High-mass star formation in the W43-MM1 protocluster

STARFORMMAPPER

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Overview

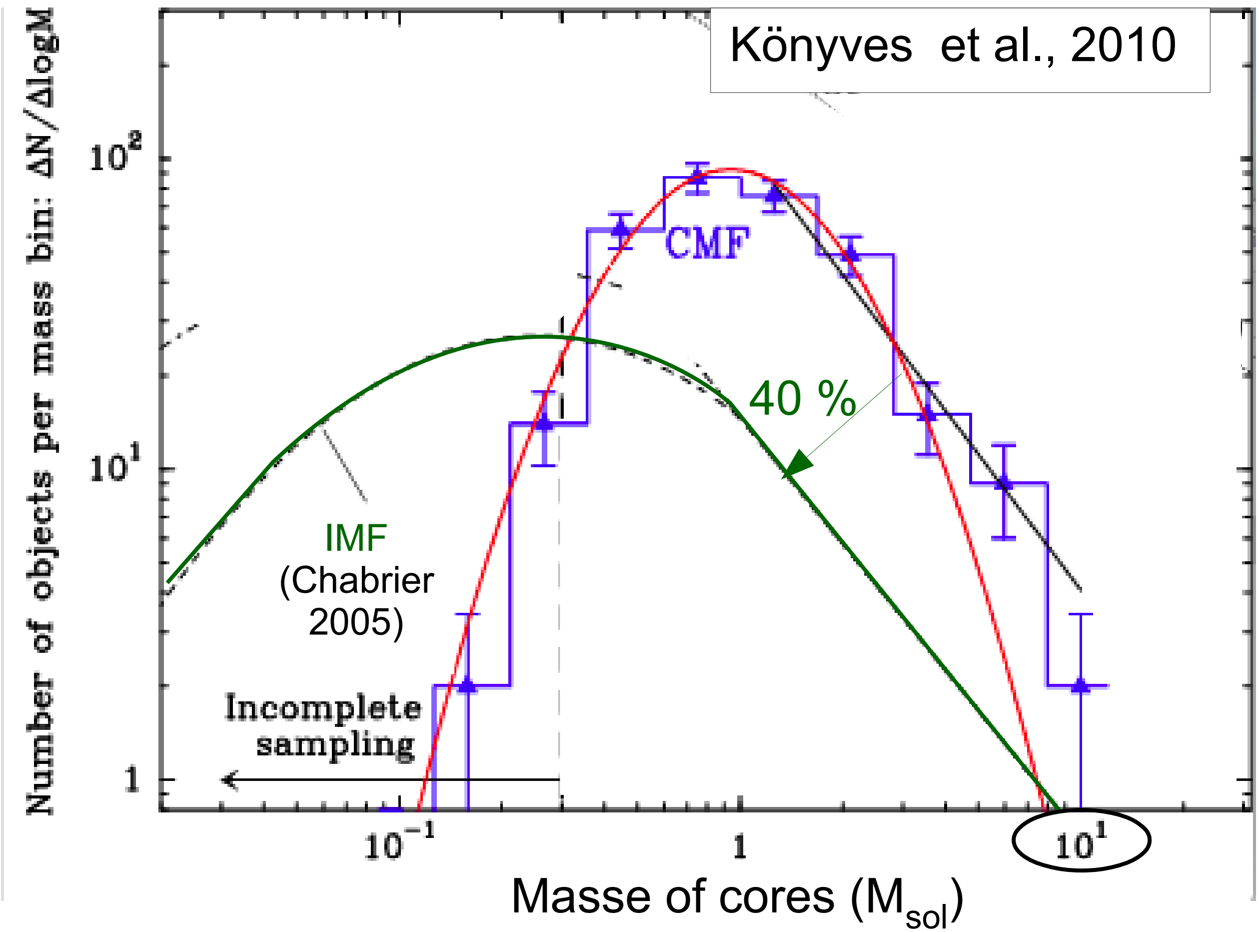
1) Introduction and data analysis

2) Cores characterization: CO, SiO and ^{13}CS

3) Mass calculation and CMF

Origin of stars' mass

IMF = mass distribution of stars on the main sequence
CMF = mass distribution of cores



For M_{core} = 0.5 – 10 M_{sun} :

