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A Galaxy-wide Sample of Massive Young Stellar Objects

James Urquhart

RMS Team:

Melvin Hoare, Stuart Lumsden, René Oudmaijer, Ant Busfield, Andrew Clarke, Joseph Mottram, Joseph Stead (Leeds)

Toby Moore (Liverpool JMU)

Cormac Purcell (Jodrell Bank)

Michael Burton (UNSW)

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The Red MSX Source (RMS) Survey

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The RMS Survey

Talk Outline

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- Introduction
- Colour selection of MYSOs
- Follow-up programme
- Progress and initial results
- Summary
- Future programmes

Motivation

What is a MYSO?

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- Mid and Near-IR bright
- Luminous (>10^4 L_o)
- Radio quiet → UCHII region has not formed
- Often associated maser emission
- Bipolar molecular outflow → accretion is still taking place

GL2591:Gemini JHK

B-type MYSO (see poster by K. Johnston #47)

MYSO samples

- Well characterised MYSOs number in the tens
- Not systematically found and mostly nearby
- Most samples IRAS colour selected:
  - Bias towards bright isolated sources
  - tend to avoid dense clustered environments and the Galactic mid-plane where majority of MYSOs are expected - scale height massive stars ~30' (Reed 2000)
- The limited number and selection method means they may not be representative of the general population of MYSOs

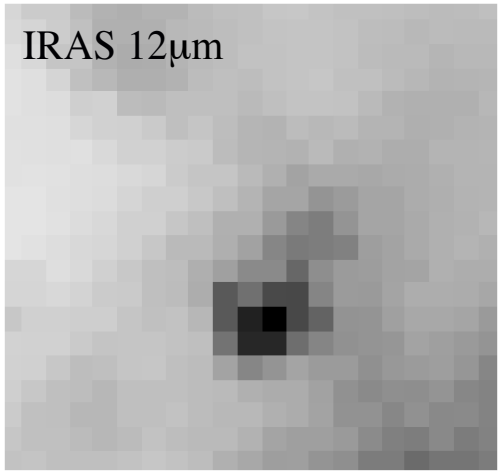
- Need well-selected sample that number in the hundreds
- Can then study properties in a statistically robust way

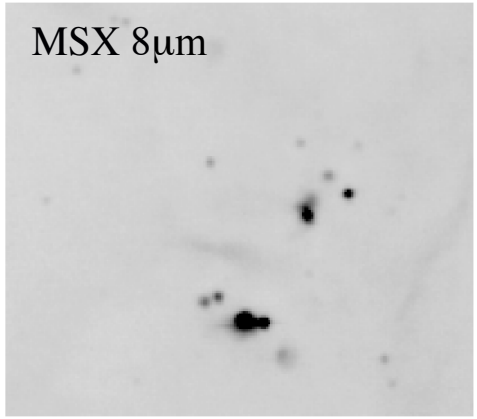
Searching for MYSOs

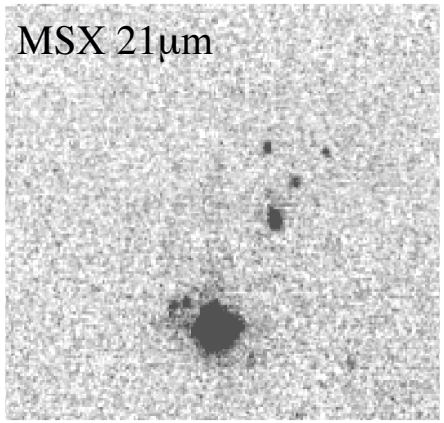
- Too obscured in near-IR
- Radio continuum too weak
- No single maser transition always present
- Molecular cores do not necessarily contain YSOs
- Need to use IR where bulk of energy emerges
- IRAS-based searches suffer from confusion

Colour Selection of MYSOs

- 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 (Lumsden et al. 2002)
- Delivers ~2000 candidates
- Many other object types with similar near- and mid-IR colours







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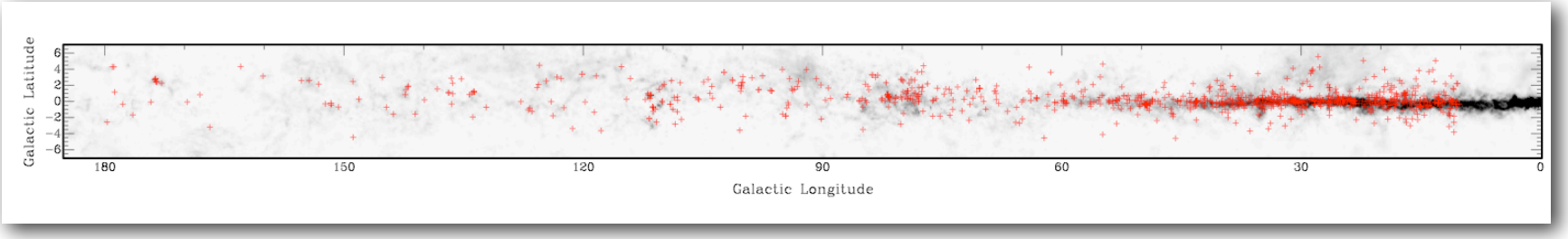

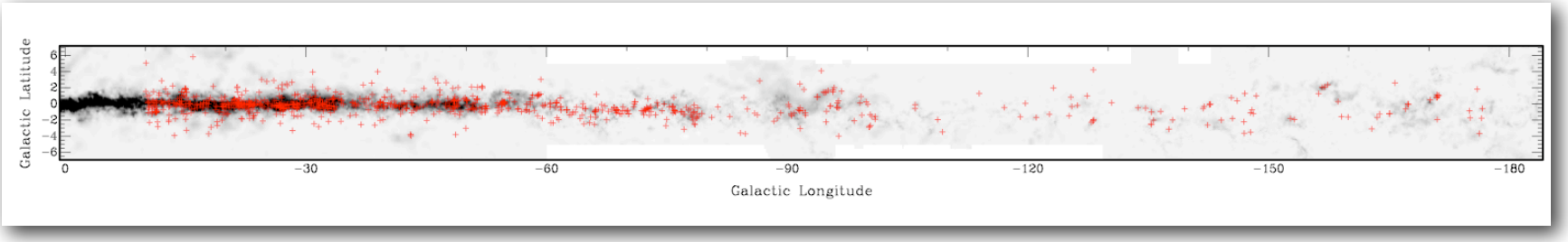

The RMS Survey

Colour Selection of MYSOs

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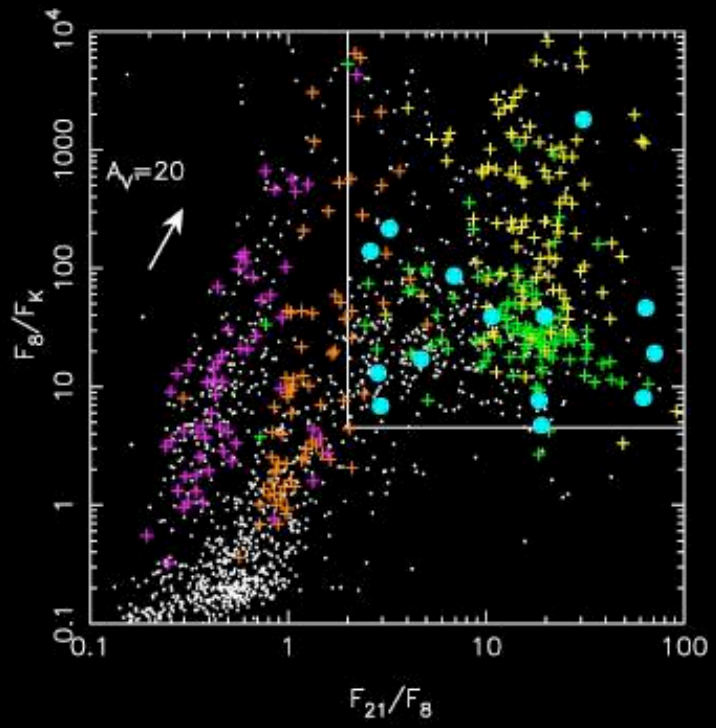

