The Red MSX Source Survey

Ultra Compact HII regions

James Urquhart
University of Leeds

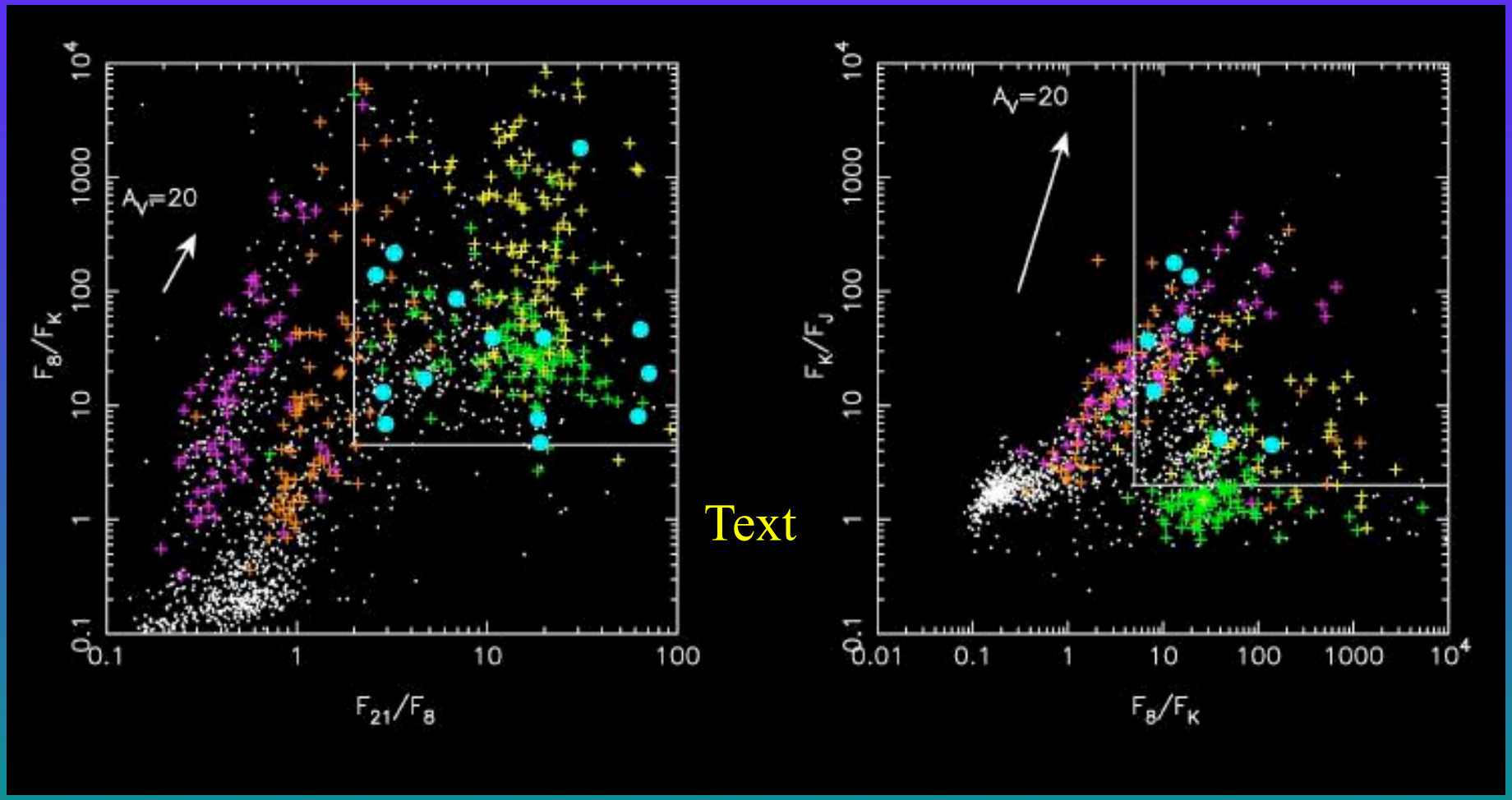
RMS Team:
Melvin Hoare, Stuart Lumsden, Rene Oudmaijer, Ant Busfield, Andrew Clarke, Joe Mottram, (Leeds)
Toby Moore (Liverpool JMU)

The Red MSX Source (RMS) Survey

- MSX survey: 8, 12, 14 and 21μm, 18″ resolution, $|b|<5^{o}$
- Colour-select massive YSO candidates from the MSX PSC and 2MASS near-IR survey
- Delivers ~ 2000 MYSO candidates
- Many other object types with similar near- and mid-IR colours, such as:
  - Evolved stars
  - Planetary Nebulae
  - Carbon stars
  - UC HII regions

Multi-wavelength Ground-based Follow-up Campaign

- Identify and eliminate confusing sources
- Begin characterisation of the genuine massive YSOs
- Observational programme includes
  - Near-IR imaging and spectroscopy
  - Mid-IR imaging
  - Molecular lines (^{13}CO and CS)
  - Radio continuum
    - Main aim to identify UC HIIs and PNe
    - MYSOs are also known to possess ionising stellar winds, but these are weak thermal radio sources ~ 1 mJy at 1 kpc

