The Herschel photometric study of the nearby star forming regions

A PACS/SPIRE GT Key project for the survey of the nearby (<500 pc) star forming regions

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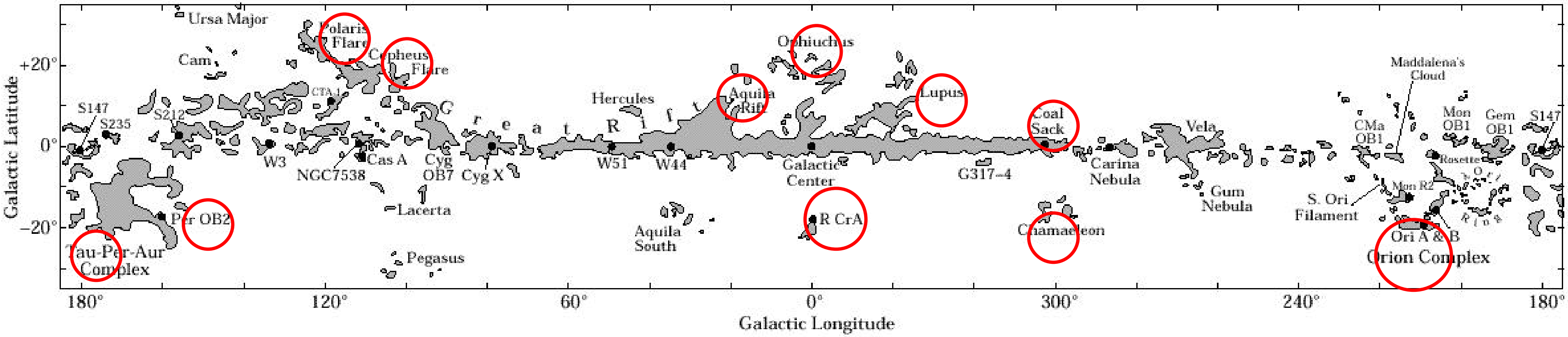
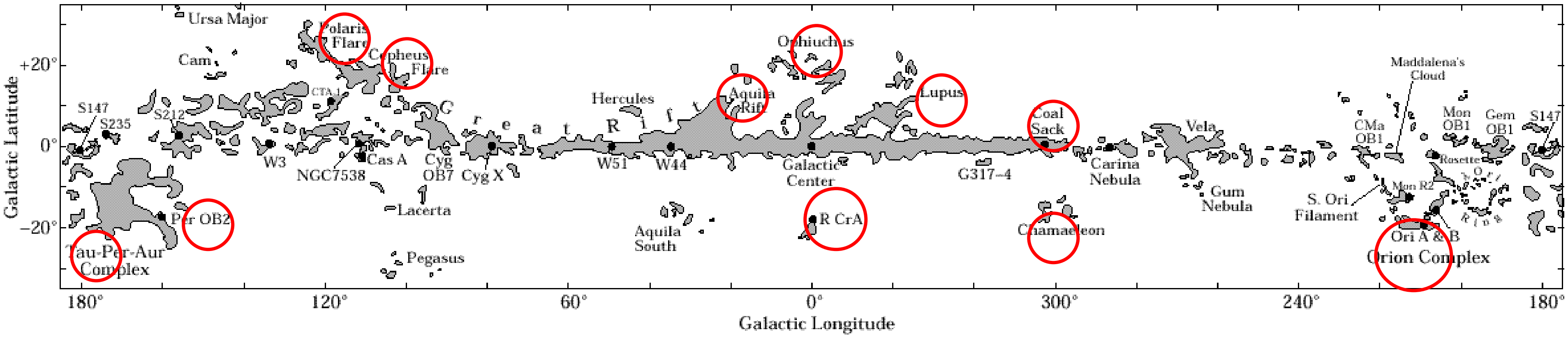


We propose an extensive imaging survey of the densest portion of the nearby clouds,

down to	~ Av 3 with SPIRE	~ 120°	20 mJy /17" beam
	~ Av 6 with PACS	~ 35°	5 mJy /13" beam

well matched with the expected cirrus noise



total time 462 hr

Motivation

Most stars form in clusters

Massive (> 8 Mo) stars form *only* in clusters, probably

5' ~ 0.7 pc

Trapezium in JHK (SOFI - NTT)

Therefore the star formation process will be understood only if the role of clusters in star formation is understood

In clusters the origin of stellar masses is hidden.

The understanding of the origin of IMF is crucial to understand stellar population in our galaxy and beyond

Motivation

Clusters forms by cloud fragmentation:

- fragmentation happens before or during the protostellar collapse ?
  (collapse may trigger further fragmentation?)

- What generates prestellar cores and their evolution in protostars

- Star formation is a fast or slow process ?

- What controls the efficiency of star formation in GMC,
  there is a minimum core mass for SF ?

Motivation

Moreover we will also try to answer the following questions:

- Has stellar density consequences on disks evolution?
  on binary frequencies?

- How does circumstellar material evolve ?

- Which is the time scale for star formation ?

- Brown Dwarfs: how they are born ? Like low mass stars?

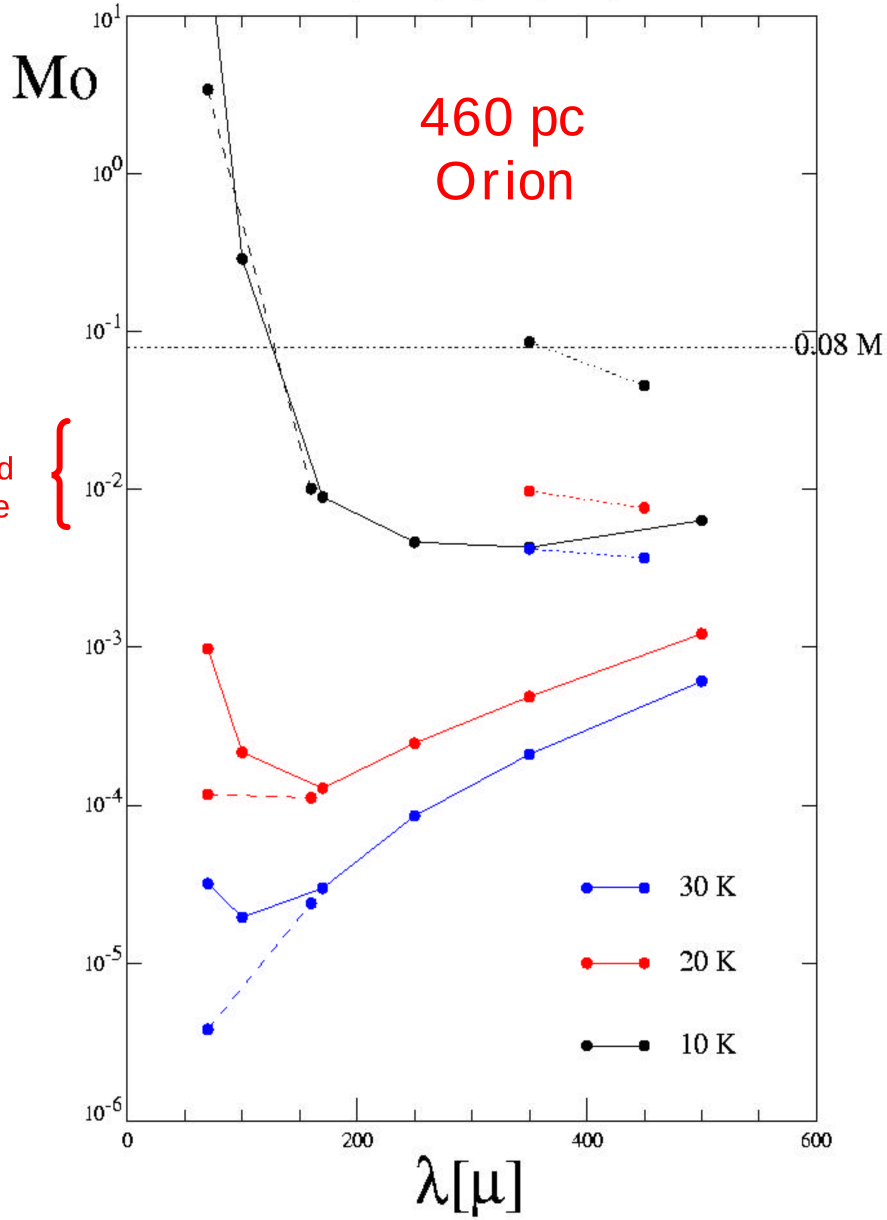
Why Herschel

Why Herschel ?