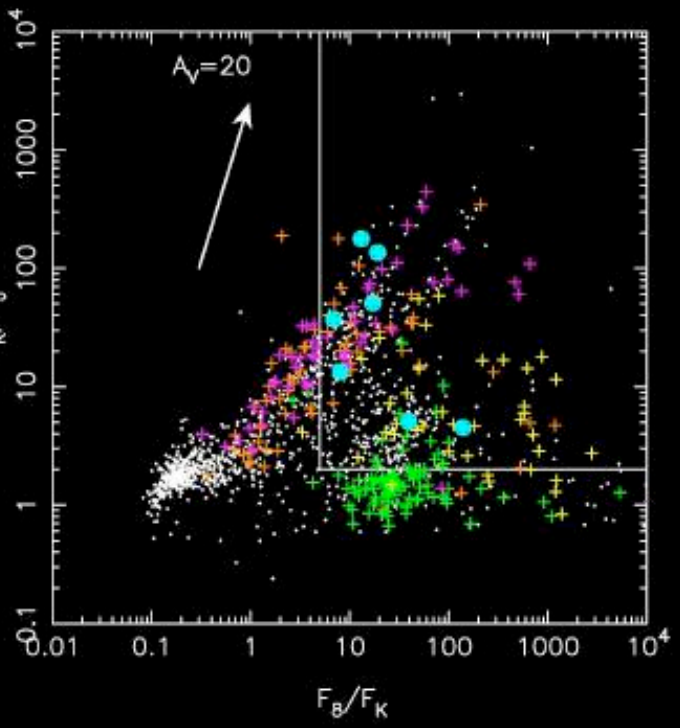

- Massive YSOs
+ UCHII regions
+ PN
+ C stars
+ OH/IR stars

Multi-wavelength follow-up campaign

Observational Programme

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- Identify and eliminate confusing sources
- Begin characterisation of the massive YSOs
- Observational programme includes
  - Mid-IR imaging (UKIRT, Gemini)
  - Radio continuum (VLA & ATCA)
  - Molecular lines (^{13}CO and CS; Mopra, JCMT, PMO, Onsala, FCRAO)
  - Near-IR imaging and spectroscopy (AAT, UKIRT, NTT)

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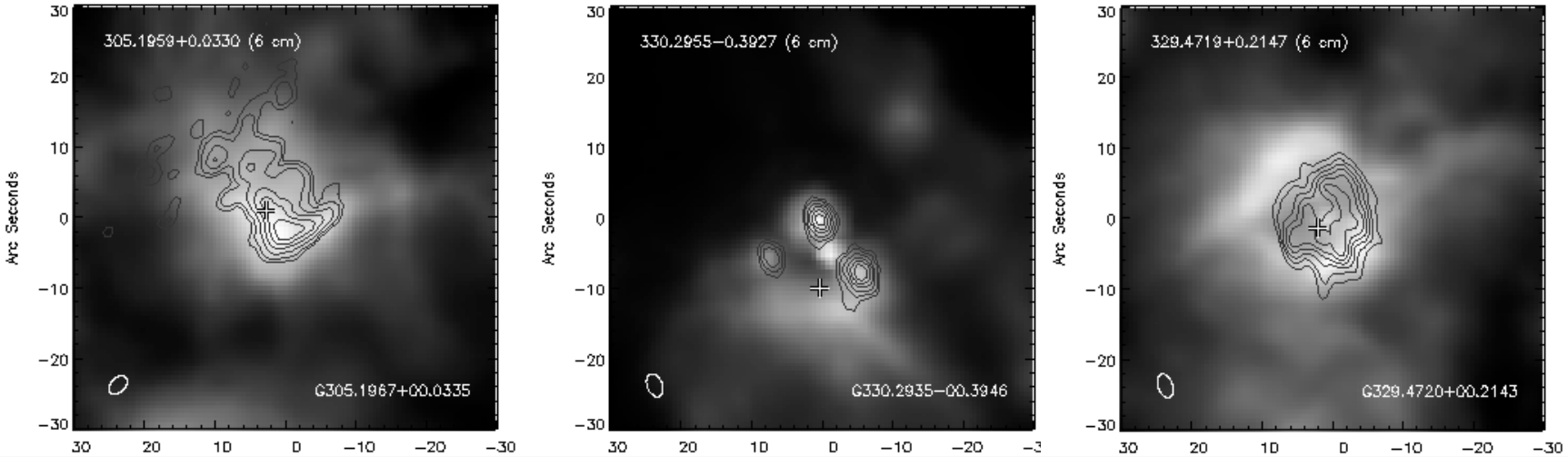
Radio Continuum

- Identify UCHII regions and small number of PNe
- 5 GHz, 2″ resolution, 0.3 mJy/beam noise level at VLA & ATCA
- 2000 objects observed (Urquhart et al. 2007)
- ~25% of sources detected in radio
- Morphologies, distribution and spectral indices consistent with these sources being identified as UCHII regions



Multi-wavelength follow-up campaign

Mid-IR Imaging

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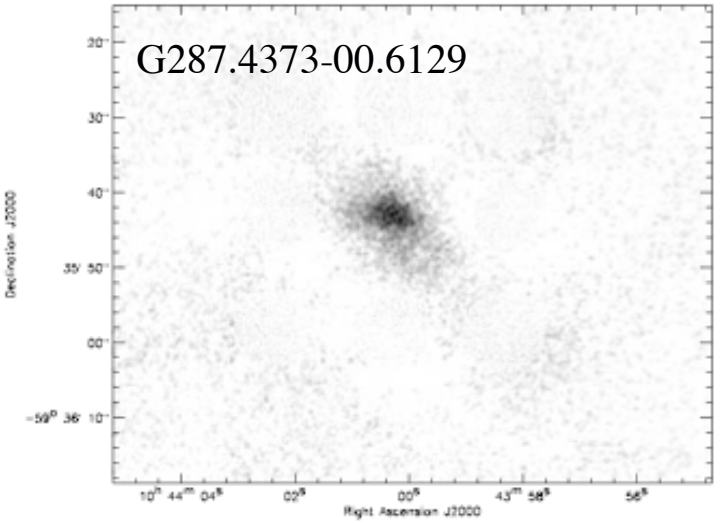
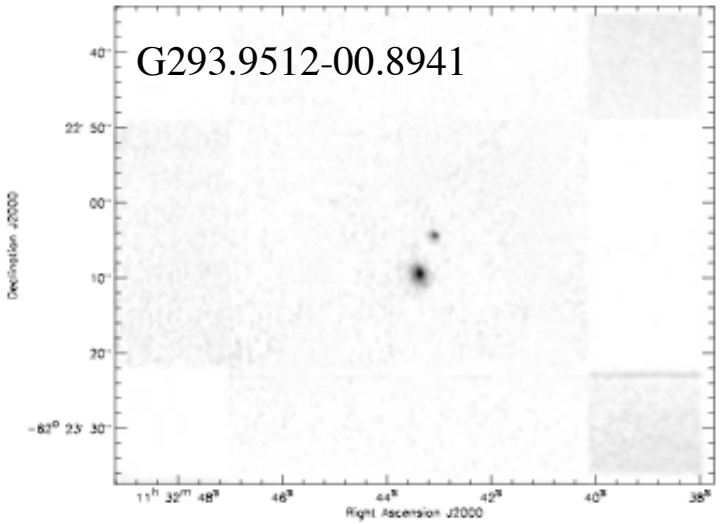
- 10μm, 0.8″ resolution at 700 objects observed & GLIMPSE
- Distinguish between UCHII regions and MYSOs
  - UCHII → Extended
  - MYSO → Point like
- Mid-IR imaging complements radio imaging in cases where UCHII and MYSOs are in close proximity
- See Mottram et al. 2007 (astro-ph/0709.2040)