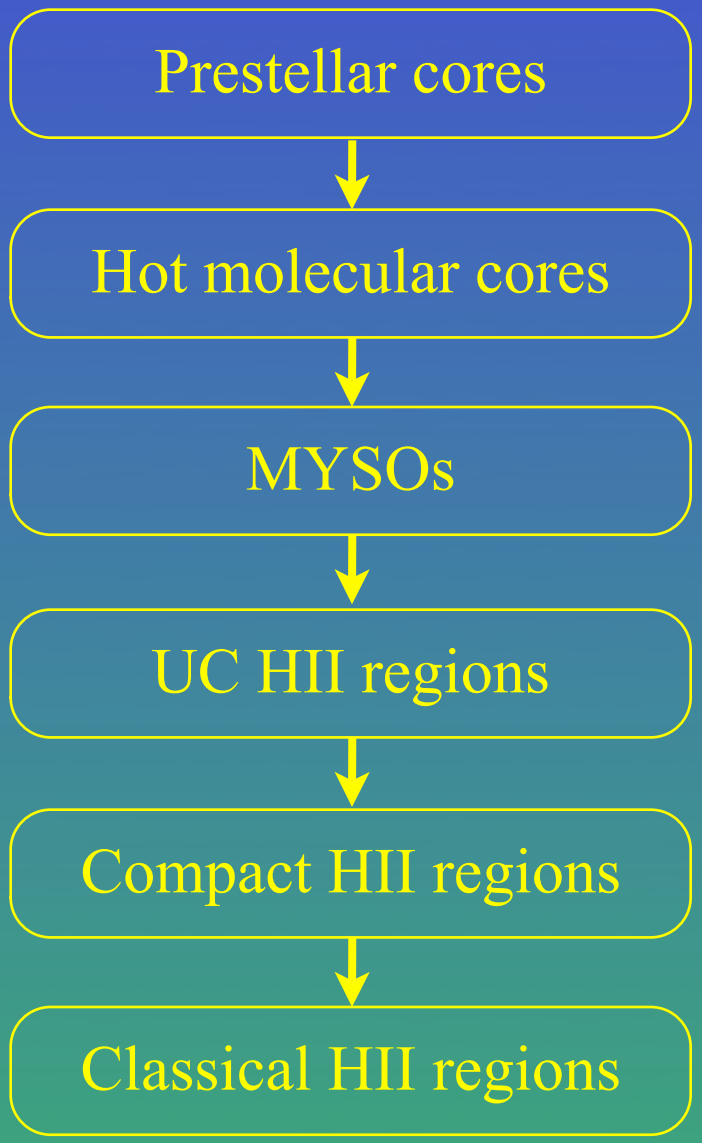


Text

- Massive YSOs + UCHII regions + C stars

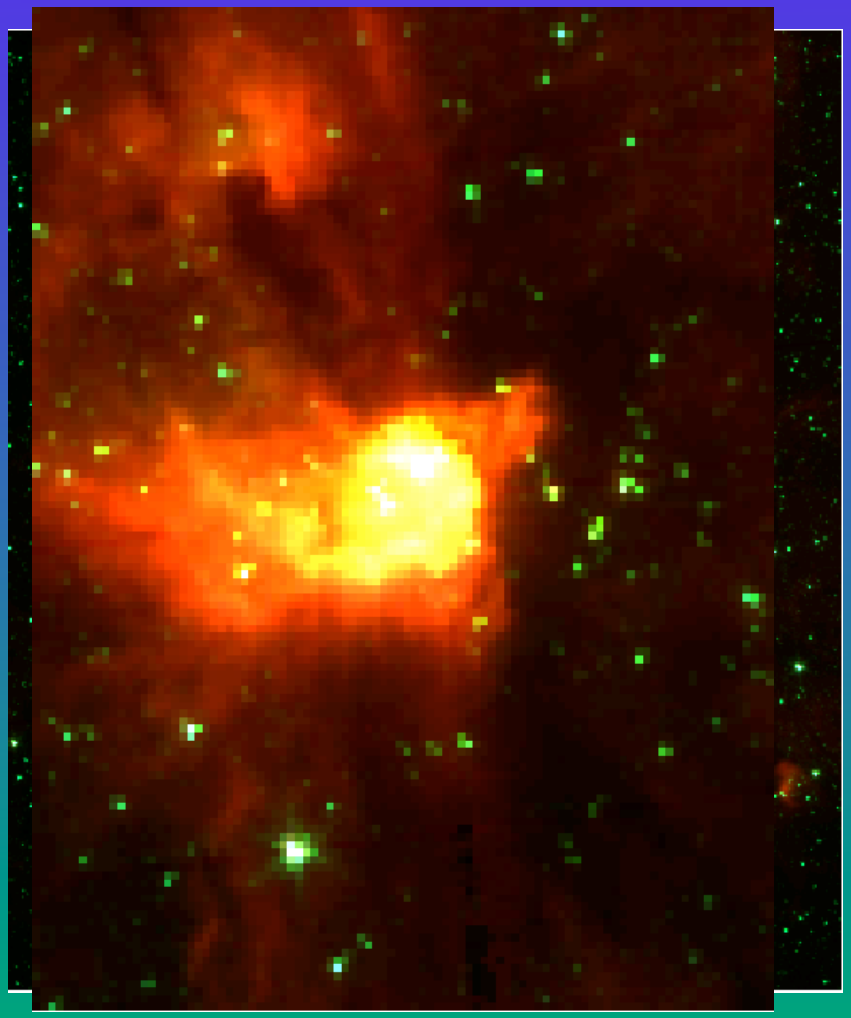
+ PN + OH/IR stars

Evolutionary Sequence



Ultra Compact HII Regions

- Early manifestations of newly formed massive stars
- Still deeply embedded within their natal molecular clouds
- All of their radiation is absorbed by dust and re-radiated at IR, submm and radio wavelengths
- Observationally characterised:
  - small size ($d < 0.1$ pc)
  - high densities ($n_e > 10^4$ cm^{-3})
  - high emission measures (EM $> 10^7$ pc cm^{-8})



G336.4917-01.4741

Spitzer IRAC three colour image: 3.6, 4.5 and 8.0

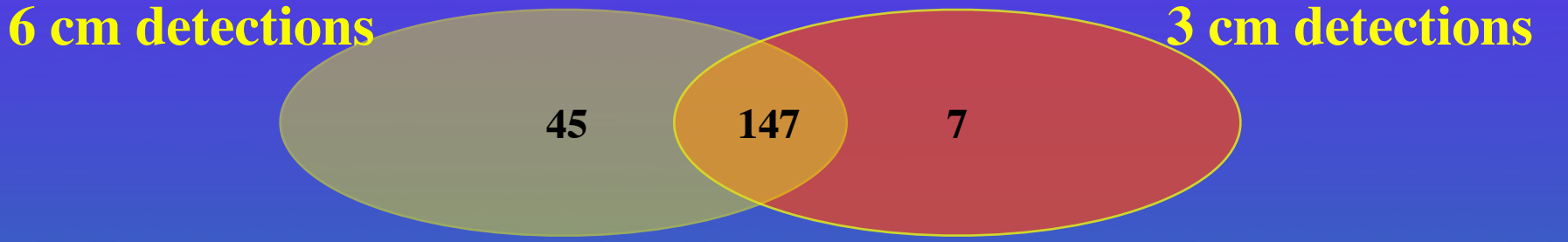
Radio Continuum Observations

- Observed 826 RMS sources at both 3.6 and 6 cm
- Resolution ~ 2″ resolution
- 10 minutes of on-source integration (5x2 minute cuts)
- Typical image rms 0.3 mJy/beam
- Primary beams 5.5’ and 9.9’ at 3.6 and 6 cm
- Largest well imaged structure:
  - ~ 20″ at 3.6 cm
  - ~ 30″ at 6 cm
- ATCA - published (Urquhart et al. 2007)

Detection Statistics

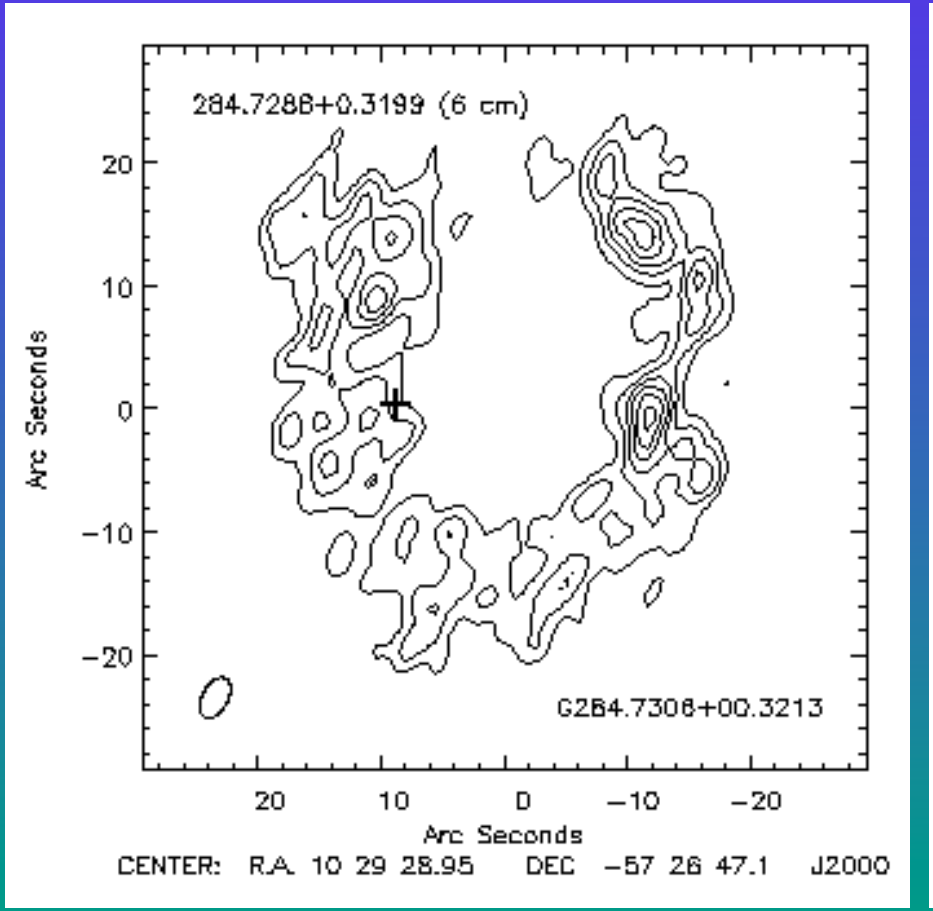
- Detected a total of ~ 380 radio sources
  - 211 associated with 199 RMS sources (~ 25%)
    - Matched radio and RMS sources within 12″
  - 10 RMS source found to be associated with 2 or more radio sources
  - searching the MSX PSC we identified a further 51 radio sources with high probability mid-IR matches
  - 127 radio sources with no mid-IR match
- No radio emission detected towards 627 RMS sources