HERSCHEL: dust mass detectable
5s 1h

HERSCHEL: unique in detecting
pre-stellar condensations

Level
Of expected
Cirrus noise



Mo= $F_?$ k D^2/B(?/T)

K=0.1(250/?)
[cm^{-2} g^{-1}]

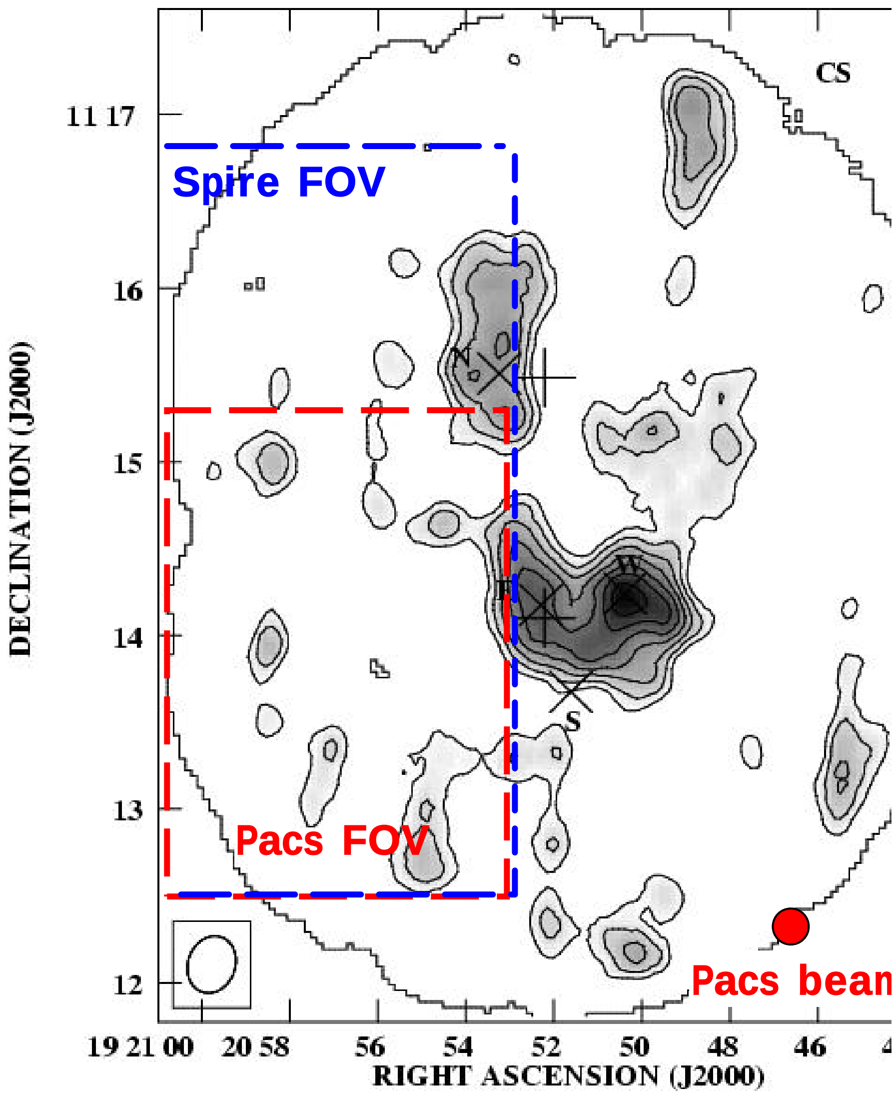
L673 D 300 pc

BIMA interferometric map CS (2-1)
(Morata et al. 2003)

It reveals clumpiness down to scale of 0.01pc
extremely time consuming

The clumps are the first stages of collapse before forming stellar cores (Class 0)

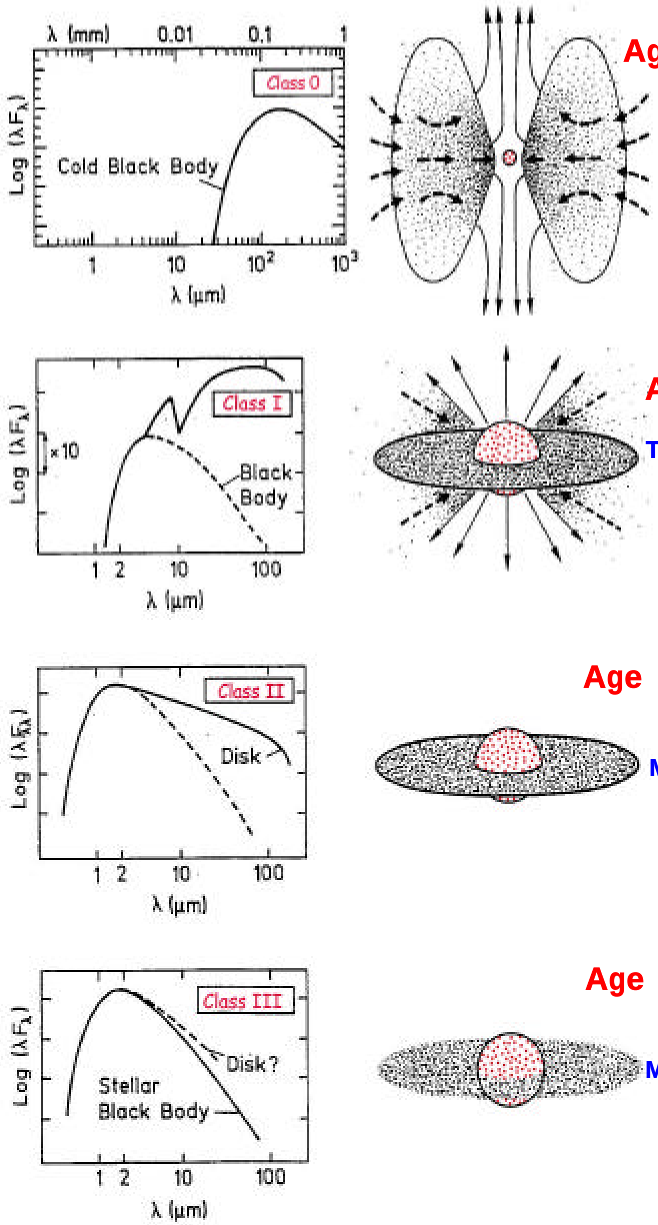
PACS	SPIRE
50 mJy S/N = 10	
2 band	3 band
6'x4'	8'x4'
0.14 h	0.1h



~10 hrs per degree^2, 50 mJy, S/N ~ 10

LOW MASS STARS EVOLUTION

Lada e Wiking 1984
Andrè et al. 1993



Age =10^3 10^4 yr

$M_{env} > M_{star}$
FIR ® Submm

Age ~10^5 - 10^6 yr

THICK ENVELOPE
IR ® Submm

Age ~ 10^6 - 10^7 yr

THICK DISK
M_{disk} ~ 0.01M℘
V ® FIR

Age ~ 10^7 - 10^8 yr

THIN DISK?
M_{disk} ~ 0.003M℘
V ® IR

PLANETS BUILDING

Herschel is unique to discriminate the different preMain Sequence phases because it is very sensitive to circumstellar material.

