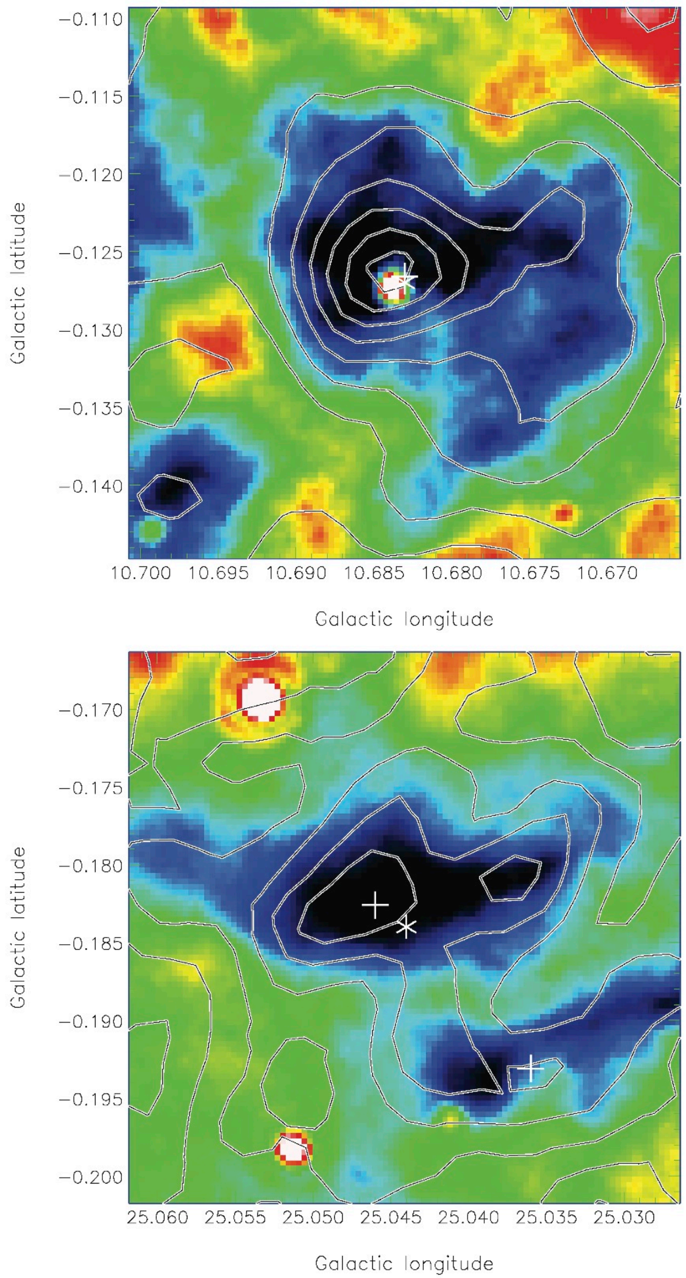
Star Formation & the FIR properties of Infrared Dark Clouds in the Hi-GAL Science Demonstration Field

Mark Thompson and the Hi-GAL Consortium

Infrared Dark Clouds

- Cold dense clouds seen in extinction against the Galactic mid-IR background (8, 24, 70 μm…)
- Possible sites of earliest stages of massive star formation that went unseen by IRAS
- Two major IRDC catalogues
  - Simon et al 2006 – MSX 8 μm
    - 10,931 clouds, decomposed into 12,774 “cores”
  - Peretto & Fuller 2009 – Spitzer GLIMPSE & MIPSGAL
    - 11,303 clouds, decomposed into ~20-50k “fragments”
- Many many follow-up studies of small sub-samples (Rathborne 2006…, Chambers 2009, Ragan 2009…)
- Can divide IRDCs into two types:
  - Active/Star-forming (masers/mid-IR/UC HIIs/EGOs)
  - Quiescent/Starless

(after Chambers 2009, Parsons 2009)



MIPS 24 μm & SCUBA 850 μm contours
Parsons. Thompson, Chrysostomou 2009

Hi-GAL programme on IRDCs

Hi-GAL has the potential to revolutionise IRDC studies in two ways:

i. Fully sampled SEDs from 70 – 500 μm
ii. Large well-selected samples across the Galactic Plane