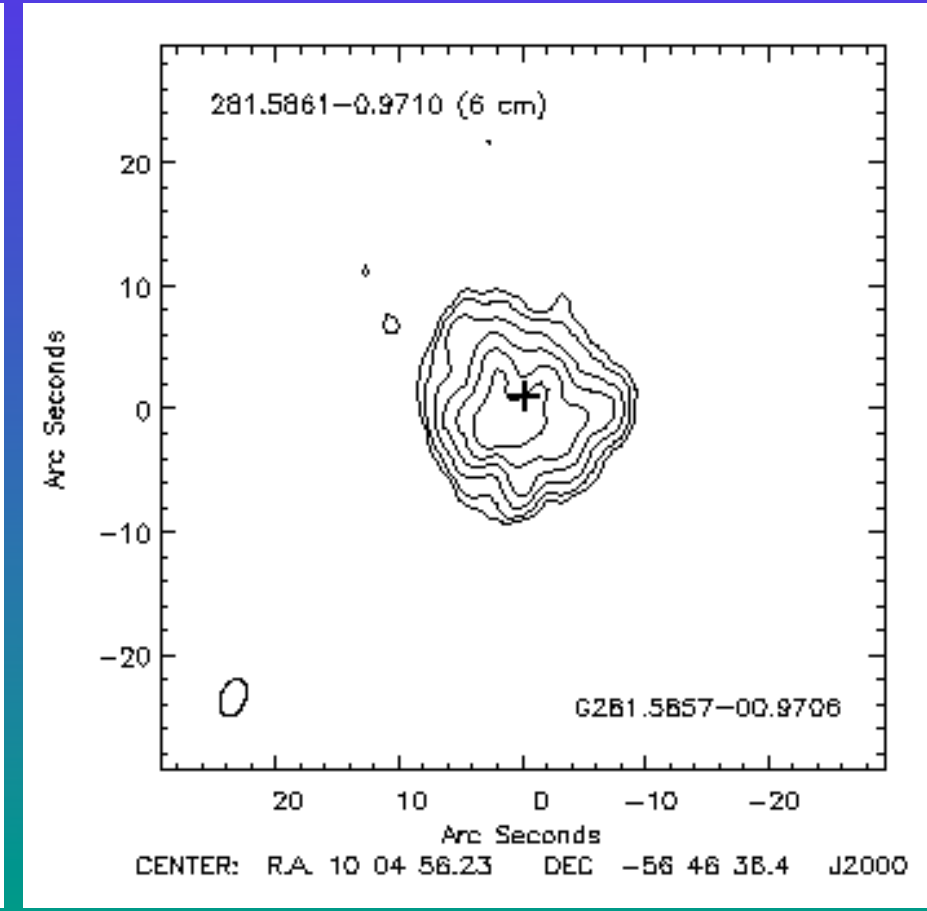
Detection Statistics



- 3 cm detections: all are unresolved and have fluxes above the 4σ rms noise level of the corresponding 6 cm image
  - optically thick nebulae
- 6 cm detections:
  - 11 of these can be explained by the different size of the primary beams
  - 26 are found to be extended at 6 cm and either poorly imaged or totally resolved out at 3 cm
  - remaining 8 would need to have negative spectral indices - possibly chance alignments

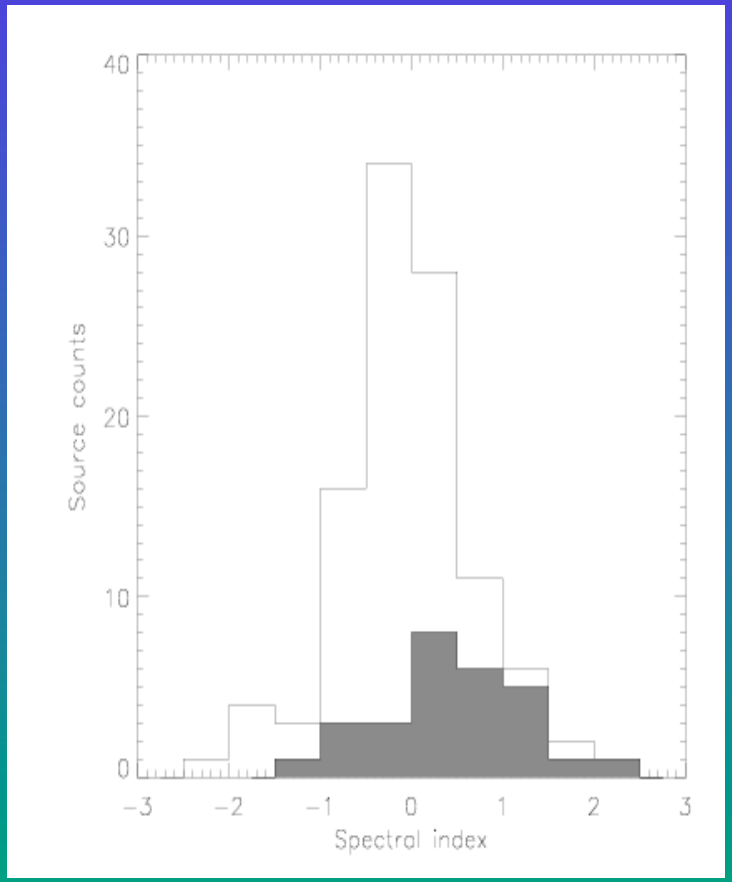
Detection Statistics





Spectral Indices

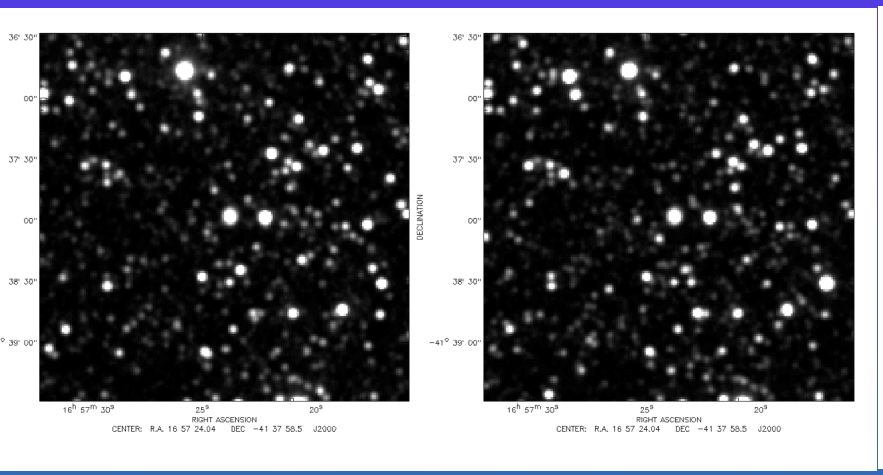
- ATCA is not a scaled array
- spectral indices
  - all sources ~ -0.2
  - unresolved ~ 0.2
- consistent with the radio emission being thermal in origin

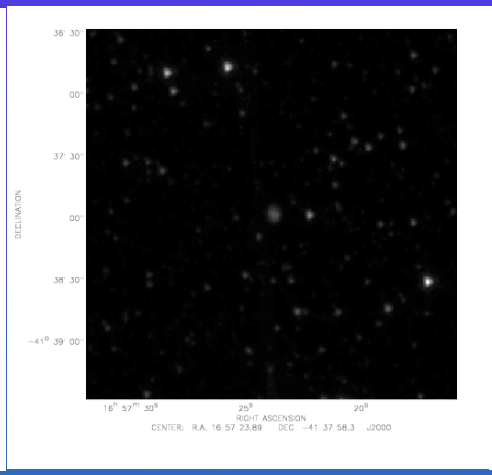


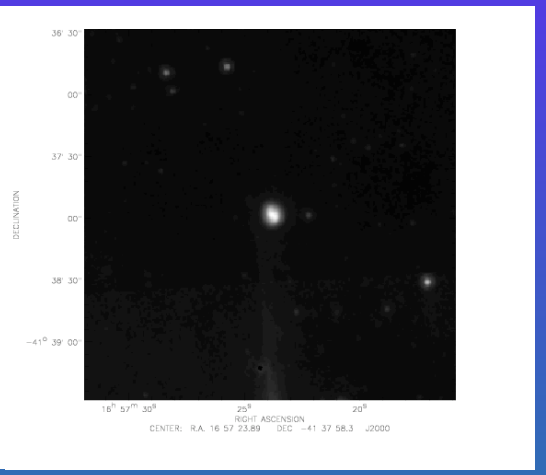
Radio Source Identification

- Using multi-wavelength data obtained from other parts of our observations programme to identify RMS sources
- Of the radio detections we have identified
  - ~ 40 Planetary Nebulae
    - isolated point sources, very weak or non-detections at ^{13}CO, no associated nebulosity
    - many identified in the literature
  - ~ 170 UCHII regions
    - red near-IR colours, surrounded by nebula emission, strong CO and CS
    - offset associated with methanol or water masers