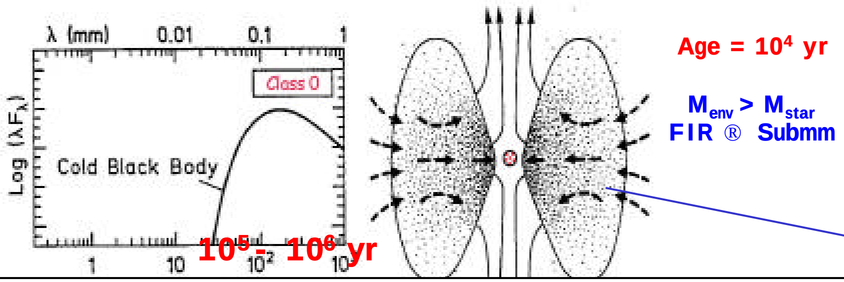
The evolution of a protostar is the evolution of its Circumstellar material

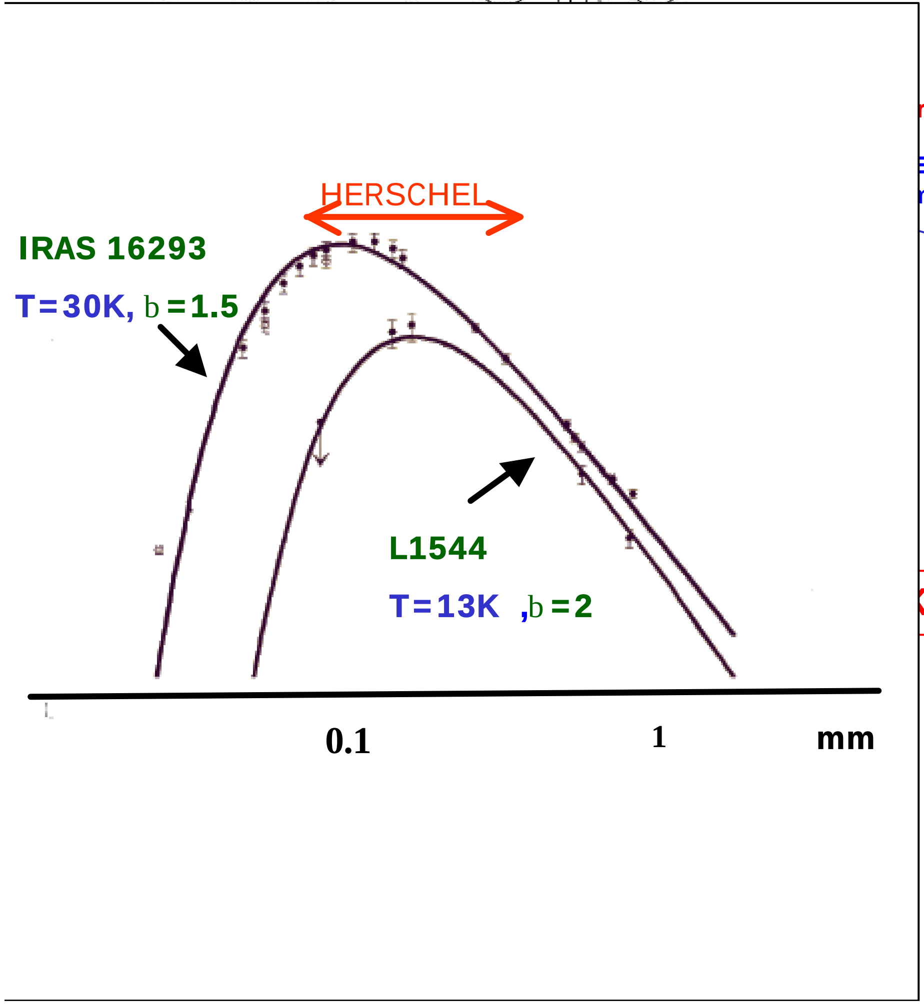
LOW MASS STARS EVOLUTION

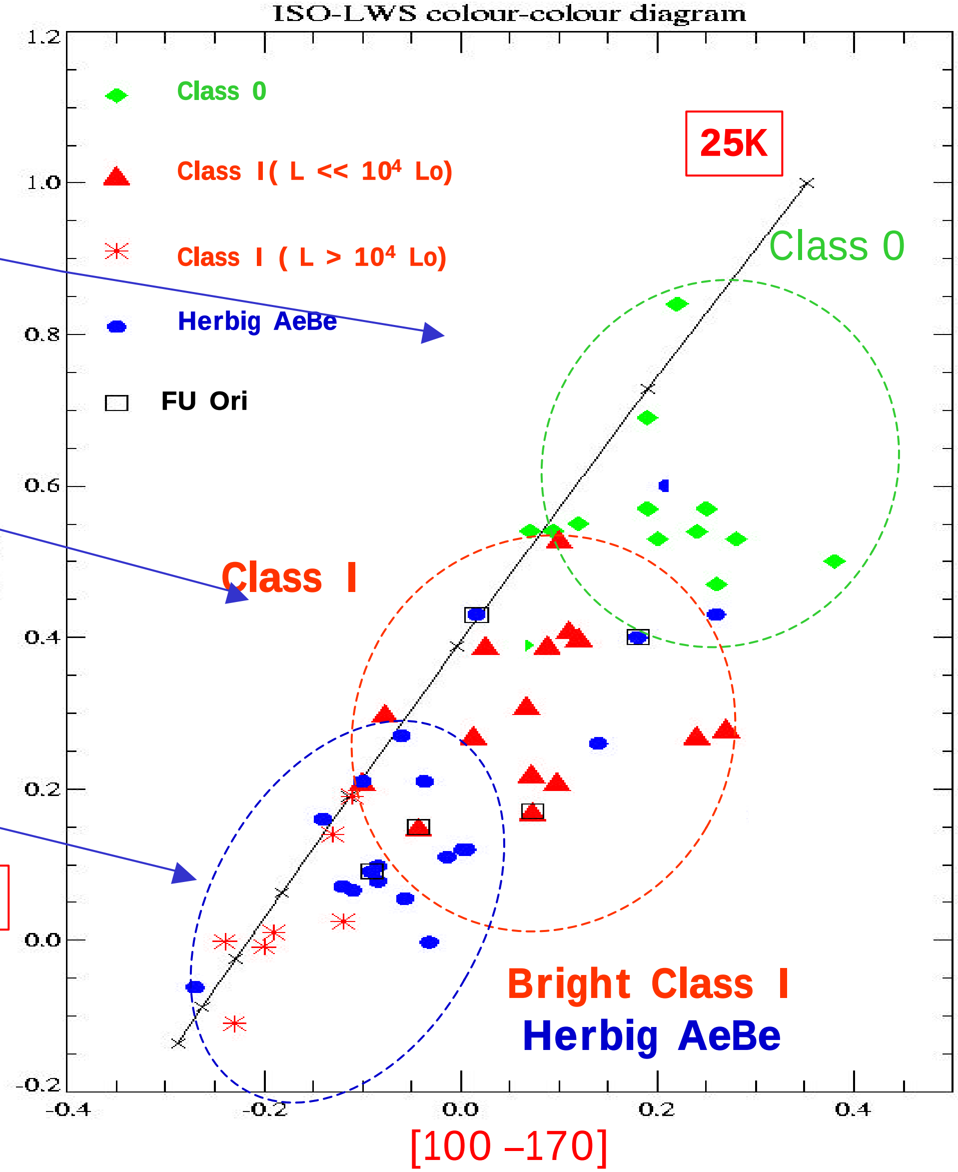
ISO LWS colour colour diagram

(Pezzuto et al. 1998, 2002)

