School of Physics and Astronomy
FACULTY OF MATHEMATICS AND PHYSICAL SCIENCES
UNIVERSITY OF LEEDS

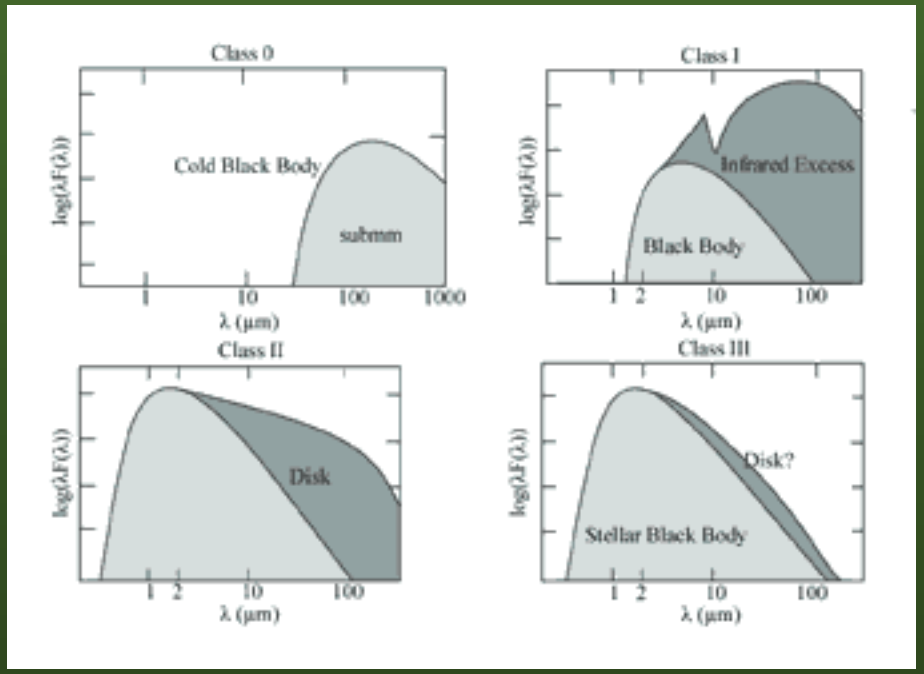
Finding all massive young stars in the Galaxy : the RMS Survey

René Oudmaijer (Leeds, UK)

Massive Young Stars:

UNIVERSITY OF LEEDS

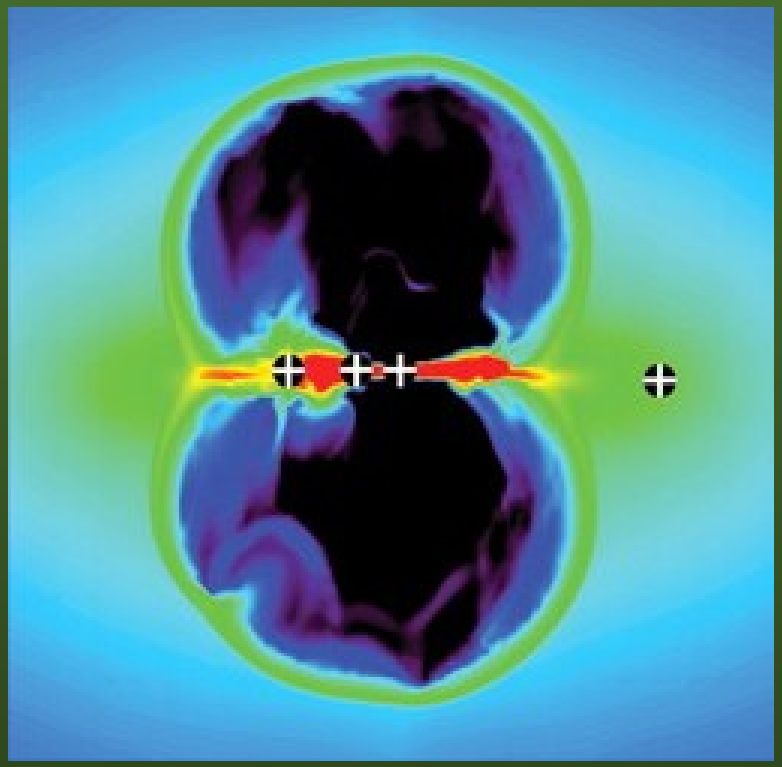
- What *is* the evolutionary sequence?
- Which physical processes control the infall and outflow?
- What is the role of triggering?



Massive Young Stars:

UNIVERSITY OF LEEDS

- What is the evolutionary sequence?
- Which physical processes control the infall and outflow?
- What is the role of triggering?

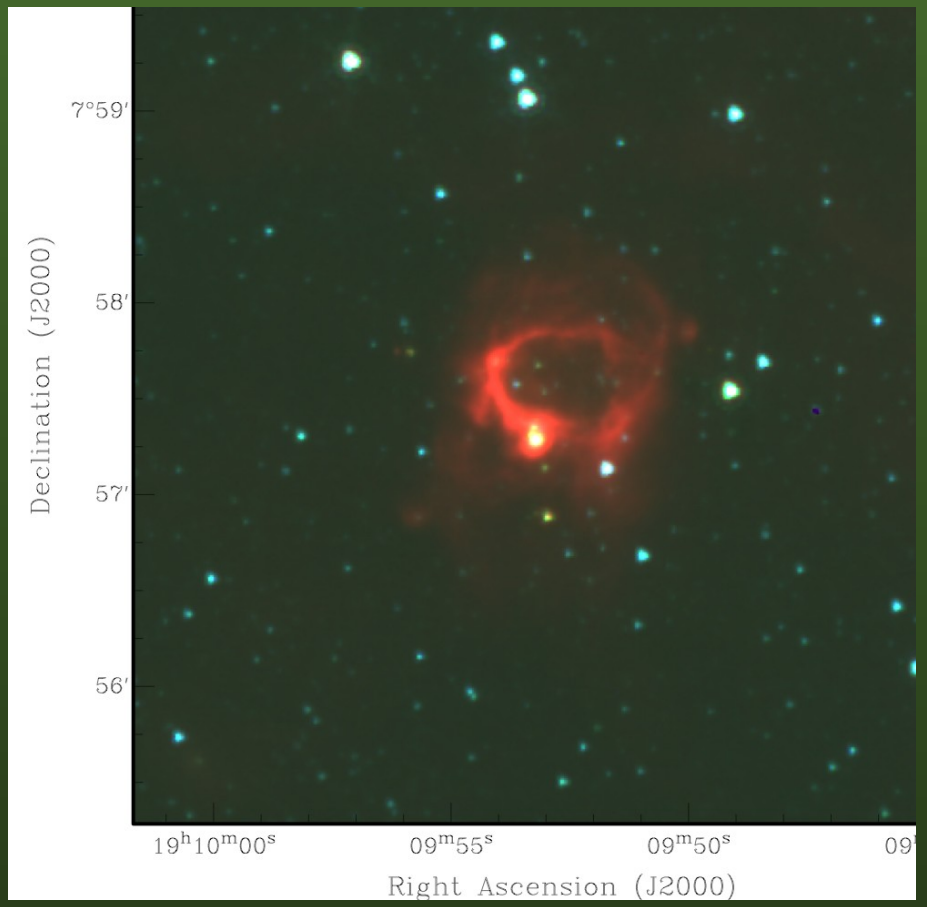


Krumholz et al 2009

Massive Young Stars:

UNIVERSITY OF LEEDS

- What is the evolutionary sequence?
- Which physical processes control the infall and outflow?
- What is the role of triggering?



