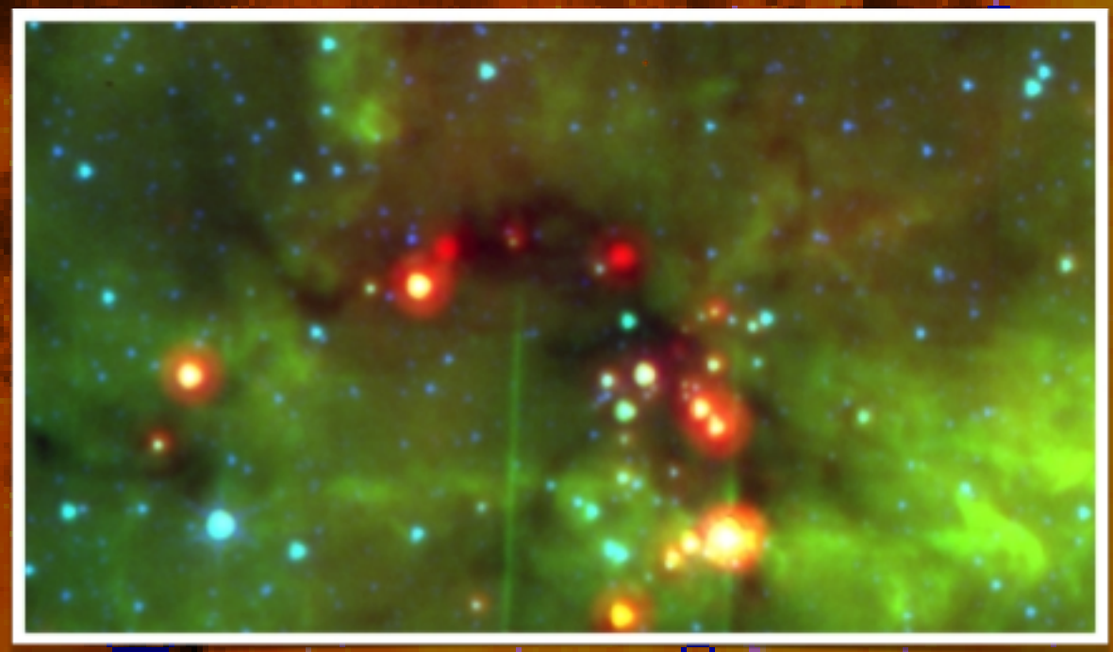
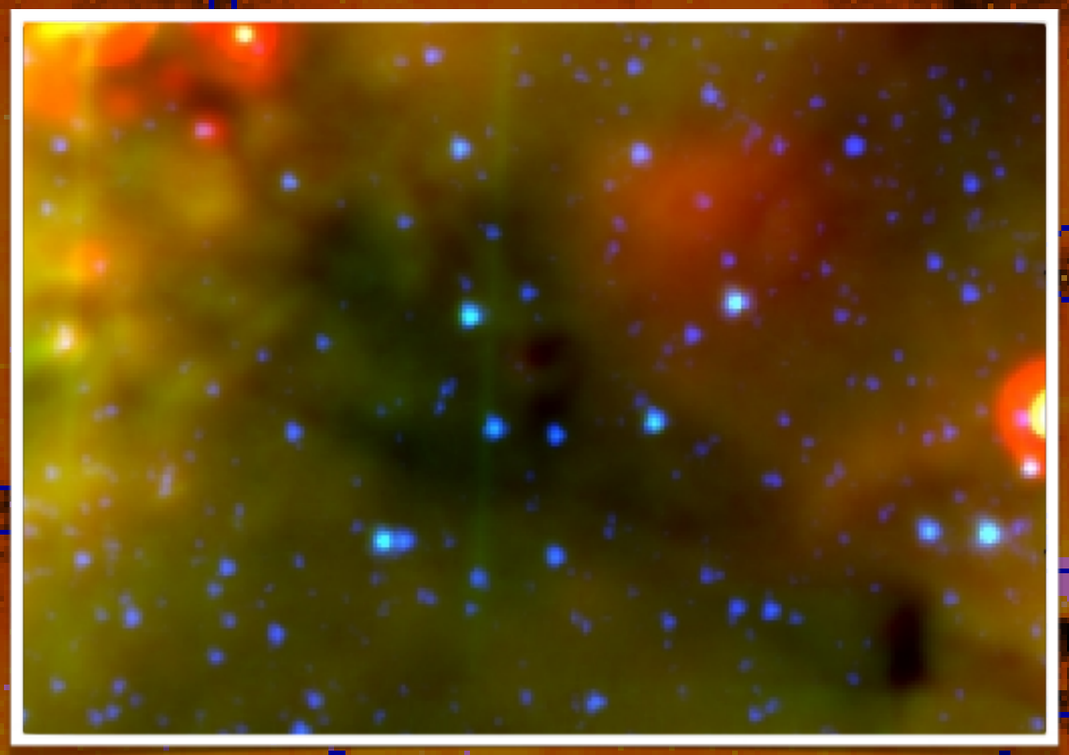
A New Comprehensive Catalogue of Infrared Dark Clouds





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Peretto & Fuller, 2009, A&A, 505, 405

Outline

- Overview of Infrared Dark Clouds

- A new catalogue of Spitzer Dark Clouds

- Stellar associations with Spitzer Dark Clouds

- Mass distribution of Spitzer Dark Clouds

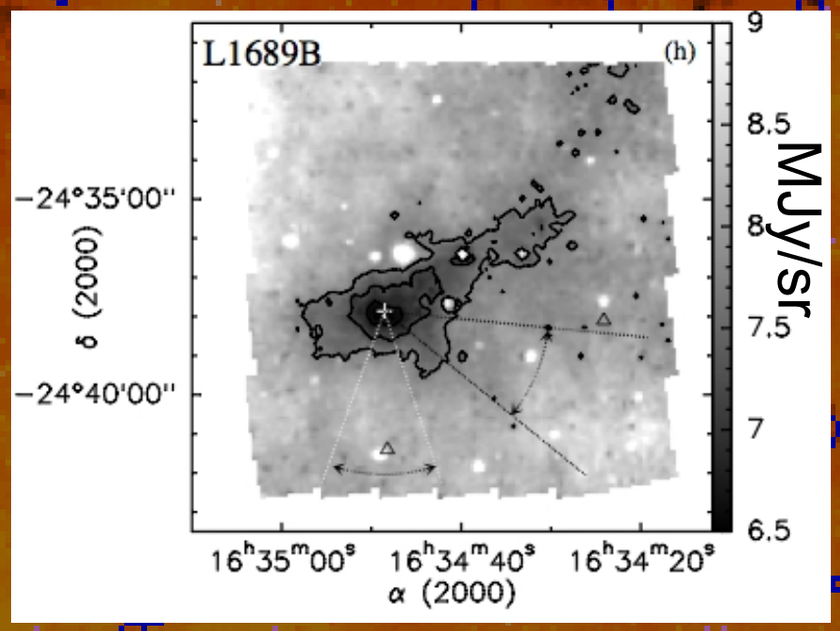
- Recent work

- Summary

Infrared Dark Clouds: History & Background

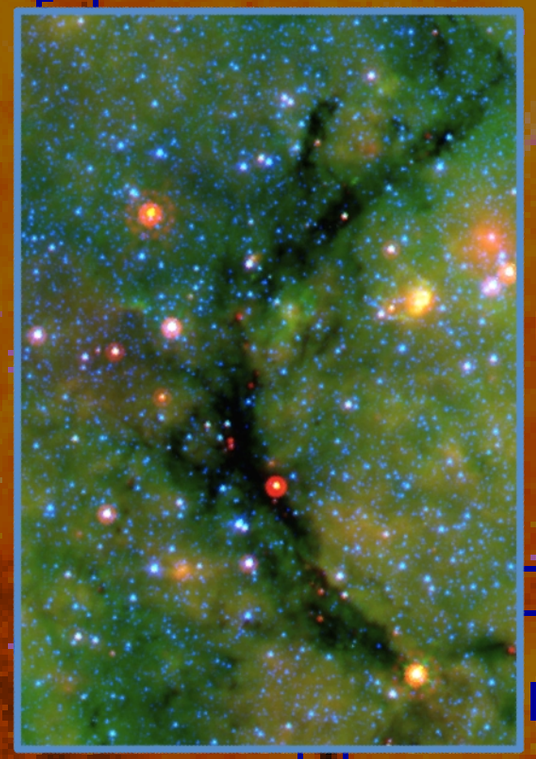
IR silhouettes against background emission
First detection of IRDCs by Pérault et al (1996) with ISO
Most extensive catalogue compiled from MSX observations

- Common objects in Galaxy
- Dense molecular clouds detected in dust continuum emission
- Similar to classical molecular clumps
- Associated with star formation (including massive star formation)
- Column density structure of IRDCs well traced by 8μm extinction



7μm ISO image of a low mass IRDC

(Bacmann et al. 2000)

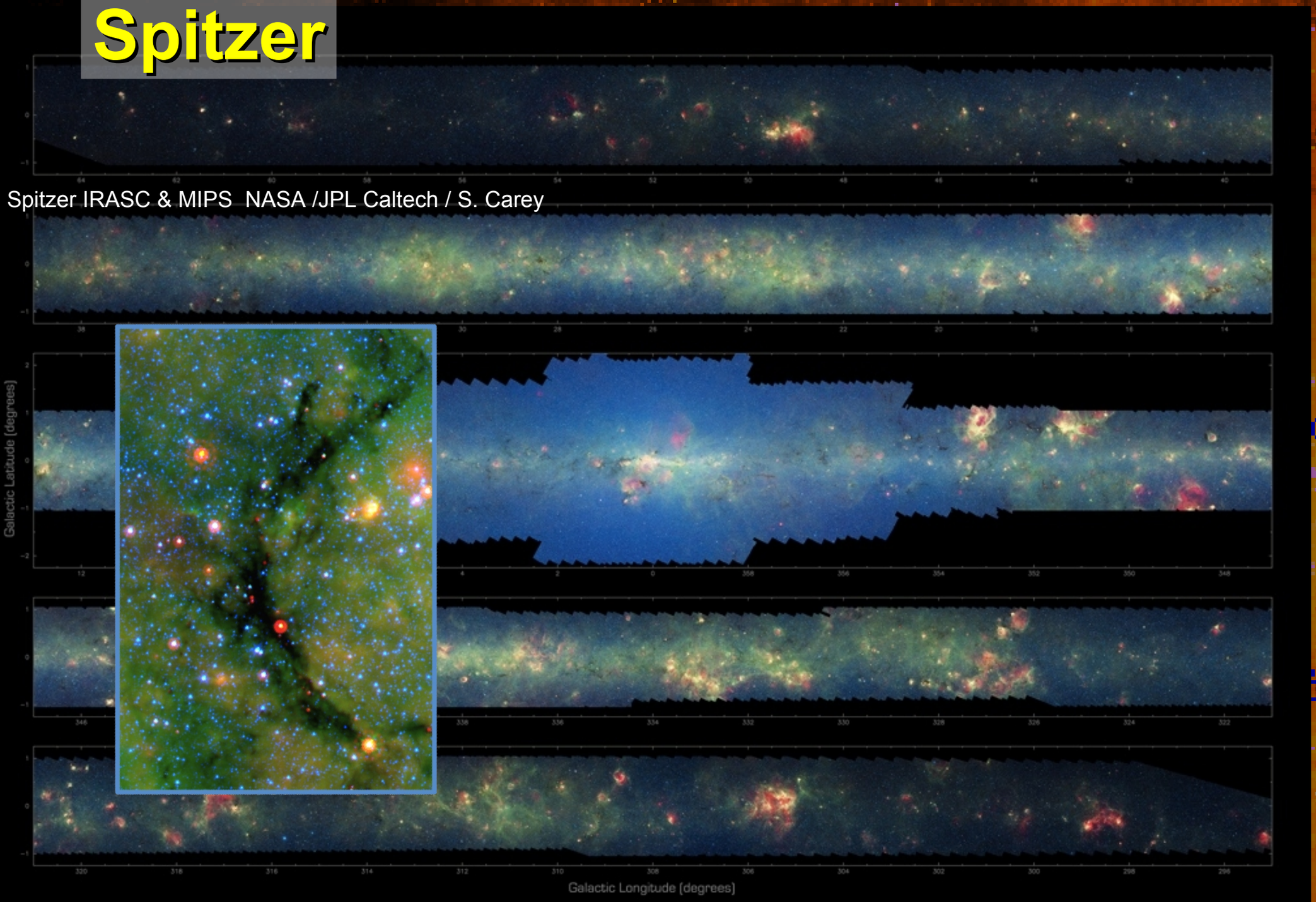


Spitzer GLIMPSE

Spitzer IRASC & MIPS NASA /JPL Caltech / S. Carey

(Carey et al. 1998, 1999, 2000; Teyssier et al. 2002; Schuller et al. 2009; Vasyunina et al 2009; Teyssier et al. 2002; Ragan et al. 2006; Pillai et al. 2006, 2007; Beuther & Sridharan 2007; Chambers et al 2009; Jackson et al. 2008; Simon et al. 2006a,b; Rathborne et al 2007/2008; Wang et al. 2008; Zhang et al. 2009; Butler & Tan 2009; Ragan et al. 2009)

Spitzer

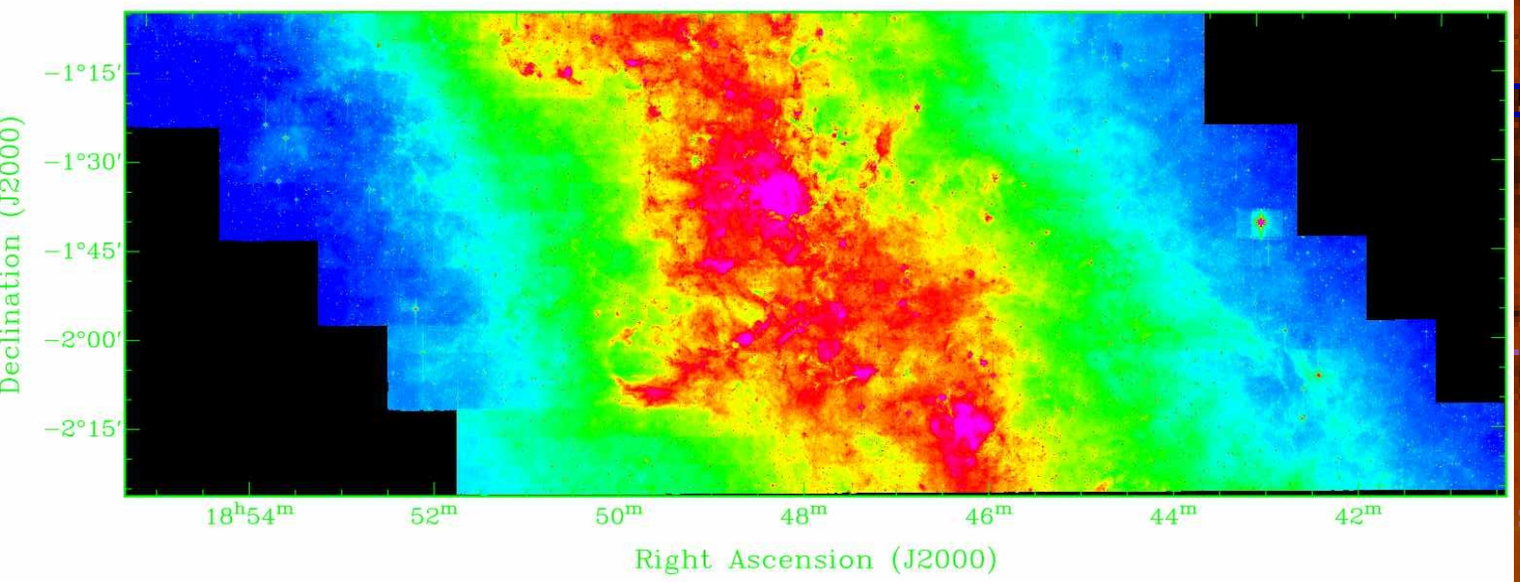


Spitzer IRASC & MIPS NASA /JPL Caltech / S. Carey

GLIMPSE region: $10^0<l<65^0$, $|b|<1^0$

Identifying the Spitzer Dark Clouds

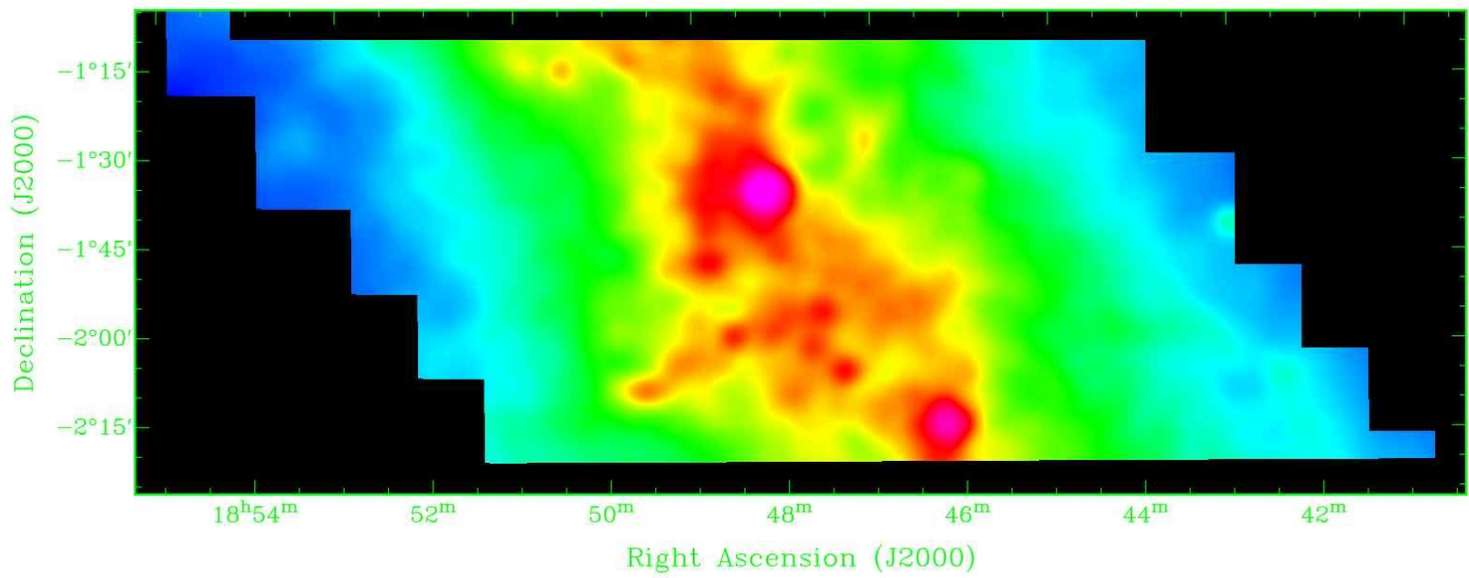
Spitzer/IRAC 8 micron block



- Combined GLIMPSE 8micron mosaics into blocks of 2^{o}x1^{o}
- Did the same with MIPSGAL 24 micron mosaics covering the same area
- Smoothed to 5 arcmin to estimate I_{MIR}