Multi-wavelength follow-up campaign

Millimetre Line Observations

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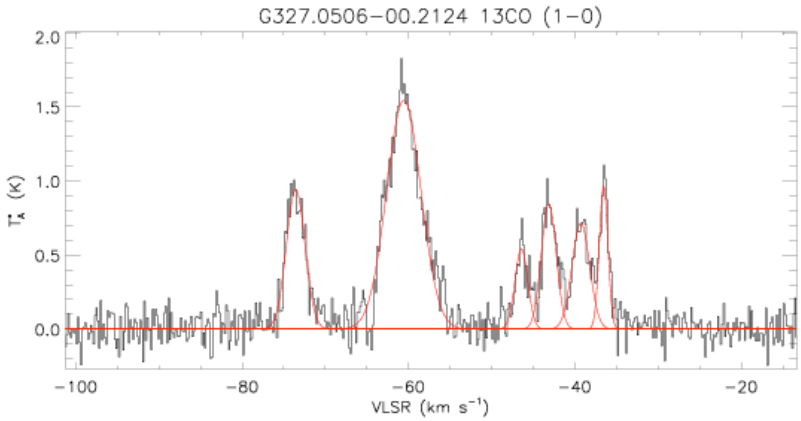
- Obtain kinematic distances
- Identify nearby low-luminosity YSOs, evolved stars (~200)
- 2000 sources observed - complete
- Using Brand and Blitz (1993) rotation curve
- Two difficulties:
  - Multiple components towards many sources (~50%)
    - Masers + CS
  - Most sources (80%) are located within the solar circle i.e. distance ambiguities!
    - HI Self-absorption (IGPS)
    - See Busfield et al. 2006



Multi-wavelength follow-up campaign

Near-IR Imaging and Spectoscopy

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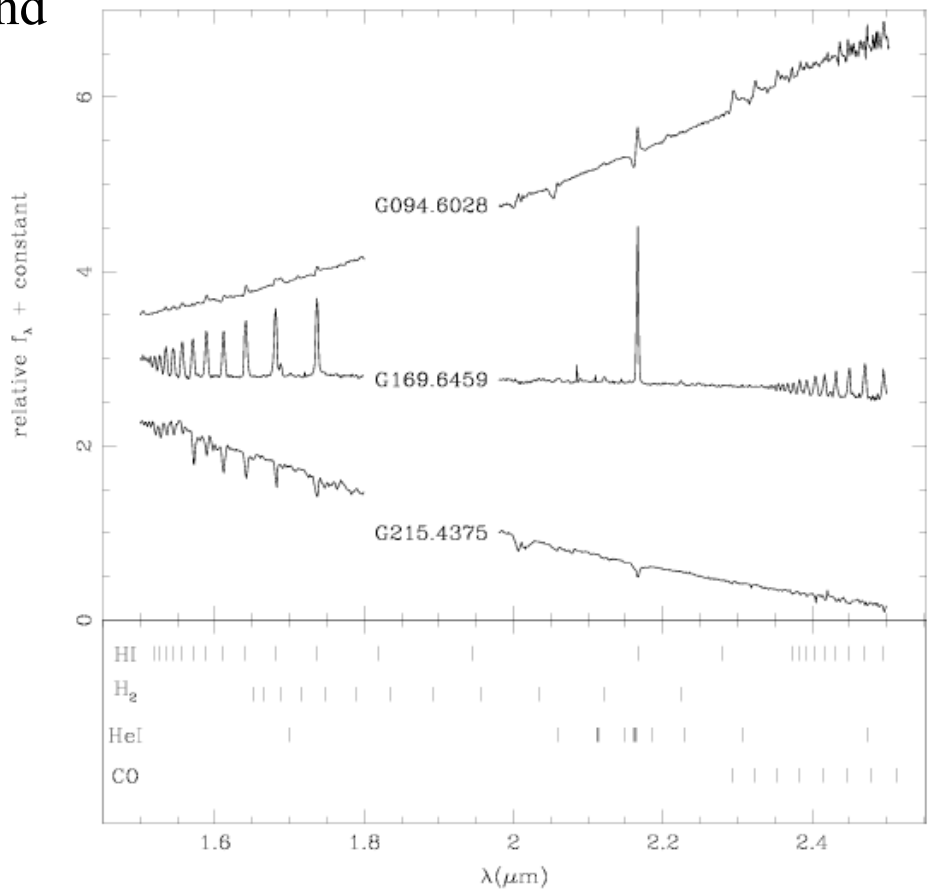
- Identify remaining evolved stars and confirm identified MYSOs
- K-band imaging + 2MASS
- 400 targets observed
- H+K band spectroscopy
- ~250 targets observed



Preliminary Results

Source Identification

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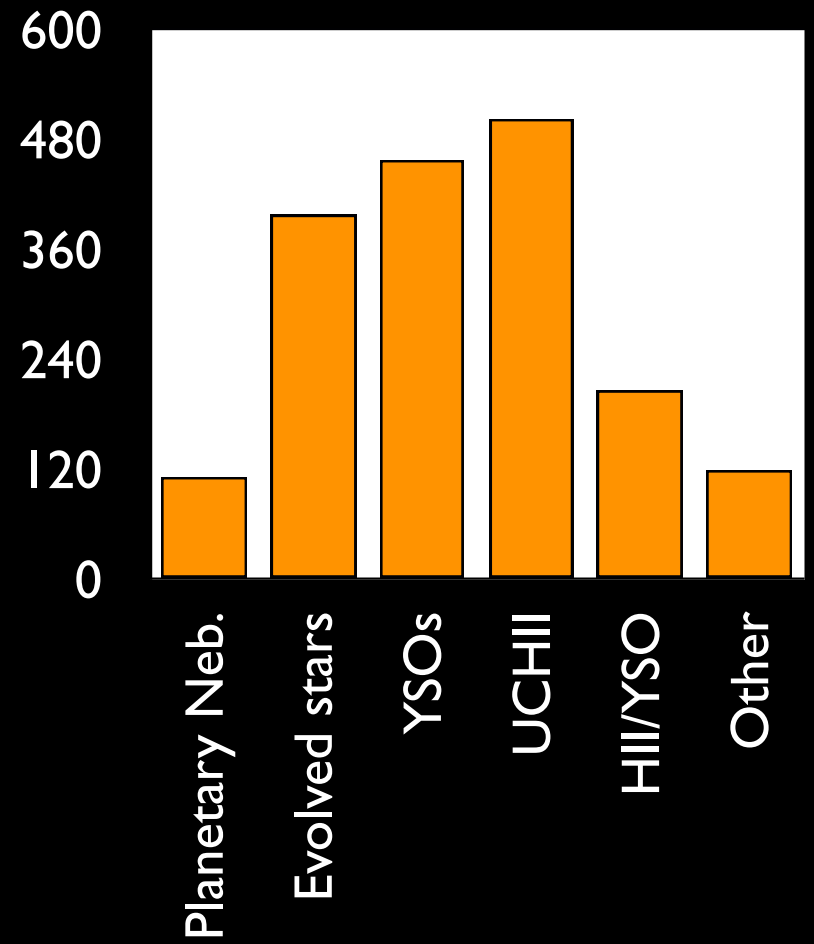