Urquhart et al in prep

Evolutionary Outline

UNIVERSITY OF LEEDS

Hot Core → MYSO → UCHII → OB Star

SED:

Sub-mm → Mid-IR → Mid/Near-IR → Near-IR/Visual

Masers:

CH_3OH → H_2O → OH

Radio:

No radio → Weak Radio → Strong Radio

(Based on an outline by Cormac Purcell)

Massive Young Stellar Objects

UNIVERSITY OF LEEDS

- Luminous (>10^4 $L_\odot$) IR source
- Bipolar molecular outflow
- Often associated maser emission
- Compact, ionised wind (v~100 km s^{-1})
- Well-studied MYSOs number in the tens
- Serendipitously found and nearby
- May not be representative
- Need well-selected sample that numbers in the hundreds

- GL2591
- Gemini JHK

The RMS Survey for MYSOs

UNIVERSITY OF LEEDS

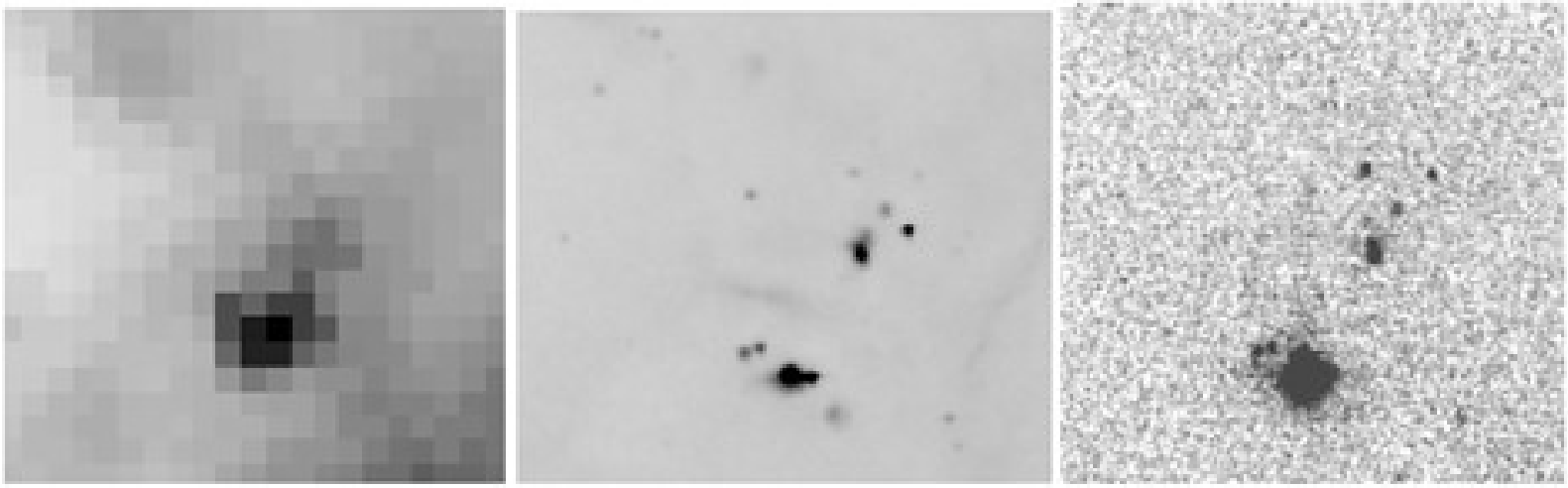
The Red MSX Sources Survey: A systematic search for massive young stellar objects (MYSOs) throughout the Galaxy

RMS Team:

- Melvin Hoare, Stuart Lumsden, René Oudmaijer, Ant Busfield, Andrew Clarke, Heather Cooper, Ben Davies, Joseph Stead, Willem-Jan de Wit (Leeds)
- Toby Moore (Liverpool JMU)
- Cormac Purcell (Manchester)
- Michael Burton (UNSW)
- James Urquhart (ATNF)
- Joseph Mottram (Exeter)
- Zhibo Jiang (PMO)

IRAS vs MSX

UNIVERSITY OF LEEDS



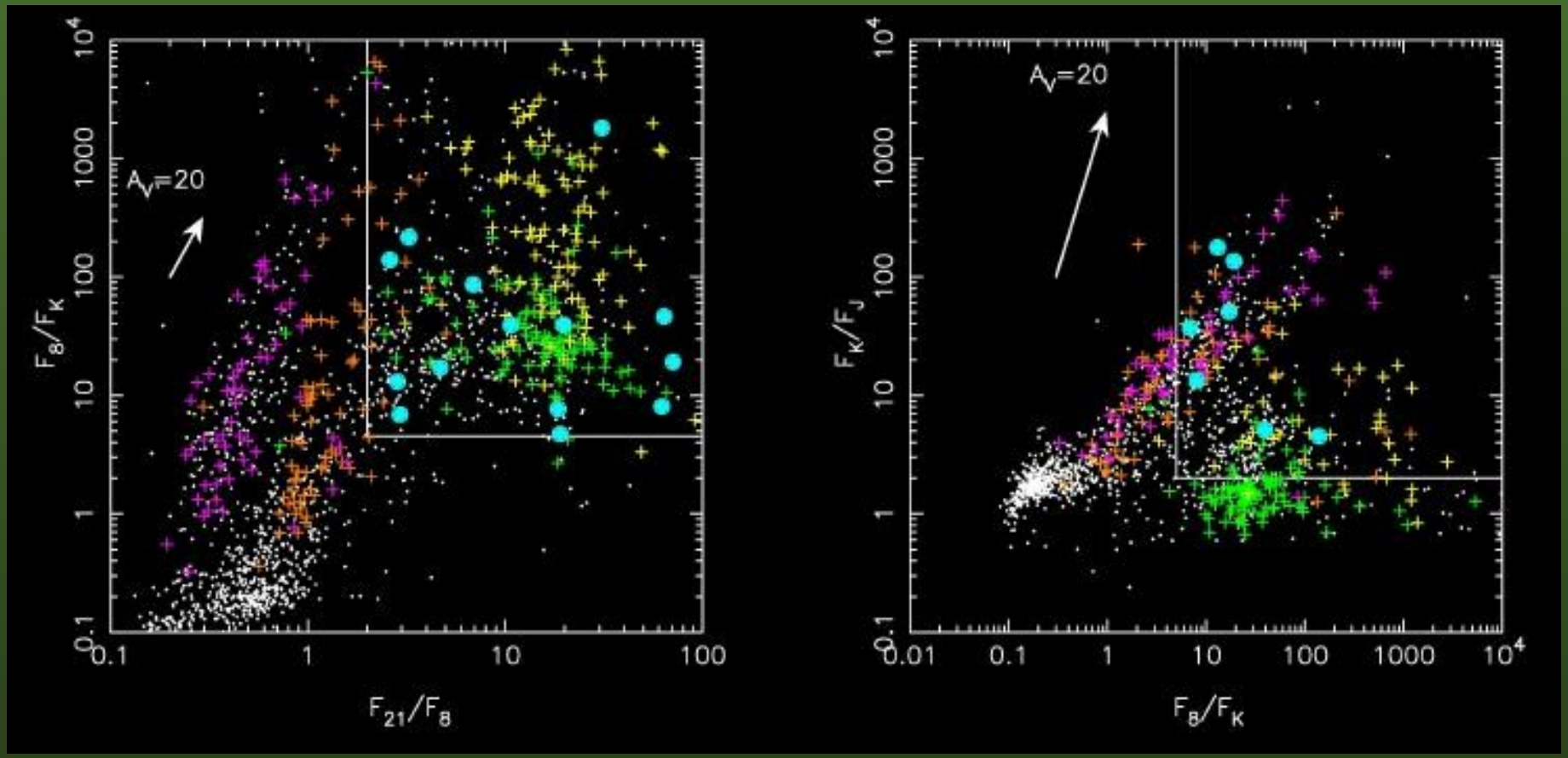
IRAS 25μm MSX 8 μm MSX 21 μm

Selected all red objects from MSX catalogue – 2000 objects

(Lumsden et al. 2002)

Colour Selection of MSX Sources

UNIVERSITY OF LEEDS



- Massive YSOs

(Lumsden et al 2002)