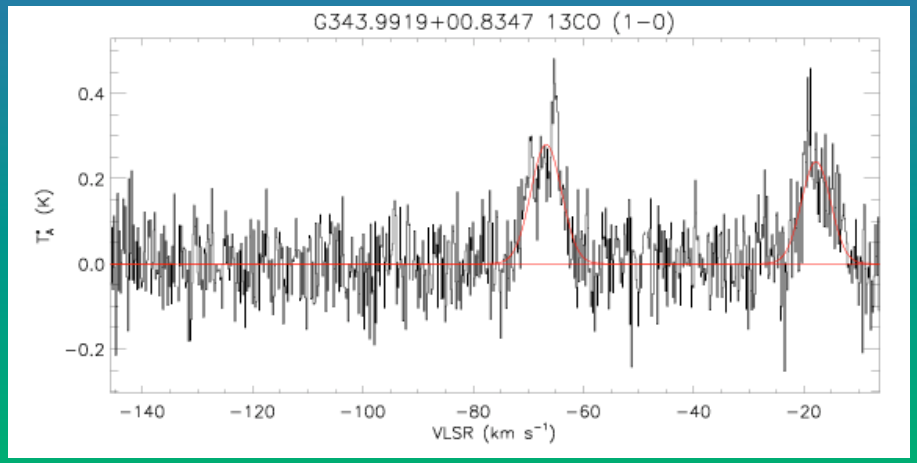
Example PN: G343.9919+00.8347

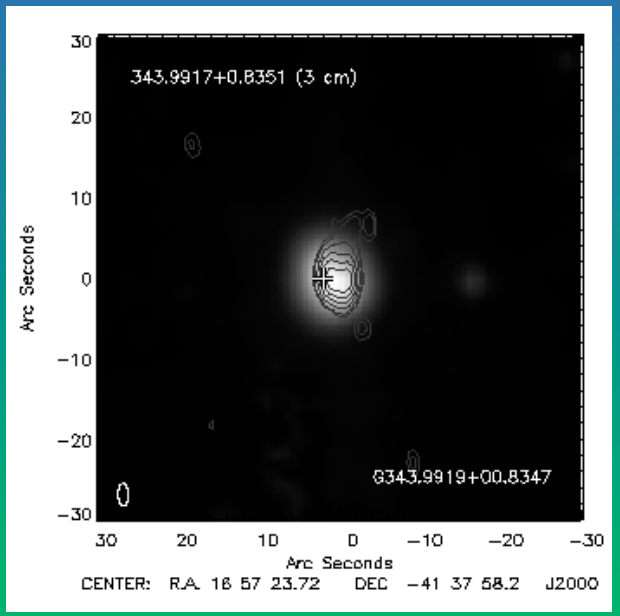




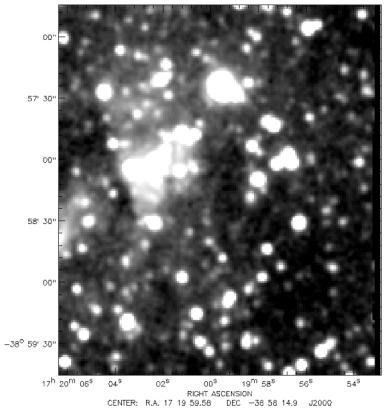


J band K band 3.6 Micron 8.0 Micron

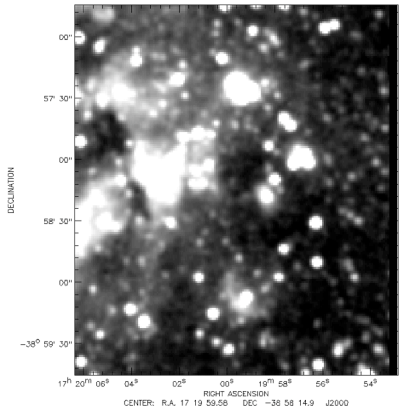




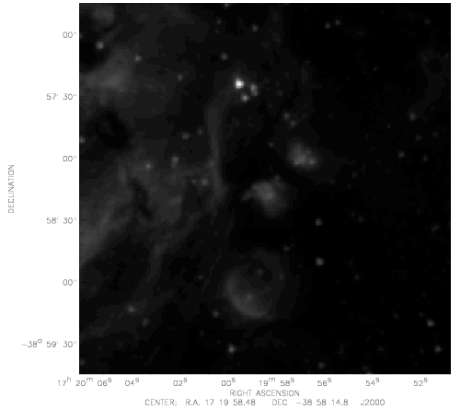
Example UCHII: G348.6855-01.0364



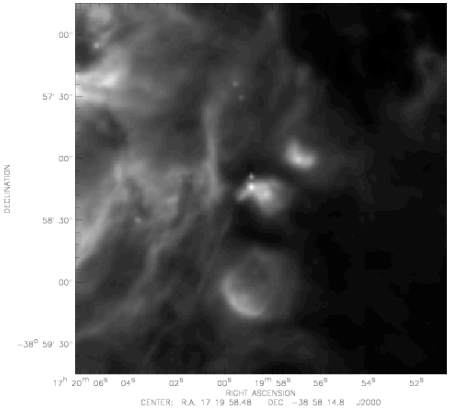
J band



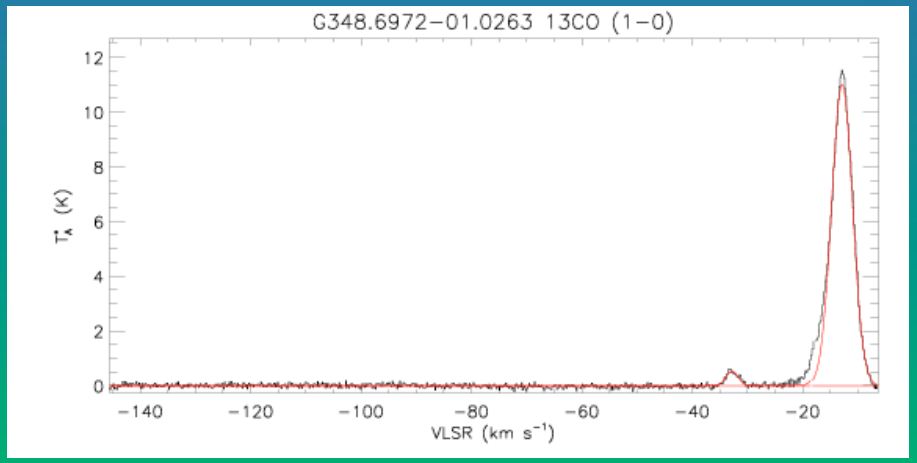
K band

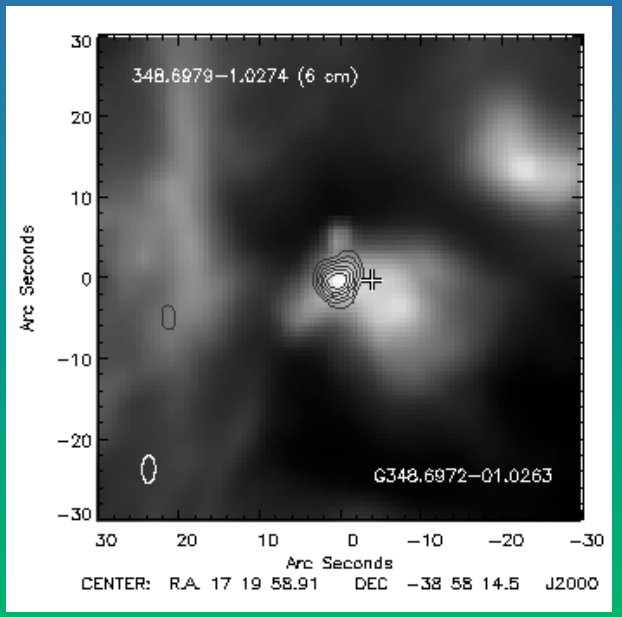