CMF/IMF comparison

(e.g. Motte+98, Alves+07, Enoch+08, Könyves+15, ...):

$$IMF = \epsilon_{core} . CMF$$

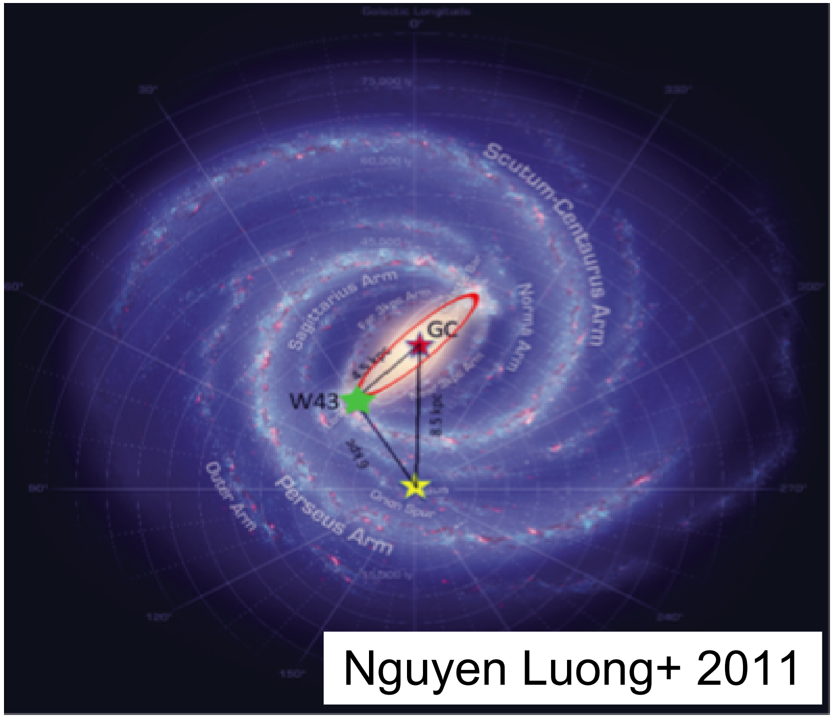
with $\epsilon_{core} \sim 0.4$

→ Stars mass set by cores fragmentation

Open question: What is the IMF origin for massive stars ($M_* > 8\ M_{sun}$)?

→ need to observe massive cores ($M_{core} > 20\ M_{sun}$)

W43-MM1: a mini-starburst region



- d = 5.5 kpc
- SFE ~ 25 % in 10^6 years
  (~ 0.25 M_{sun} / yr, Motte+ 2003)