+ UCHII regions

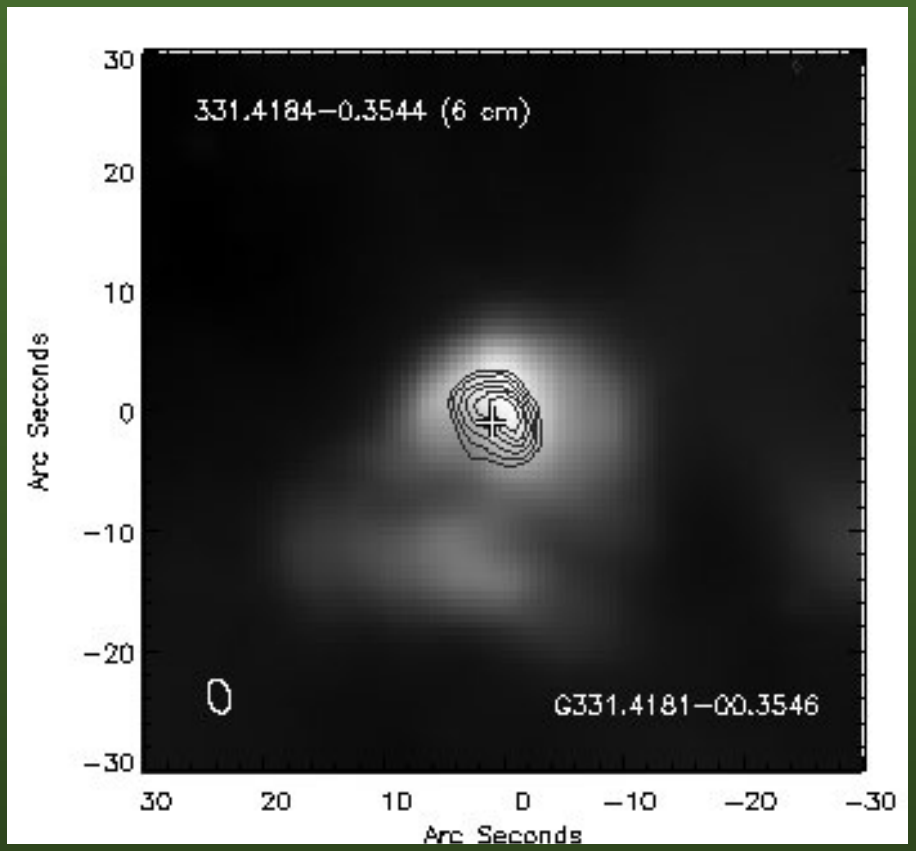
+ PN

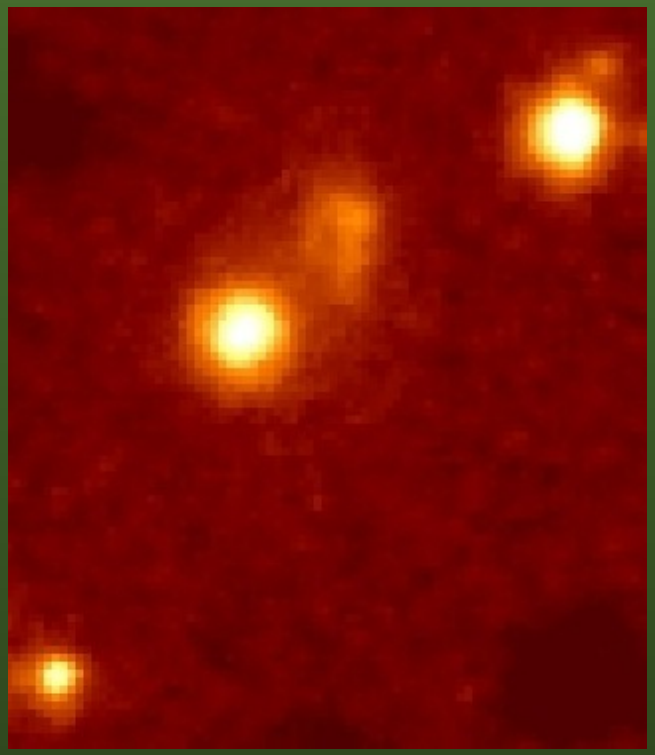
+ C stars

+ OH/IR stars

Multi-Wavelength Campaign to select genuine MYSOs

UNIVERSITY OF LEEDS

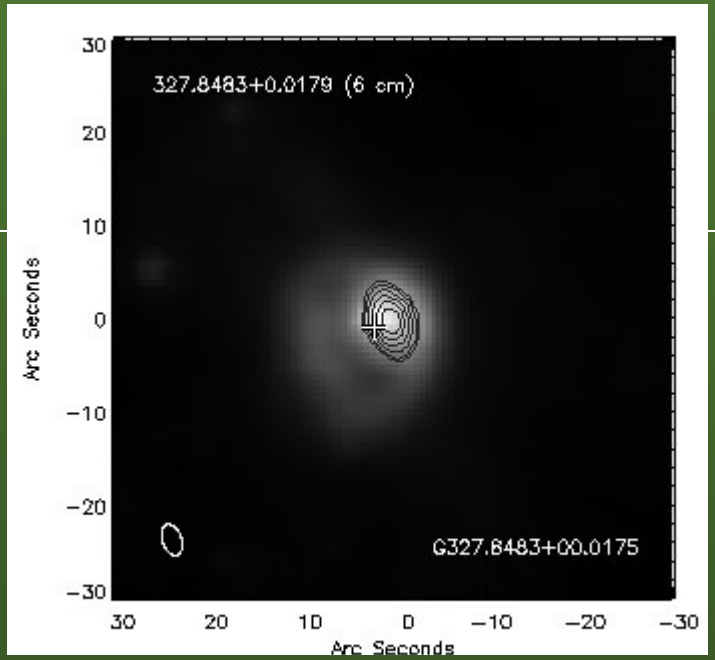


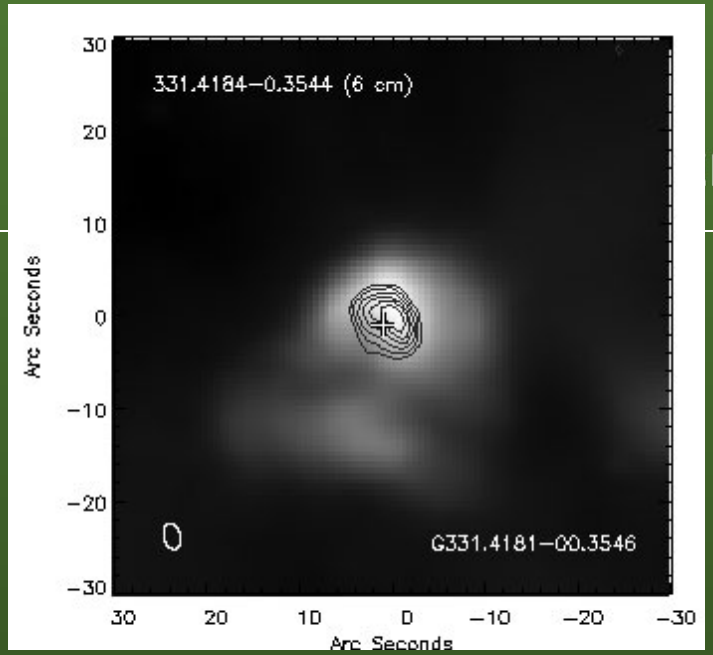


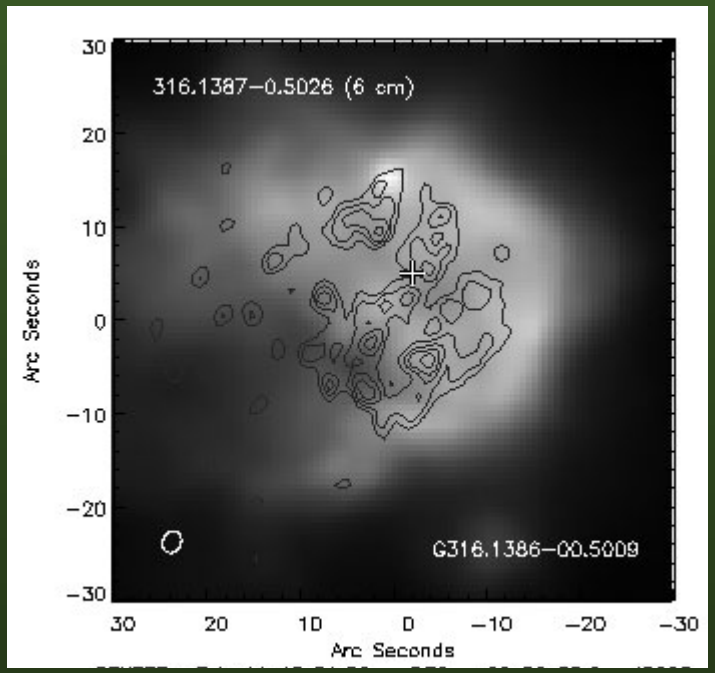
20”