Preliminary Results

Galactic Distribution MYSOs + UCHII

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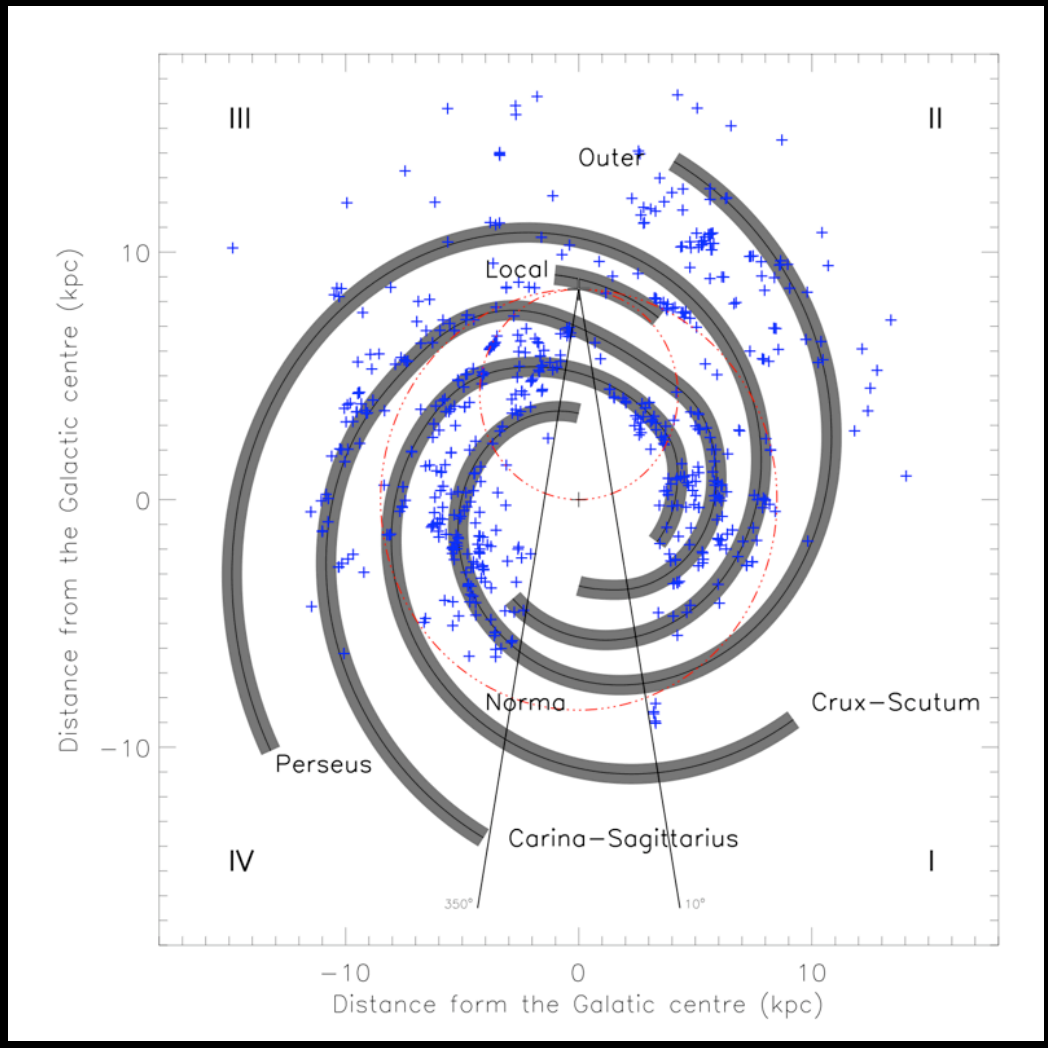

Rotation curve from Brand and Blitz 1993

Spiral arm structure from Cordes & Lazio 2004

Preliminary Results

Luminosity Distribution

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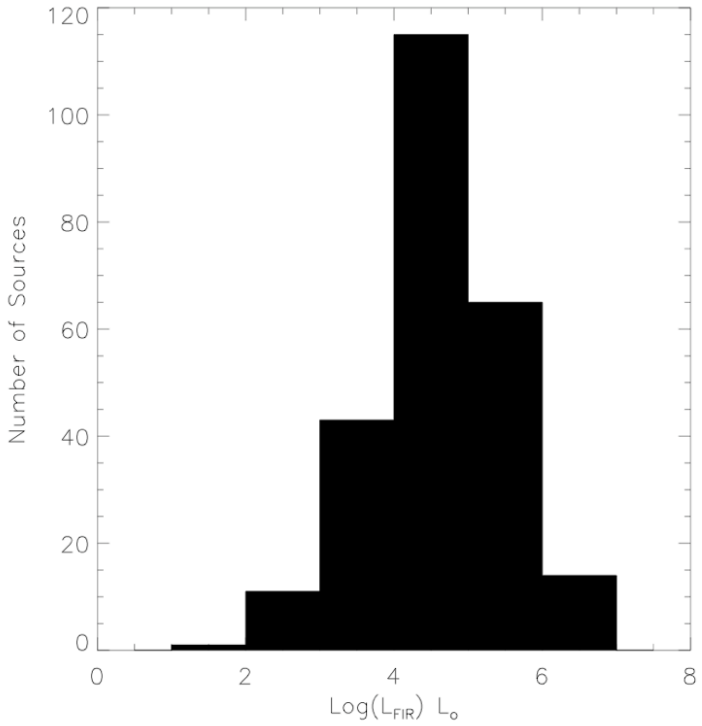
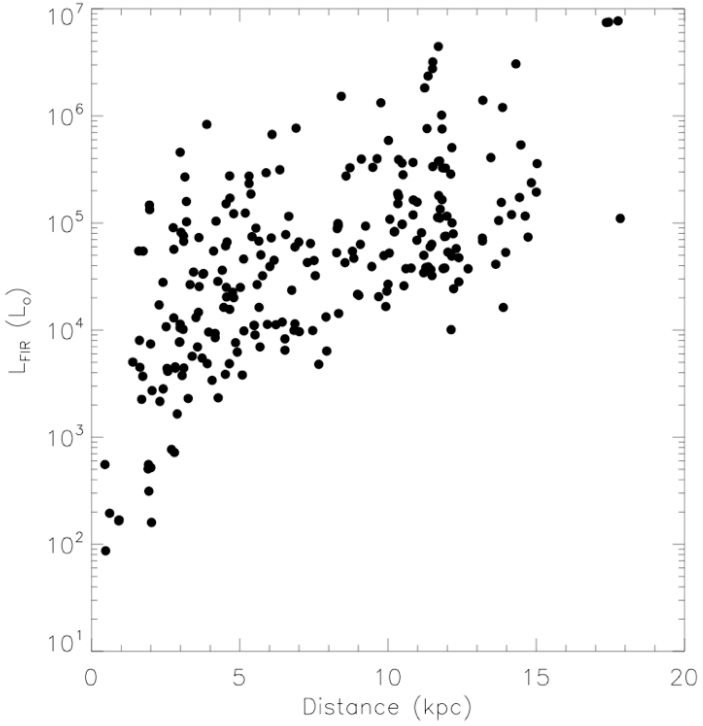
Luminosities have been estimated using the IRAS fluxes (i.e. Emerson 1988)