Hi-GAL Working Group on the Formation of Molecular Clouds are currently pursuing the following IRDC projects with the Science Demonstration Phase data:

- Pixel by Pixel SED fitting of a sample of IRDCs, led by Nicolas Peretto
  Peretto et al 2010 (submitted to special issue), and also see talk here by Peretto et al
- Detailed Radiative Transfer modelling, led by Lucy Wilcock
  uses PHAETHON code to model extinction & emission, see poster here by Wilcock et al
- Comparison of IR-bright & IR-dark clouds, led by Cara Battersby
  uses Elia et al 2010 Hi-GAL compact source catalogue
- Statistical investigation of IRDC properties, led by Mark Thompson
  uses Elia et al 2010 Hi-GAL compact source catalogue

A sample of IRDCs in the Hi-GAL Science Demonstration Field

Cross-match IRDC cores from the Simon et al 2006 catalogue with compact sources from the Hi-GAL compact source catalogue (see talk by Davide Elia at ESLAB & Elia et al 2010, A&A accepted)

Use same technique as with SCUBA Legacy Catalogue (Parsons et al 2009), i..e nearest neighbour + by eye checks

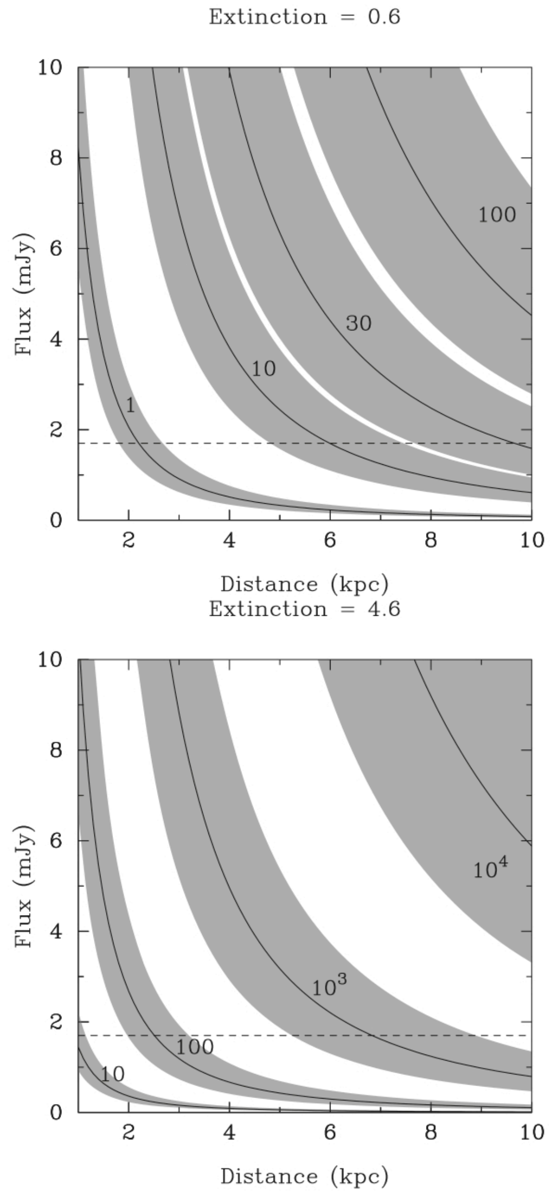
Take clean Hi-GAL photometric sample from Elia et al 2010:
Stage 3b band-merged catalogue (318 sources in l=30 field)

Working to improve band-merging & source detection in complex IRDC environments, so very much a work in progress

Determine IRDC properties by simple greybody fitting to PACS & SPIRE fluxes

Identify presence of star formation via MIPSGAL 24 μm sources (sensitive to embedded objects L ~ 10 – few 100 $M_\odot$)