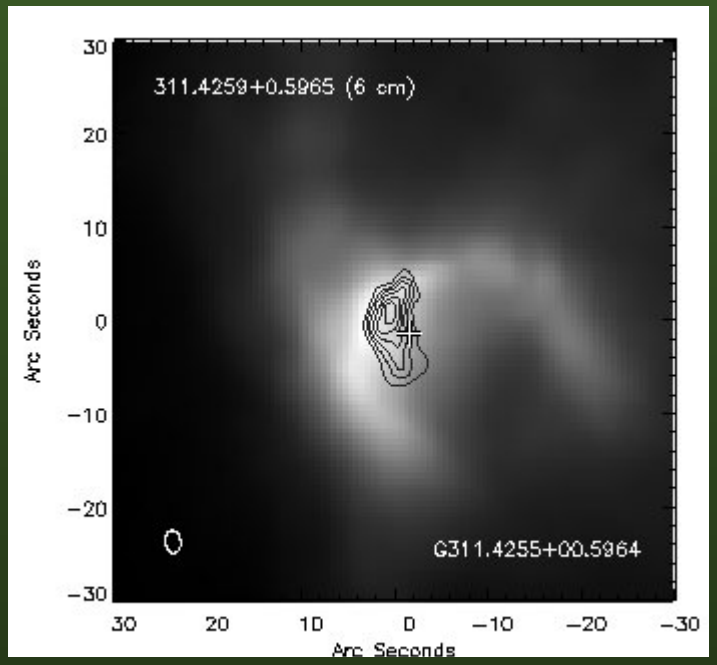
Arcsecond resolution radio and mid-IR imaging to separate UCHII regions and MYSOs (incl. CORNISH and GLIMPSE)

(Urquhart et al 2007, Mottram et al. 2007)







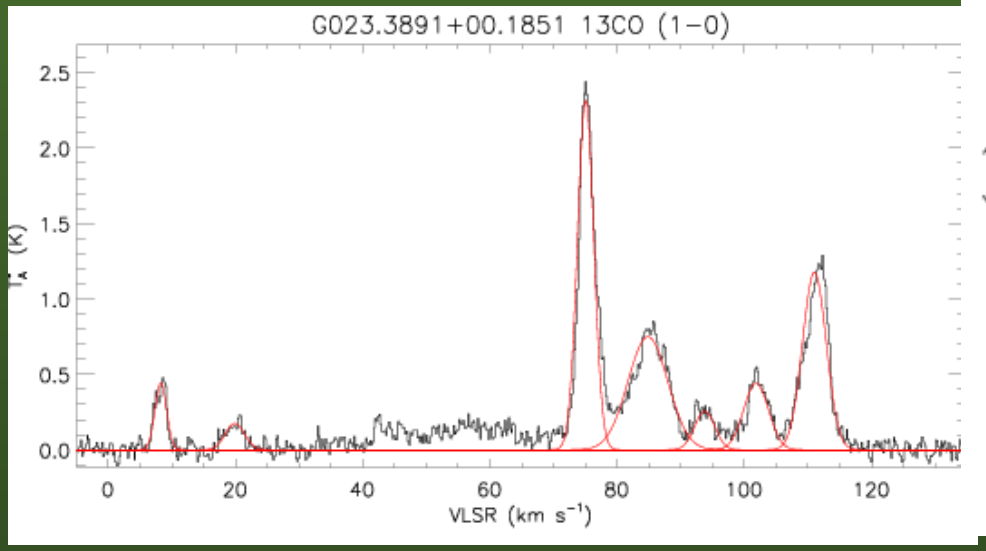


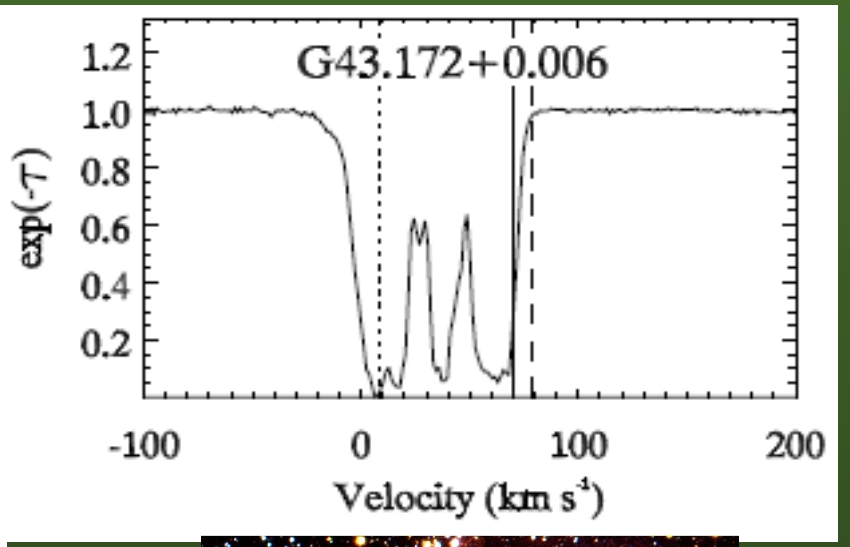
Contours: 6 cm

Greyscale: 8 μm

Distances

UNIVERSITY OF LEEDS



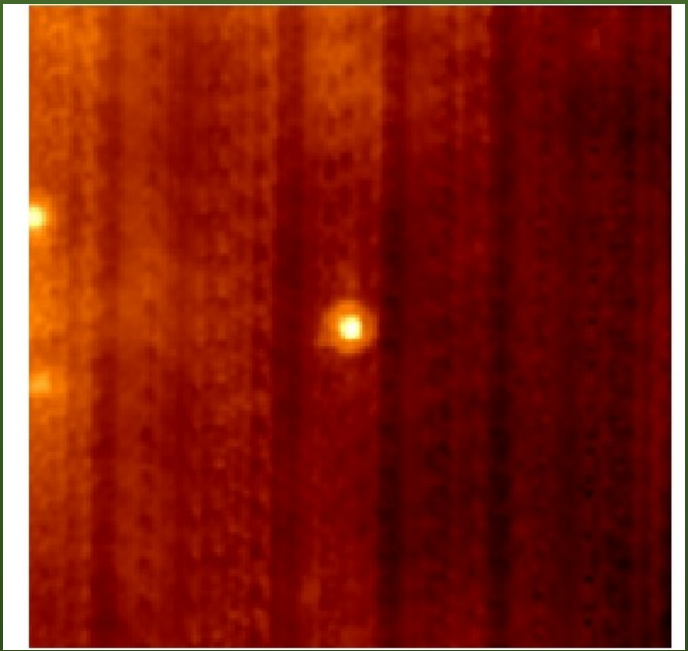


Kinematic distances determined and ambiguities being resolved (inc. GRS, IGPS and UKIDSS)