Lada e Wiking 1984
Andrè et al. 1993

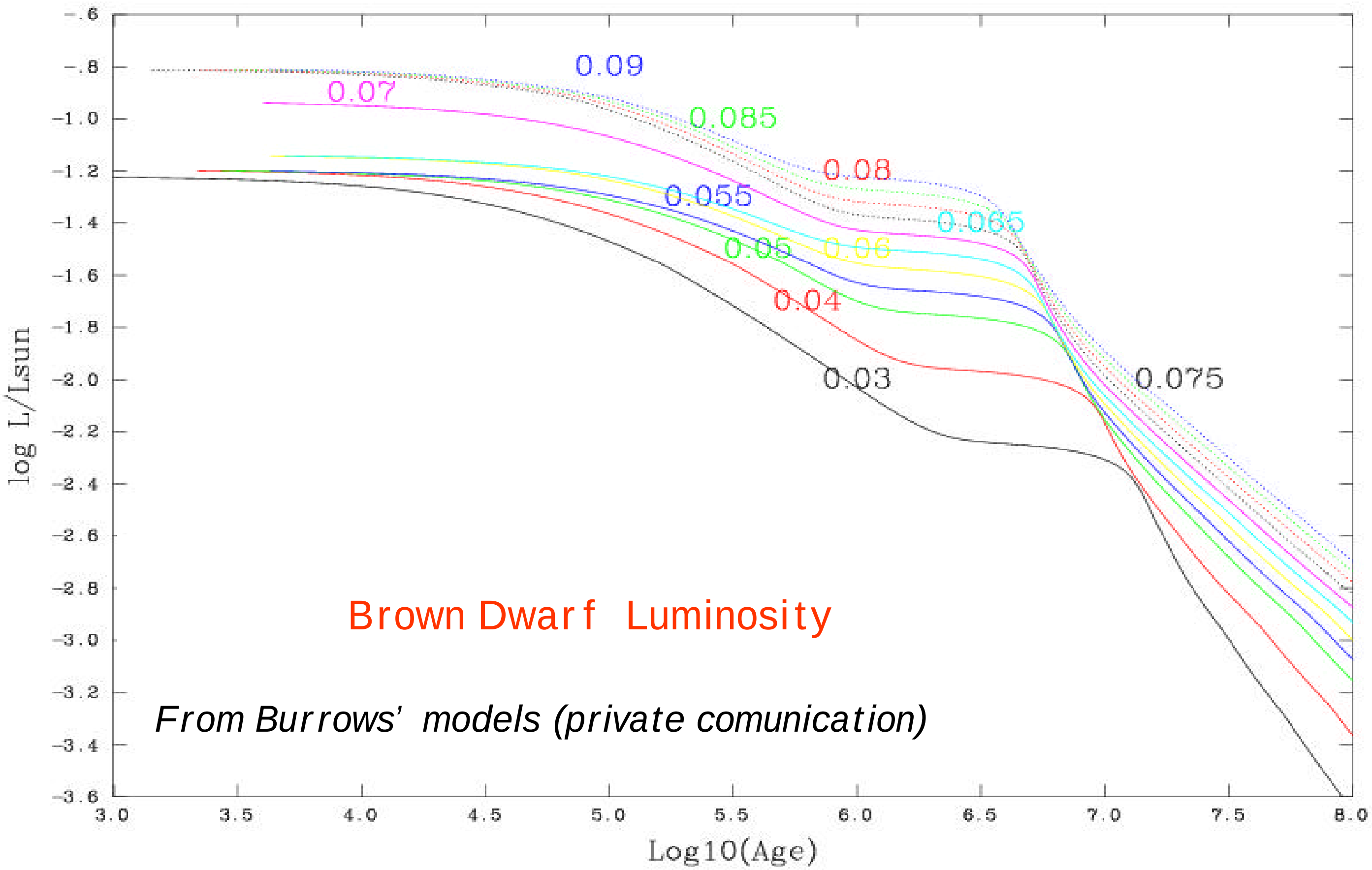






In the selected areas we expect to detect:

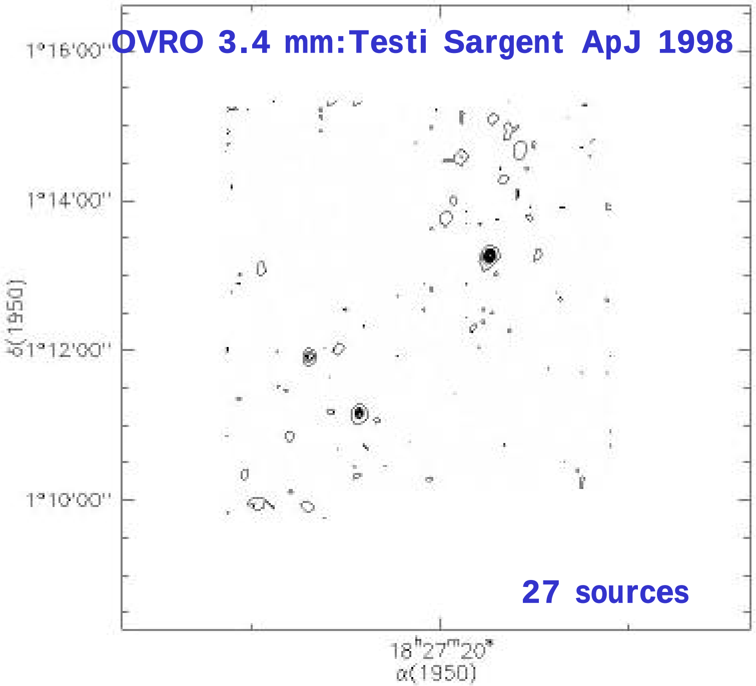
•nearly all the Low mass stars and Brown Dwarfs of the selected regions (the limit will be the cirrus noise):

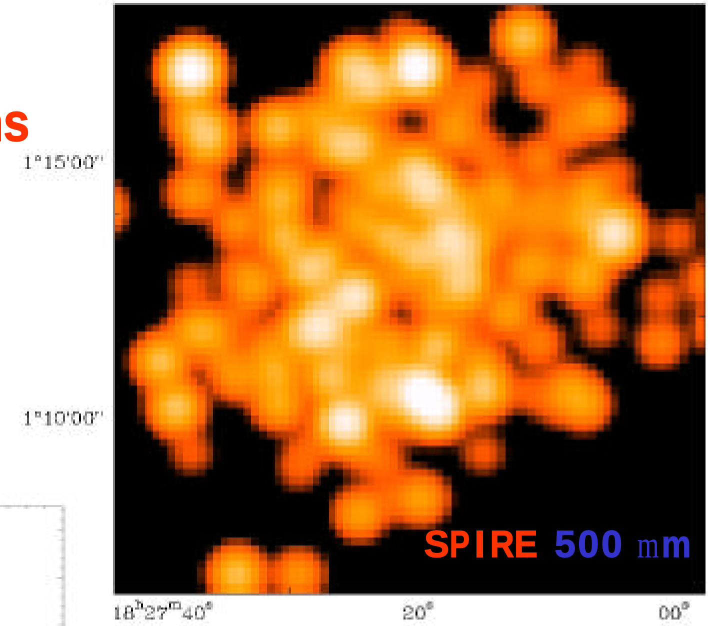


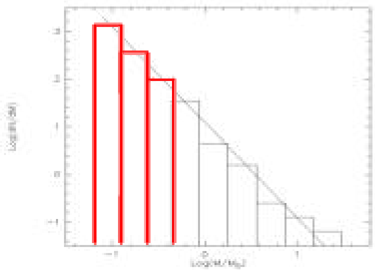
What limits the surveys ?