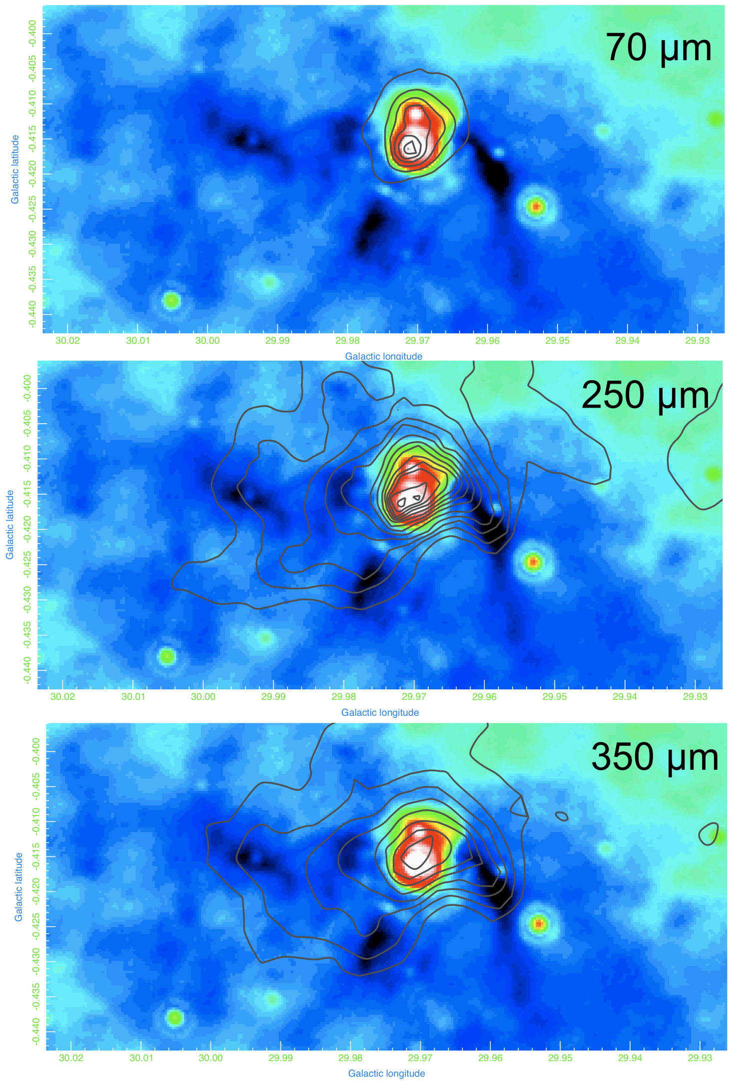
Resulting sample of 36 IRDC cores with SEDs sampled from 24 to 500 μm and known distances. 50% of cores associated with 24 μm point source & 50% quiescent



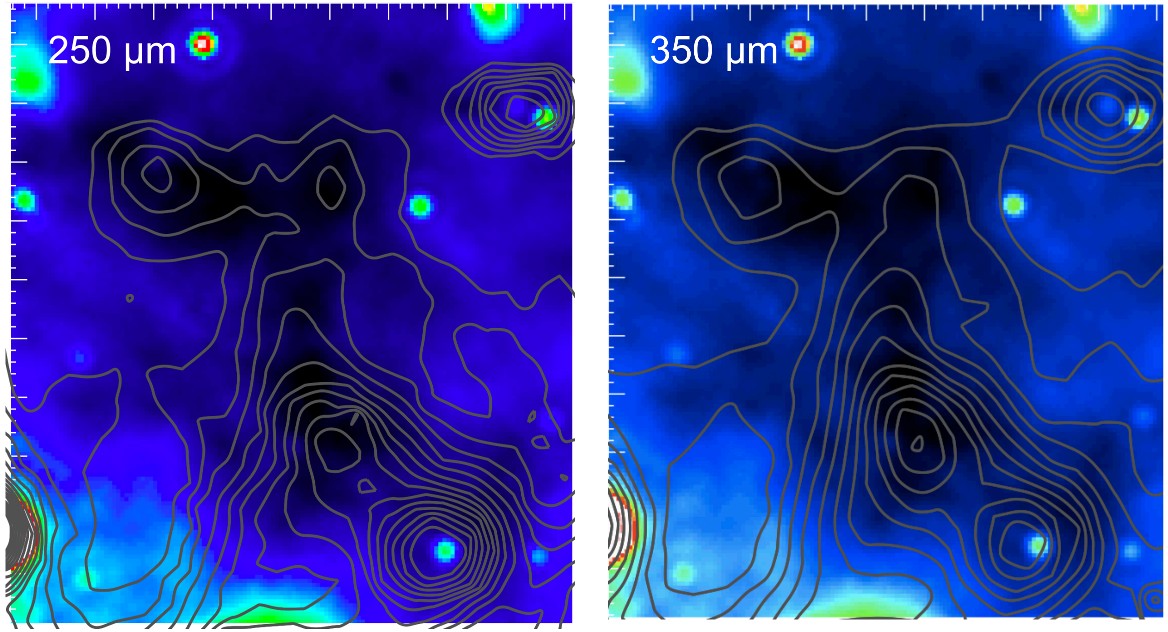
MIPS sensitivity to embedded sources, following Dunham et al 2009 c2d results