3.6 Micron

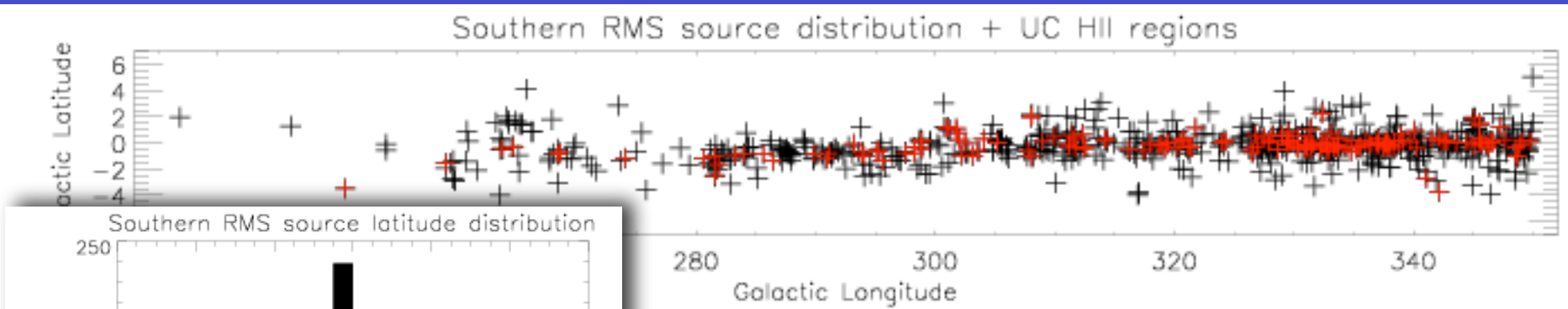


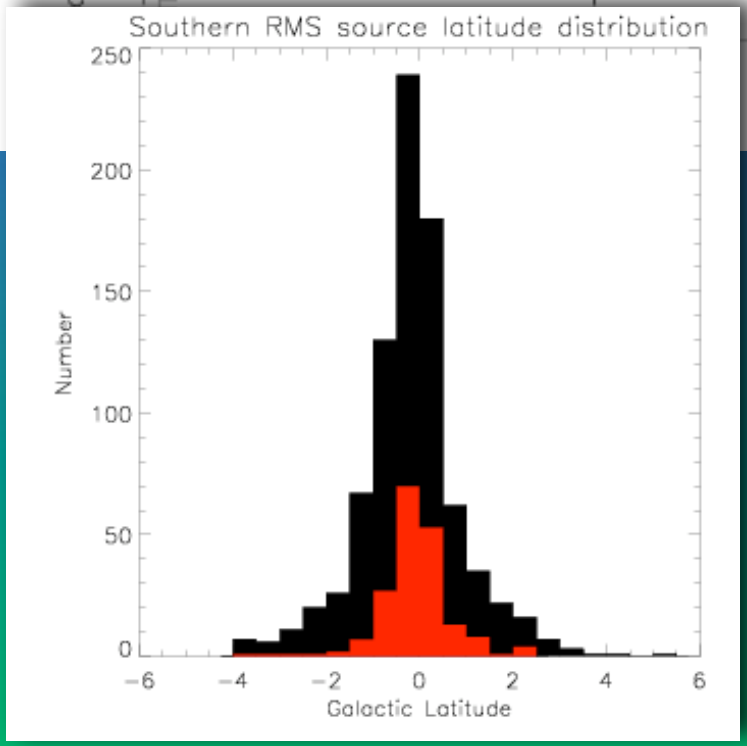
8.0 Micron





Distribution of Radio Detections



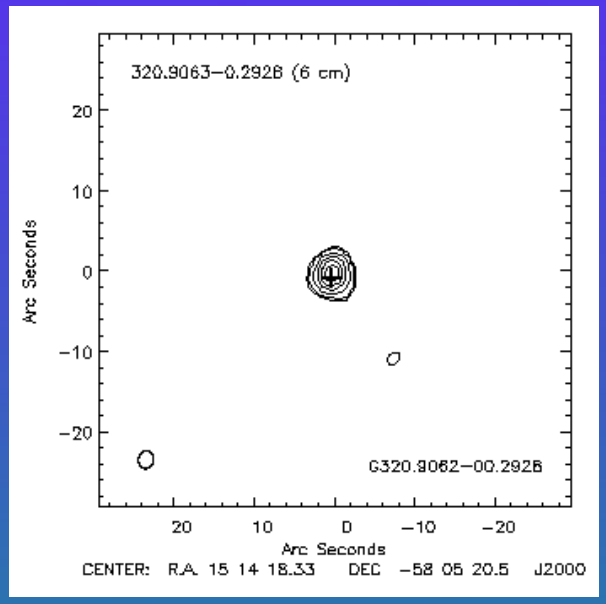


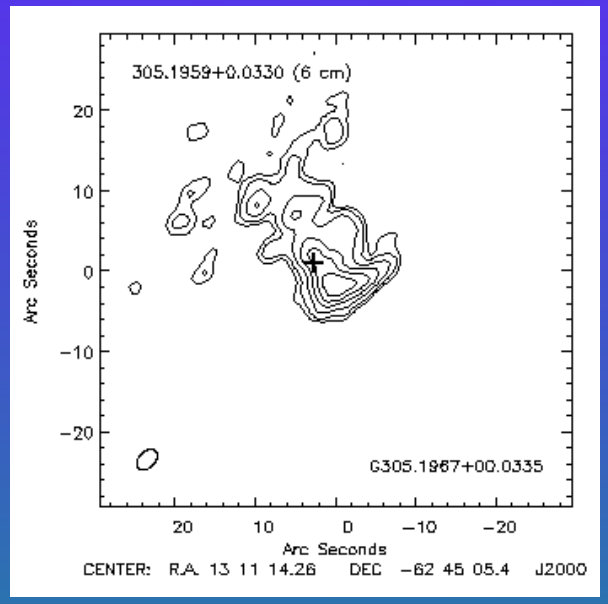
i) Distribution of radio sources correlated with Galactic plane

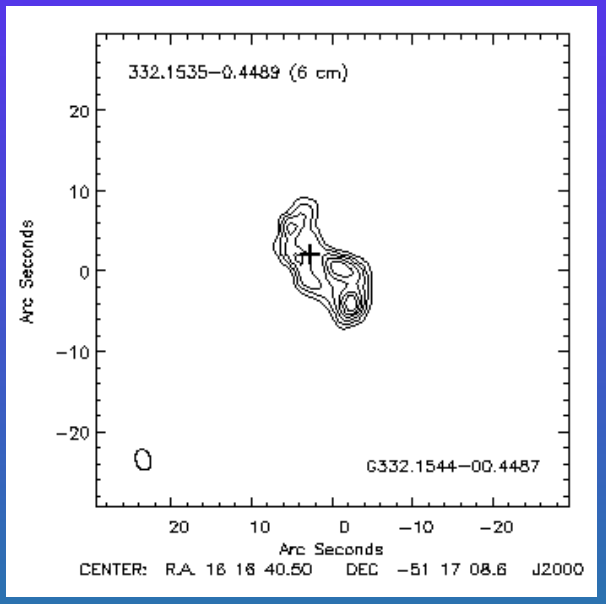
ii) Scaleheight of ~0.5°

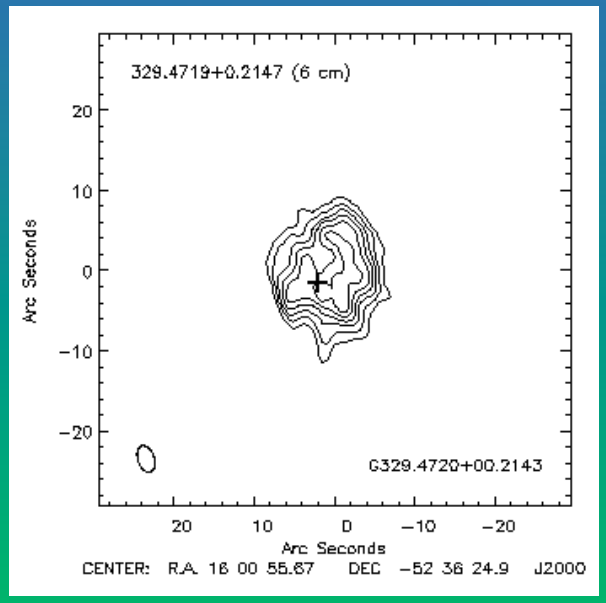
iii) We find ~ 90% of UC HIIs within 1° of the Galactic plane