See poster by J. Mottram #71

Summary

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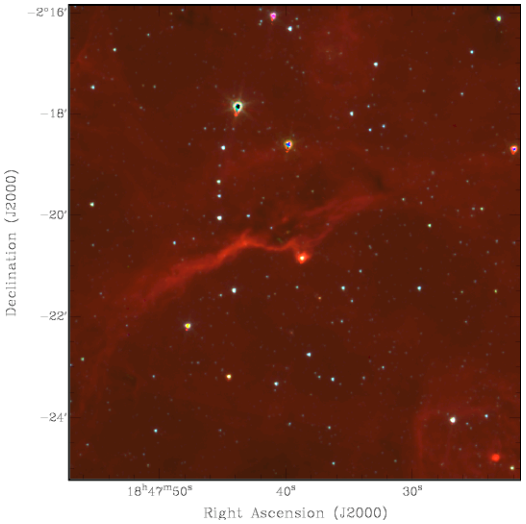
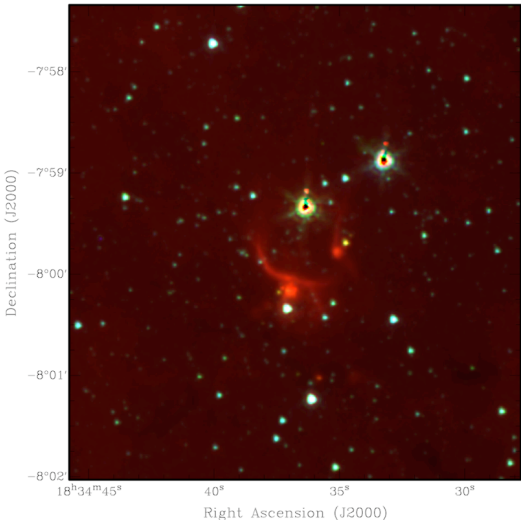
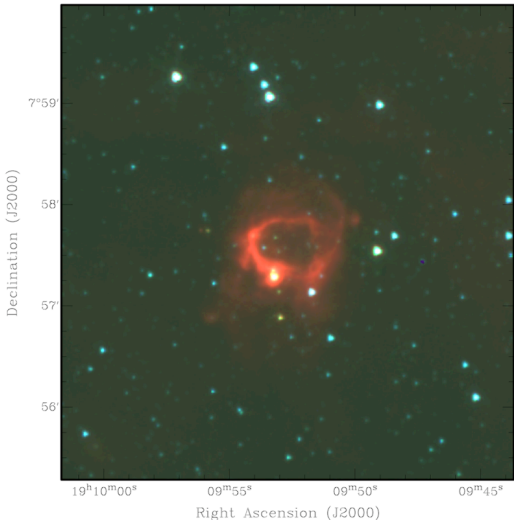
- The RMS survey will deliver ~500 massive YSOs over the whole galaxy
- In addition will identify ~500 compact and UCHII regions
- Luminosity function of MYSOs and UCHIIs
- Investigate triggering and clustering as a function of Galactic location
- High spatial/spectral resolution studies of well-selected sub-samples for infall, accretion and outflow characteristics
- Sample will be available at www.ast.leeds.ac.uk/RMS

Further Work

- Broadband chemical study of distance limited sample of MYSO
- Outflow studies (Mopra and JCMT)
- Accretion disks (VLTI, Gemini)
- Search for associated water masers and ammonia studies (Mopra)
- Studies of potentially triggered regions (IRAM 30m + CARMA)







The RMS Survey

Distribution of RMS Sources

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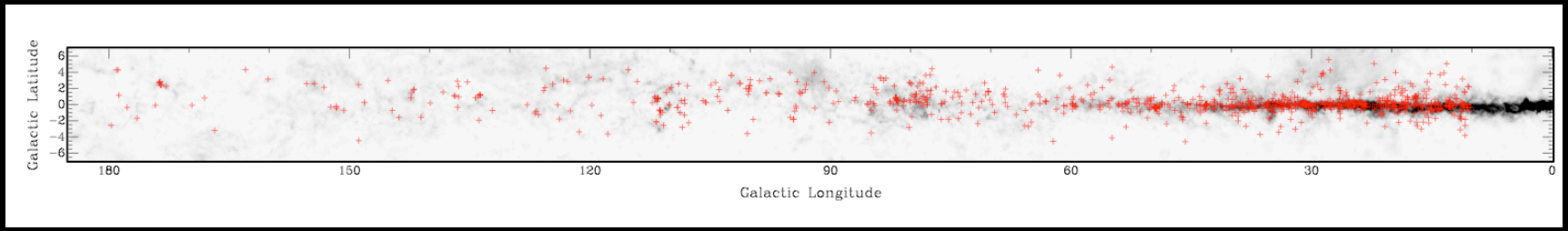
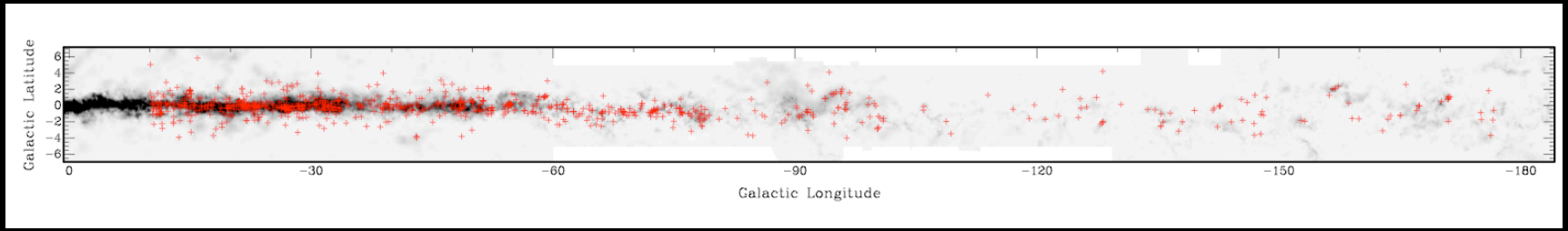


Northern Galactic Plane



Southern Galactic Plane

Multi-wavelength follow-up campaign

GLIMPSE 8μm + 6cm radio contours

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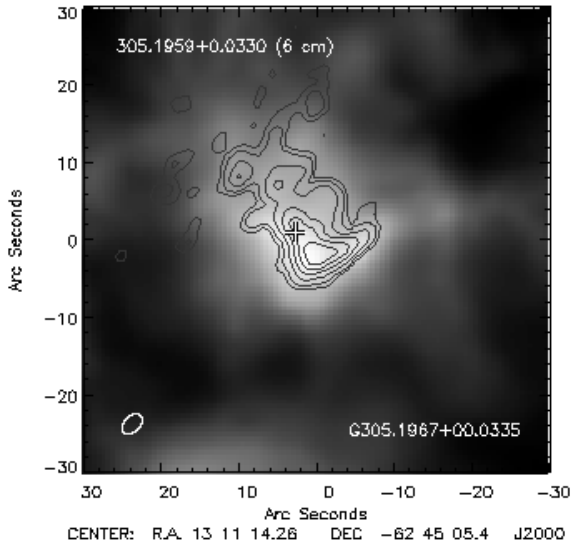