Some examples

G29.97-0.42



G30.86-0.21



70 µm traces embedded point sources

250– 500 µm traces the clouds

Agrees with talk by Compiegne yesterday

(colourscale = MIPSGAL 24 µm)

Preliminary results

With obvious caveat of small sample size…

All cores well fitted with greybody models with:

T ranging from 10 – 20 K

N ranging from $5 \times 10^{22} - 5 \times 10^{23}$ cm^{-2}

Good agreement with pixel by pixel SED results

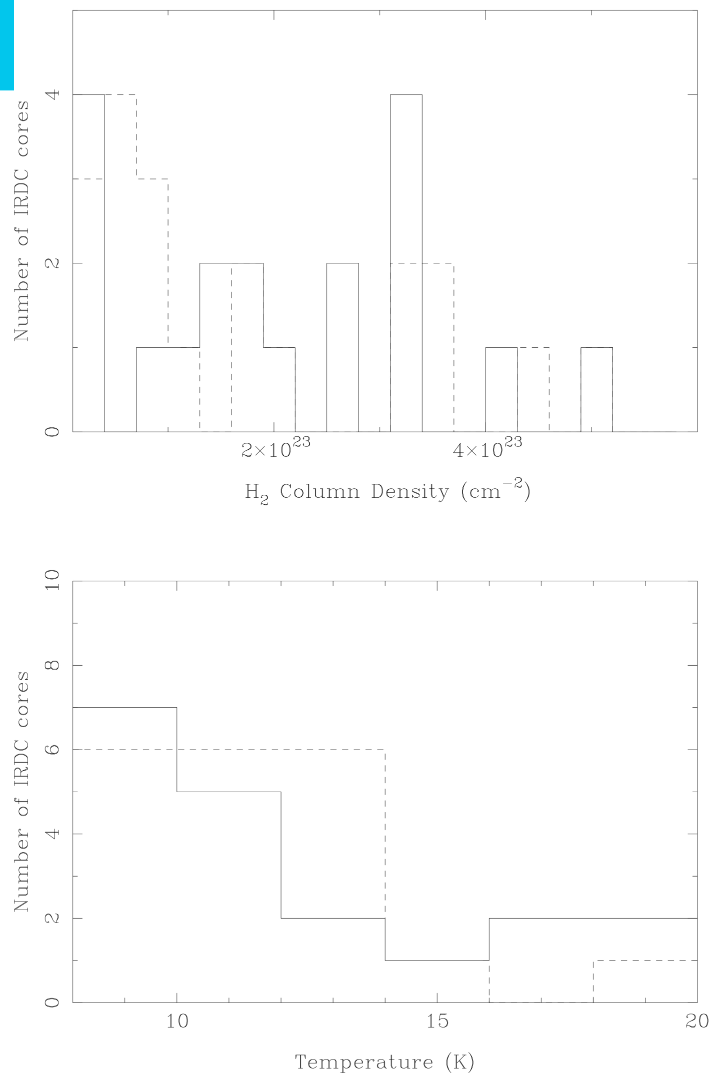
70 µm correlates with presence of 24 µm source

70µm not fitted well by greybody (excluded from fits)