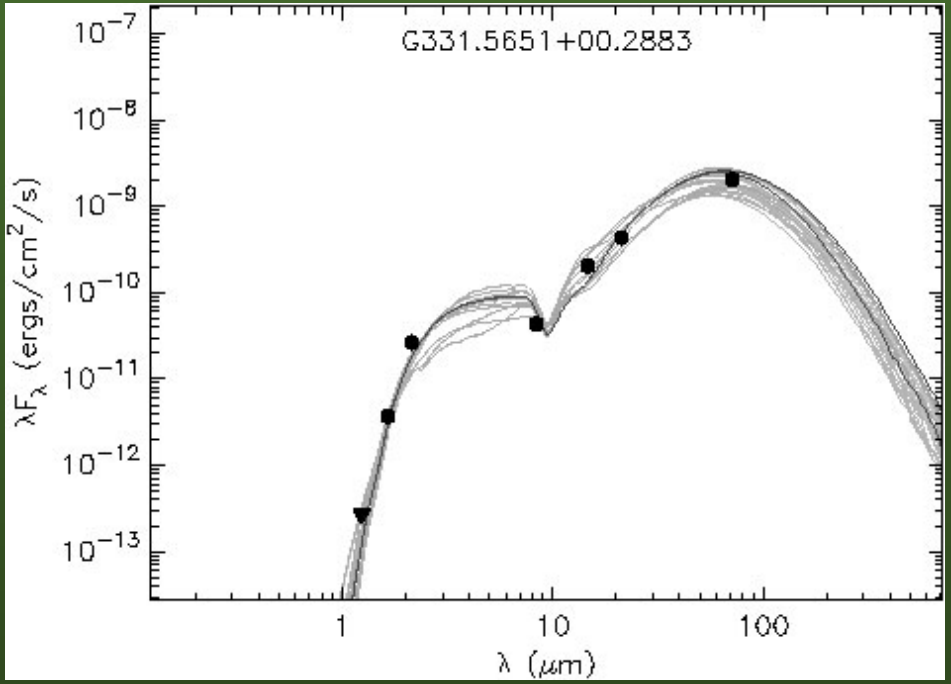
(Urquhart et al 2007;2008;Busfield et al 2006)

Luminosities

UNIVERSITY OF LEEDS



MIPSGAL 70μm (15’ across)



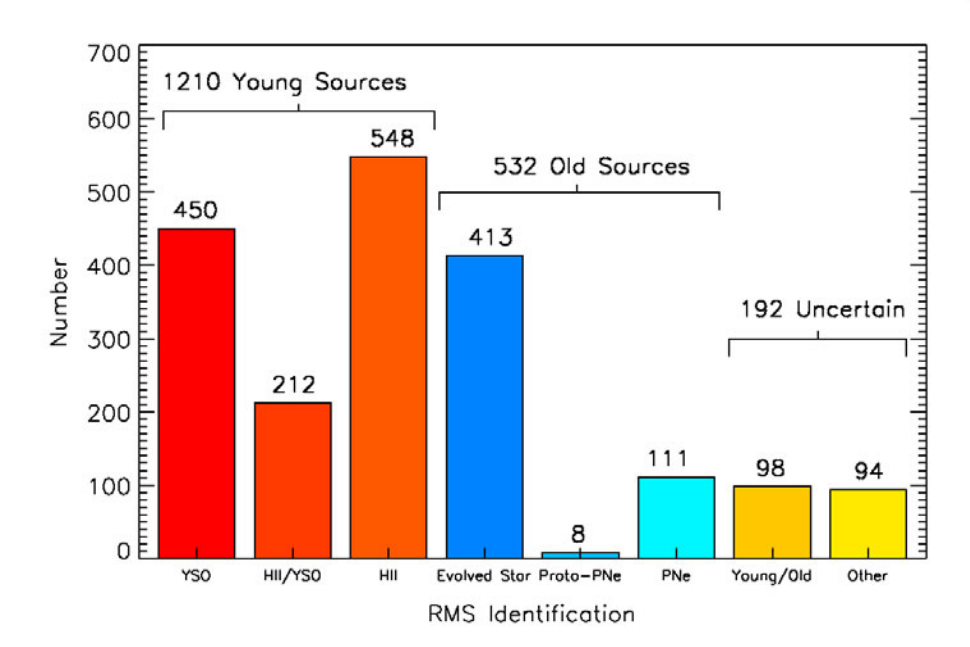
SED fitting (Robitaille et al 2007)

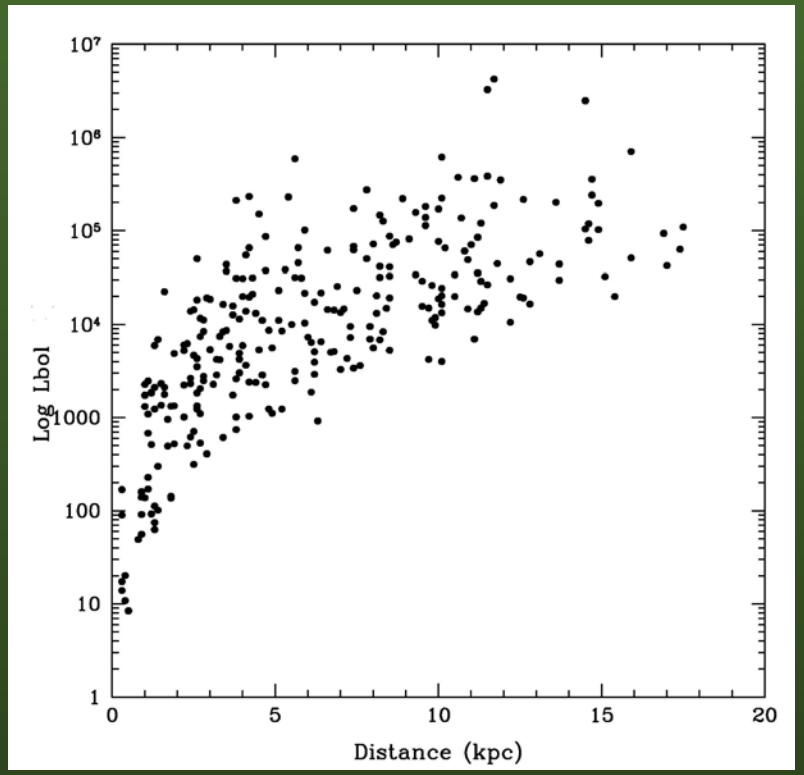
Far-IR fluxes (corrected for non-linearities) are combined with the distances to yield the luminosities (MIPSGAL and Hi-GAL)

(Poster H-P14 by Joe Mottram)