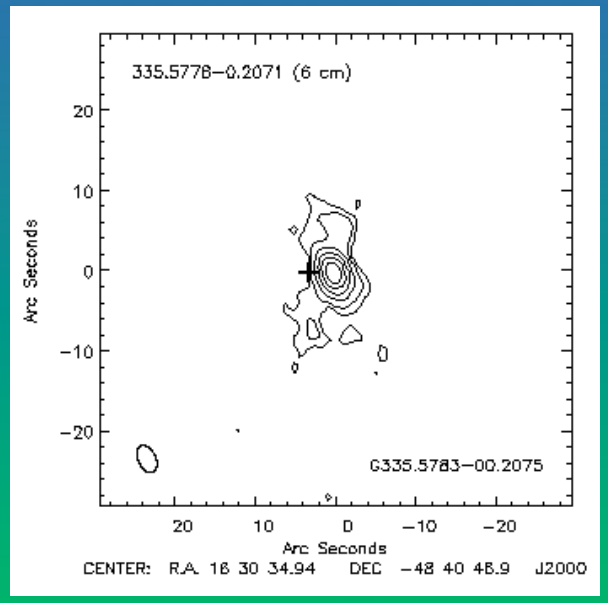
Radio Morphologies

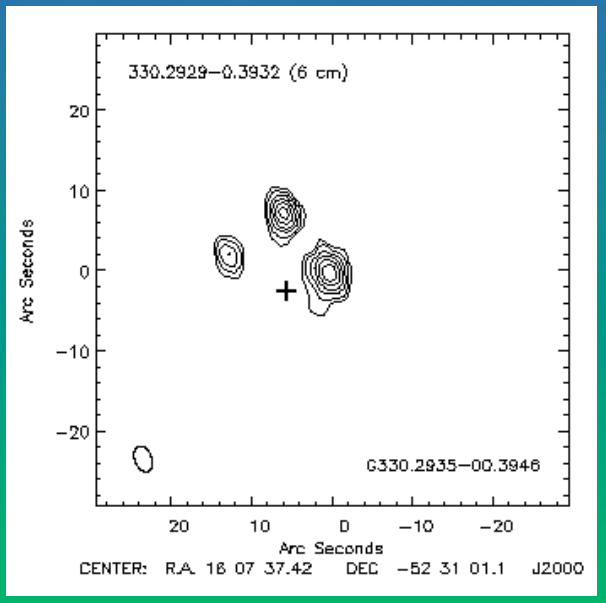


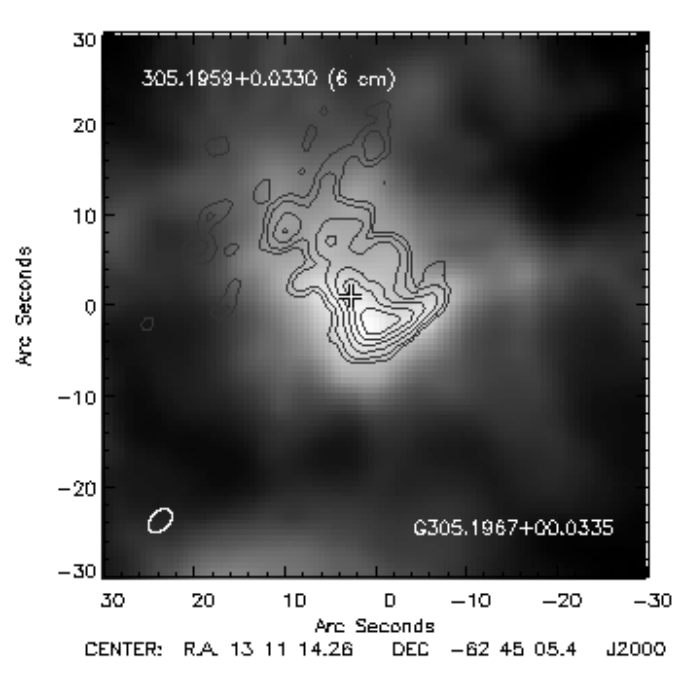


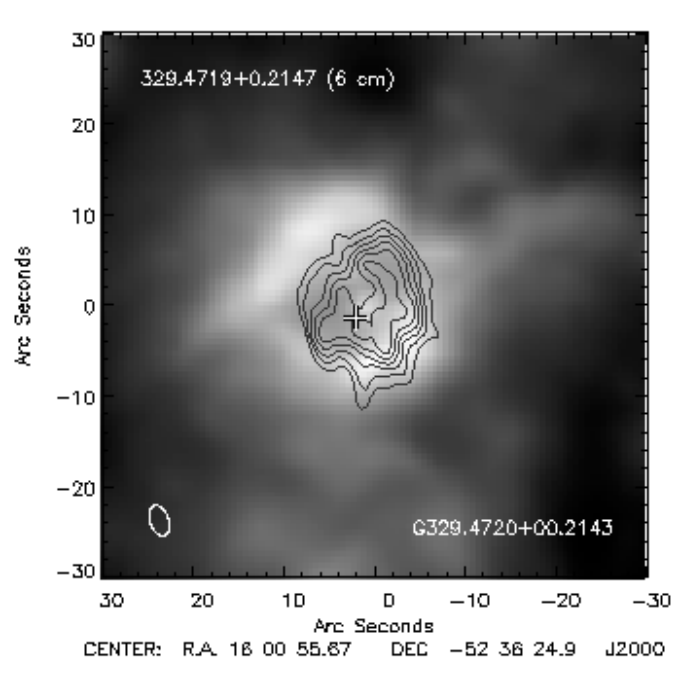


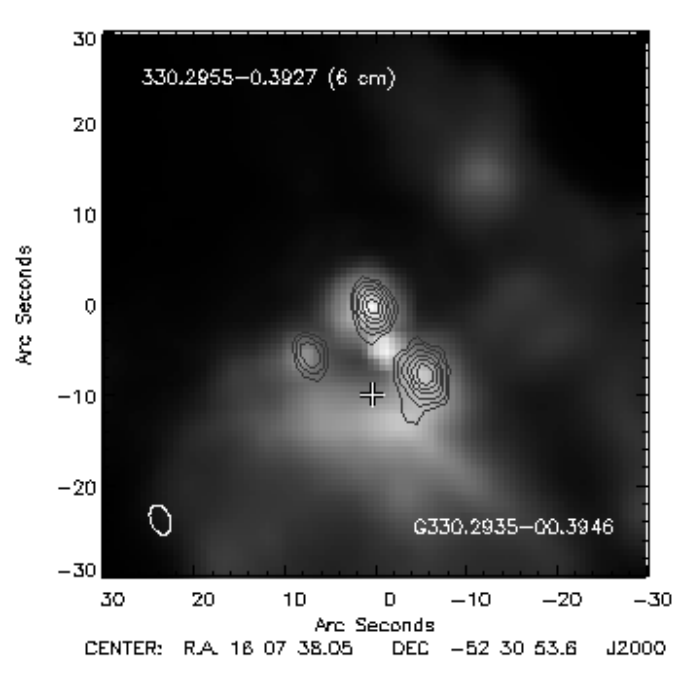


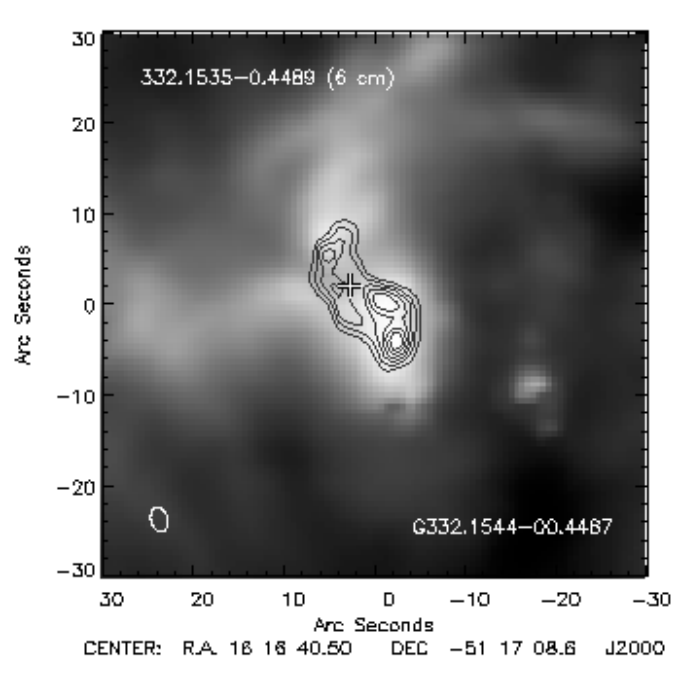





305.1959+0.0330 (6 cm)
G305.1967+00.0335
Arc Seconds
Arc Seconds
CENTER: R.A. 13 11 14.26 DEC -62 45 05.4 J2000

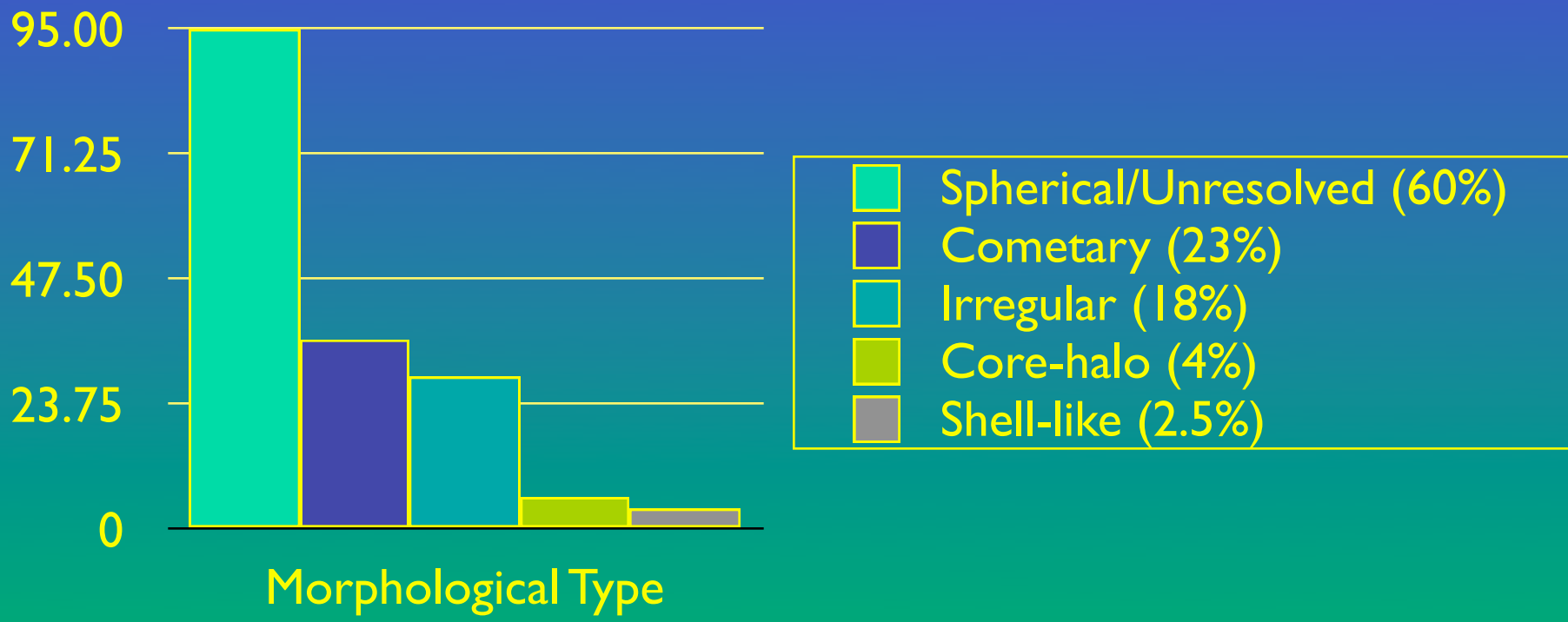

329.4719+0.2147 (6 cm)
G329.4720+00.2143
Arc Seconds
Arc Seconds
CENTER: R.A. 16 00 55.67 DEC -52 36 24.9 J2000


330.2955-0.3927 (6 cm)
G330.2935-00.3946
Arc Seconds
Arc Seconds
CENTER: R.A. 16 07 38.05 DEC -52 30 53.6 J2000