No evidence for evolution in T or N between cores with/without 24 µm sources

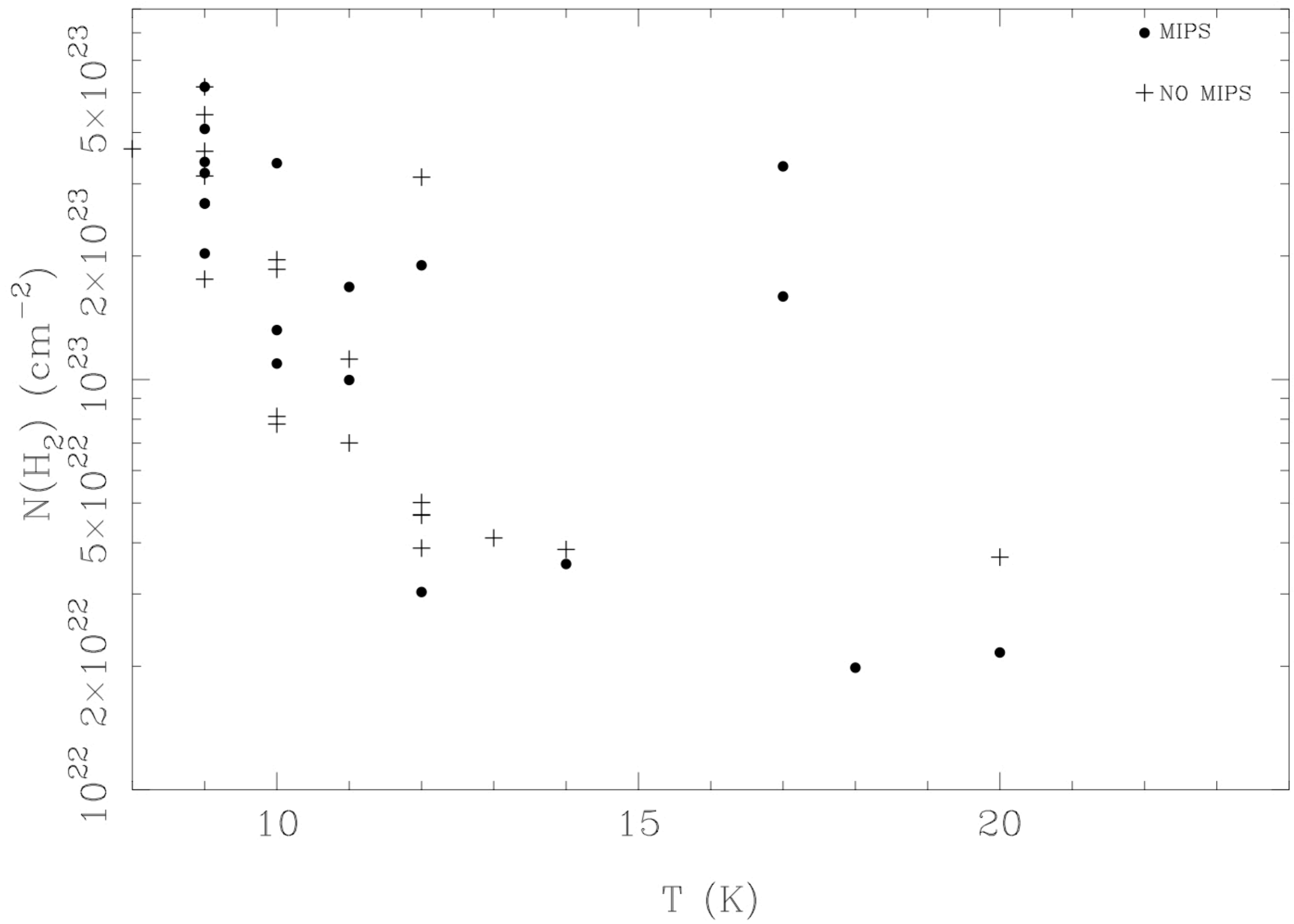
Cores are drawn from the same population?

Onset of heating sufficiently recent to not have heated the majority of the core?