- Identify and extract IRDCs
  - Connected structures τ(8μm)>0.35
  - With peaks τ(8μm)>0.7

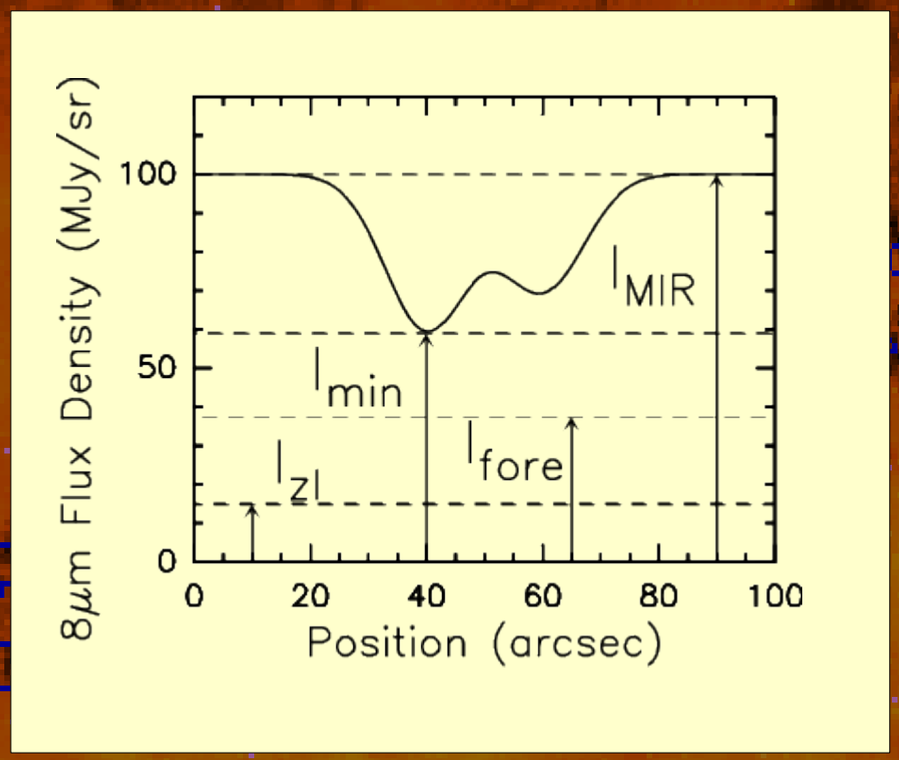
Large scale emission: I_{MIR}

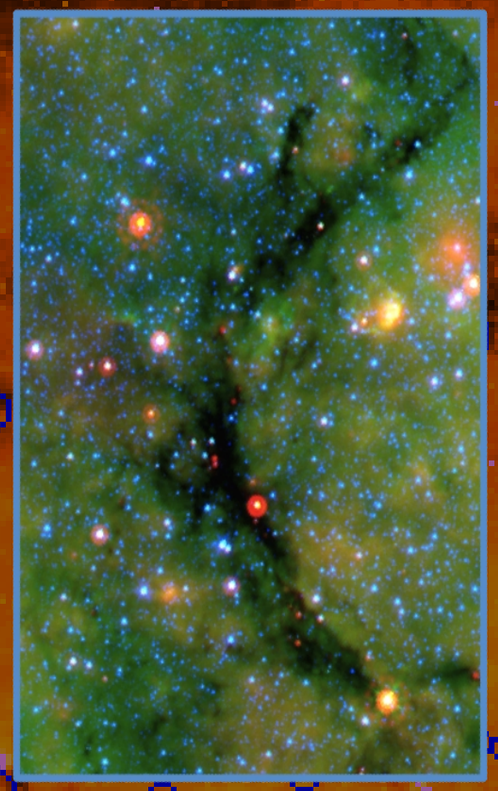


Calculating Optical Depth

$$I_{8\mu m} = I_{bg}\exp(-\tau_{8\mu m}) + I_{fore}$$

$$I_{MIR} = I_{fore} + I_{bg}$$

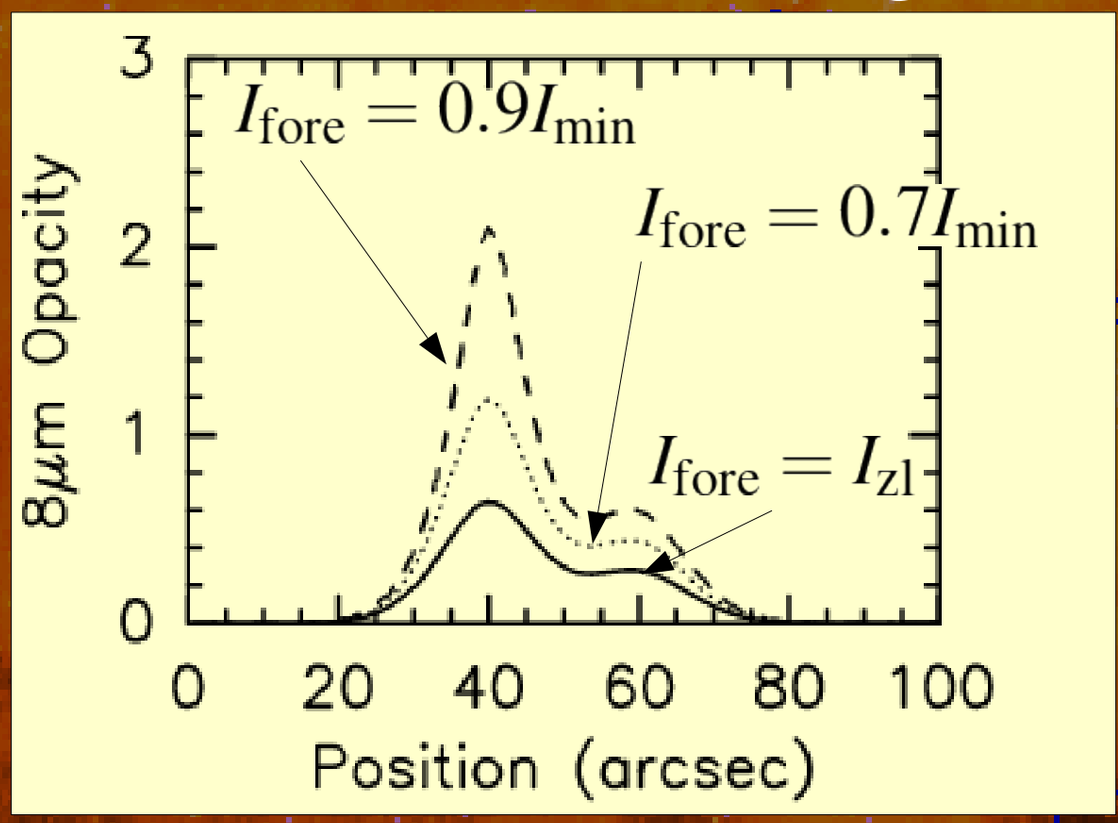




Spitzer IRASC & MIPS
NASA /JPL Caltech / S. Carey

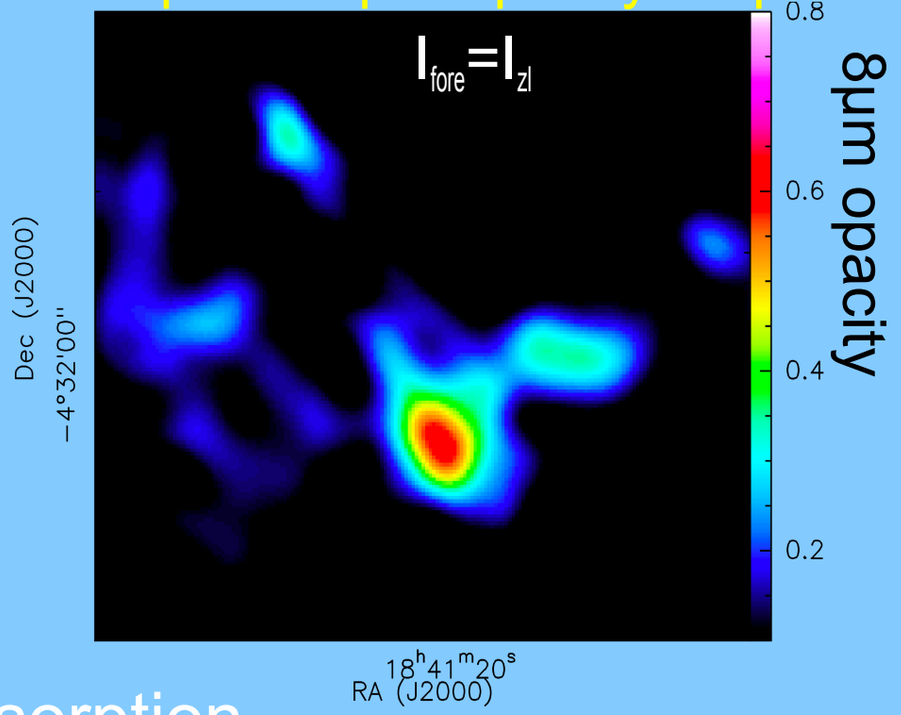
$$\tau_{8\mu m} = -\ln\left(\frac{I_{8\mu m} - I_{fore}}{I_{bg}}\right)$$

We need to constrain the foreground intensity to recover the opacity structure of the clouds



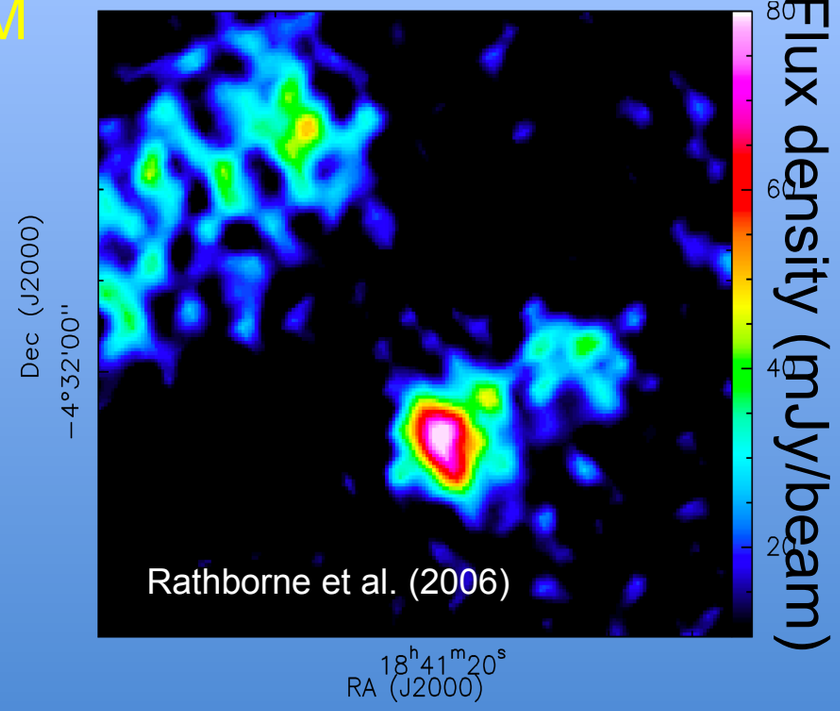
The Foreground

Spitzer 8μm opacity map

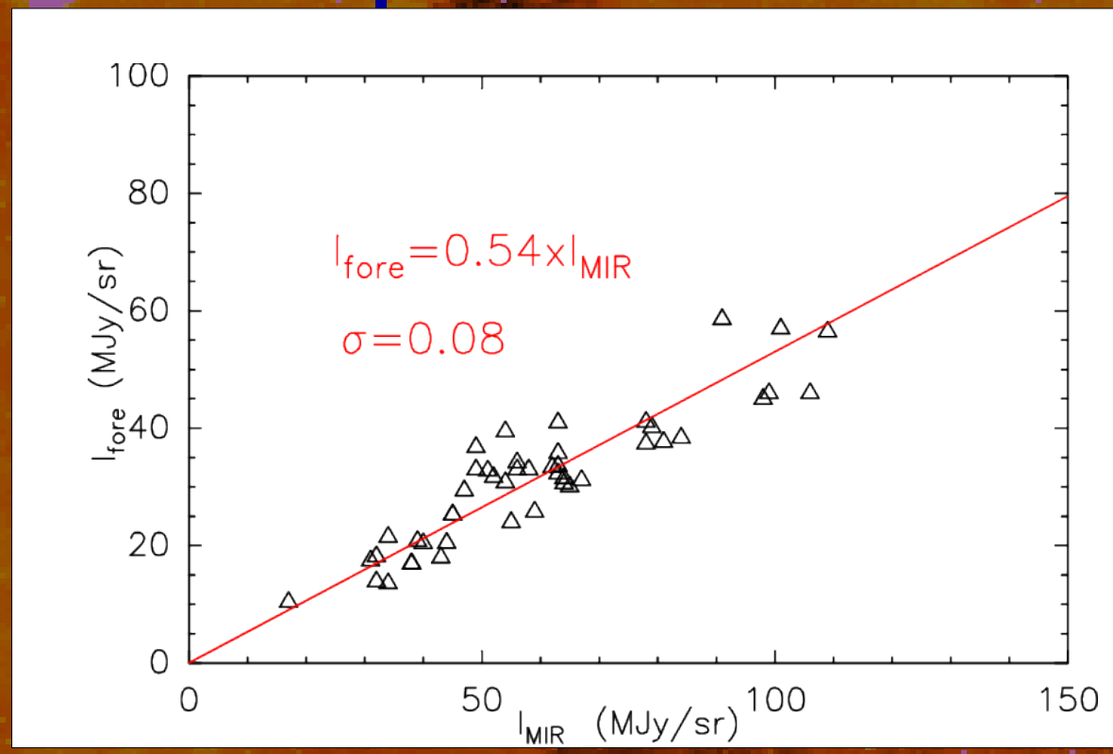


Absorption

IRAM 30m



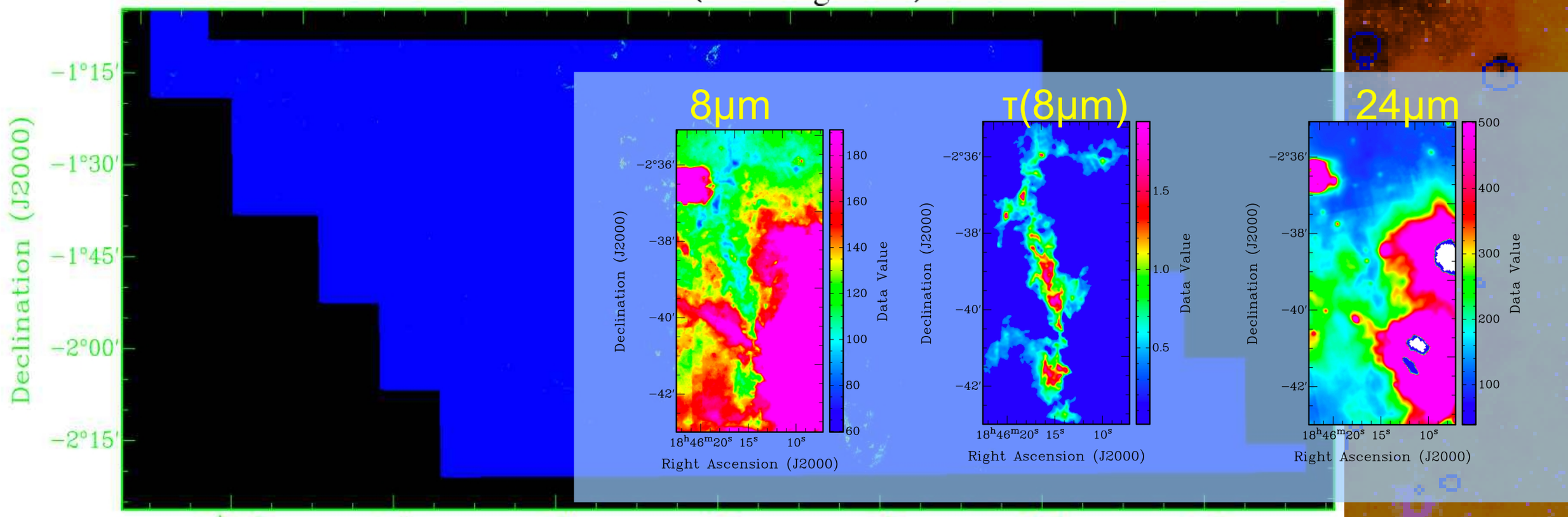
Emission $\tau_{8\mu m}^{em} = 20 S_{1.2mm}(\mathrm{Jy})$