332.1535-0.4489 (6 cm)
G332.1544-00.4467
Arc Seconds
Arc Seconds
CENTER: R.A. 16 16 40.50 DEC -51 17 08.6 J2000

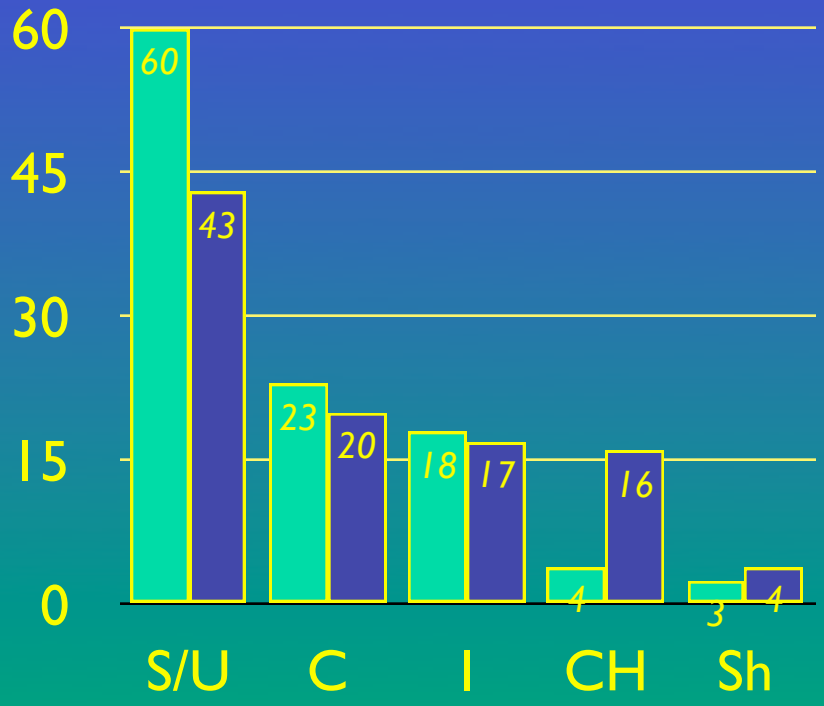
Radio Morphologies

- Used the Wood and Churchwell (1989) criteria to classify our detections



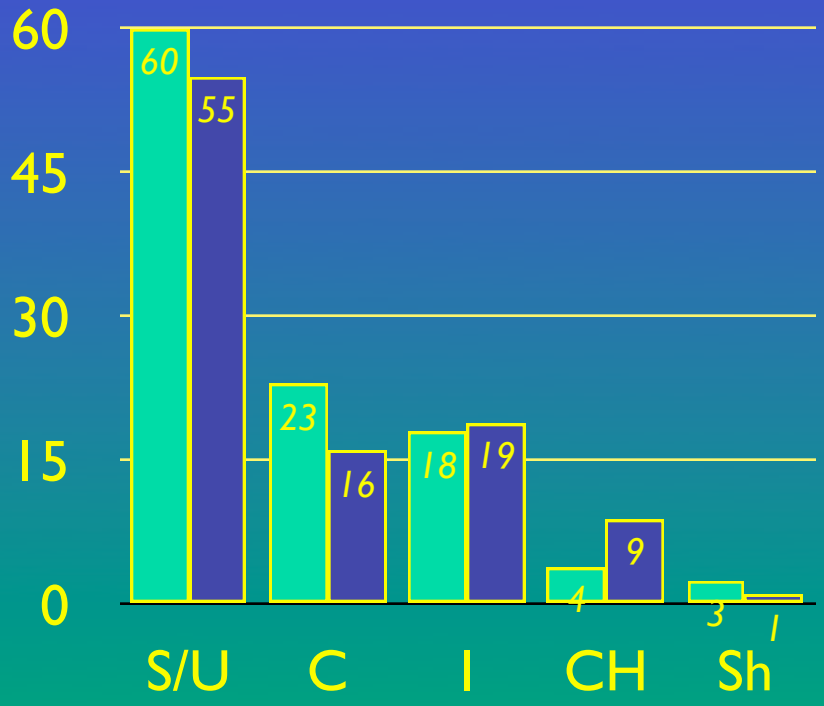
Radio Morphologies

- Comparison with Wood and Churchwell 1989



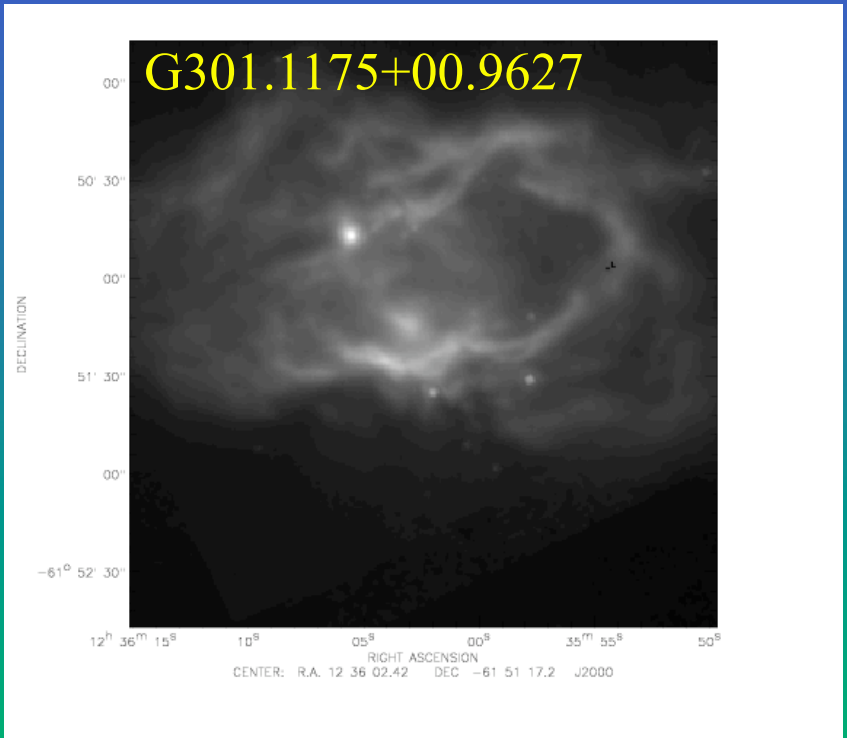
Radio Morphologies

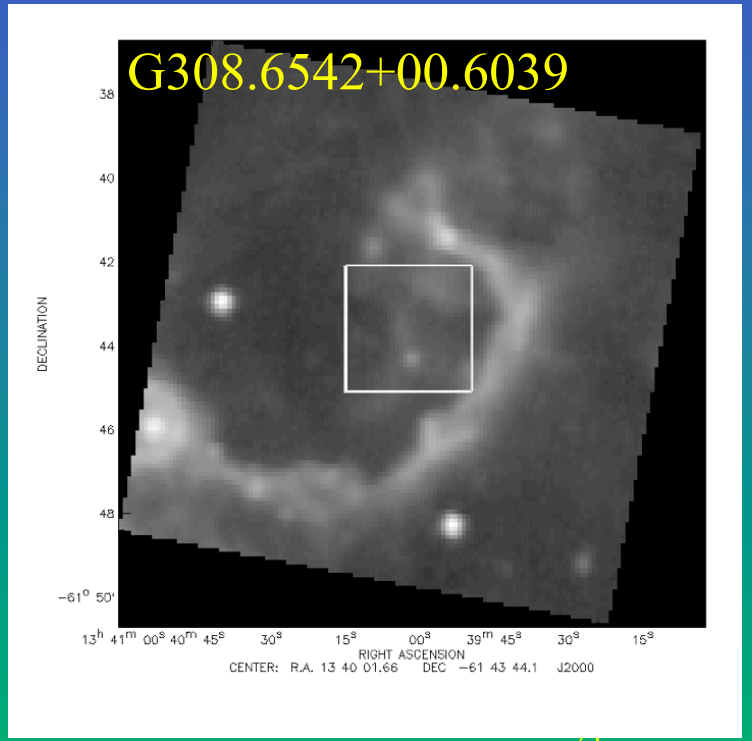
- Comparison with Kurtz et al. 1994



Additional HII regions

- We have identified from Mid-IR images (e.g., GLIMPSE, TIMMI2) another ~130 compact HII regions
- These are too large to have been successfully imaged with ATCA