Solid = MIPS 24 µm
Dashed= No MIPS 24 µm

Preliminary results – T vs N

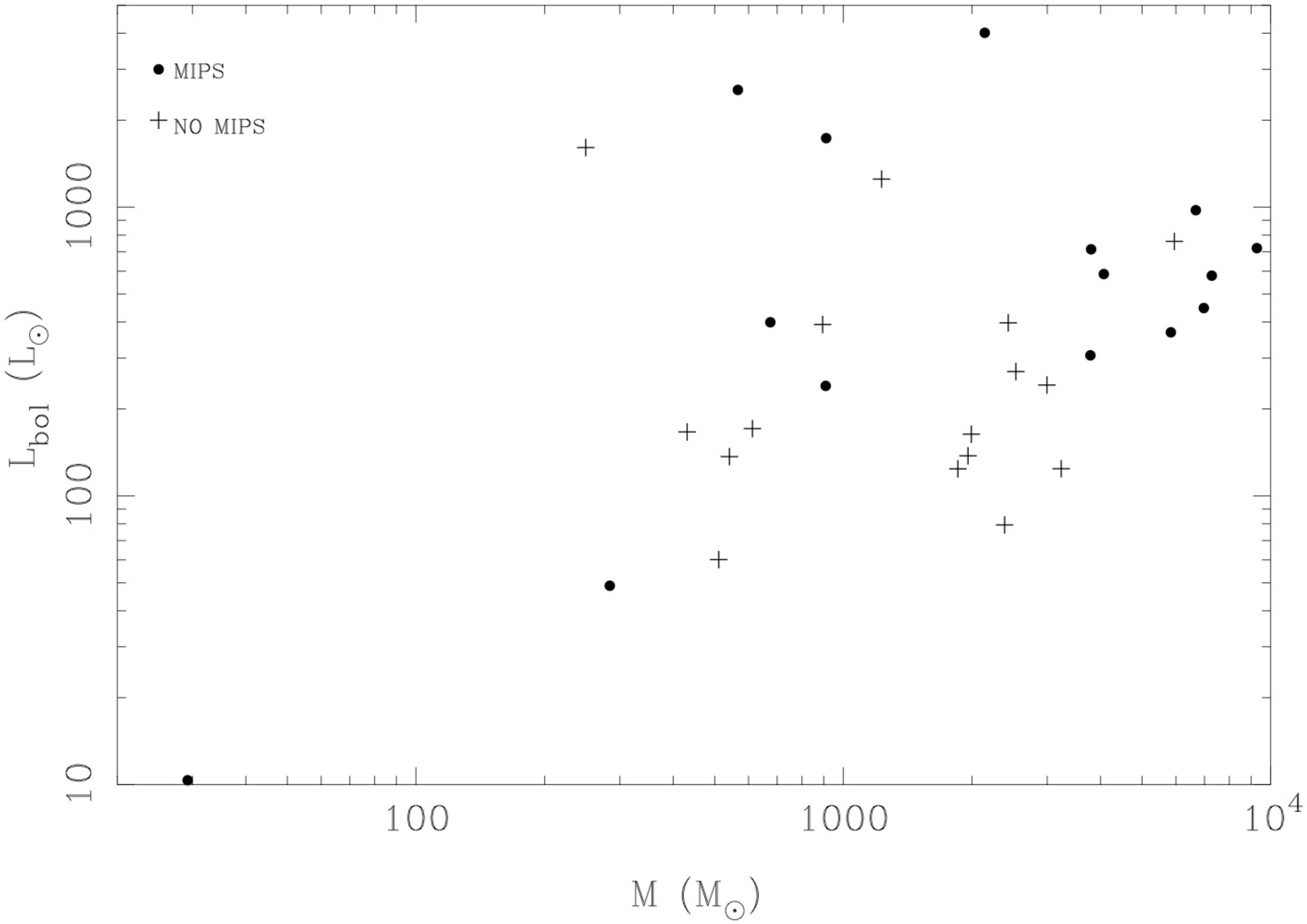


Good agreement with Peretto pixel-by-pixel SED fits

No obvious trend but most sources without MIPS detections are < 15 K

Note cold high column density sources – early stages of massive star formation?