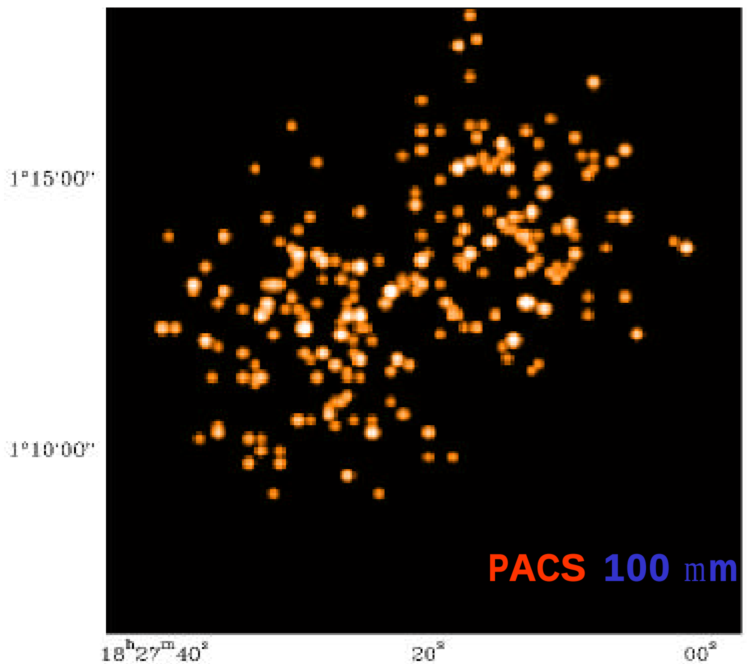
Serpens Core Simulations

50 mJy

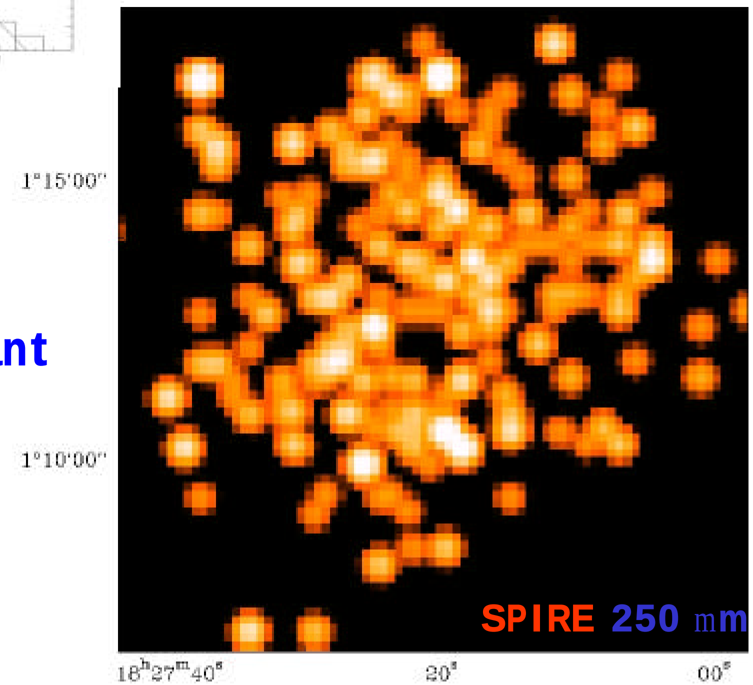




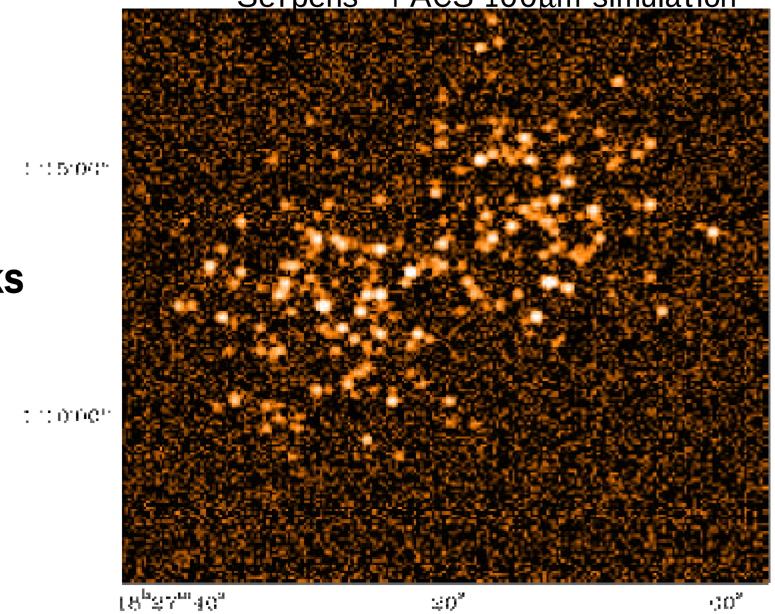




310 pc distant

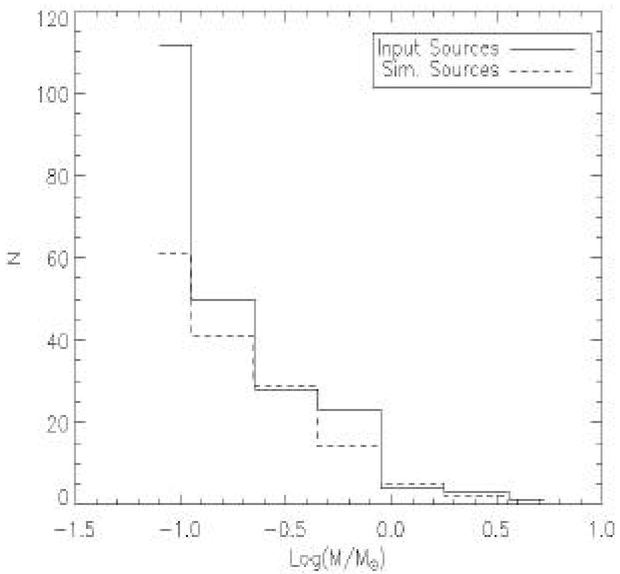


Source Crowding



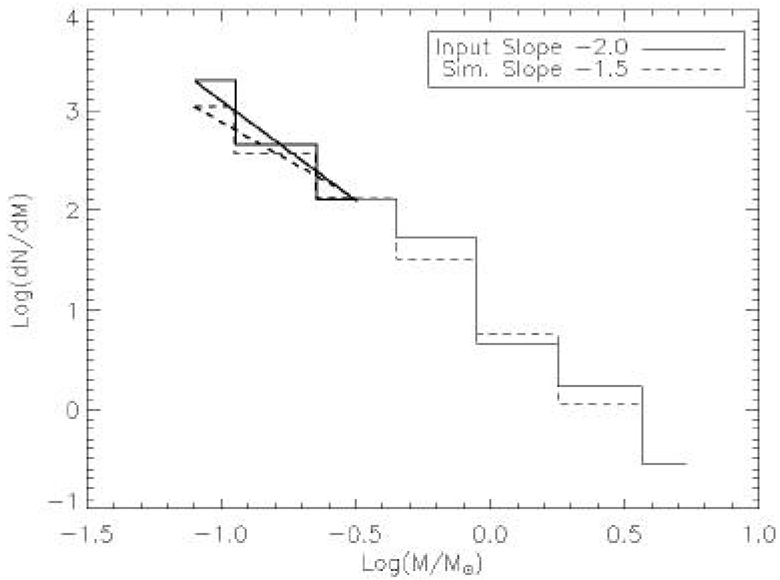
- **220 input sources**
- **2D-Gaussian distribution around subclustering peaks**
- **Cluster radius ~0.2 pc**

310 pc distant



Reduction with DAOFIND:

we miss 30% of the sources because of crowding (and not sensitivity) problems



Cirrus noise

Confusion noise of extended sources id mean square difference of the sky brightness F(x) in the position x- d and x :

$$P(d) = < [F(x-d) - F(x)]^2 > \qquad [Jy^2/sr]$$

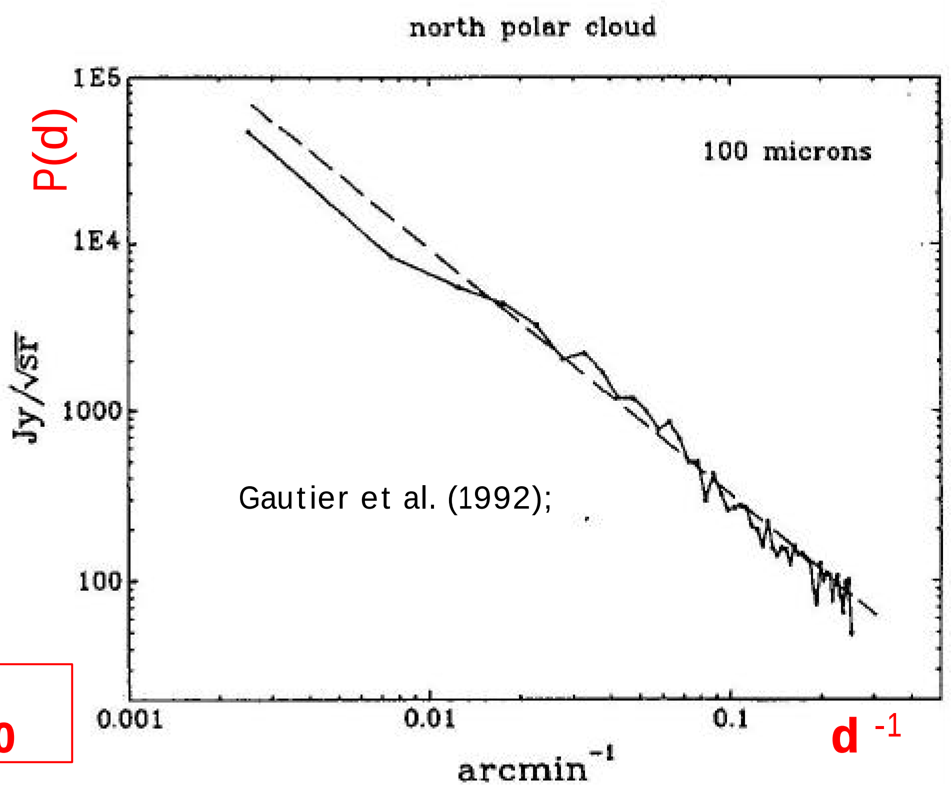
IRAS and COBE/DIRBE observations (Gautier et al. (1992); Wright (1998)) found to be generally well represented by a power low

$$P = P_0 (s_0 / s)^{-3}$$

P_0 depends from source brightness

s_0 = 0.01 arcmin

$$\boxed{P_0 = 1.4\ 10^{-12}\ F_0}$$



Selected regions

Table 1: List of fields to be surveyed with SPIRE(scan speed 60"/sec)