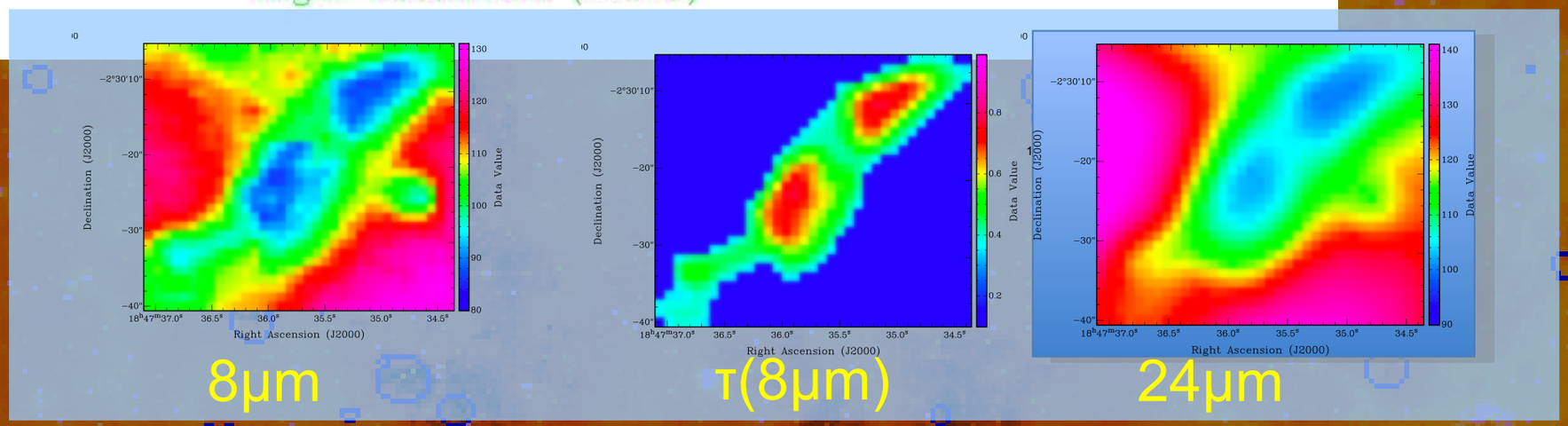


Linear correlation between I_{fore} and I_{MIR}

8 micron opacity:

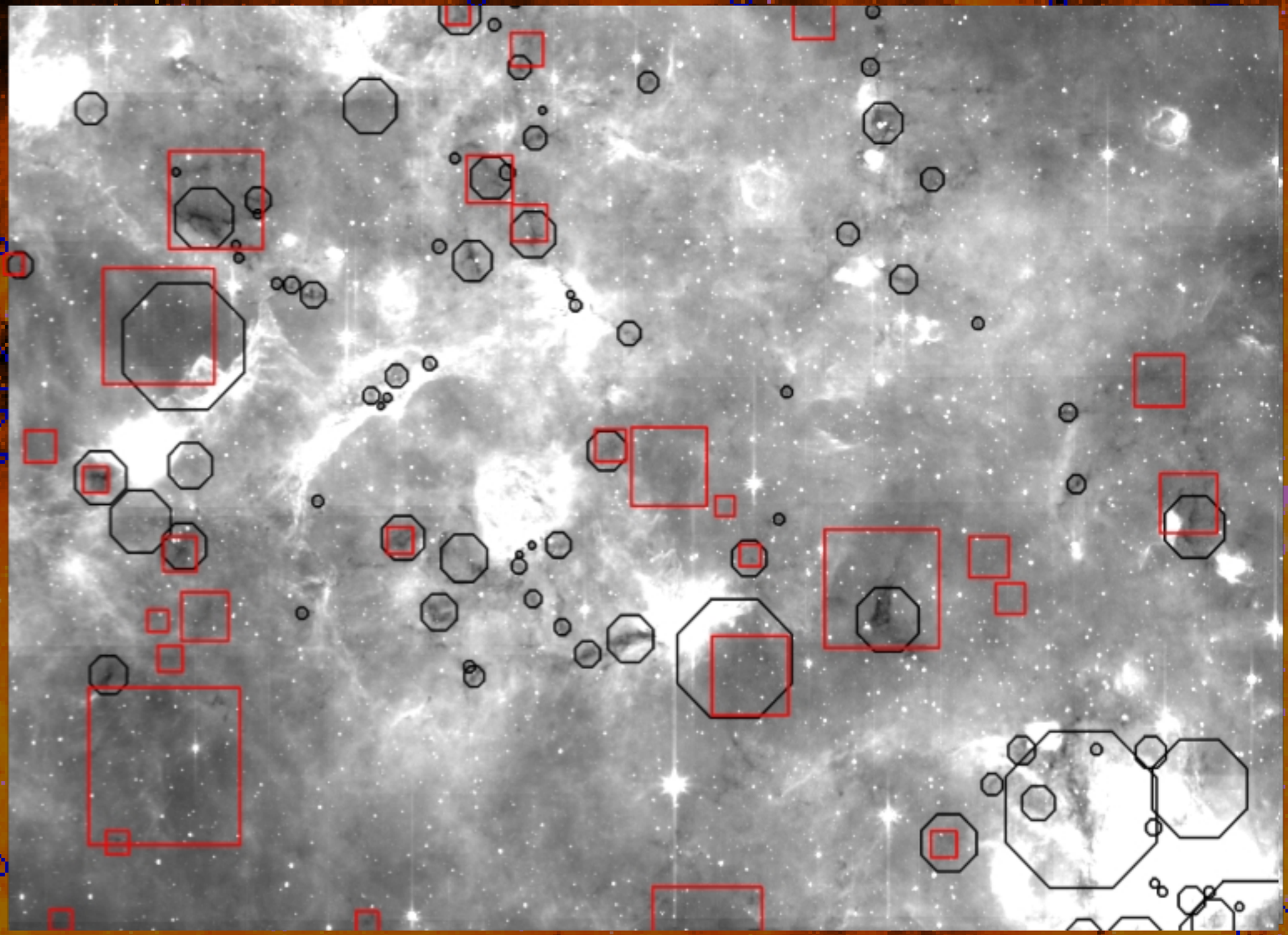
$$\tau_{8\mu m} = -\ln\left(\frac{I_{8\mu m} - I_{fore}}{I_{bg}}\right)$$





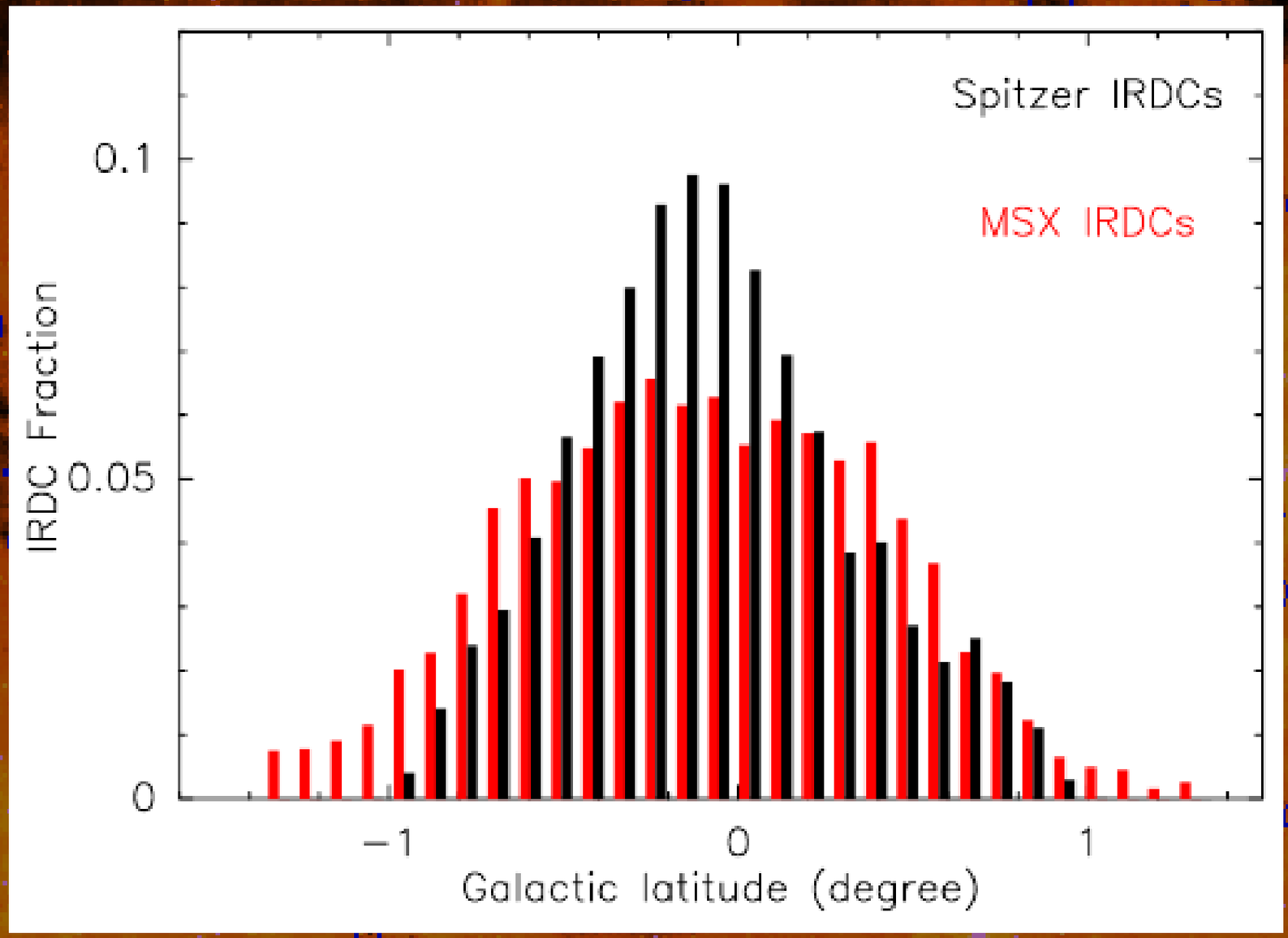
Extracted all structures above $N(H_2)$= $1x10^{22}$ cm^{-2} with peaks above $N(H_2)$ = $2x10^{22}$ cm^{-2}

Comparison with MSX Catalogue



Only 20% of the Spitzer dark clouds are detected by Simon et al. (2006)

Latitude Distribution



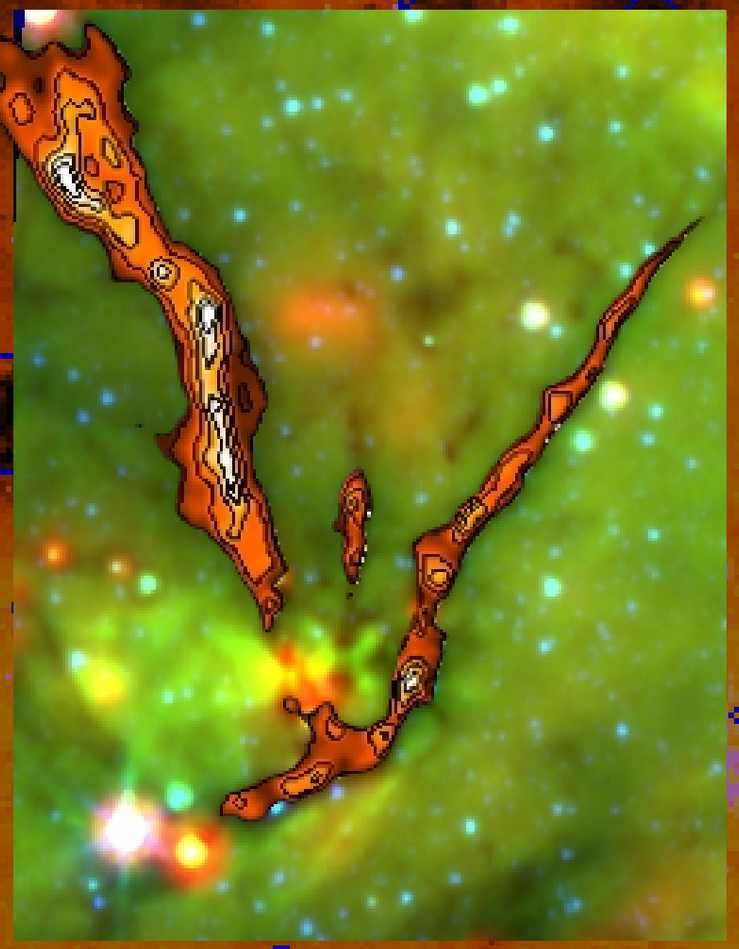
Spitzer dark clouds more peaked towards the Plane

The SDC Catalogue

1 arcmin

The general case

The exception



10 arcmin

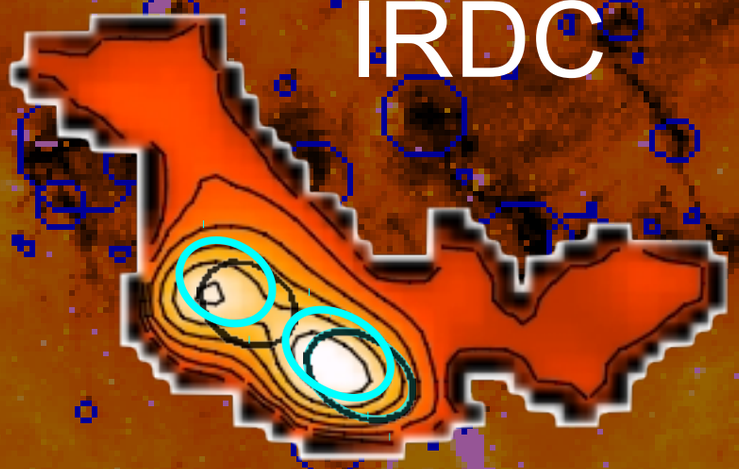
A total of 11303 Spitzer dark clouds identified

	Radius (arcsec)	Asp. Ratio	Peak τ	Peak $N(H_2)$ $x10^{22}$ cm^{-2}
Average	31	2.2	1.1	3.3
Range	5 - 311	1 - 9	0.7 - 7.5	2.1-23