Preliminary results – M vs L

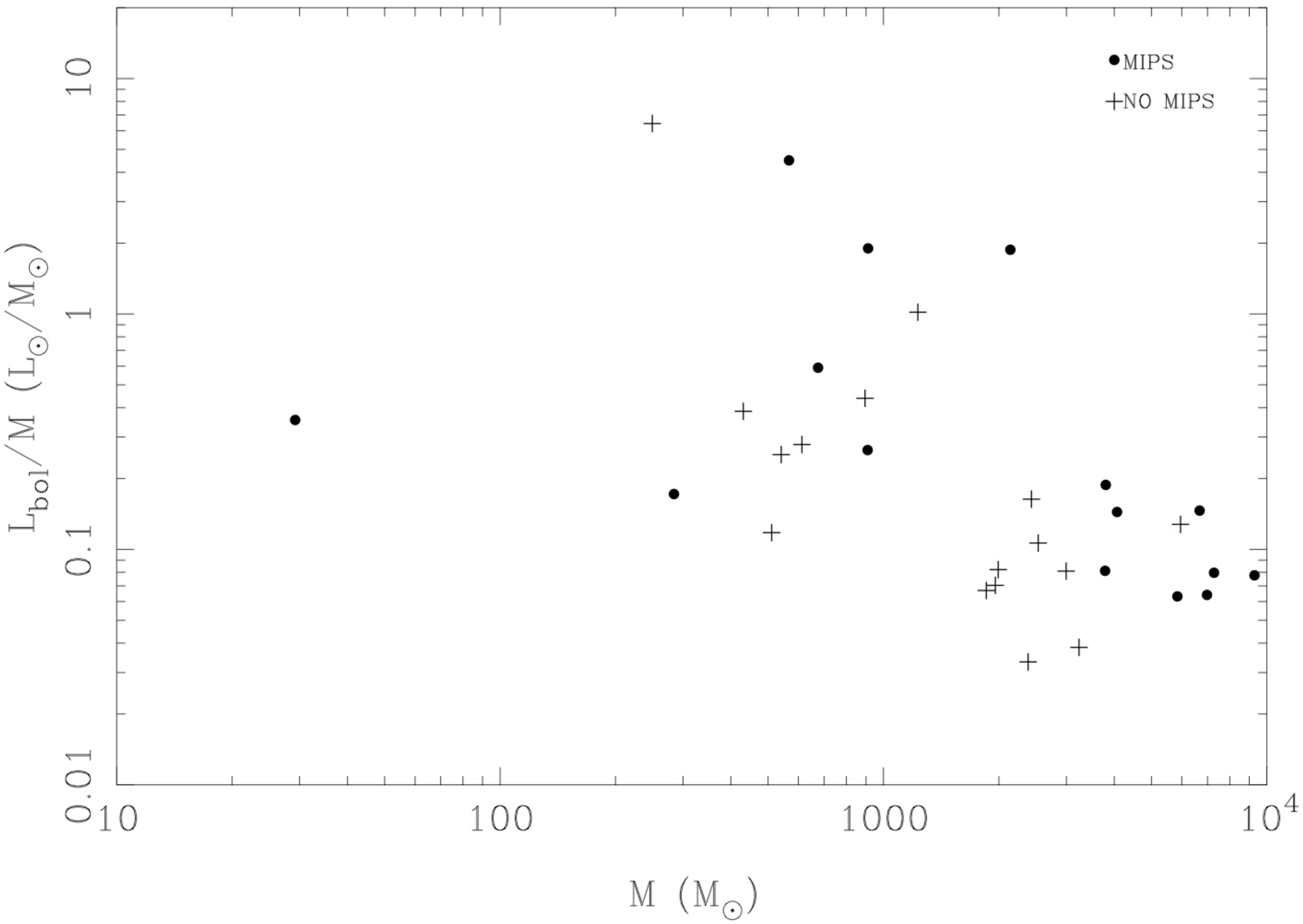


Masses mostly a few hundred to few thousand solar masses

Luminosities few hundred to few thousand solar luminosities

MIPS detected sample slight trend toward higher mass

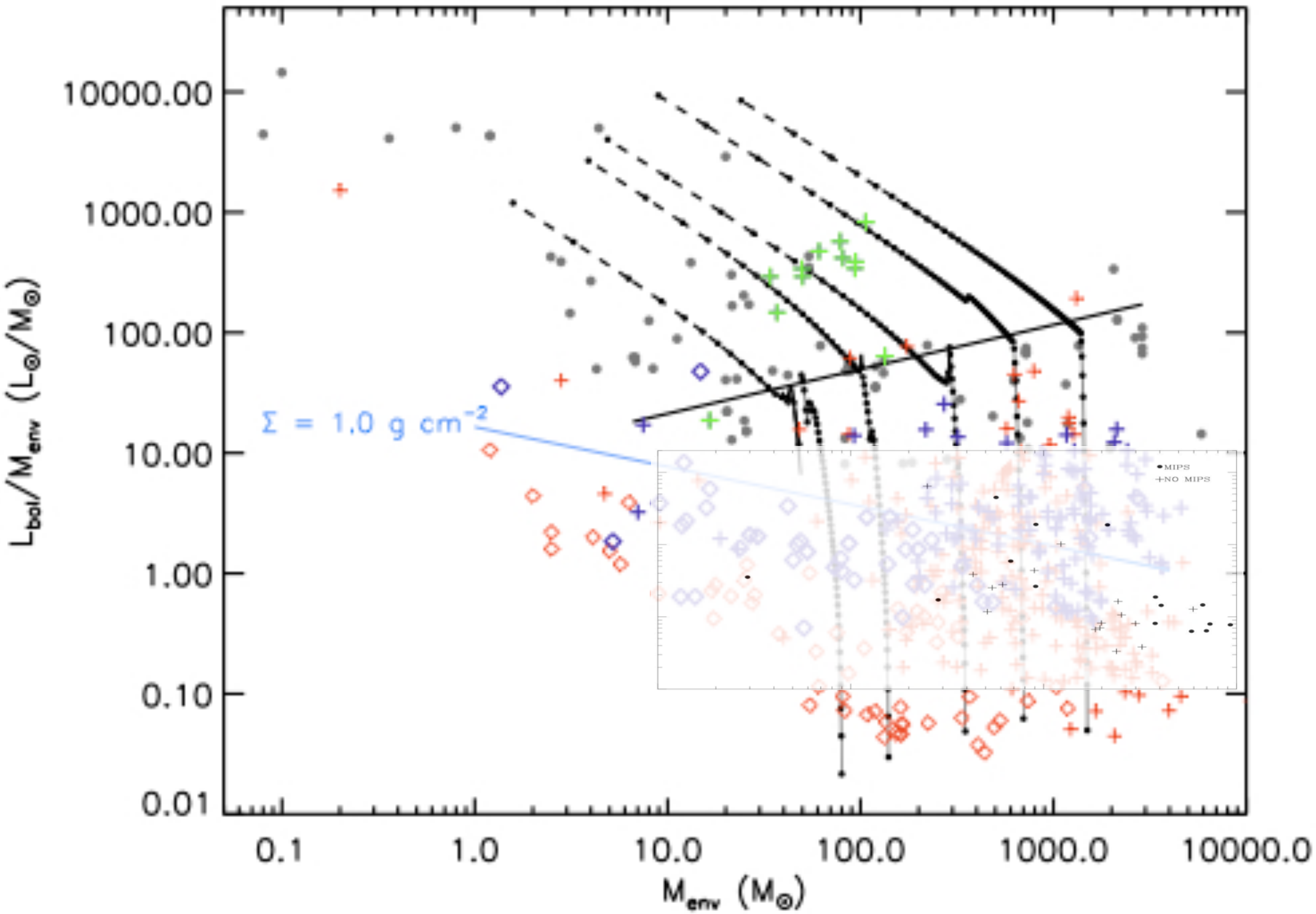
Preliminary results – M vs L/M



Again, no really obvious trends except MIPS detected sources tending to be higher mass

Mostly massive but not luminous objects

Preliminary results – M vs L/M



IRDC cores fall in the lower right corner of all Hi-GAL sources in M vs L/M

Early evolutionary state?

What comes next

- Must increase sample size by improving source extraction & band-merging
  - Need to cope with IRDCs being in extinction at 70 μm but strong emission by 250 μm (from shadows to light…)
  - Complex and crowded environments make source-finding difficult
  - Can naturally increase sample size by mapping more of the Plane

- Include warm component in greybody fits to IRDCs with MIPS & PACS detections

- Investigate correlations with other star formation tracers
  - Class II Methanol Masers from the MMB Survey
  - UC HII regions from CORNISH 5 GHz Survey (see poster by Cesaroni)
  - Massive YSOs from the RMS Survey
  - H_2O masers, EGOs, outflows…