Cloud complex	Area (deg^2)	Distance (pc)	IRAS B100 (MJy/sr)	250-μm cirrus noise (1-sigma) (mJy/beam)	250-μm required rms (mJy/beam)	Mass (10-s) sensitivity[1] (M_{sun})	Required time (hr)	Responsible Team (s)
Taurus	25	140	35	10	20	0.02	24.5	Cardiff/Saclay
Taurus	5	140	35	10	10	0.01	19.5	Saclay/Orsay
Ophiuchus	12.5	140	80	35	20	0.02	12	Saclay/Cardiff
Pipe nebula	3	140	80	35	20	0.02	2.9	Saclay
Polaris flare	4	150	10	3	10	0.01	15.6	Orsay/Saclay
Lupus	3	100	50	15	20	0.01	2.9	Rome/RAL
Coalsack	1.5	150	150	90	20	0.02	1.5	Saclay
Cham I/III & Musca	4	160	20	5	10	0.01	15.6	HSC/Orsay
Corona Australis	3	170	30	10	10	0.01	11.7	RAL/Cardiff
Serpens Aquila rift	12.5 12.5	260	70 150	30 90	20	0.07	12 12	Rome/RAL Saclay
Perseus	4	300	20-50	5-15	10	0.04	15.6	Rome/Canada
IC 5146	1	400	90	40	20	0.15	1	Marseille
Cepheus flare	9	440	20	5	20	0.2	9	Canada
Orion A Orion B	10 10	450	75	20	20	0.2	10 10	Rome/Canada Saclay/Cardiff

I 120°

Total 175.8 hr

(1) Mass sensitivity achieved at 250 μm and 350 μm if Td=10 K; the mass sensitivity is worse by only ~70% at 500 μm. If Td>10 K, the mass sensitivity is better than the quoted number at all wavelengths.

Table 2: Preliminary list of fields to be surveyed with PACS (scan speed 6"/sec)

Cloud complex	Area (deg^2)	Distance (pc)	IRAS B100 (MJy/sr)	170-µm cirrus noise (1-sigma) (mJy/beam)	Mass (10-s) sensitivity[(1)] (M_{sun})	Required time (hr)
Taurus	1.0	140	35	4	0.015	10.6
Ophiuchus	2.5	140	80	14	0.015	26.6
Polaris flare	0.5	150	10	0.5	0.015	5.5
Lupus	1.0	100	50	7	0.007	10.6
Coalsack	1.0	150	150	35	0.015	10.6
Cham I/III & Musca	1.5	160	20	2	0.02	16.0
Corona Australis	0.5	170	30	3	0.02	5.5
Serpens	1.0	260	70	11	0.05	10.6
Perseus	2.0	300	35	4	0.06	21.3
Orion A + B	5.0	450	75	13	0.14	53.2
	16°					Total 170.5 hr

(1) Mass sensitivity achieved at 170 µm if Td=10 K; in this case, the mass sensitivity is worse by an order of magnitude at 110 µm. If Td=15 K, the mass sensitivity is better than the quoted number by more than a factor of 5 at both wavelengths.

Table 4: **Alternative list of fields to be surveyed with PACS (max. scan. speed of 24″/sec)**

Cloud complex	Area ($\deg^2$)	Distance (pc)	IRAS B_{100} (MJy/sr)	(1σ) Cirrus Noise at 170μm (mJy/beam)	Required $rms_{170\mu}$ (mJy/beam)	(10σ) Mass Sensitivity[a] ($M_\odot$)	Required Time (hr)
Taurus	2.0	140	35	4	5	0.015	21.2
Ophiuchus	5.0	140	80	14	10	0.03	13.3
* Pipe Nebula	0.5	140	80	14	10	0.03	1.5
Polaris flare	0.5	150	10	0.5	5	0.015	5.5
Lupus	1.0	100	50	7	5	0.007	10.6
Coalsack	1.0	150	150	35	10	0.03	2.7
Cham I/III + Musca	2.0	160	20	2	5	0.02	21.2
Corona Australis	1.0	170	30	3	5	0.02	10.6
Serpens/Aquila Rift	9.0	260	70	11	10	0.1	23.9
Perseus	2.0	300	35	4	5	0.06	21.3
* IC 5146	0.5	400	90	16	10	0.25	1.5
* Cepheus flare	1.0	440	20	2	5	0.14	10.6
Orion (A+B)	10.0	450	75	13	10	0.28	26.6
	35.5°						170.5

(a) Mass sensitivity achieved at 170 μm if $T_d = 10$ K.
(b) Galactic-plane region where the intrinsic level of cirrus noise is very uncertain.

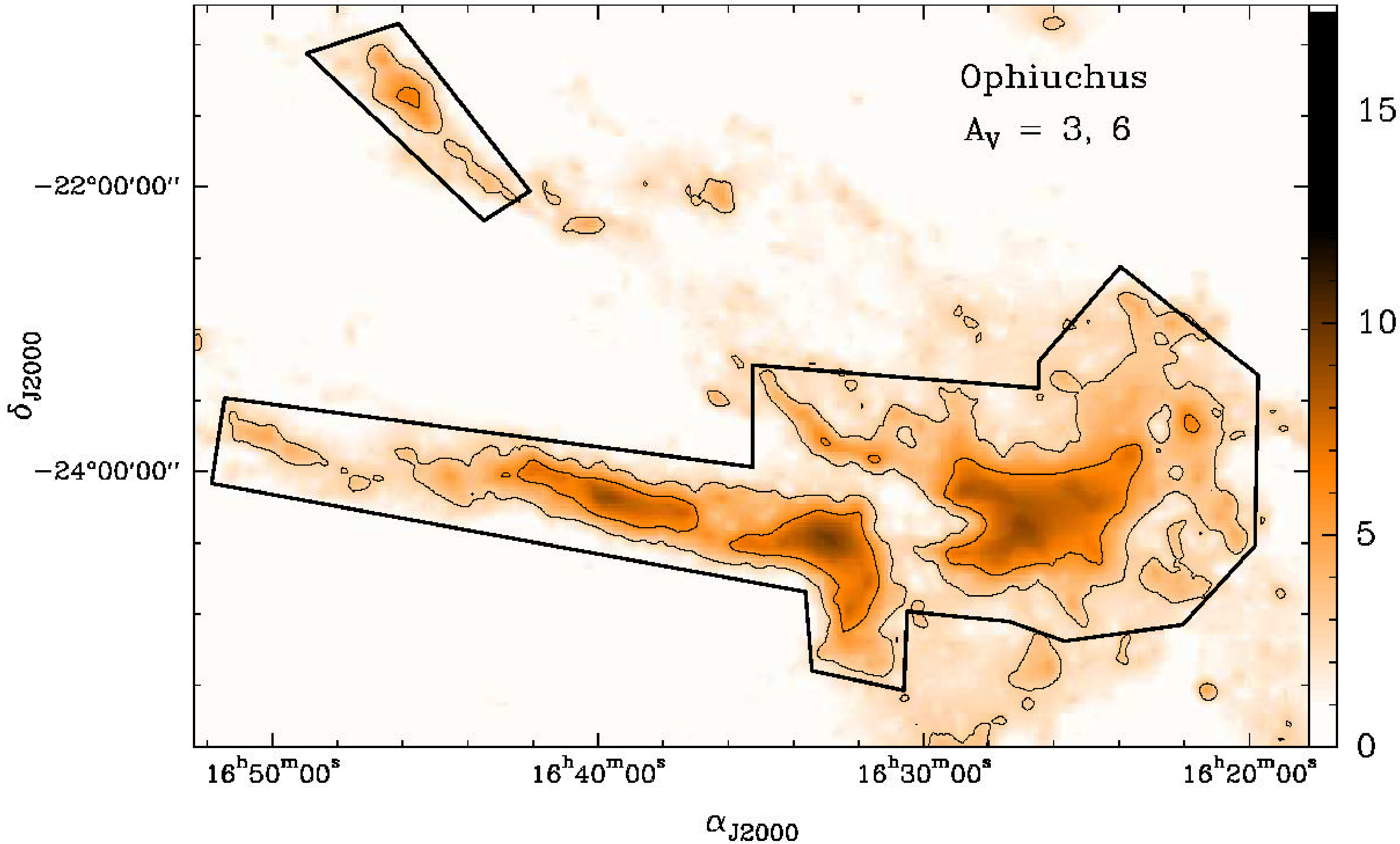
Observing Strategy

- We use optical NIR **extinction map** to define the boundary of the fields to be observed
- We plan to use the **maximum scanning speed**