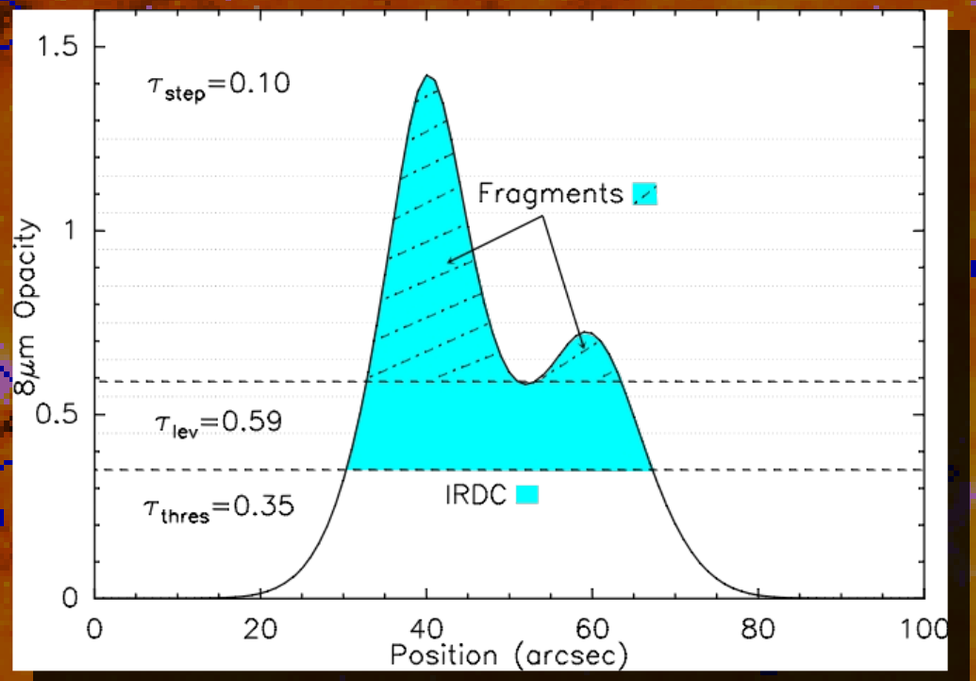
Substructure of Clouds: Fragments

Extraction/definition of the structures observed in IRDCs

IRDC

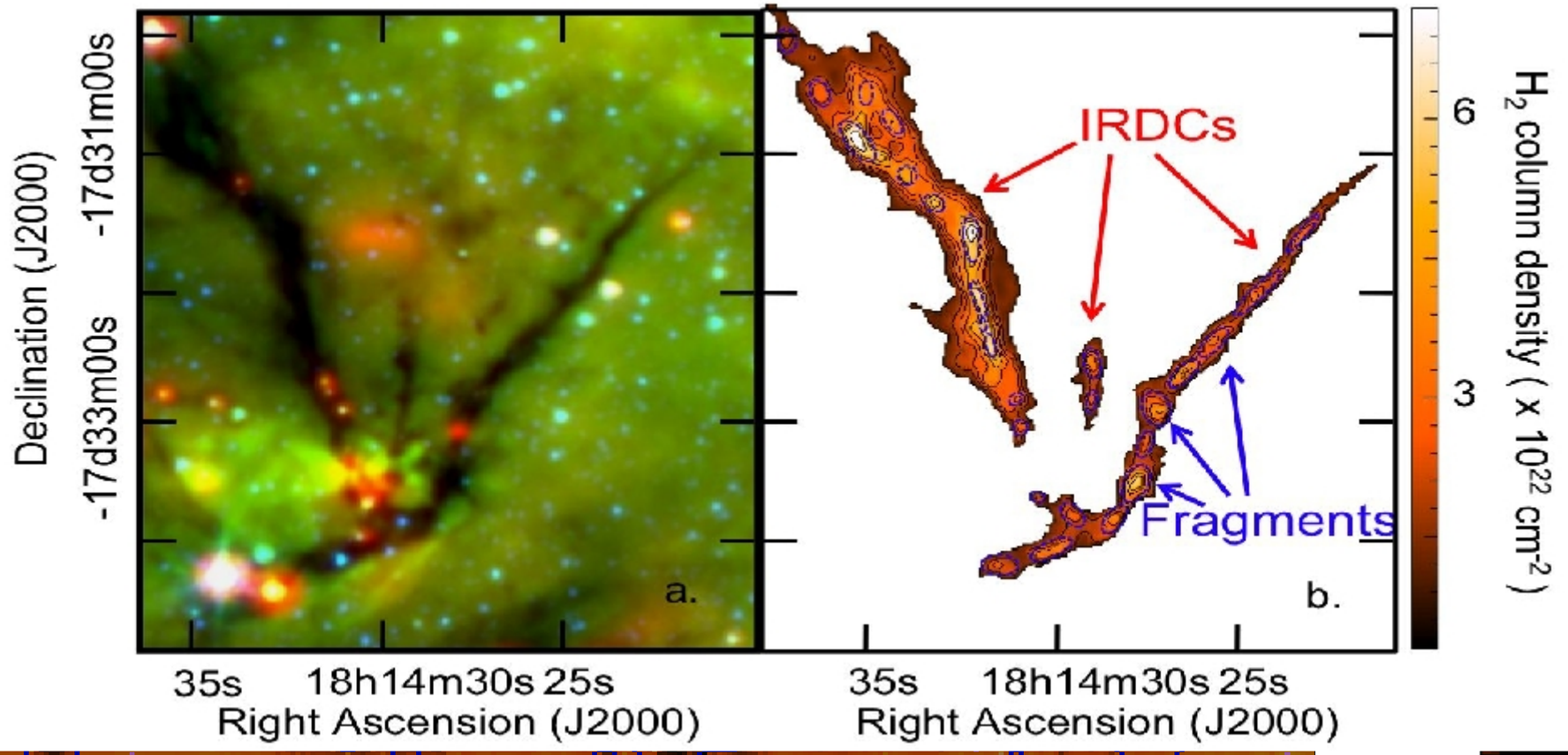


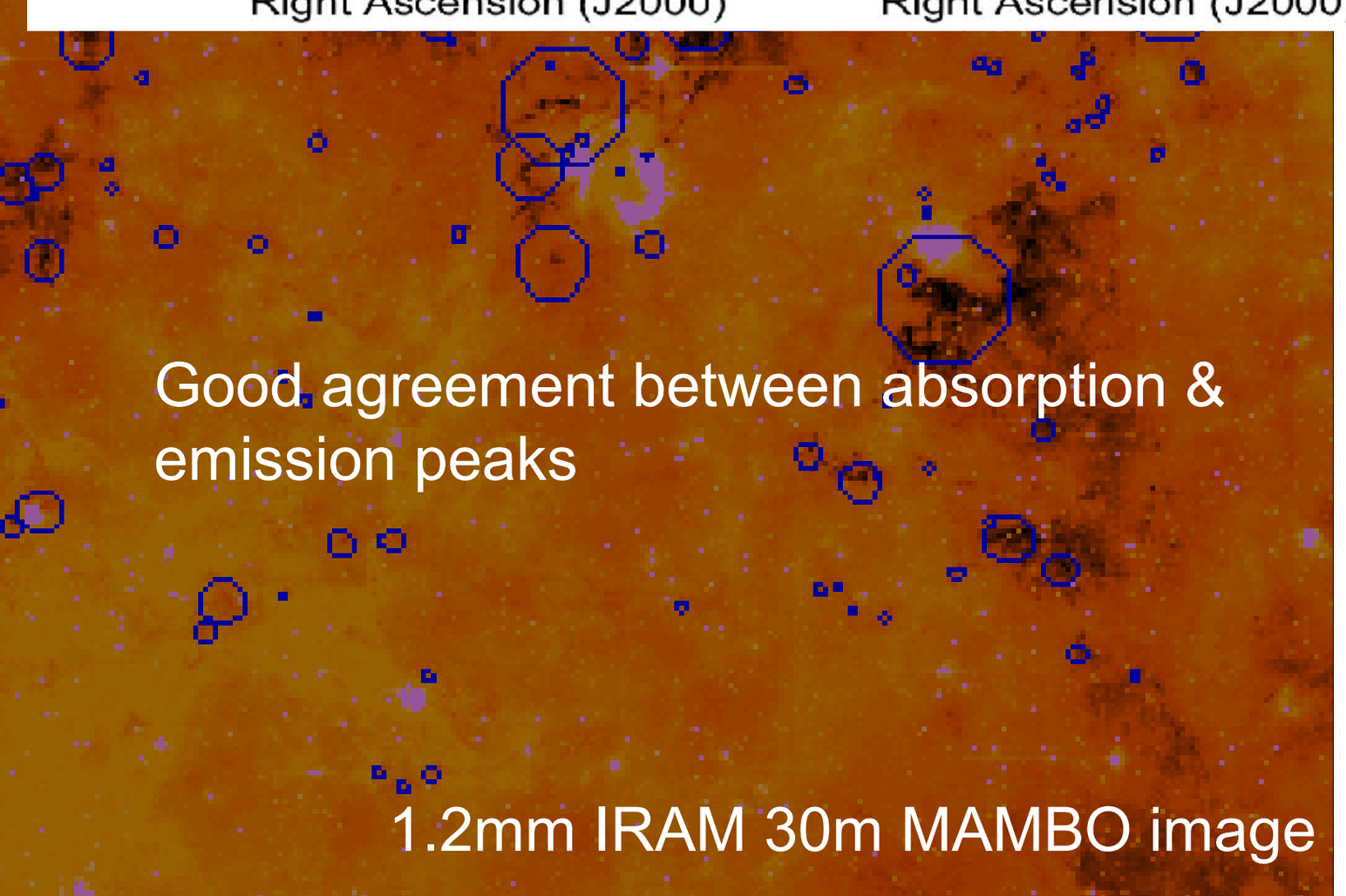
Fragments

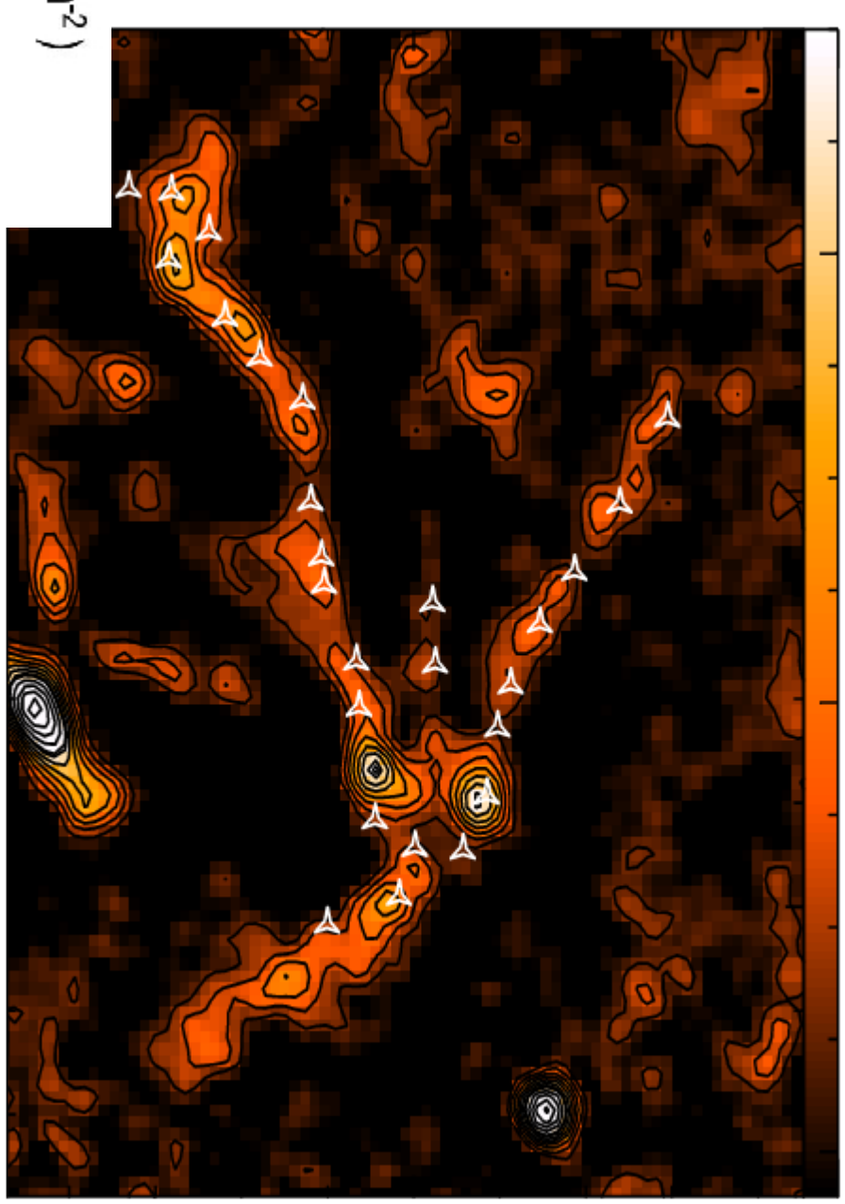


~50000 fragments in 11303 IRDCs (~10% of the mass in the fragments)

Fragments & Filaments: Absorption & Emission

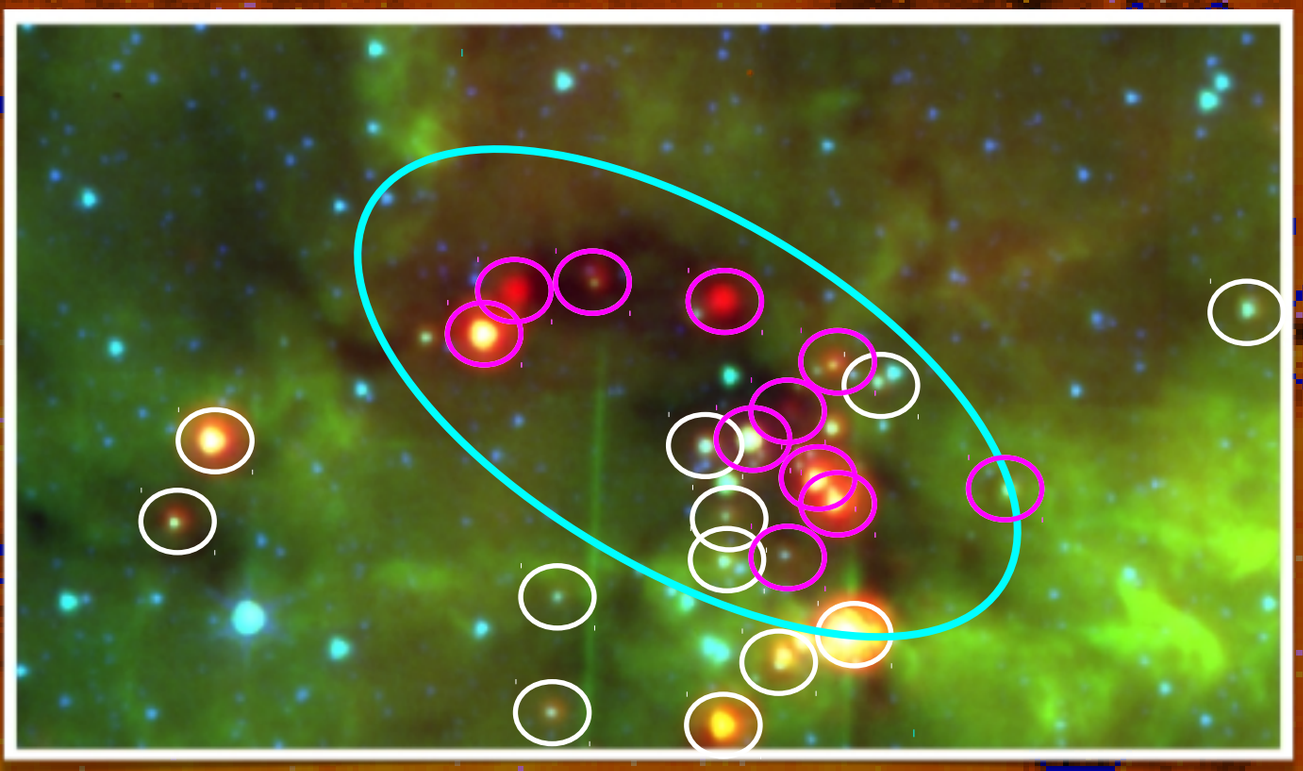




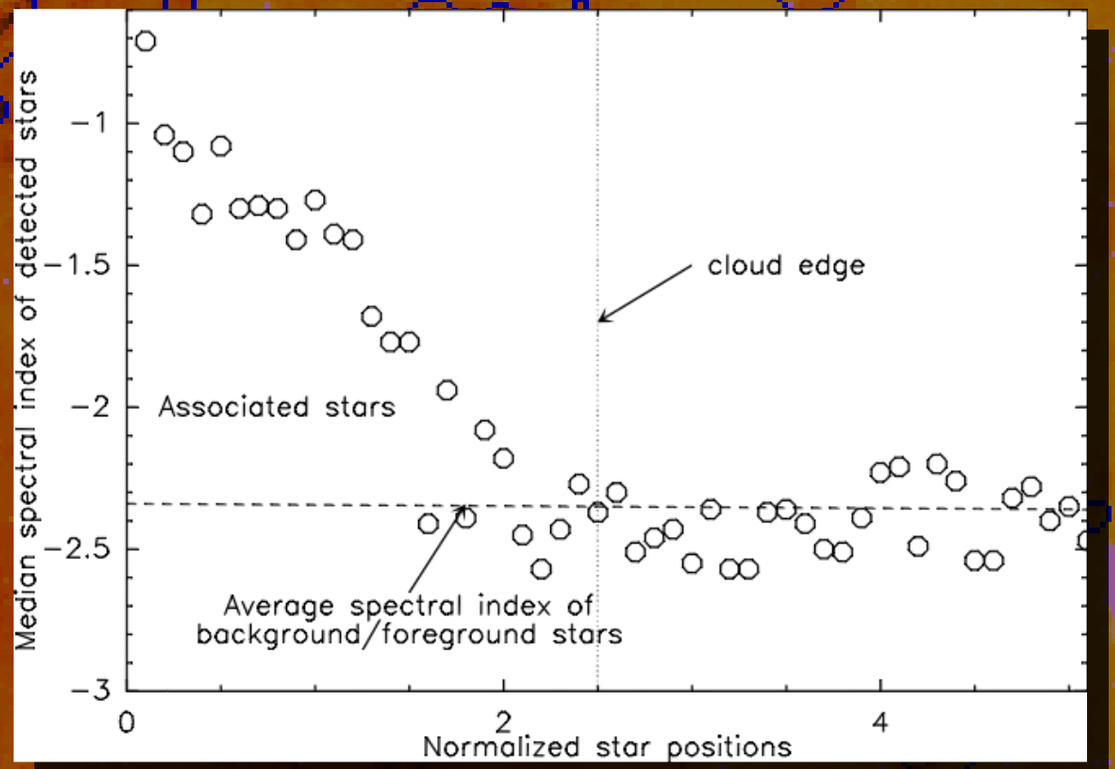


Associated Stars

Extracted all 24μm and 8μm stars within the fields of the 11303 IRDCs in order to calculate 8 to 24μm spectral index