Source Identification

UNIVERSITY OF LEEDS





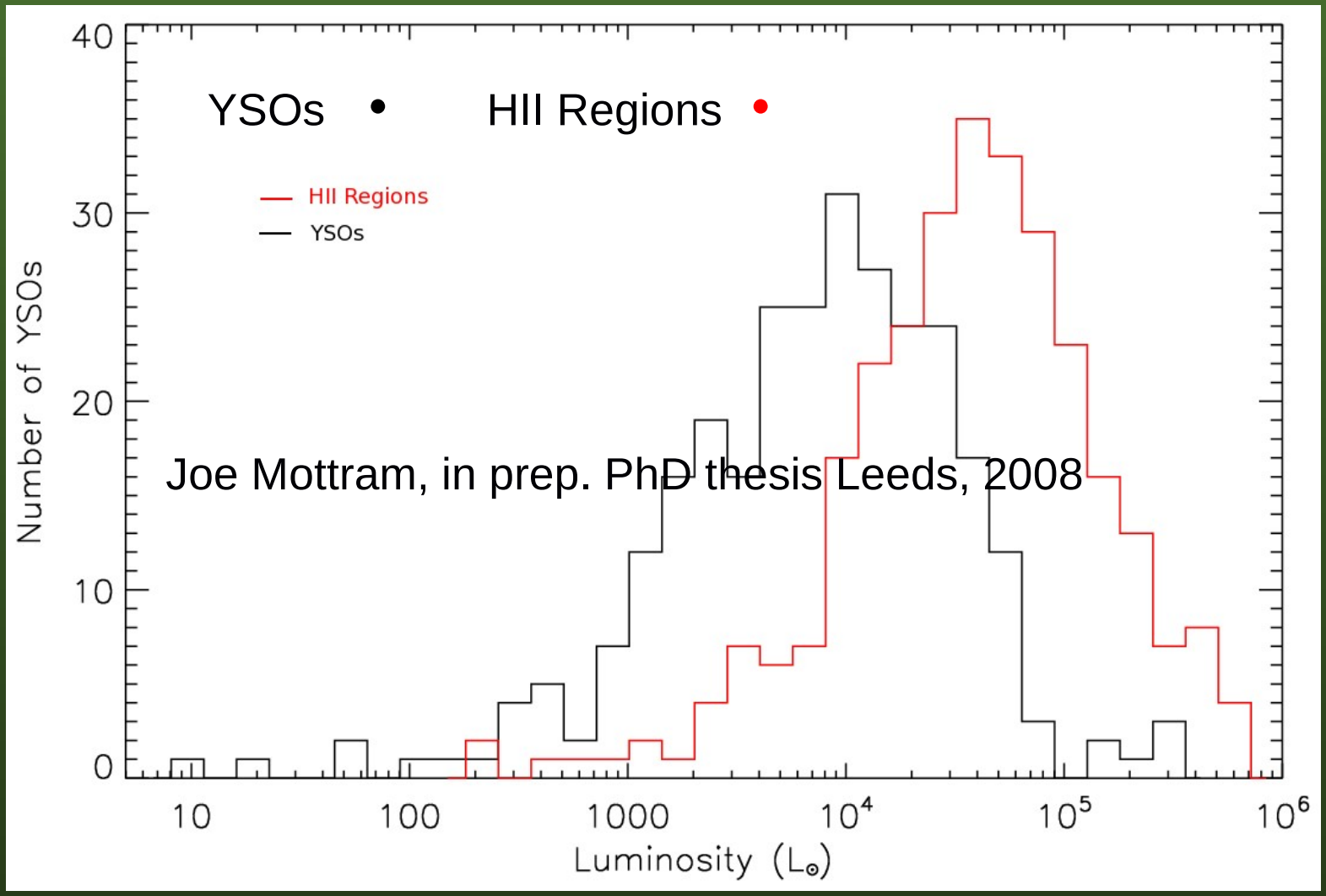
Sample definition complete.

From distances: sample is Galaxy wide.

Mottram, PhD thesis 2008

Luminosity Distribution

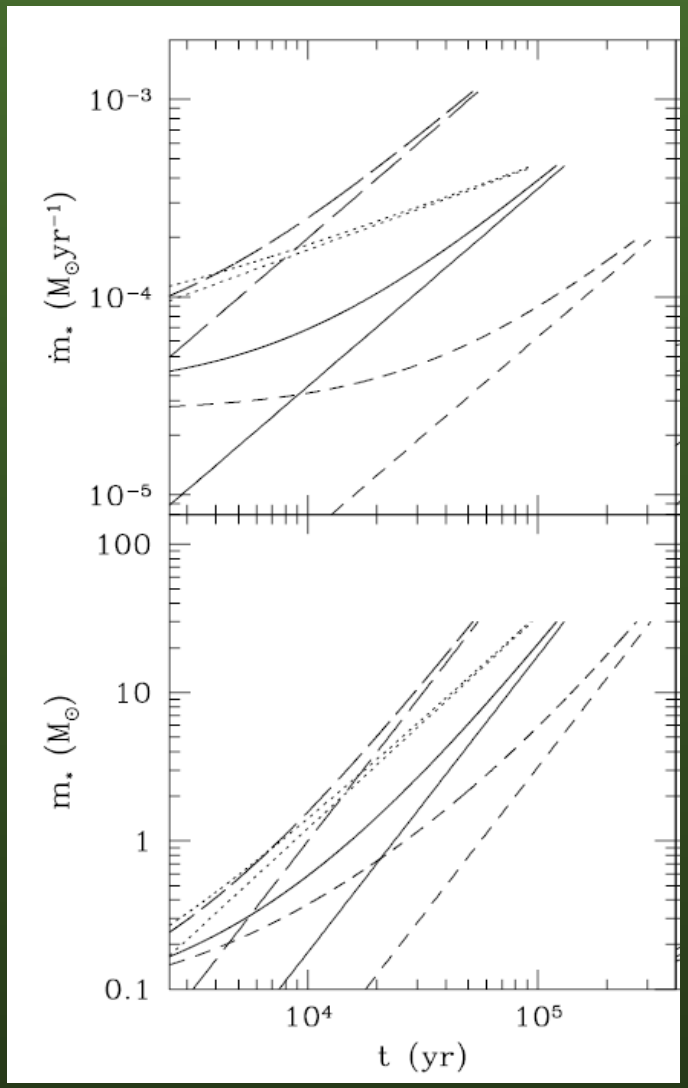
UNIVERSITY OF LEEDS

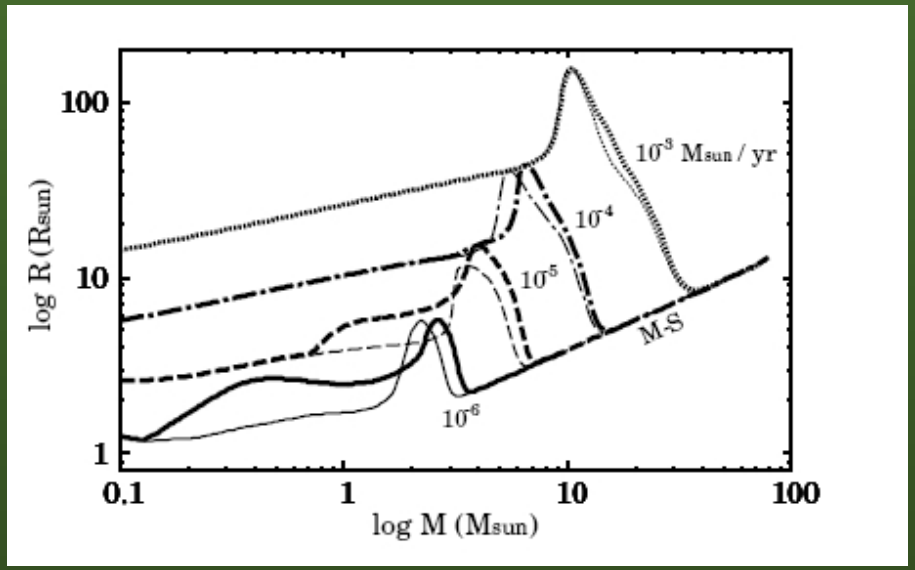


Joe Mottram, in prep. PhD thesis Leeds, 2008

Testing Star Formation Models

UNIVERSITY OF LEEDS





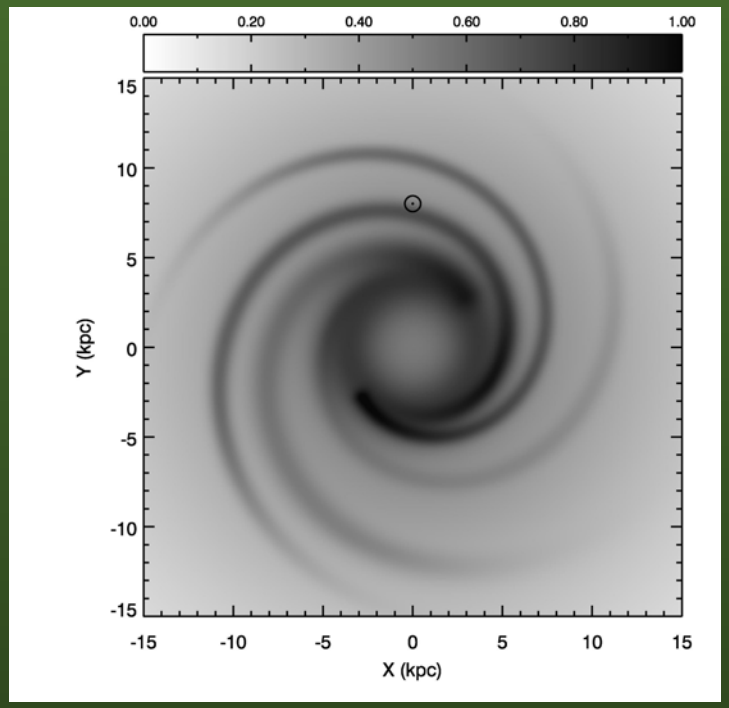
Hosokawa & Omukai (2008)