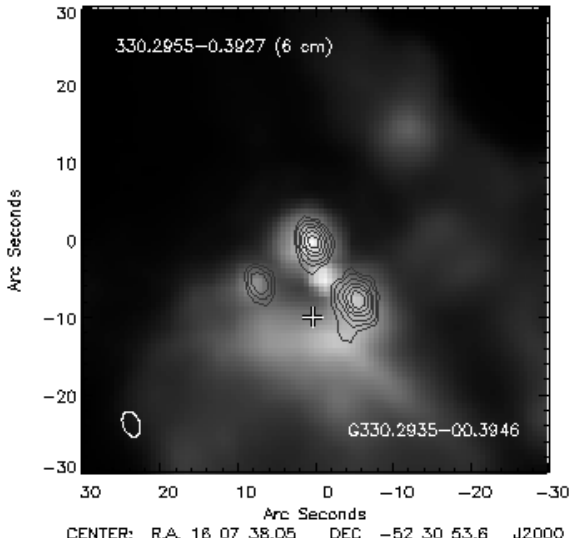

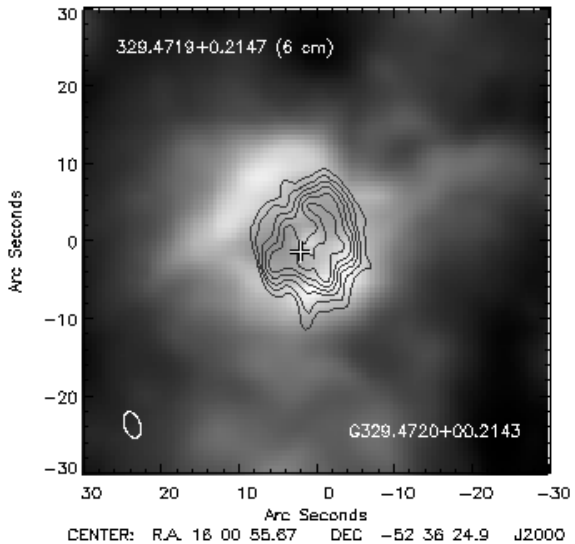

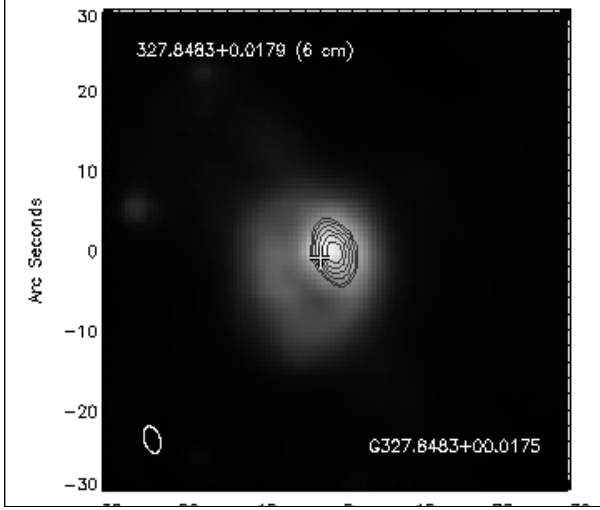

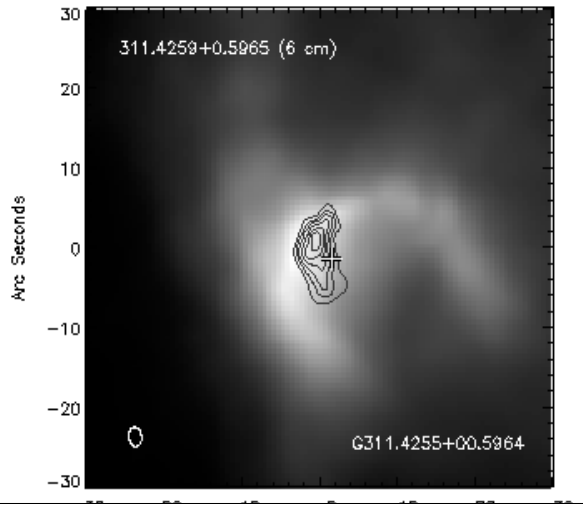

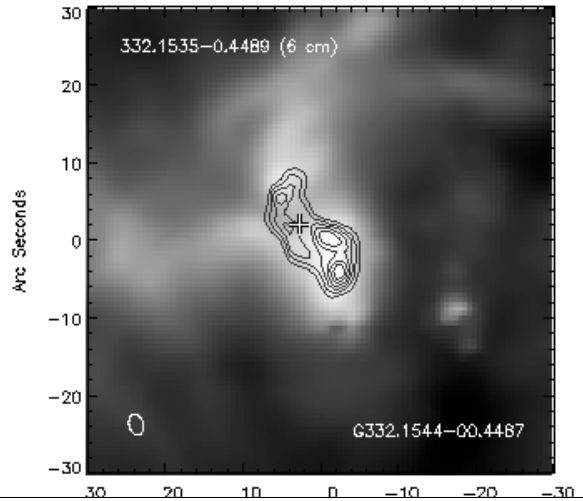

Preliminary Results

Longitude-Velocity Distribution

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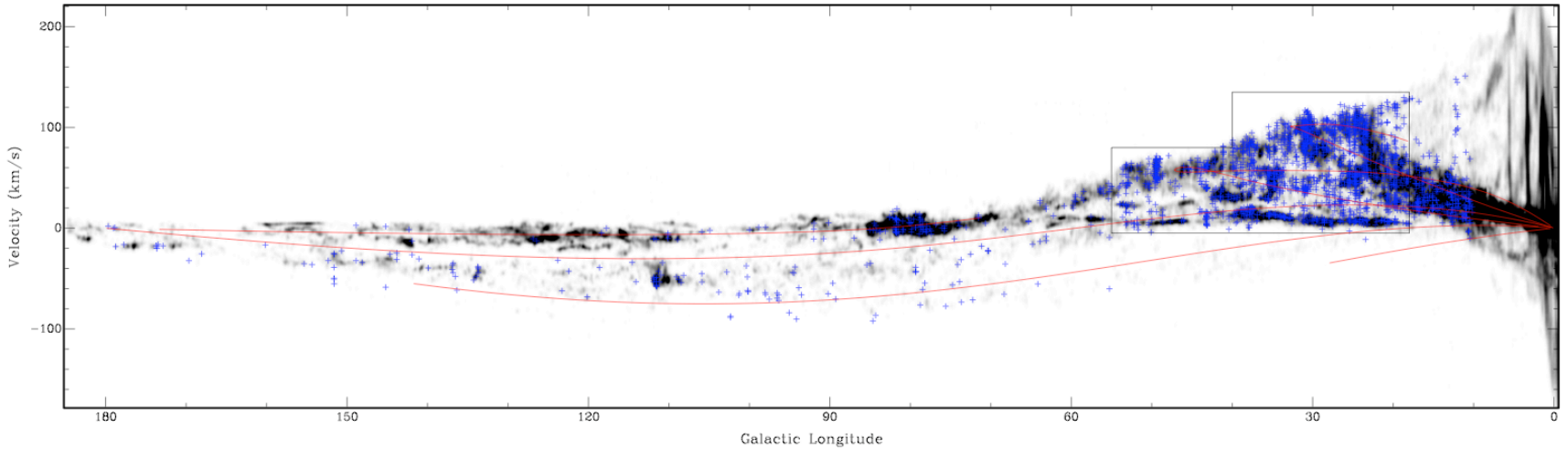