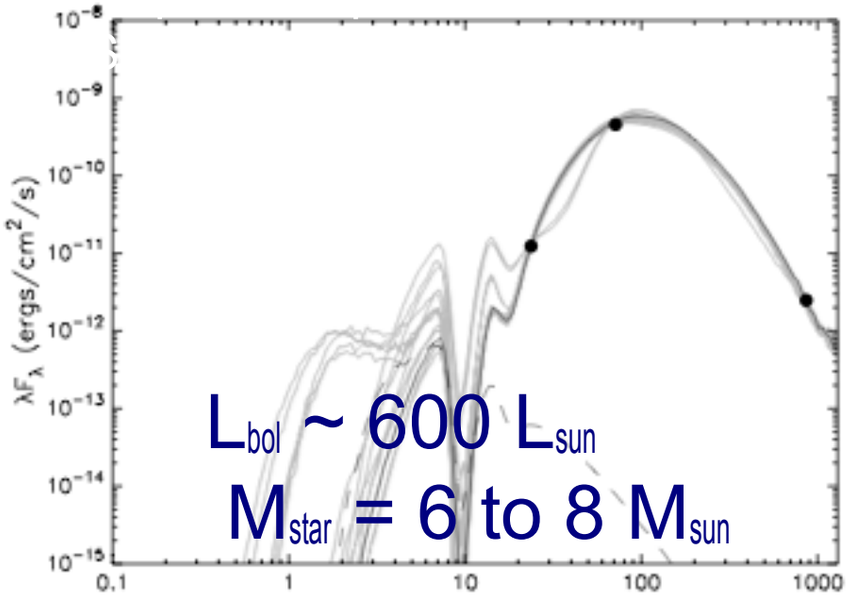


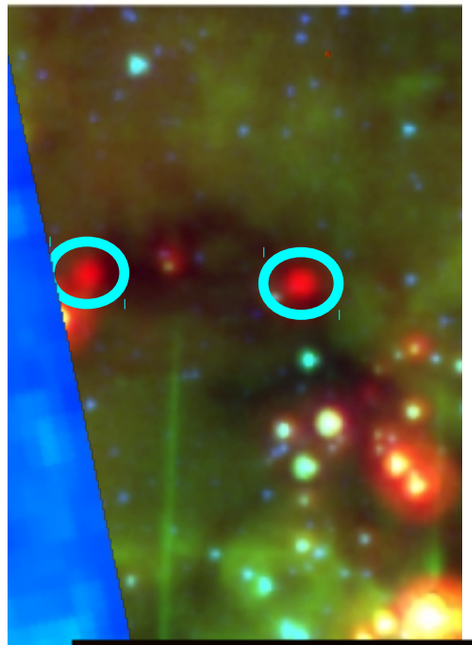
$$\alpha[8-24] = \frac{d\log(\lambda F_\lambda)}{d\log(\lambda)}$$

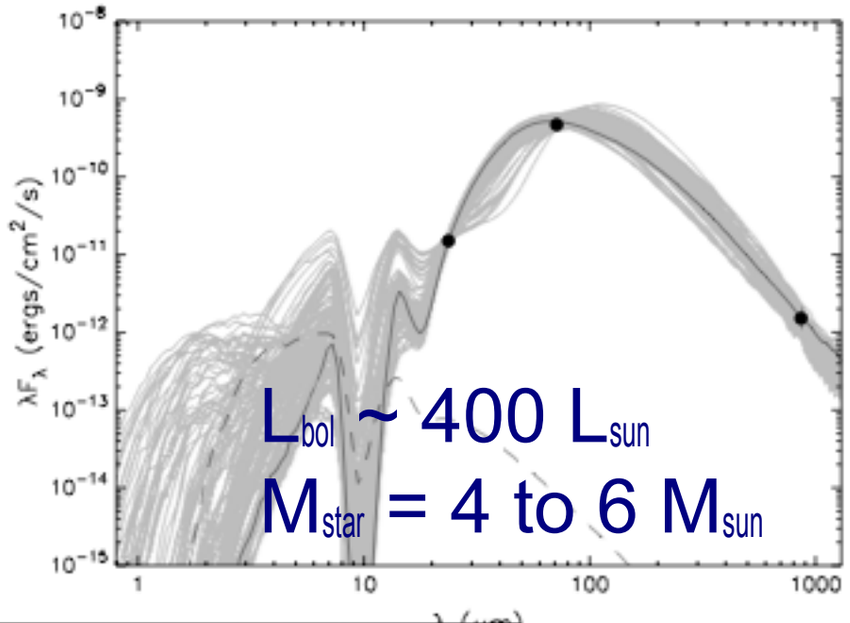


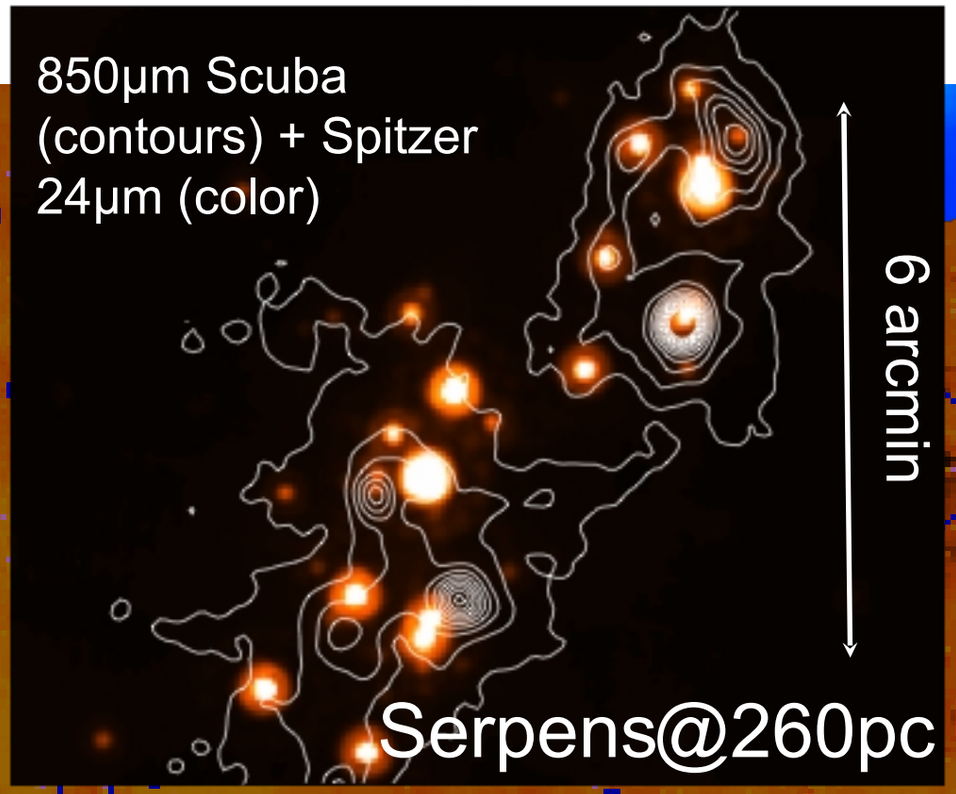
32% of the IRDC have 24μm star association, for a total of ~ 6000 24μm point-like sources - a majority of clouds do not have any signpost of star formation ($L_* > 100\ L_0$)