Puffed up star cooler: no HII

McKee & Tan (2003)

Testing Star Formation Models

UNIVERSITY OF LEEDS



Simulated Star Formation:

Star Formation follows gas distribution Galaxy

Assume SF rate $3M_{\theta}$ yr^{-1}

Let it evolve for 1 Myr

When on MS, compute radio emission

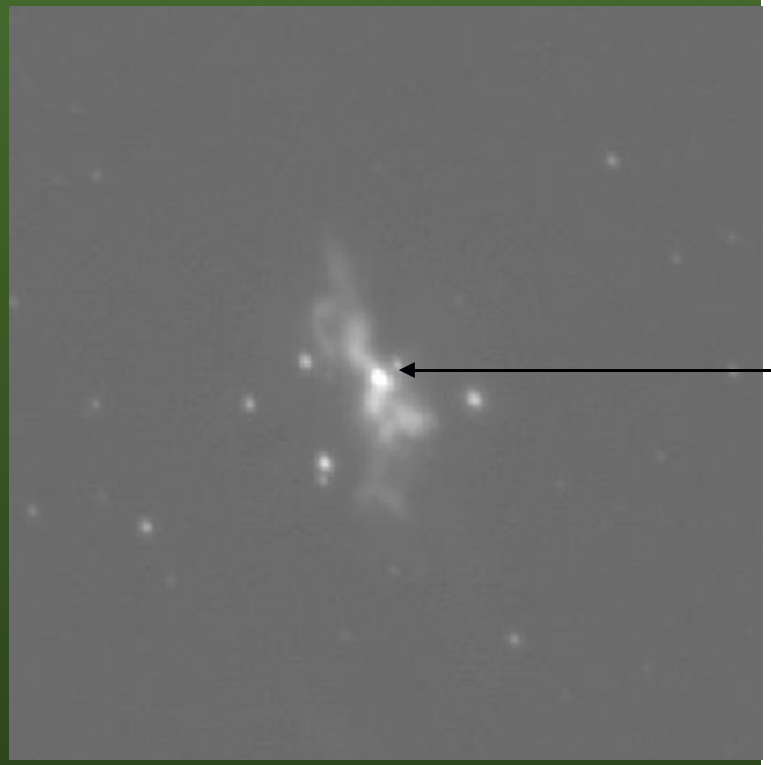
Then select using RMS criteria (distance, IR, L, radio flux)

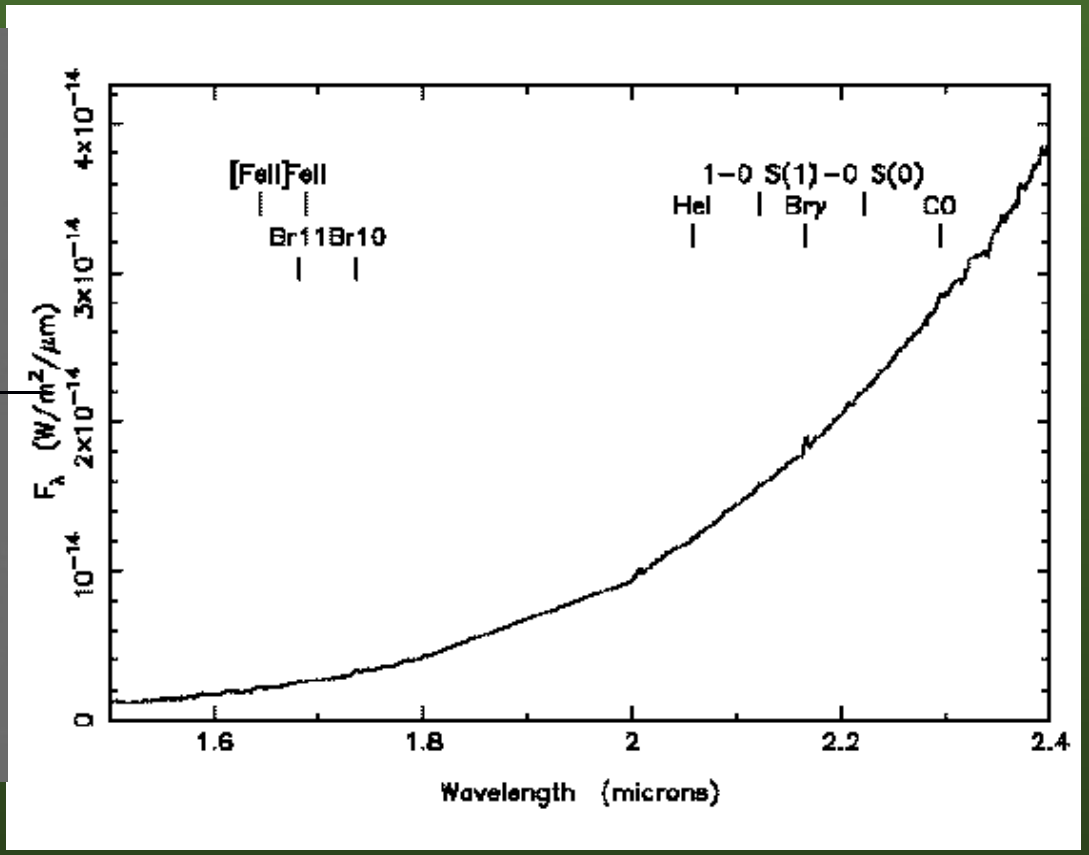
Work in progress : galactic distribution, numbers and luminosity distribution well reproduced already (Davies et al. in prep 2009)