Total number of Compact and UCHII regions

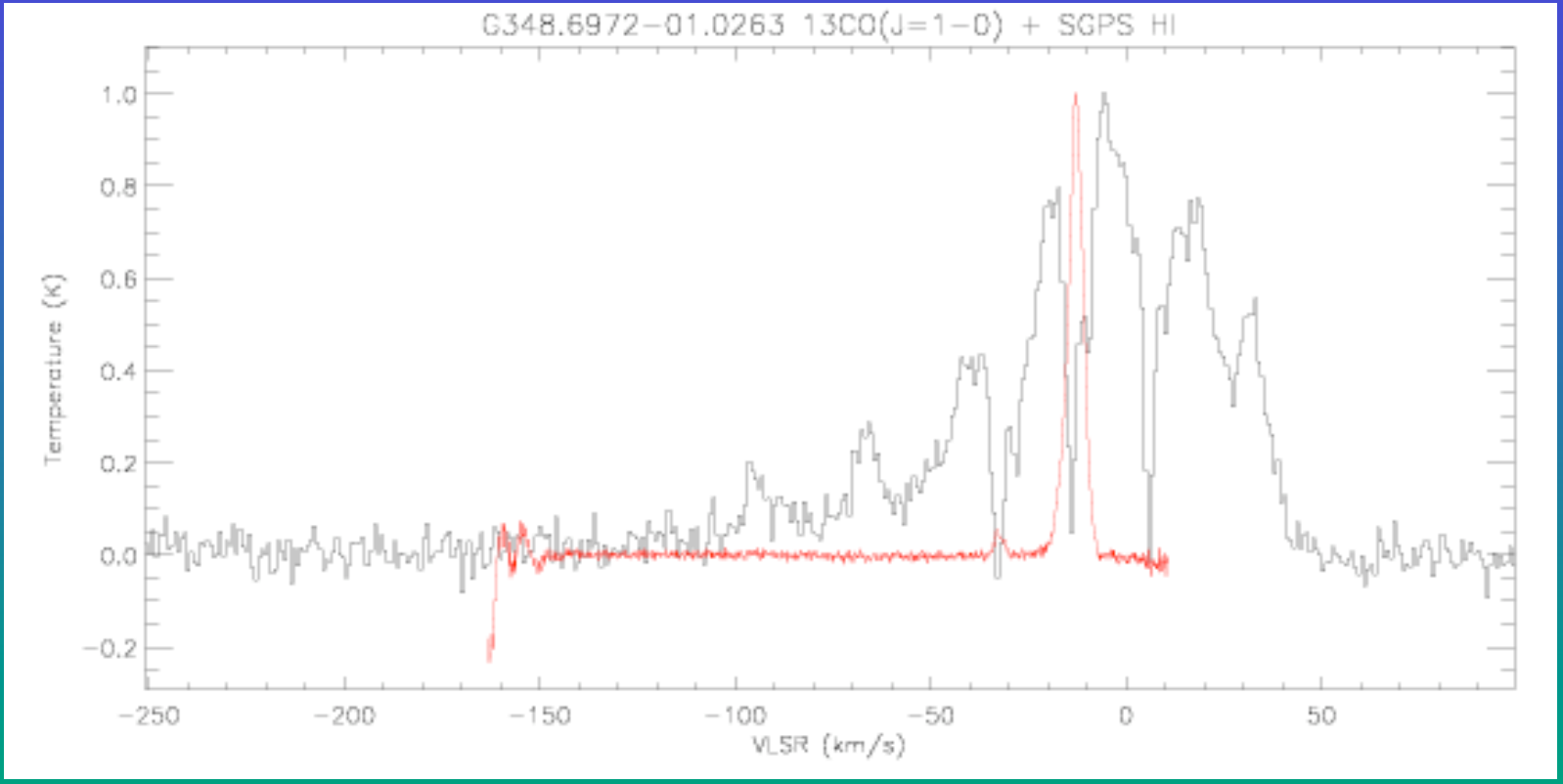
- In the southern hemisphere we have identified ~ 300 compact and UCHIIs
  - This leaves ~ 500 MYSOs candidates
- Our programme of radio observations in the North is also nearing it completion
  - VLA observations
  - Archival data obtained from Giveon et al. 2005, Wood and Churchwell 1989, Kurtz et al 1994, and CORNISH
- Combined will produce a catalogue of ~ 600 HII regions the majority of which are currently unknown

Kinematic Distances

- We have obtained ^{13}CO spectra towards all RMS sources
  - Mopra, Onsala, JCMT, Purple Mountain Observatory
  - archival data from the Galactic Ring Survey (GRS)
- Using the source V_{LSR} with which when combined with rotation curve allows the kinematic distances to all RMS sources (Brand and Blitz 1993)
- Two difficulties:
  - Multiple ^{13}CO components detected towards 60% of sources (follow-up CS obs, methanol & water masers)
  - 80% of sources are located within the solar circle - two possible distances (HI self-absorption, data taken from the IGPS)

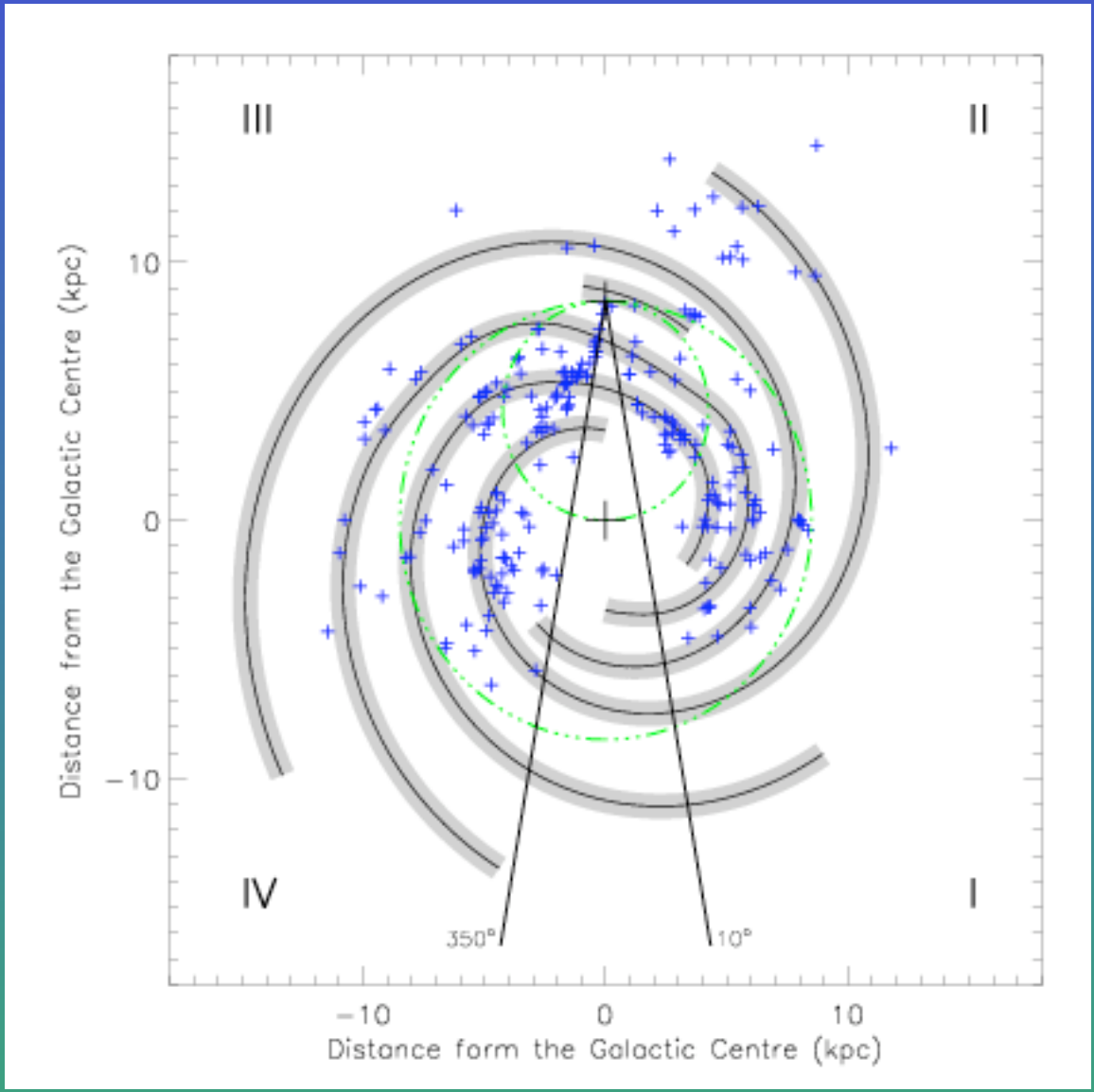
Distance Ambiguity

G348.6855-01.0364



Jackson et al. 2002 & Kolpak et al. 2003

Galactic Distribution of UCHIIs



Rotation curve from Brand and Blitz & spiral arm structure from Cordes & Lazio 2004

Summary

- The RMS survey will deliver ~ 500 massive YSOs over the whole galaxy
- In addition will identify ~ 600 compact and UCHII regions
- Allow the systematic investigations of e.g.
  - Infall/outflow with ALMA/CARMA
  - Accretion/winds with VLT(I), Gemini
  - Jets/equatorial winds with e-MERLIN/EVLA
- All ATCA radio data has been recently published in A&Aq
- For more information and access to our database see the RMS project web page at www.ast.leeds.ac.uk/RMS