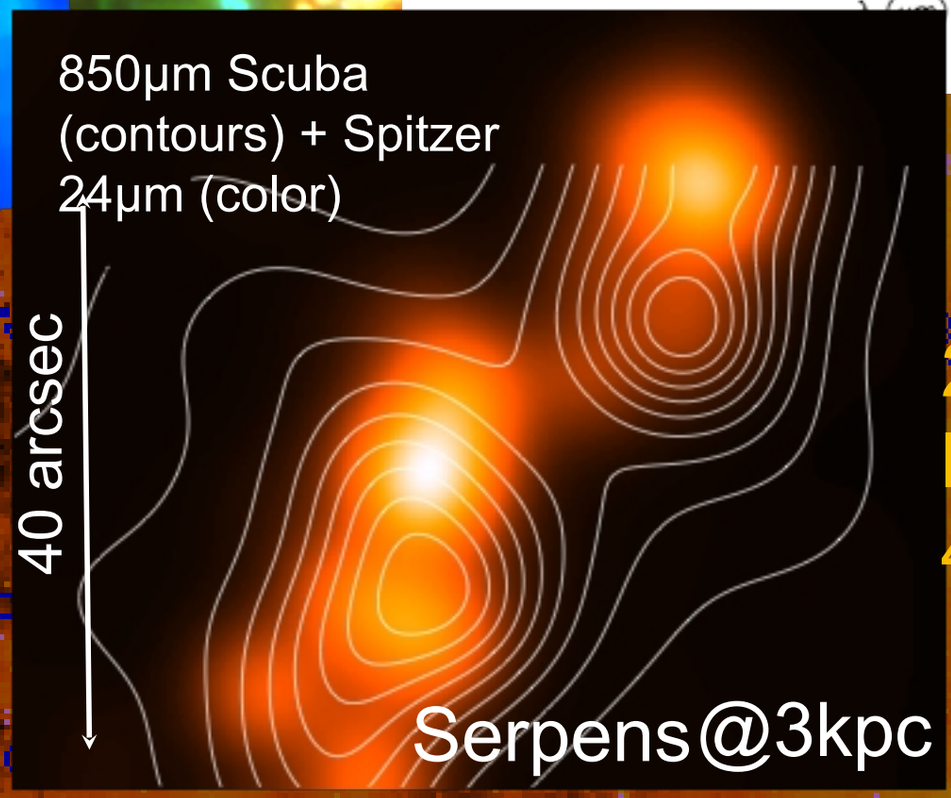
Nature of the Stars







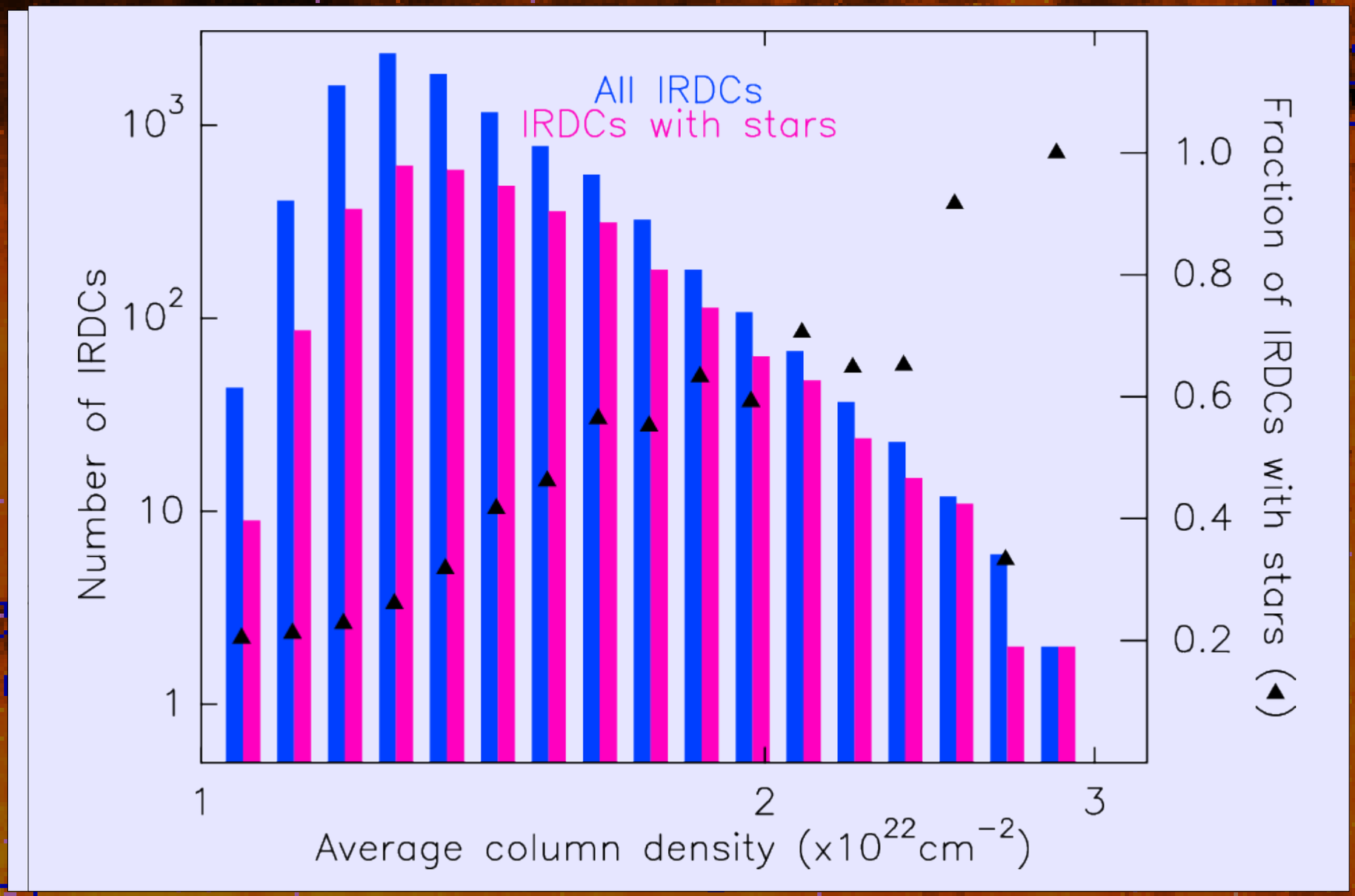




24μm peaks lower than 4MJy/sr

-> Serpens-like protoclusters are not detected

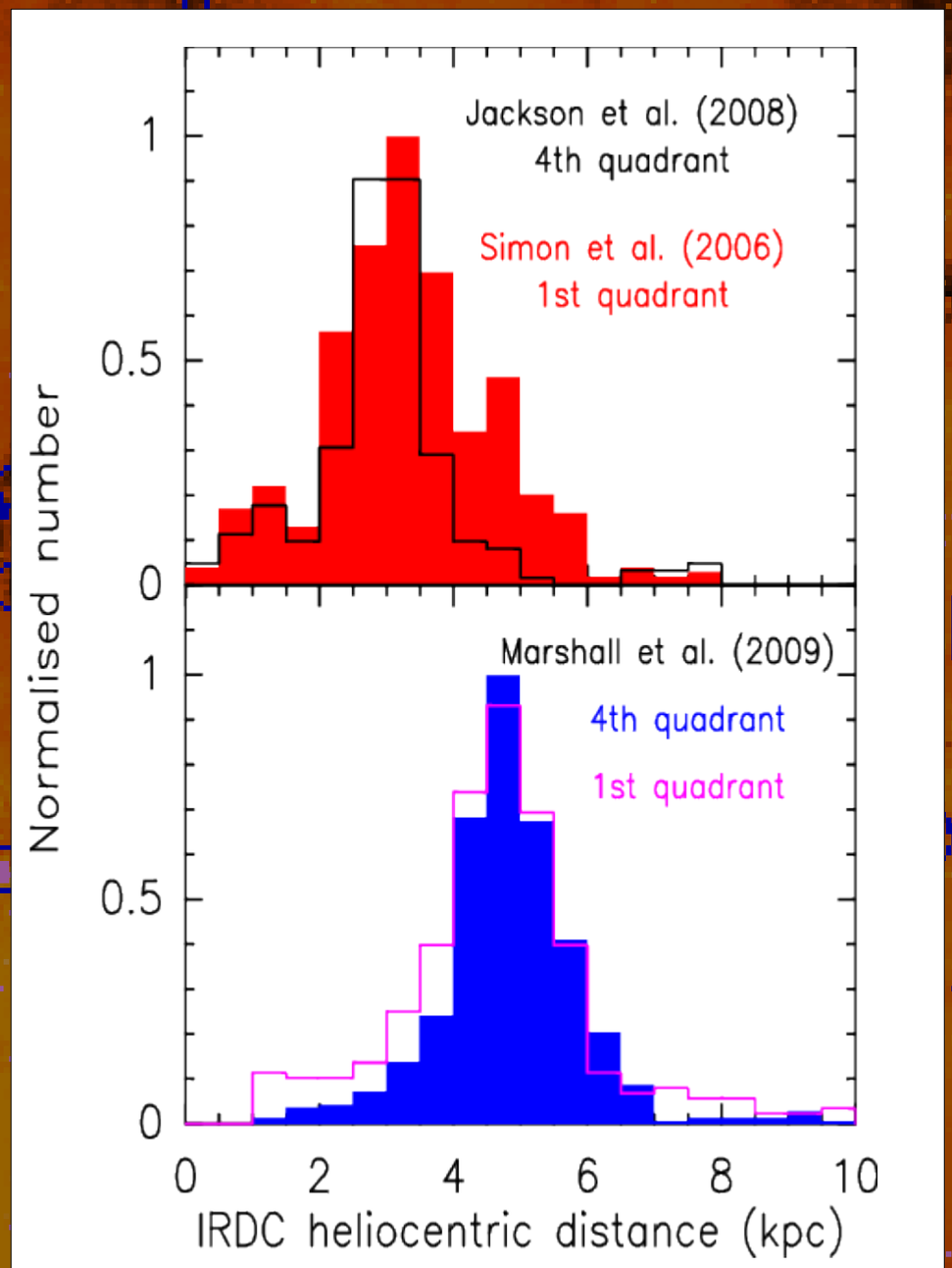
Star Formation

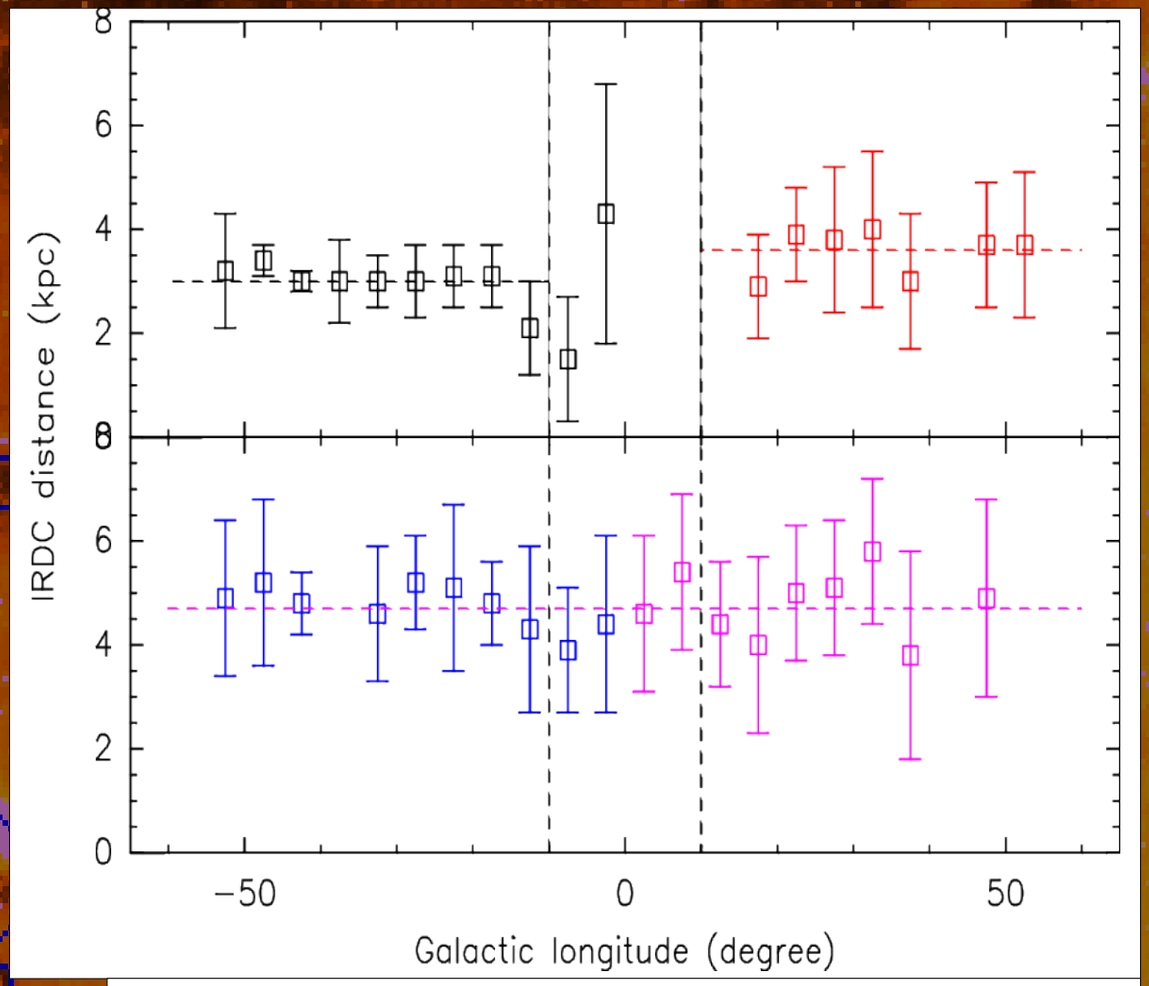


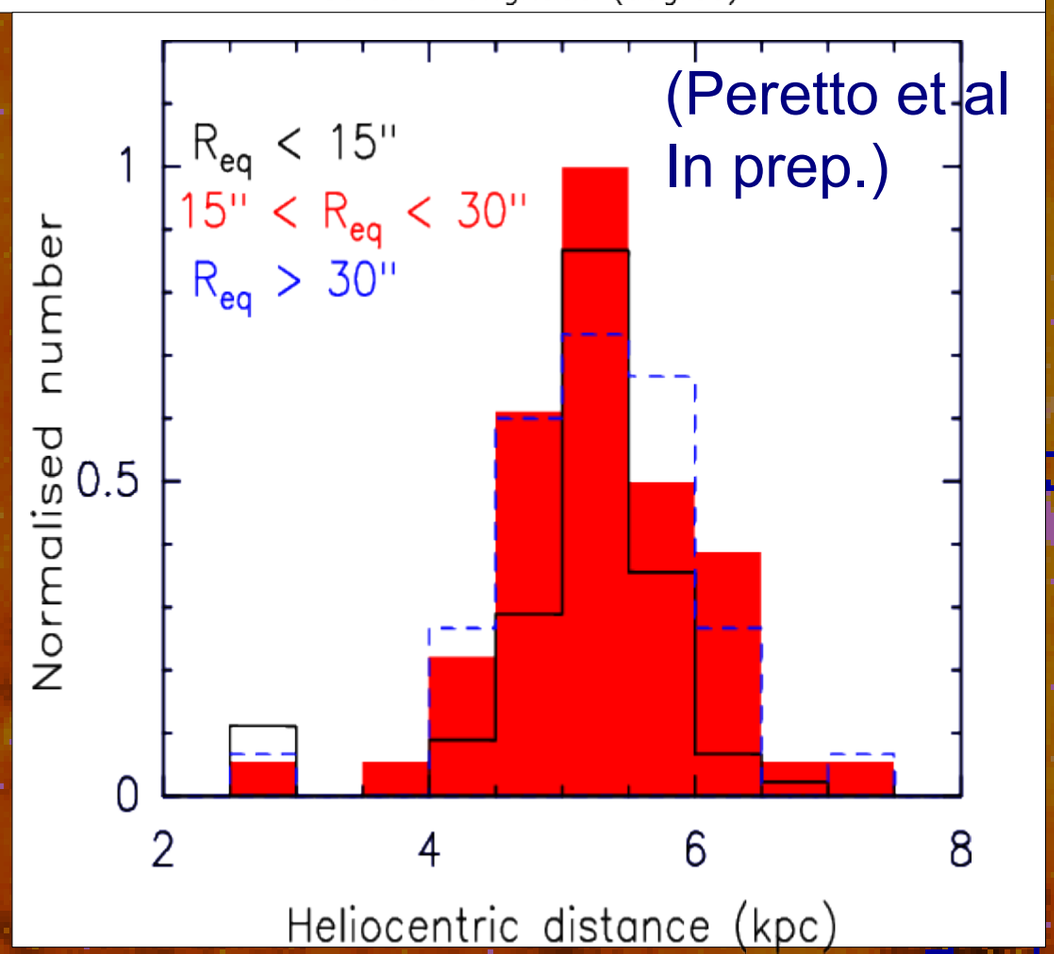
Stars associated with the minority of clouds
BUT all large and high column density clouds are associated with stars

Distances

- Well behaved
- No longitude dependence
- No size dependence



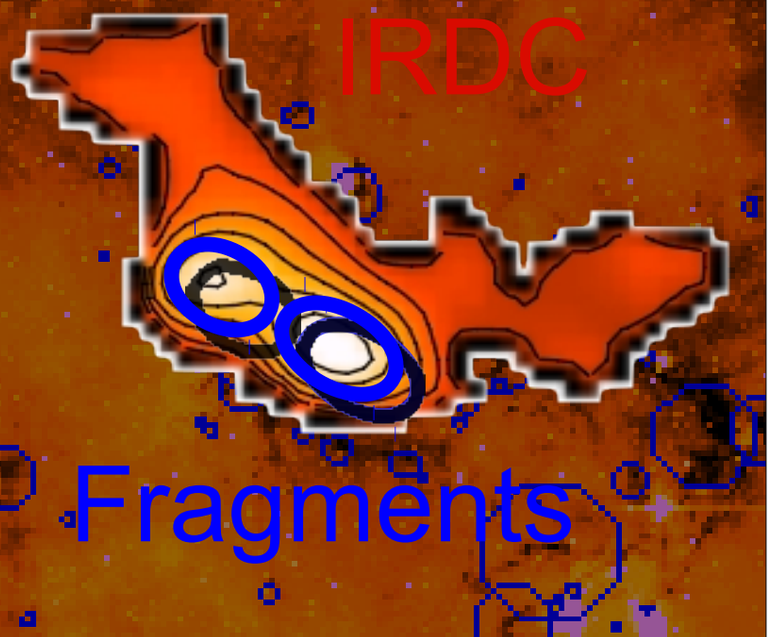


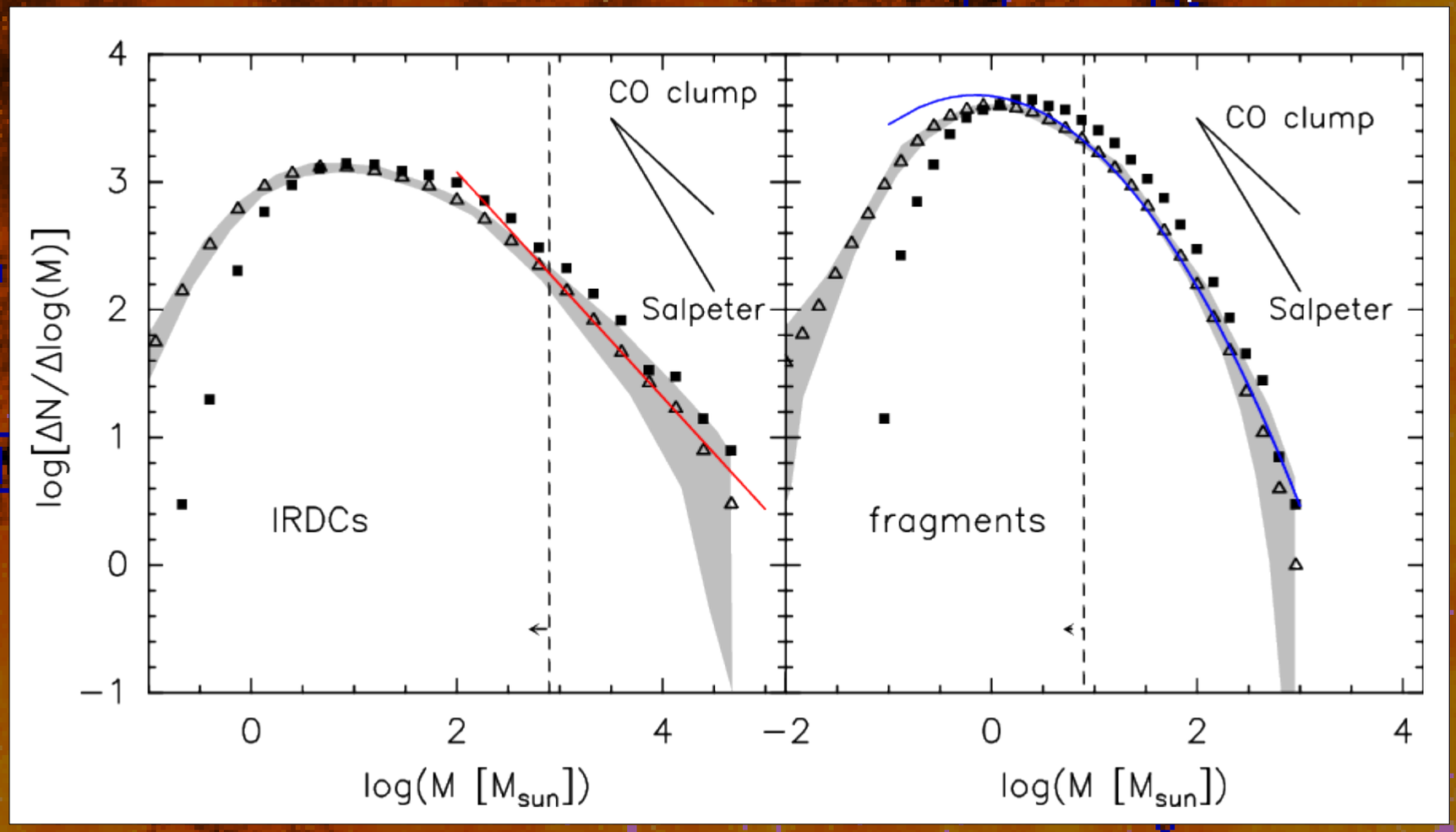


Mass Distribution of Spitzer Dark Clouds

11303 IRDCs and 50000 fragments

Peretto & Fuller ApJ Submitted



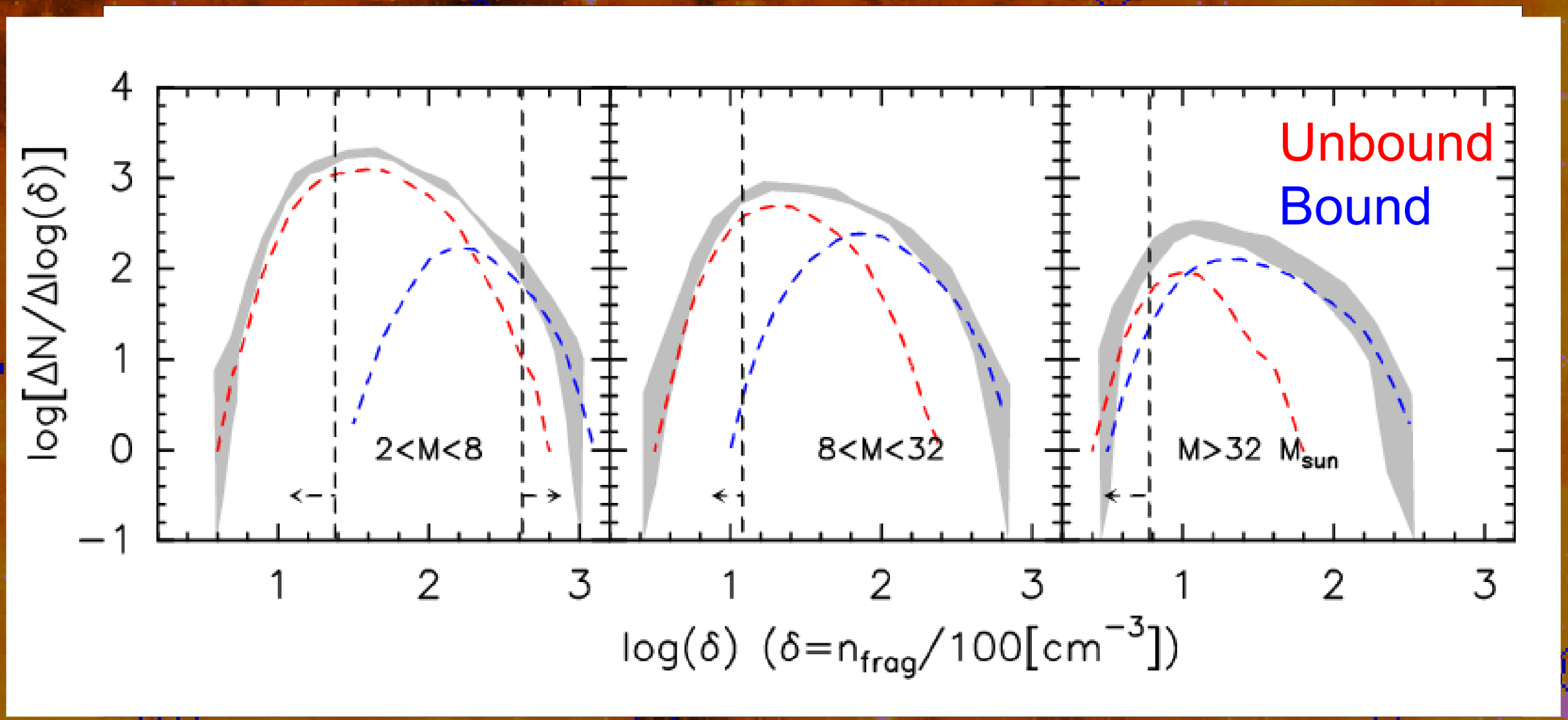


Steepening of the mass distribution from IRDCs to fragments:
For IRDCs best fit gives $\Delta N/\Delta \log M \propto M^{-0.78}$ similar to CO clumps
Fragments steeper, more similar to IMF, lognormal?

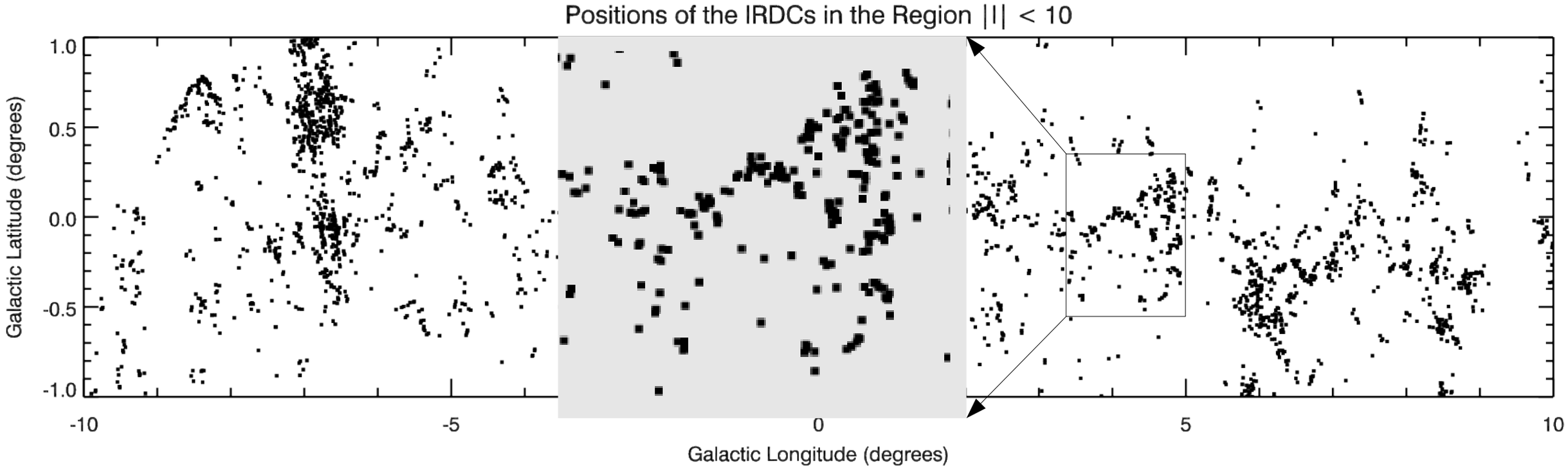
Why?