Davies et al 2009, in prep

IR Spectroscopy

UNIVERSITY OF LEEDS



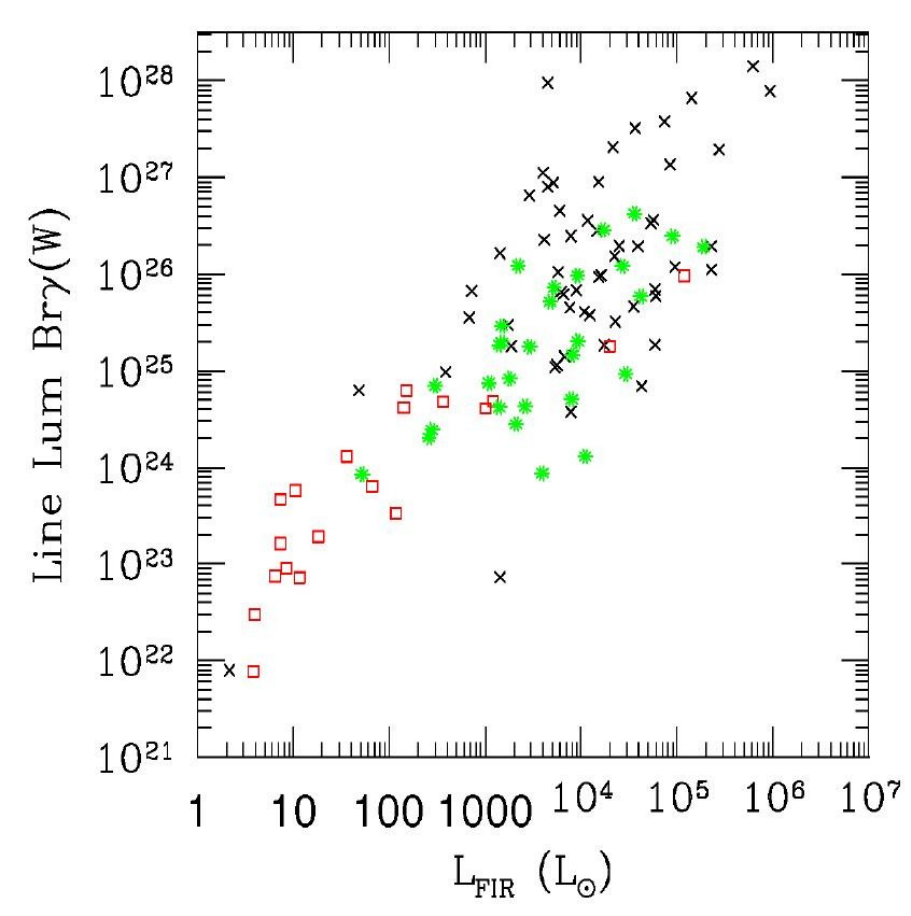


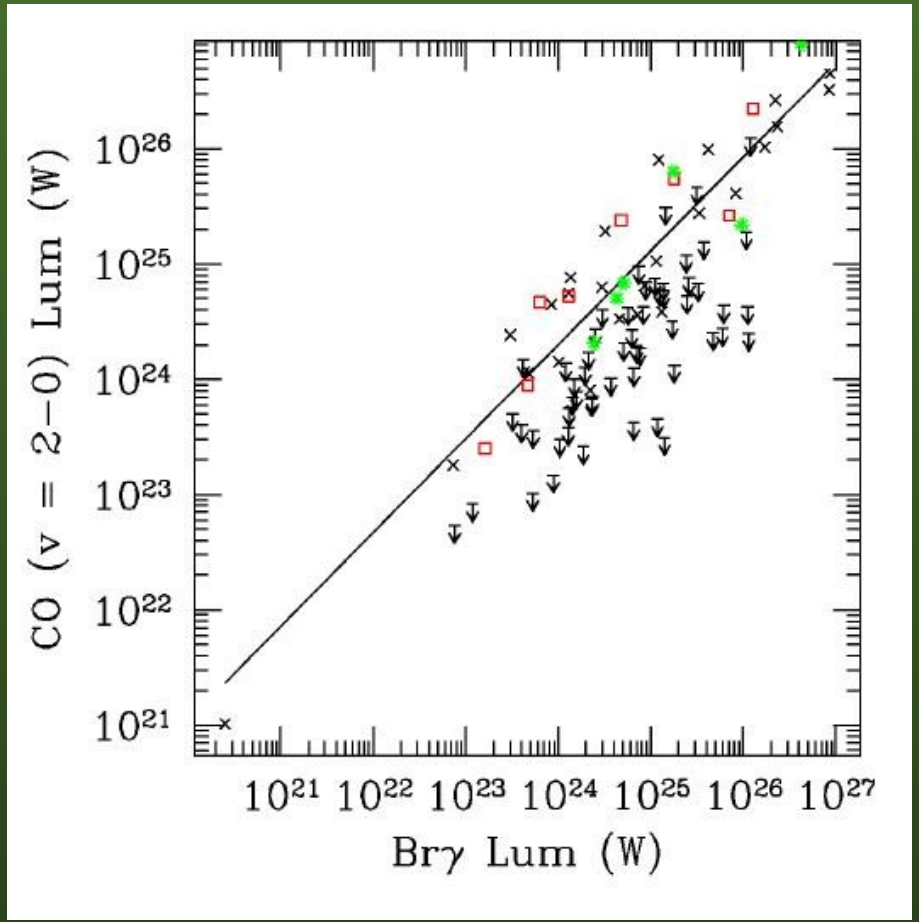
Low resolution near-IR spectra have been obtained for about 500 YSOs

(Cooper in prep, Clarke et al 2006)

Emission Line Properties

UNIVERSITY OF LEEDS



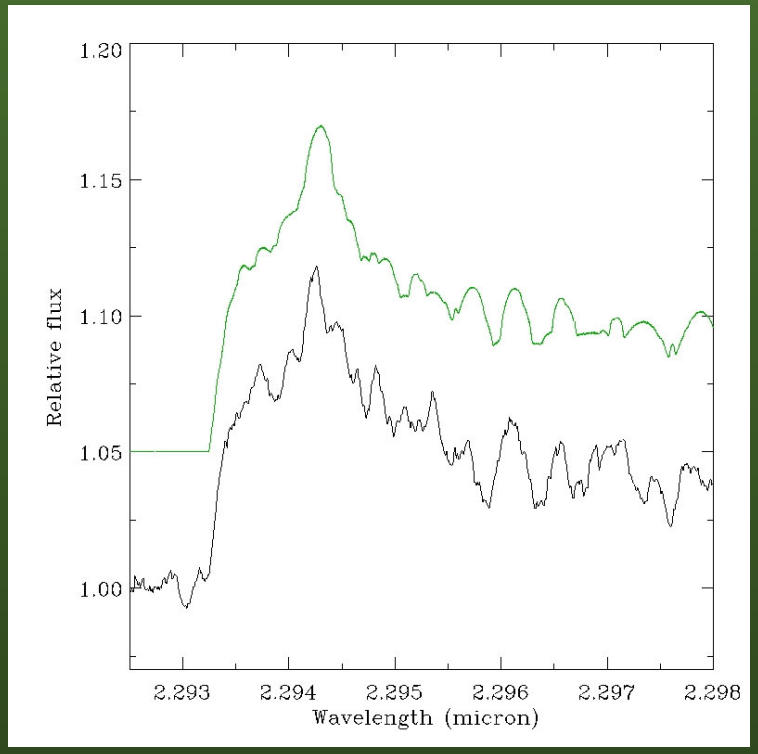


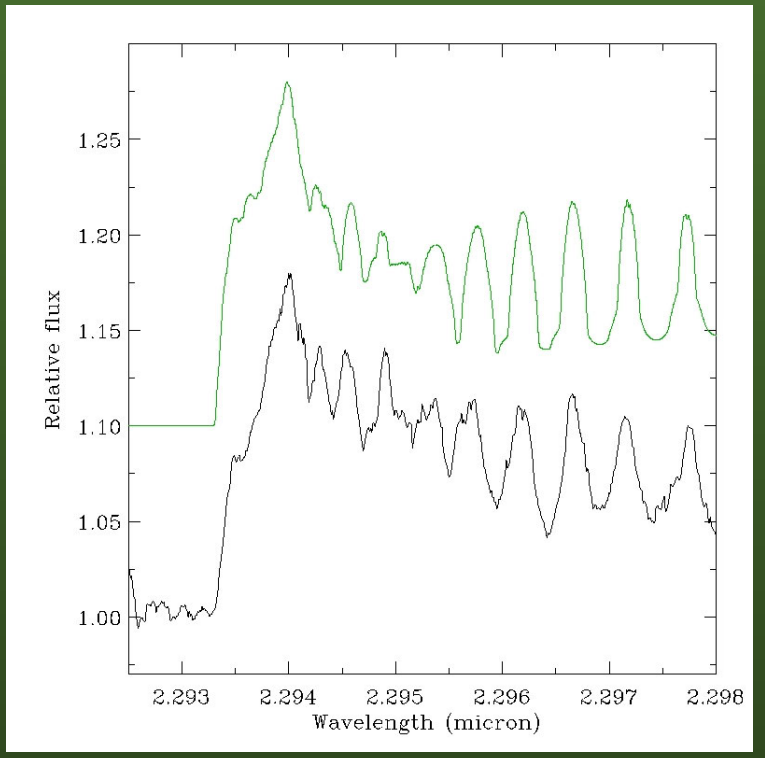
- Carr (1990) observations of TTauri stars
- * Ishii et al (2001) observation of HAeBes
- X RMS, Clarke PhD thesis 2007

Brγ luminosity (accretion proxy for lower mass stars) follows well known relation with L to higher mass. CO too

Line Profile Modelling

UNIVERSITY OF LEEDS





Black lines: CRIRES data, Green : preliminary fits: de Wit et al 2009, in prep

CO 2.3μm lines can be modelled using rotating disk

30% of targets show CO emission : disk accretion

Scope for higher percentage, FeII

Summary

UNIVERSITY OF LEEDS

RMS project fruitful:

Generated a well-defined list of 500 Massive Young Stellar Catalogue and data on **www.ast.leeds.ac.uk/RMS**

First results :

I MYSOs lower luminosity than central stars HII regions → pin down quantitatively using synthetic models

II Large detection rate disk diagnostics → disk accretion dominating the formation

Follow-on studies underway, spectroscopy, imaging, NIR/IR/mm interferometry, clustering