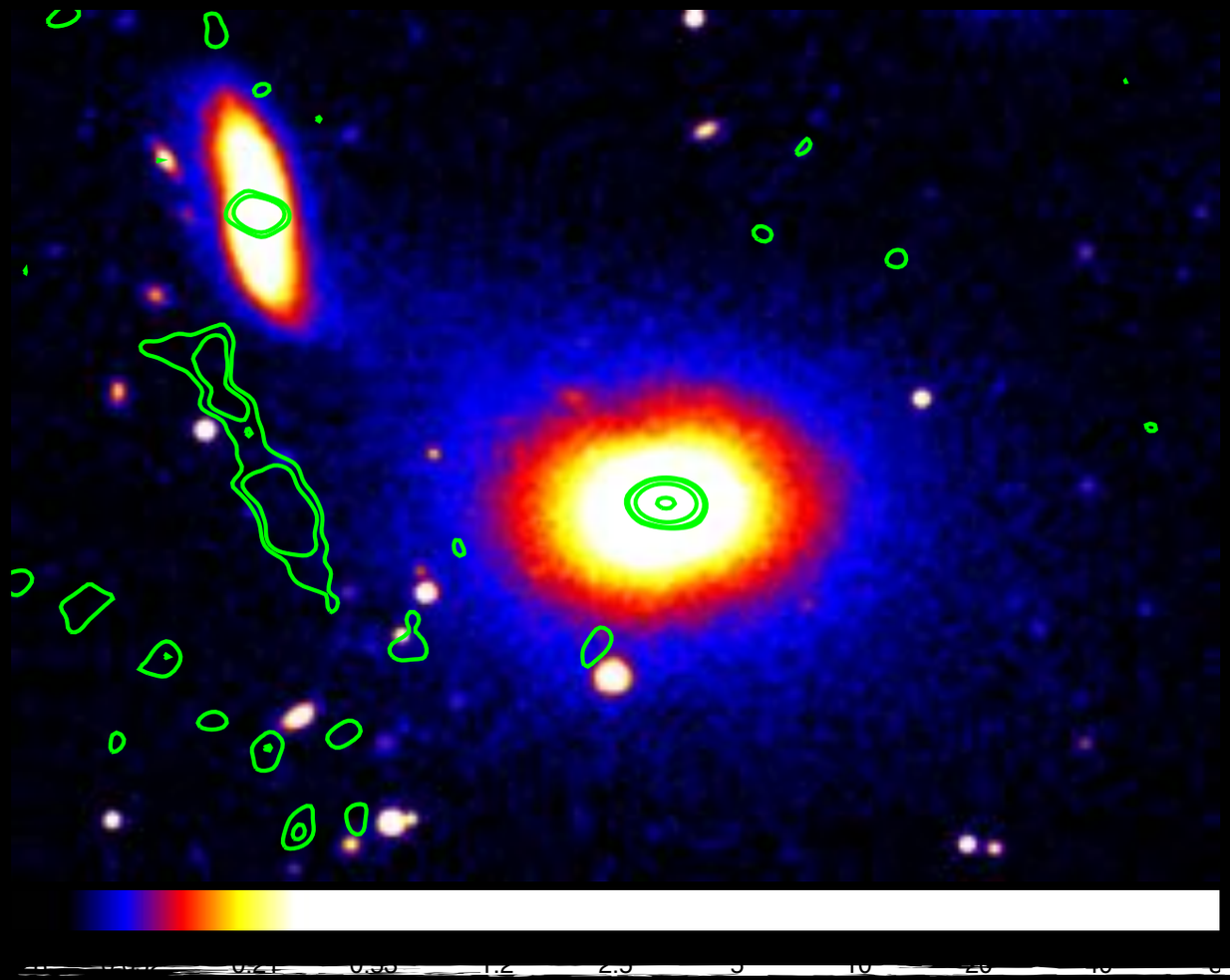
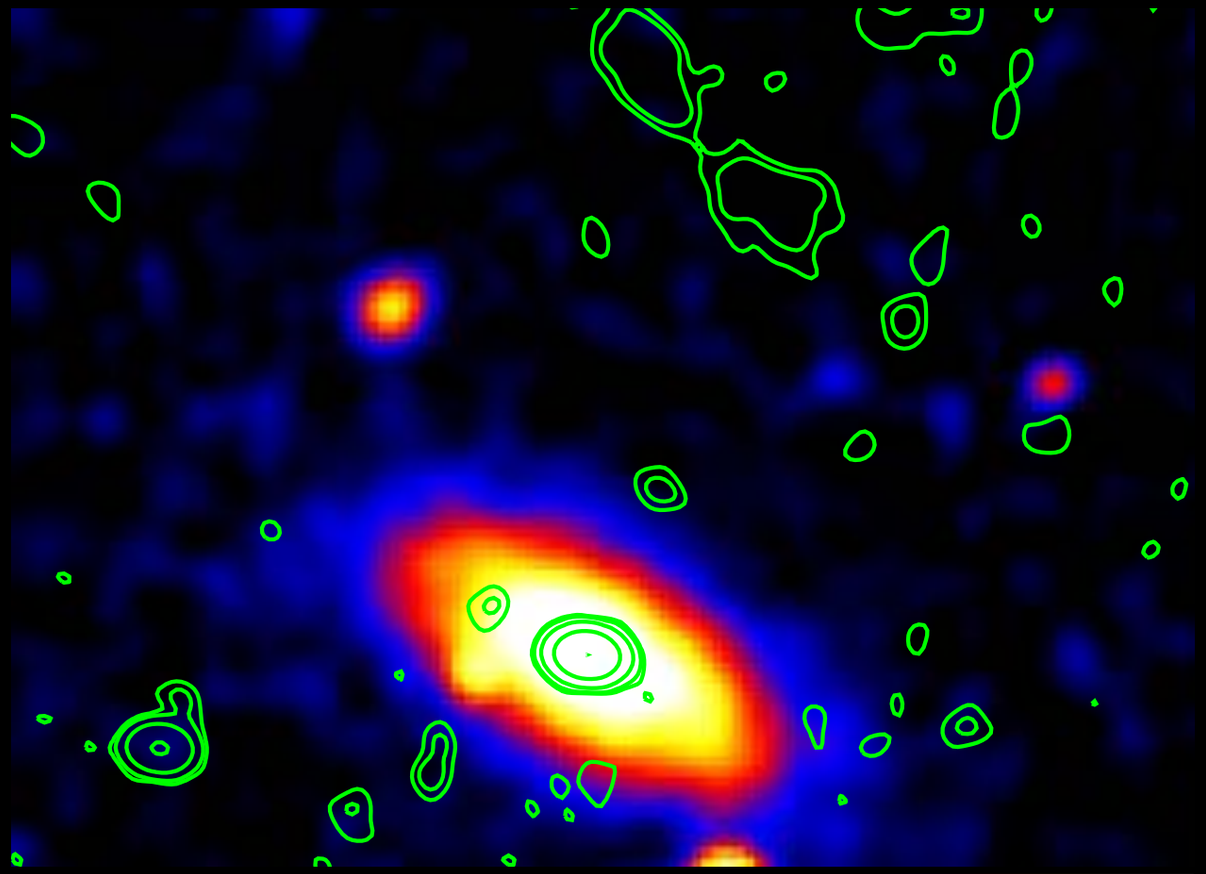


Figure 9. Map of the 4.6-8.1 GHz spectral index, constructed from ATCA data. The overlaid contours trace the 4.89 GHz emission detected by the VLA. The contour levels are the same as in Figure 8, with an additional contour level at 3.5 per cent of the peak surface brightness.

RELIC EMISSION AT 610 MHZ ?





- Ark402: 30 kpc away, NGC4418: 14 kpc away
- Could these be from past Seyfert activity cycles ? If yes, it reduces the single outflow lifetime by 1.6 compared to what Gallimore+ deduced from simple calculations, e.g., lifetime = 55 x 10^8/2 Myr

SUMMARY

- Observed 29 S7 Seyfert galaxies with the GMRT at 610 and 1390 MHz. (New GMRT data acquired for 9 additional S7 Seyferts.)
- Detected a larger fraction of KSRs compared to the VLA 5 GHz study (44% versus 55%)
- KSRs are typically not aligned with the host galaxy minor axes
- Detection of host galaxy emission increased by a large fraction at 610 MHz. This contaminates AGN emission especially if weak. Spectral indices inadequate for separating AGN / SF contributions
- Diffuse relic-like emission with no obvious optical counterparts seen close to some sources. If associated, this has implications for the lifetime of outflows
- Further analysis is underway