Not bound vs. unbound

Mass/Density Distributions of Fragments

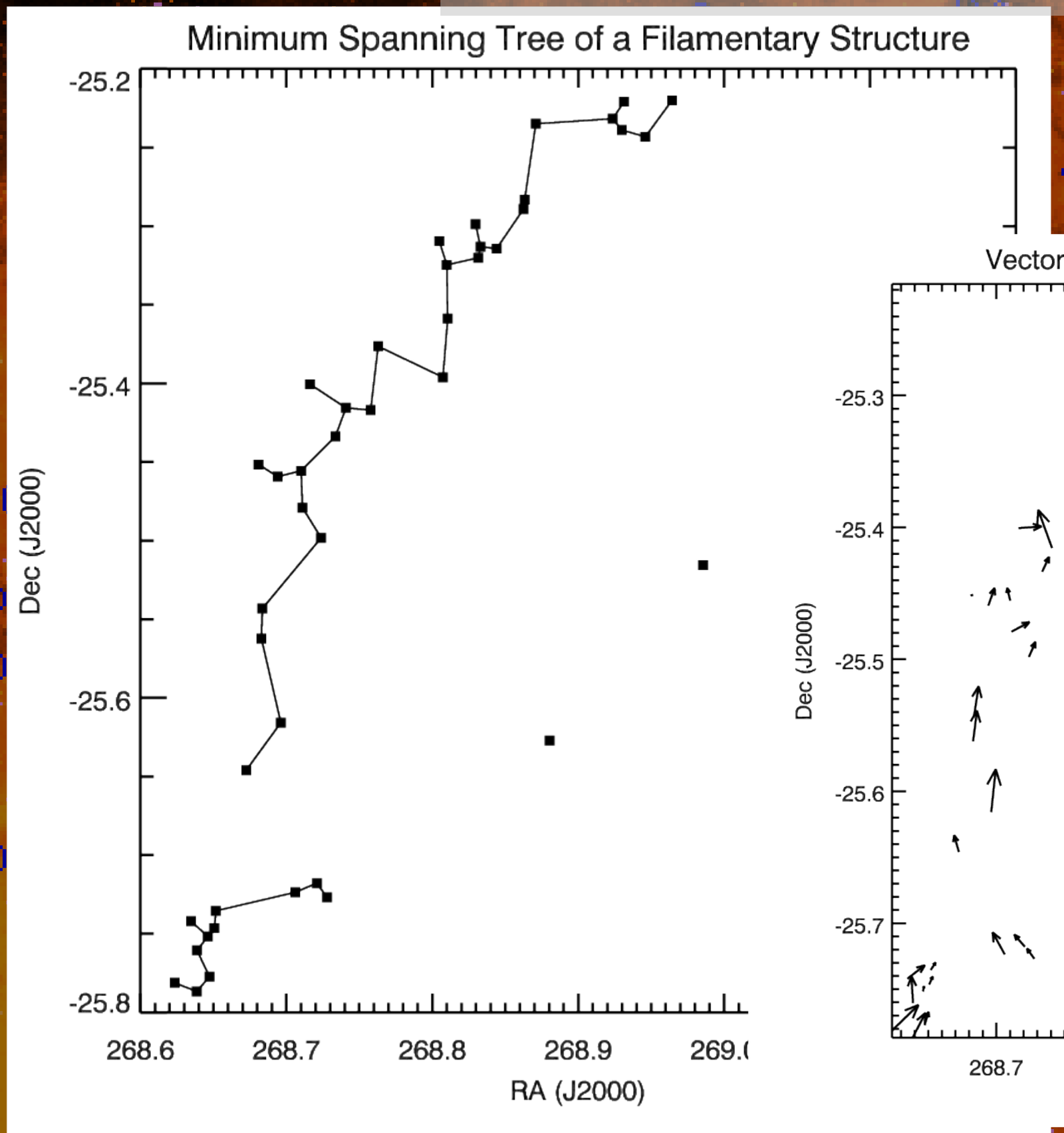


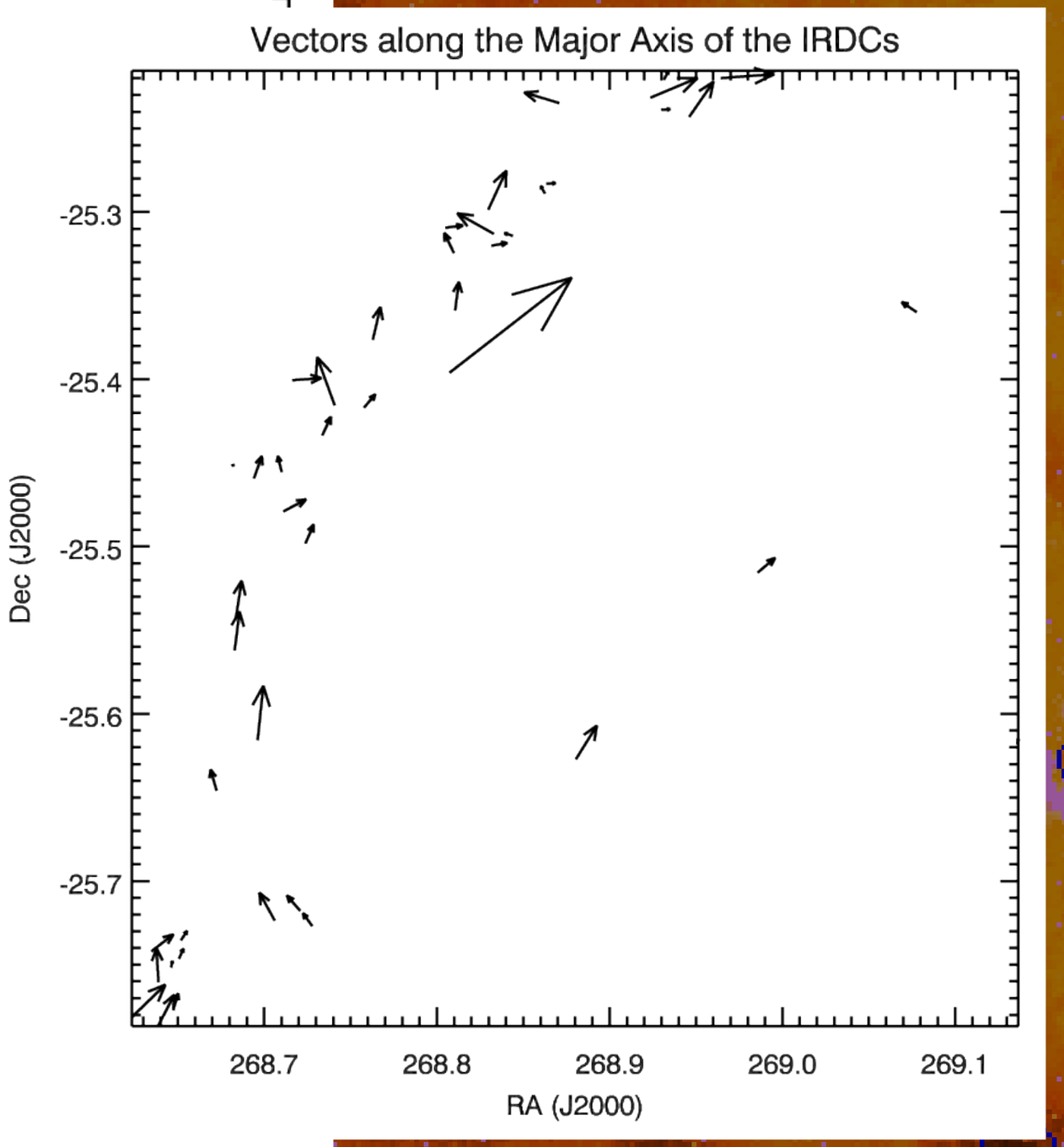
Extension to the Galactic Centre, |l|<10°



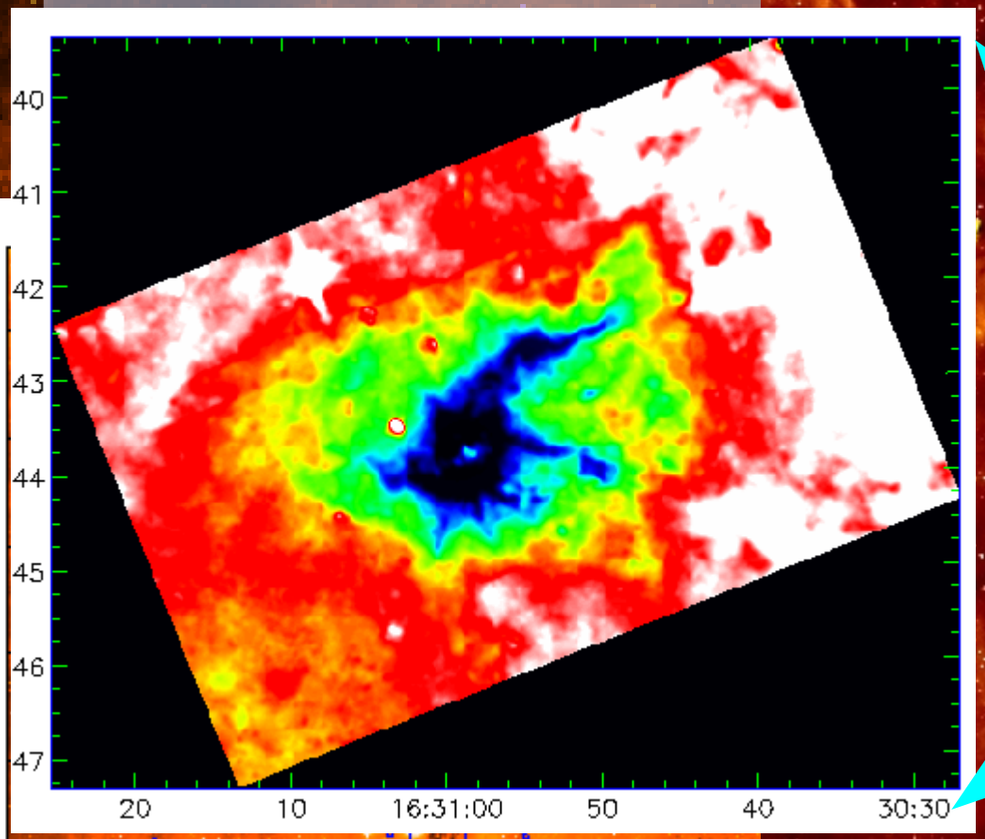
- Additional 3500 clouds
- From CH_3OH maser associations, some R<3kpc

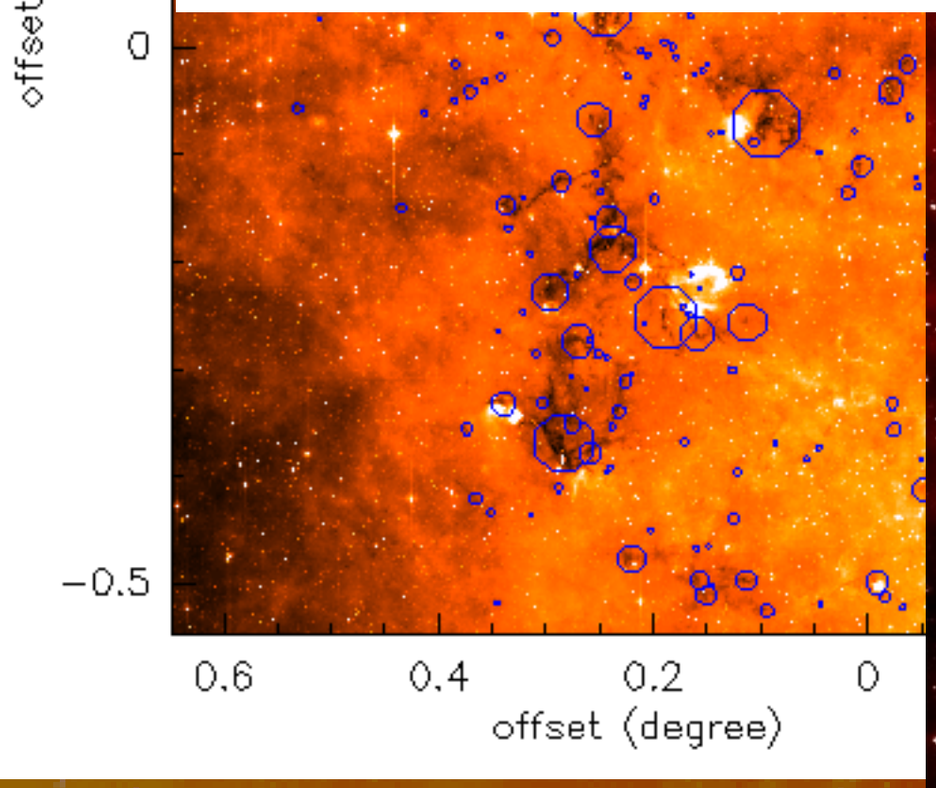
Filaments


Minimum Spanning Tree of a Filamentary Structure
-25.2
-25.4
-25.6
-25.8
Dec (J2000)
268.6
268.7
268.8
268.9
269.(
RA (J2000)


Vectors along the Major Axis of the IRDCs
-25.3
-25.4
-25.5
-25.6
-25.7
Dec (J2000)
268.7
268.8
268.9
269.0
269.1
RA (J2000)

Structur





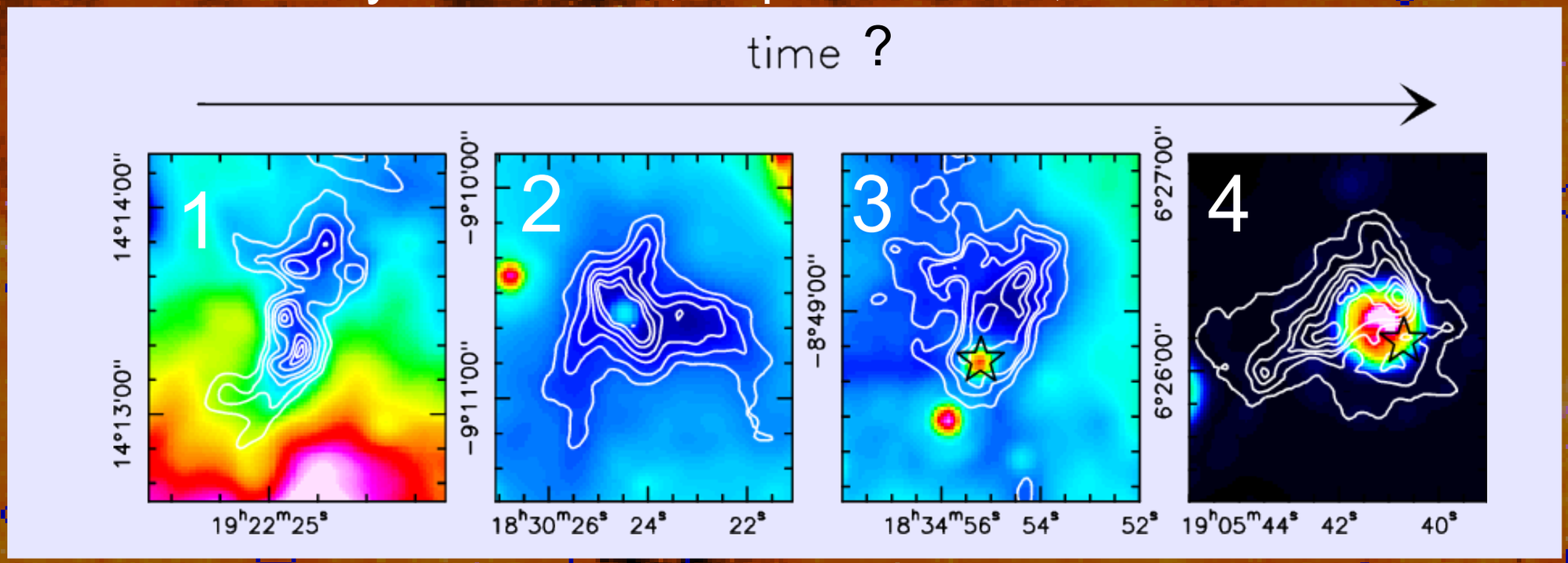
Mopra
^{13}CO
J=1-0

-49 km/s to -42 km/s
-40 km/s to -37 km/s

Evolution & Star Formation

$N(H_2)>10^{23}$ cm^{-2}

Column density – contours; 24μm – colour; methanol maser - star

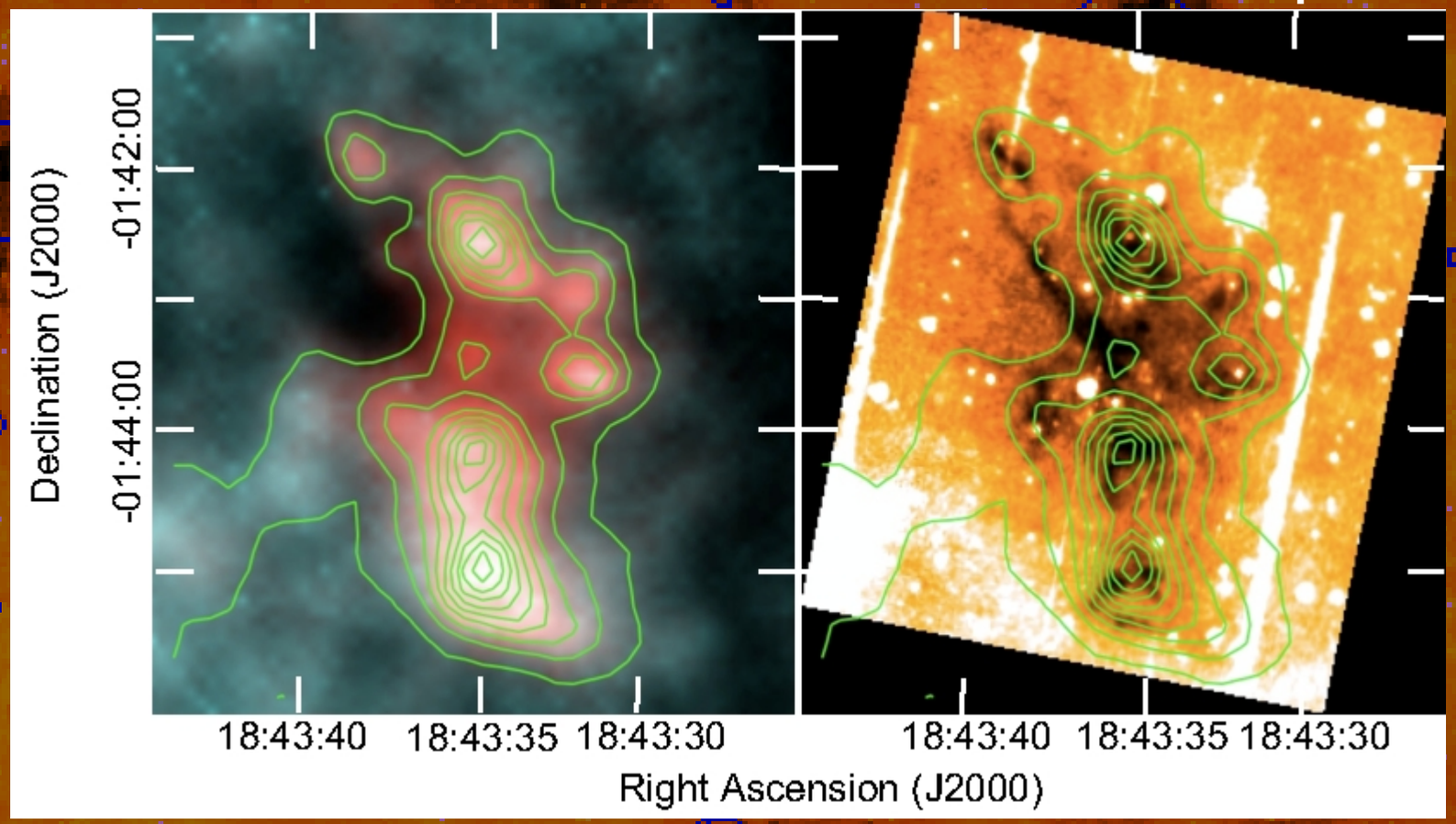


Group	8μm	24μm	Methanol maser	Fraction
1	✗	✘	✘	0.68
2	✘	✓	✘	0.1
3	✘	✓	✓	<0.01
4	✓	✓	✓	0.02