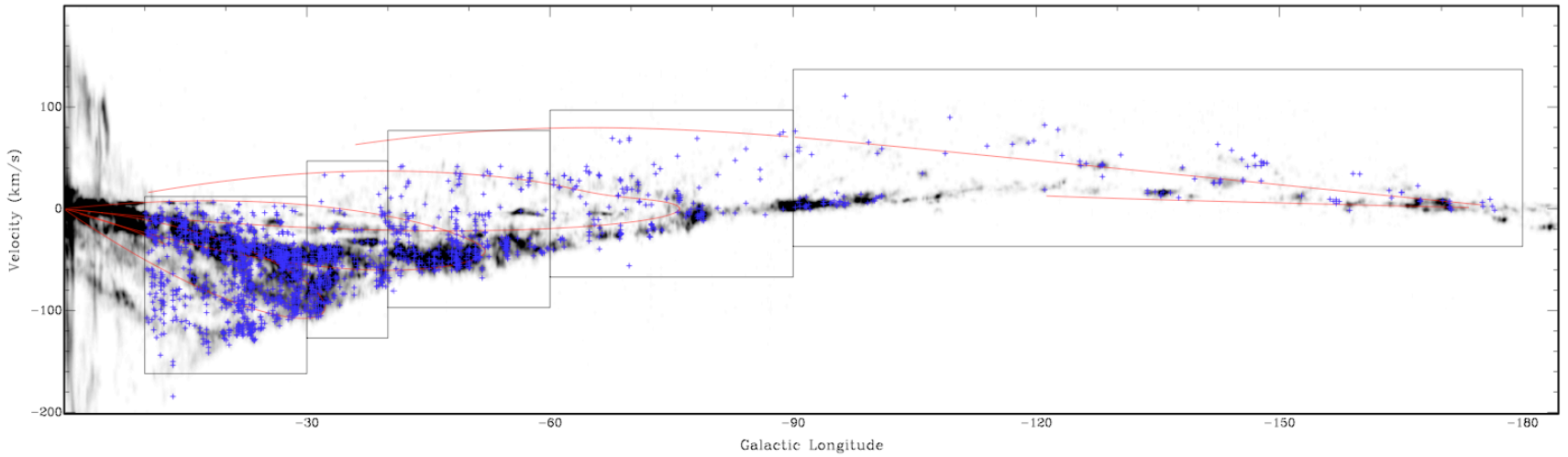

Preliminary Results

Longitude-Latitude Distribution

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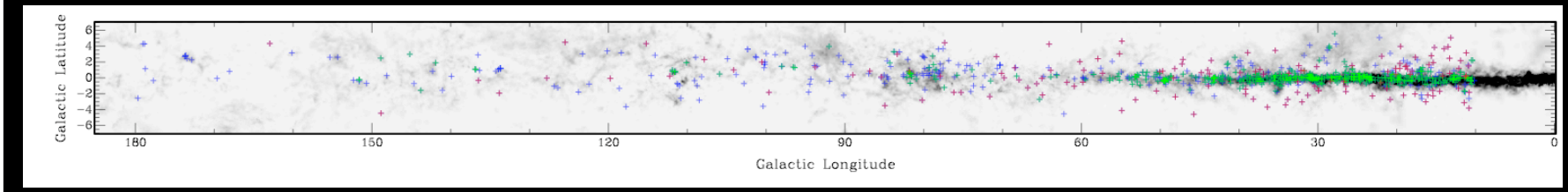
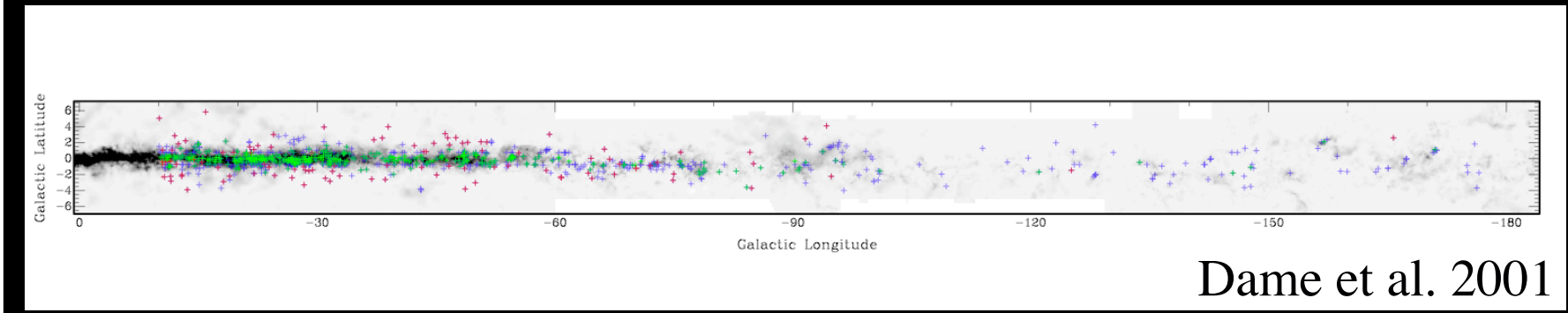


Northern Galactic Plane



Dame et al. 2001

Southern Galactic Plane

Multi-wavelength follow-up campaign

Solving Distance Ambiguities

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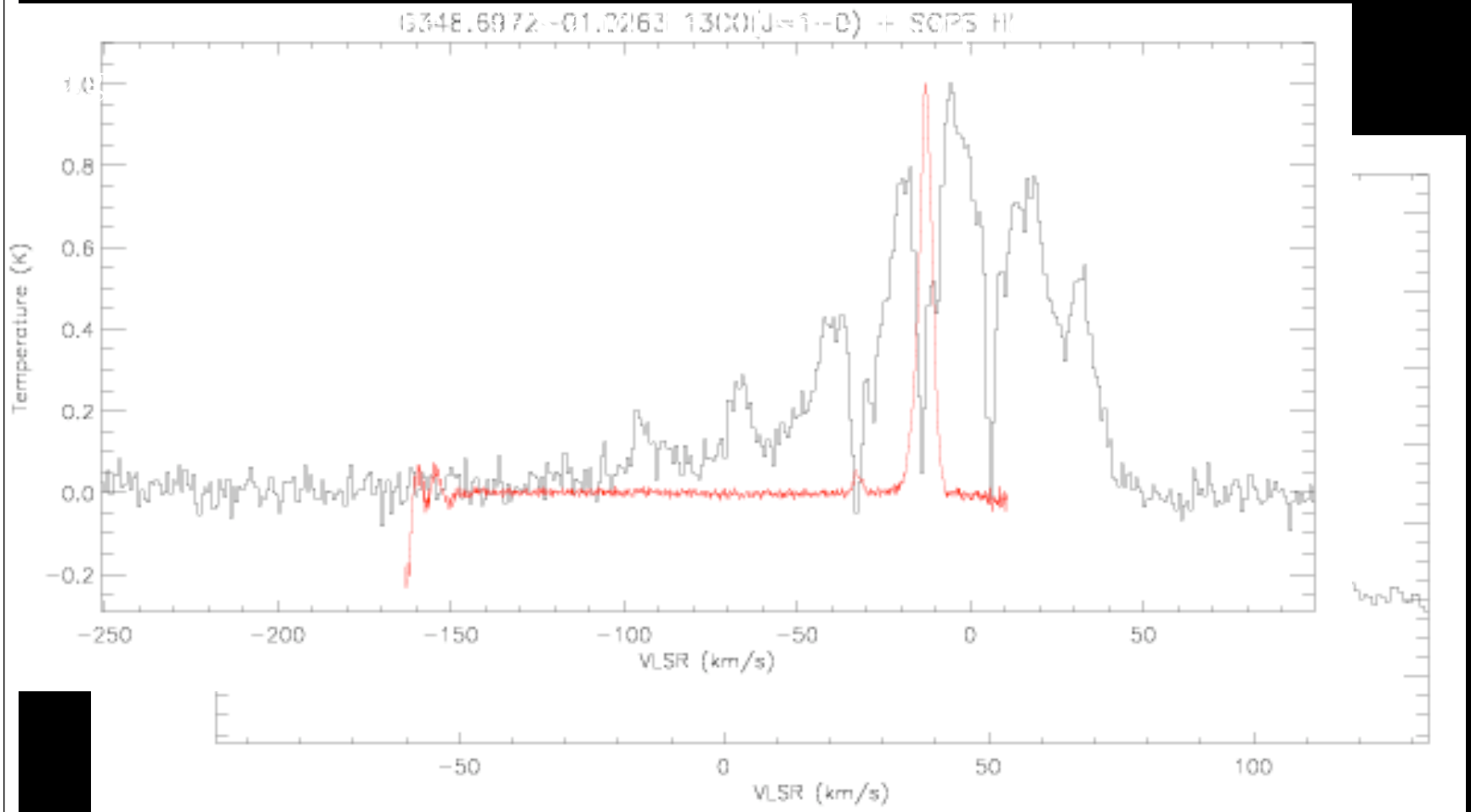

Future programmes

- Luminosity function of MYSOs and UCHIIs
- Investigate triggering and clustering as a function of Galactic location
- High spatial/spectral resolution studies of well-selected sub-samples for infall, accretion and outflow characteristics