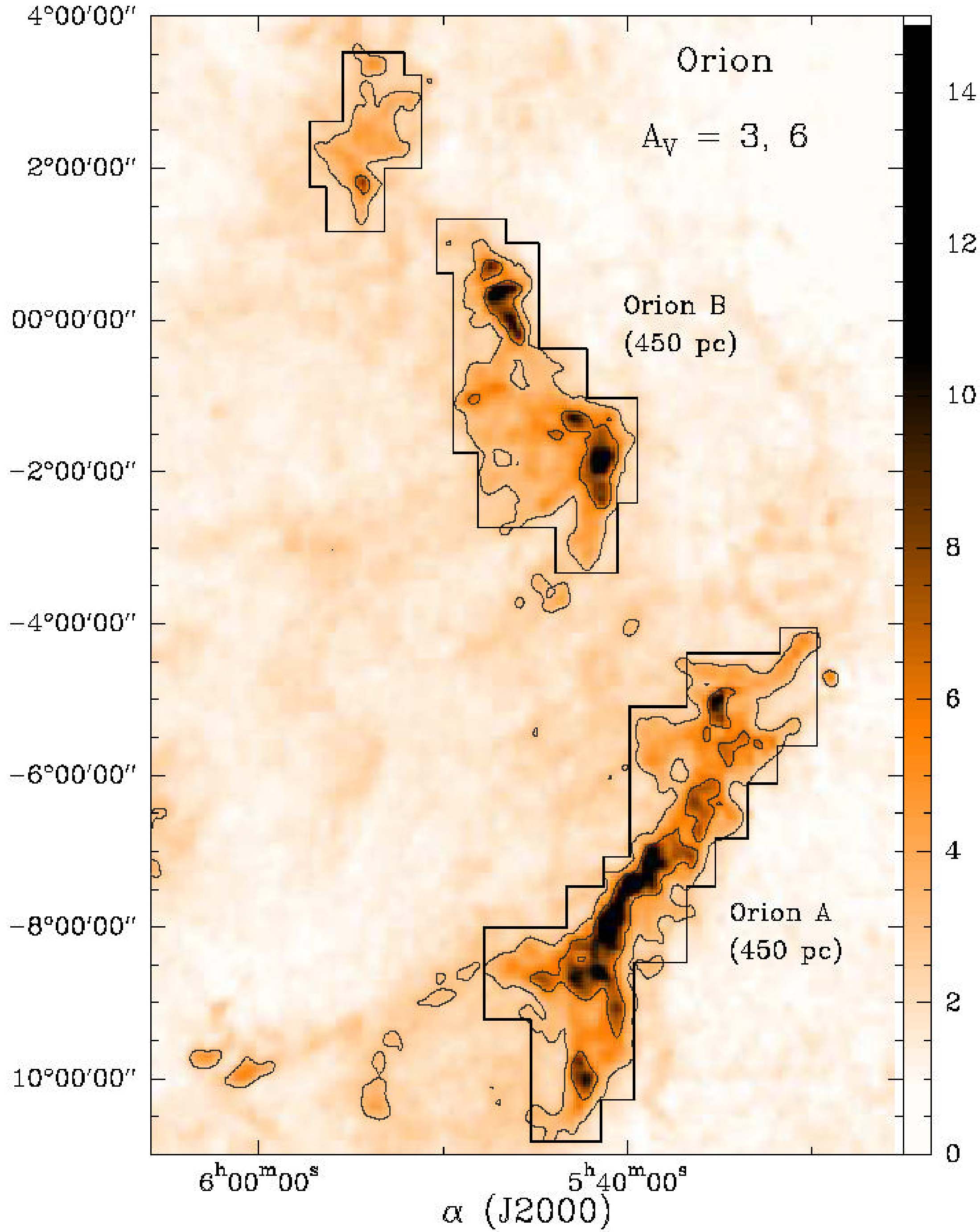
  - 60"/sec SPIRE 1s $rms_{250\mu m}$ 20 mJy /17" beam
  - 6"/sec (24 ?) PACS 1s $rms_{170\mu m}$ 5 mJy / 13" beam

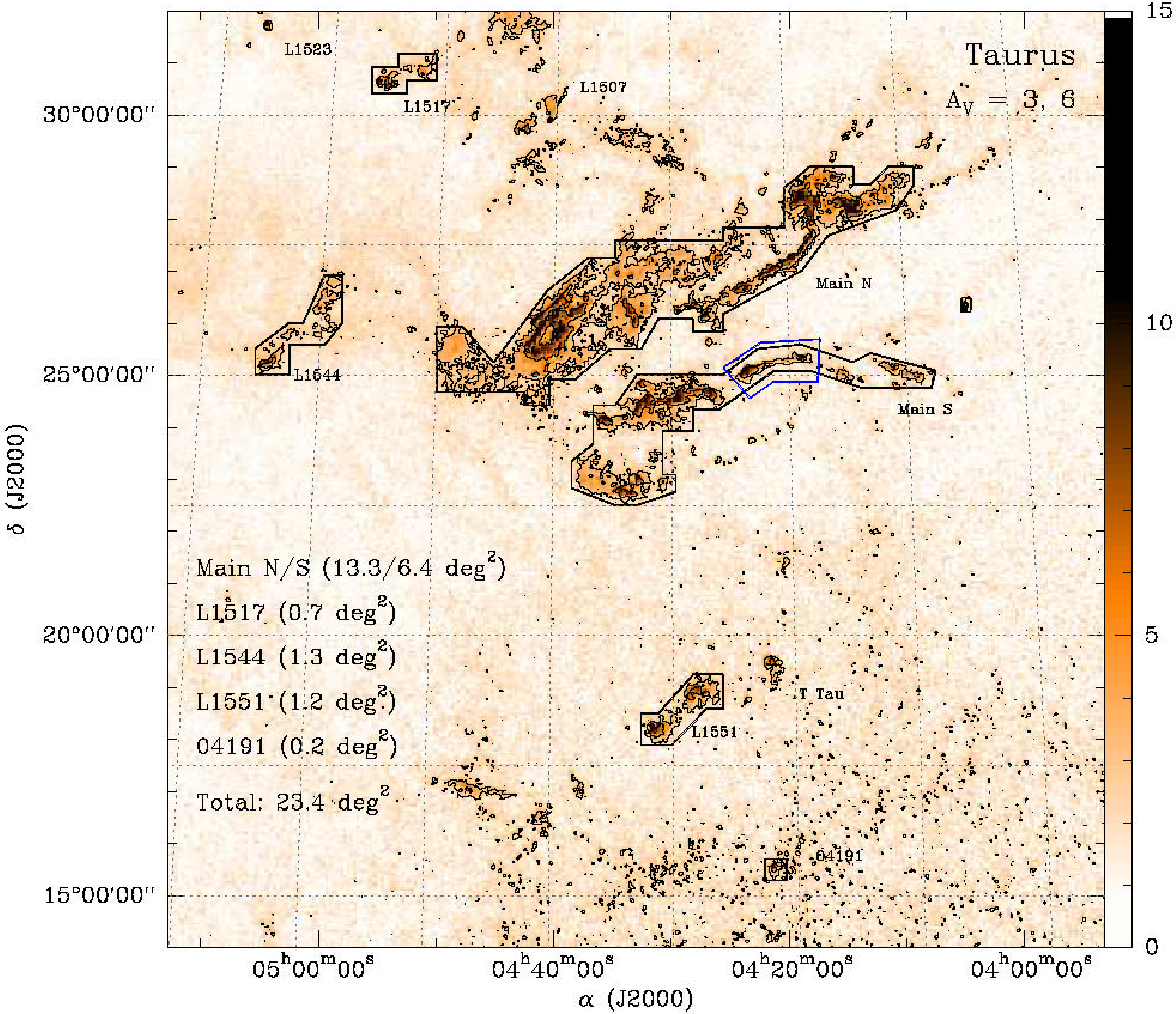
  Assuming Td = 10 K (starless clouds) => $N_{H2} \sim 4\ 10^{21}$ (Av ~ 3-4)