SDCs & Herschel

HiGAL 250μm contours
160μm colour

8μm Spitzer +
HiGAL 250μm



HiGAL survey of GLIMPSE regions at 70μm to 500μm detecting SDCs
Analysis of SDCs in SDP data by Peretto et al. (AA in press; poster 22)
Map temperature and density

Summary

Constructed a new database of Spitzer dark clouds (~11000 IRDCs) using GLIMPSE (10^0<|l|<65^0, |b|<1^0) + 3500 in region |l|<10^0

Constructed a list of YSOs associated with these IRDCs (~6000 YSOs)

Overall one third of these IRDCs are associated 24micron stars, but all large and high column density are associated with stars

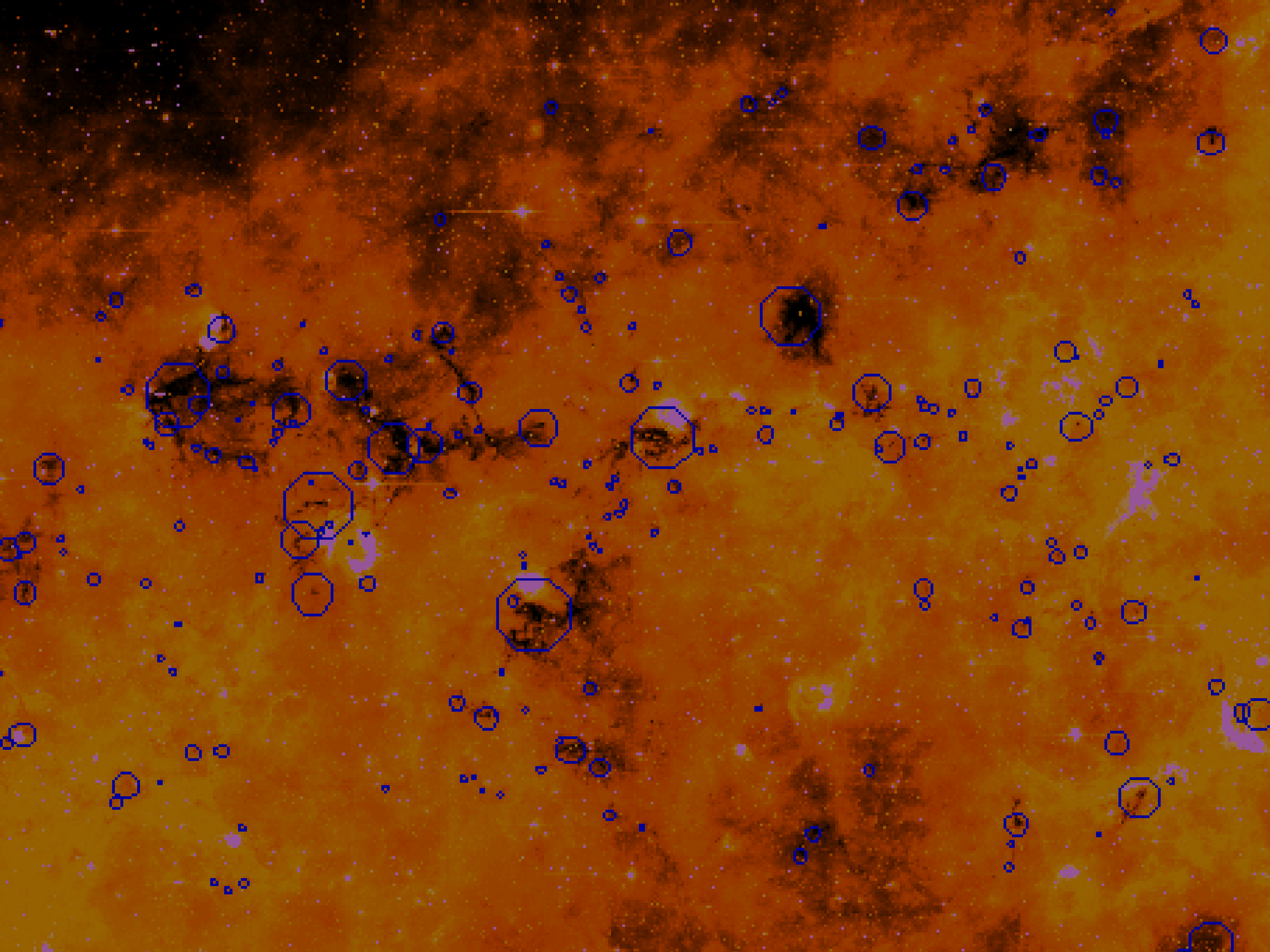
Transition from CO clump mass distribution to IMF-like mass distribution can be resolved within IRDCs.

Many filamentary structures

Identify possible evolutionary groups

www.irdarkclouds.org

Initial catalogue: Peretto & Fuller 2009, A&A, 505, 405
Mass/density distributions: Peretto & Fuller 2010 ApJ submitted
Star association: Peretto & Fuller 2010, A&A, in prep.
Temperature structure: Peretto et al 2010; Poster 22



Online catalogue

www.irdarkclouds.org

www.manchester.ac.uk/jodrellbank/sdc

Spitzer Dark Clouds

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Nicolas Peretto Log out

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- Show column names

Cloud: SDC23.015-0.177 (index: 1445)

Positions

Centroid position

l:	23.02005	b:	-0.19555
RA(2000):	278.47955	Dec(2000):	-8.90241
	18:33:55.1		-8:54:09

Peak position

l:	23.01548	b:	-0.17749
RA(2000):	278.46118	Dec(2000):	-8.89814
	18:33:50.7		-8:53:53

IR Properties

l_mir 117.94 l_min 70.88 grad_l_mir 0.352

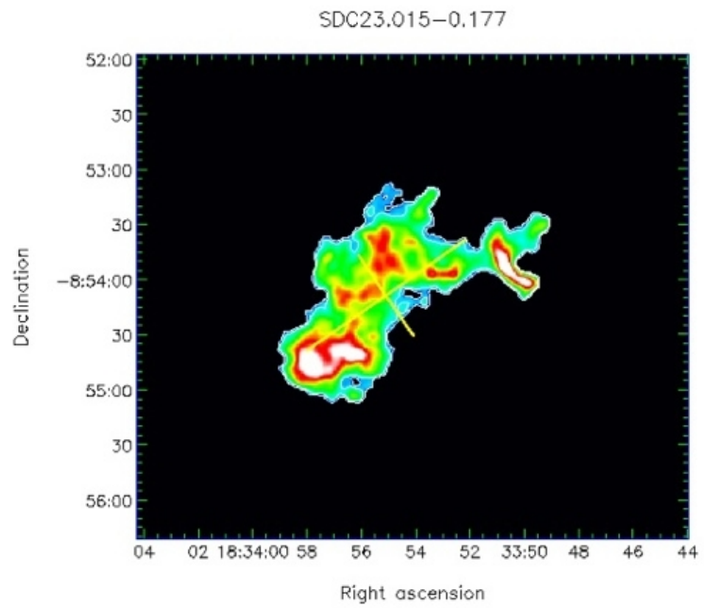
Size

Max 105.9 Min 53.3 PA -55.43 R equiv. 65.47

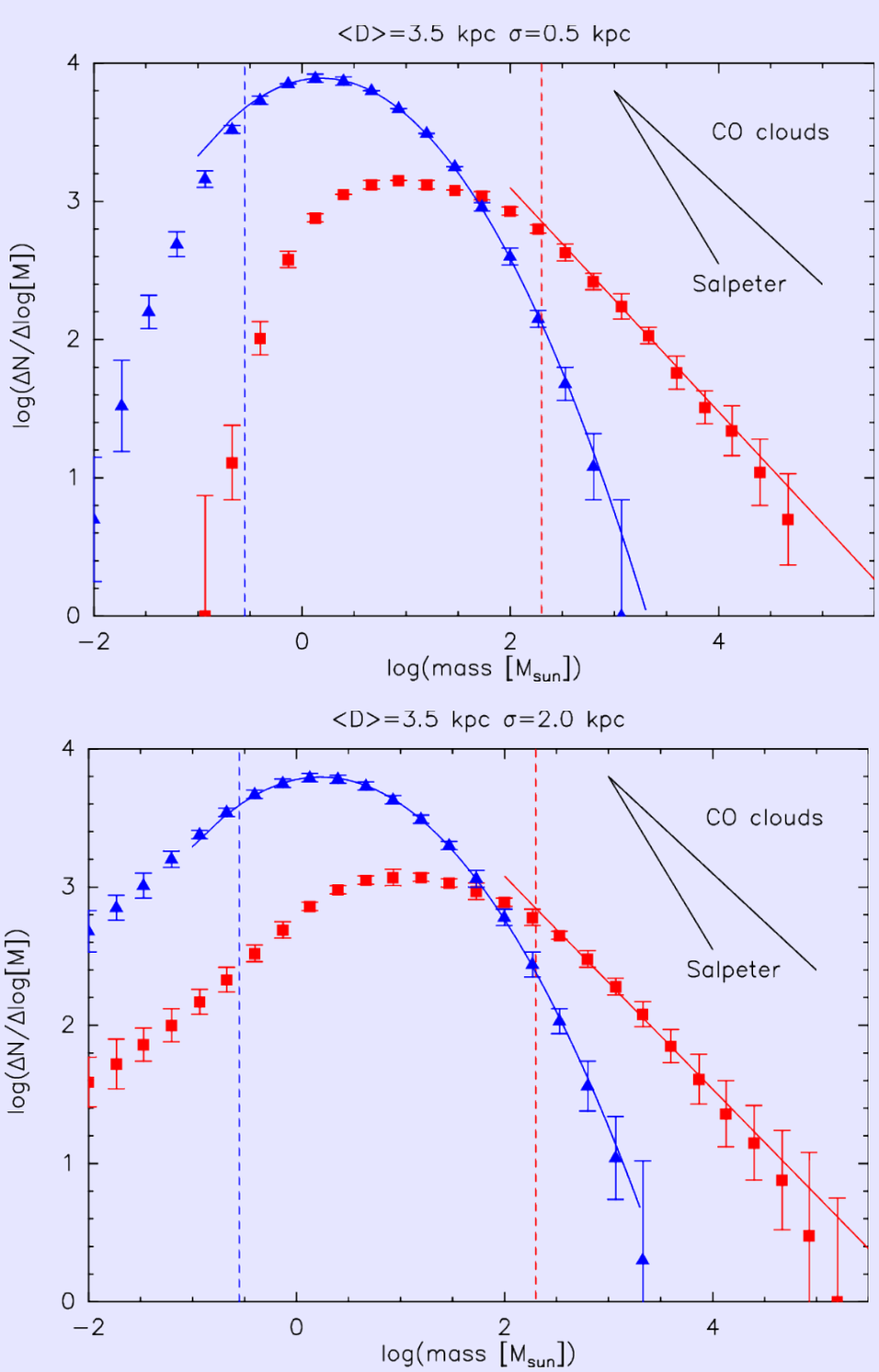
Average tau	0.576	Peak tau	1.592	Saturation tau	5.198
N stars	0	Star density	1.05	Fragments	

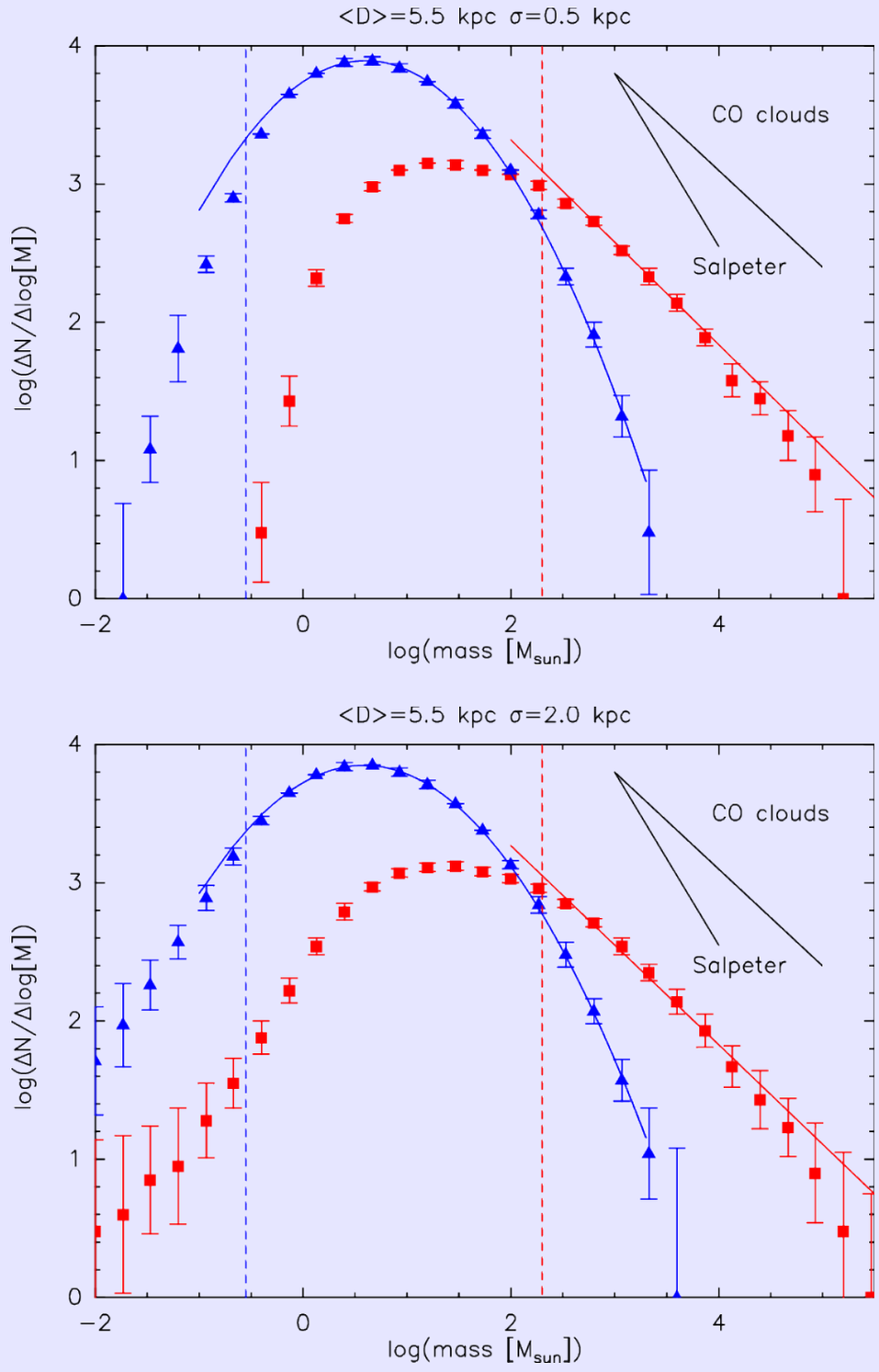
Optical Depth Image

The image shows the optical depth and the cloud size. If there are any 24 micron sources associated with the cloud there are shown on a second image.



Effect of Distance Assumptions





Completeness