Statistical Studies

- Luminosity function of MYSOs and UCHIIs (R_G, environment)
- Lifetime of MYSO phase (L)
- Clustering of MYSOs and UCHIIs
- Triggering by UCHIIs, OB stars, SNRs

Preliminary Results

Longitude-Velocity Distribution

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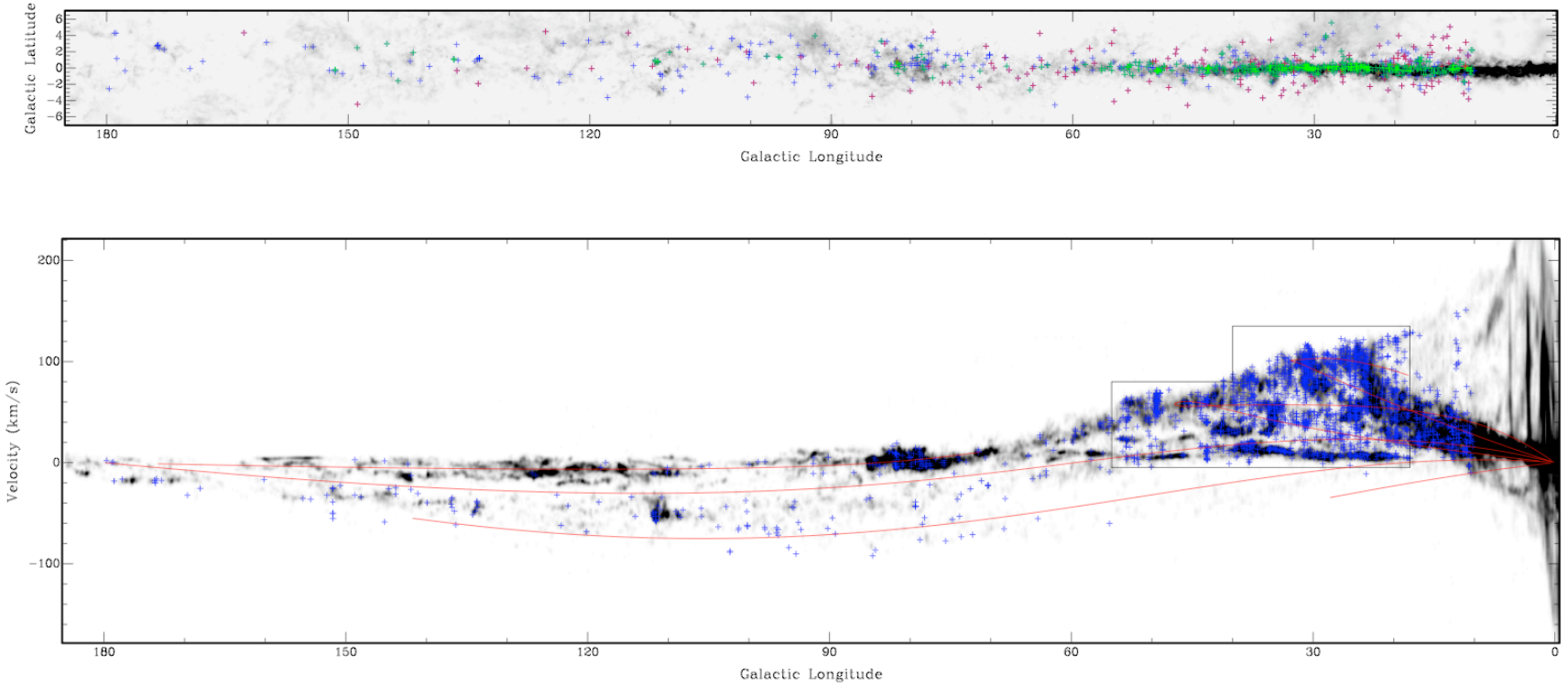
Northern Galactic Plane



The RMS Survey

Multi-wavelength follow-up campaign

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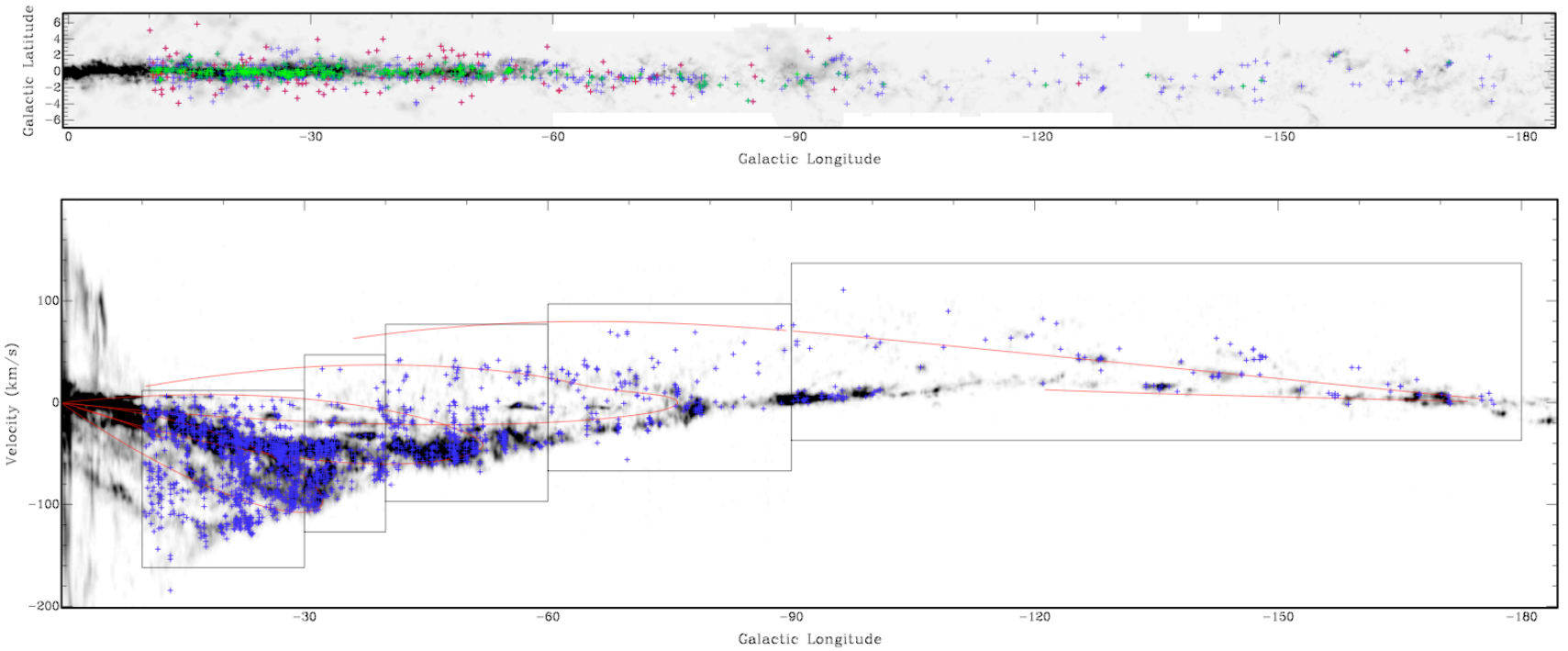
Southern Galactic Plane



These notes have been designed to help you to conform to the recommended best practice

It is recommended that all headings are set in Arial Regular 24pt.

- All following text should be in Arial Regular 20pt.
- Use **bold** to highlight rather than *italics* or underlining (as these can make words appear to 'run together')
- Bullet points or numbers are easier to read than continuous prose
- For maximum impact, avoid overcrowding slides - limit your points to a maximum of 6 per page

Multi-wavelength follow-up campaign

Example Spectra

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