In some of the nearest clouds (Cham, CRA, Perseus) where cirrus noise is expected to be lower, we will reach 10 mJy /17" beam with SPIRE, to be able to decrease the mass completeness limit for proto-brown dwarfs

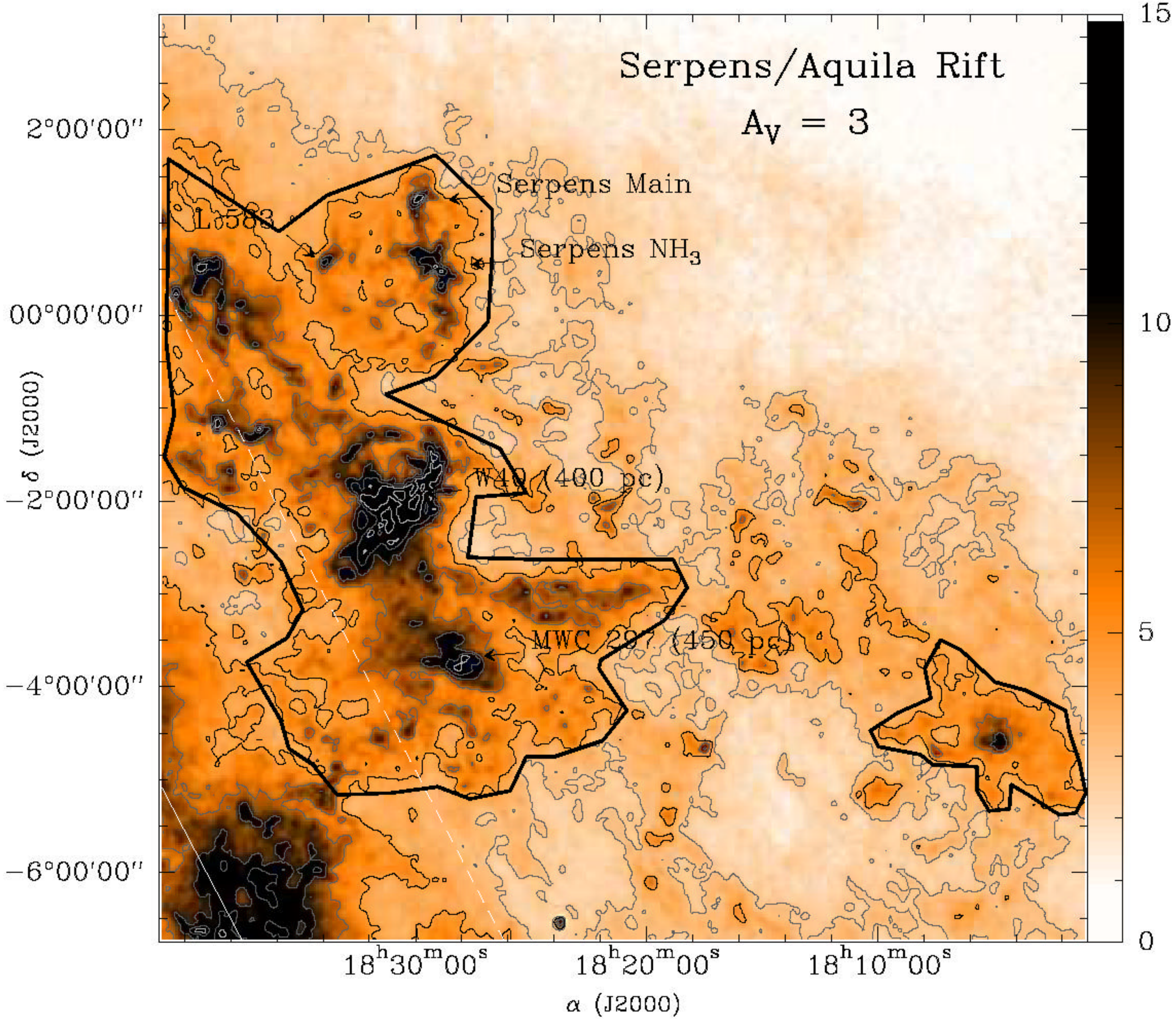


Ophiuchus
A_V = 3, 6
15
10
5
0
−22°00′00″
−24°00′00″
δ_{J2000}
16h50m00s
16h40m00s
16h30m00s
16h20m00s
α_{J2000}


Orion
$A_V = 3, 6$
Orion B
(450 pc)
Orion A
(450 pc)
4°00′00″
2°00′00″
00°00′00″
−2°00′00″
−4°00′00″
−6°00′00″
−8°00′00″
10°00′00″
$6^h00^m00^s$
$5^h40^m00^s$
α (J2000)
14
12
10
8
6
4
2
0

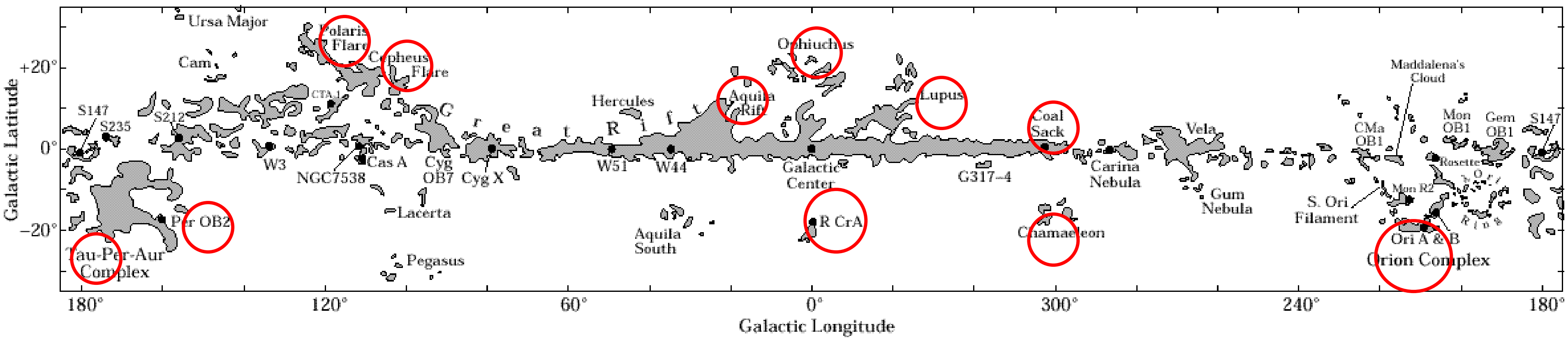


Taurus
A_V = 3, 6
L1523
L1517
L1507
Main N
Main S
L1544
T Tau
L1551
04191
Main N/S (13.3/6.4 deg^2)
L1517 (0.7 deg^2)
L1544 (1.3 deg^2)
L1551 (1.2 deg^2)
04191 (0.2 deg^2)
Total: 23.4 deg^2
30°00′00″
25°00′00″
20°00′00″
15°00′00″
δ (J2000)
05^{h}00^{m}00^s
04^{h}40^{m}00^s
04^{h}20^{m}00^s
04^{h}00^{m}00^s
α (J2000)
15
10
5
0



Serpens/Aquila Rift
$A_V = 3$
Serpens Main
L 583
Serpens NH_3
W40 (400 pc)
MWC 297 (450 pc)
2°00′00″
00°00′00″
−2°00′00″
−4°00′00″
−6°00′00″
δ (J2000)
18h30m00s
18h20m00s
18h10m00s
α (J2000)
15
10
5
0

Summary



We propose to study the densest part of the nearby clouds, mapping:

with SPIRE:

- 120 deg^2 to rms$_{250\mu m}$ 20 mJy /17" beam
- 20 deg^2 to rms$_{250\mu m}$ 10 mJy /17" beam

~180 hr

With PACS:

16 deg^2 to rms$_{170\mu m}$ 5 mJy /13" beam ~170 hr

PACS follow up ~**112 hr**

- **total** **462 hr**