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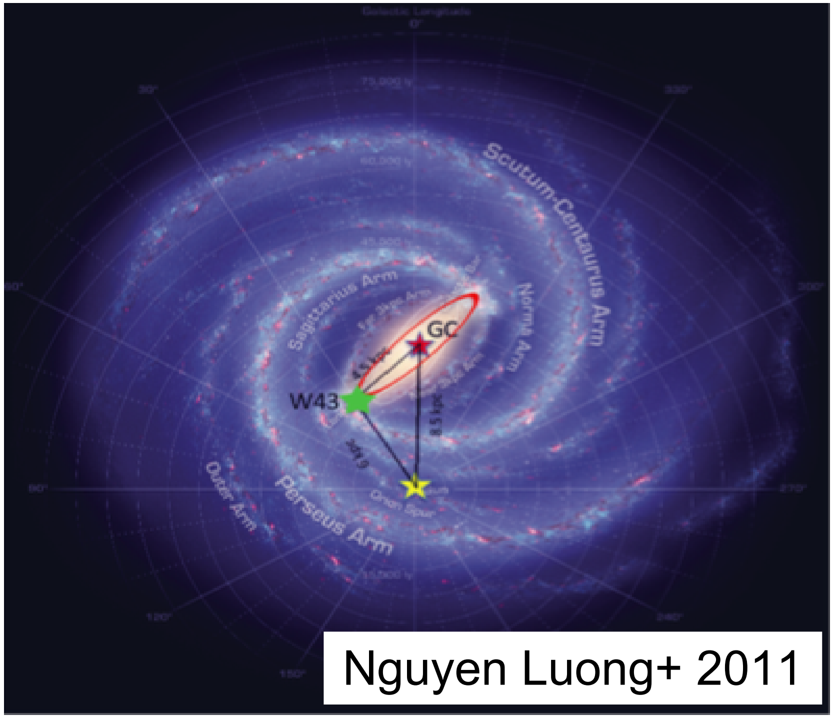
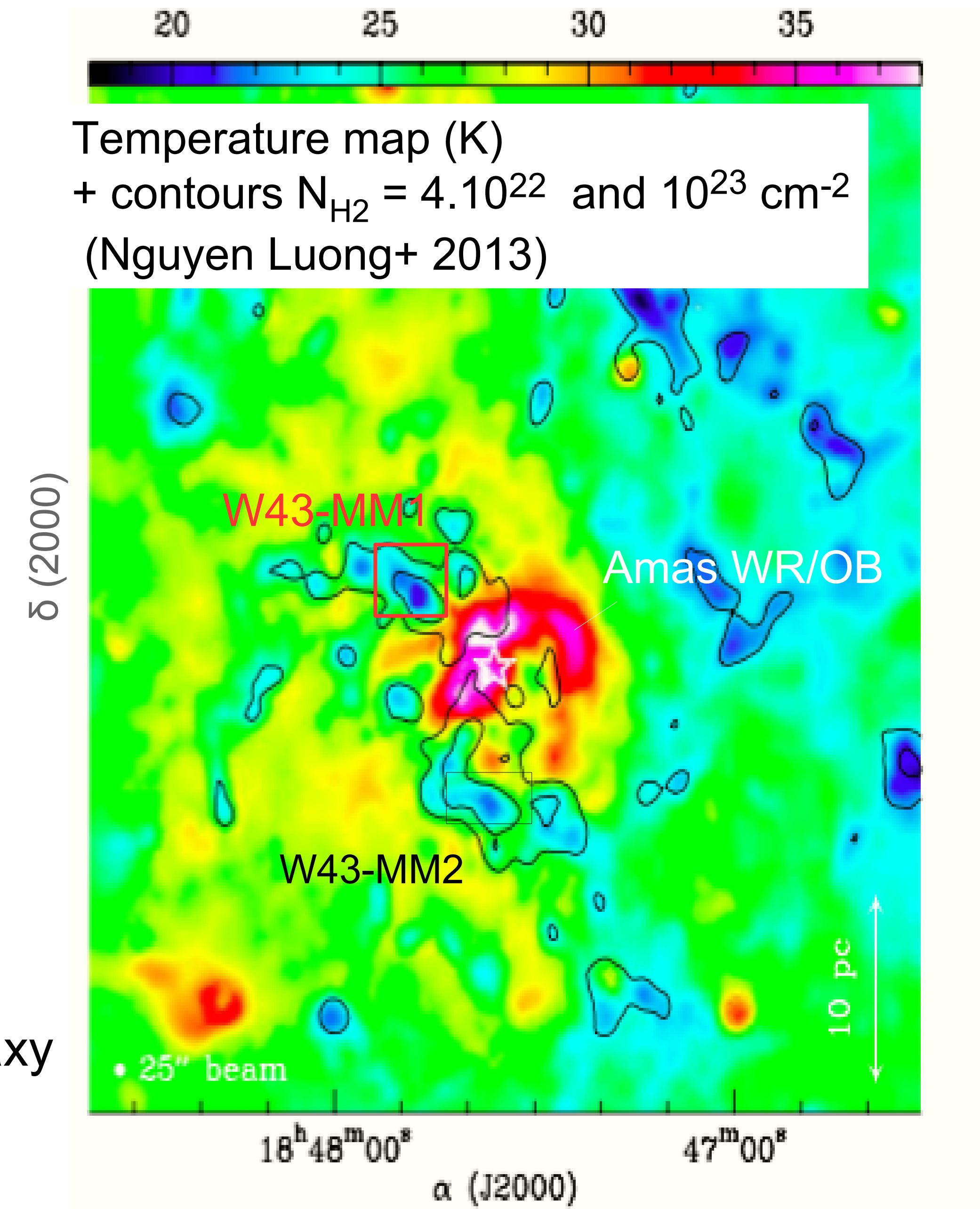




- d = 5.5 kpc
- SFE ~ 25 % in 10^6 years
  (~ 0.25 M_{sun} / yr, Motte+ 2003)

- Densest and coldest cloud in the galaxy
  (Csengeri et al. 2017)

Data set presentation

ALMA: a network of 66 antennas forming the largest sub-(mm) interferometer

- Project Cycle 2 and 3, 30h + 23h, PI Motte
- 3 configurations:
  12m compact and extended, 7m (ACA)
- Mosaic: 33 fields (12m) , 1.4 pc x 2.1 pc
- Spatial resolution to identify cores:
  0.5'' ~ 2000 AU

- Spectro-imaging at λ = 1.3 mm (216-233 GHz): 7 lines bands + 1 continuum band

SpwID	Name	Chans nb.	CtrFreq (GHz)	Chan. Width (kHz / km.s^{-1})	Total BW (MHz)
1	SiO(5-4)	960	217.1	244 / 0.3	234
5	CO(2-1)	480	230.5	977 / 1.2	469
6	^{13}CS(5-4)	1920	231.2	244 / 0.3	469
7	continuum	1920	233.4	977 / 1.3	1875

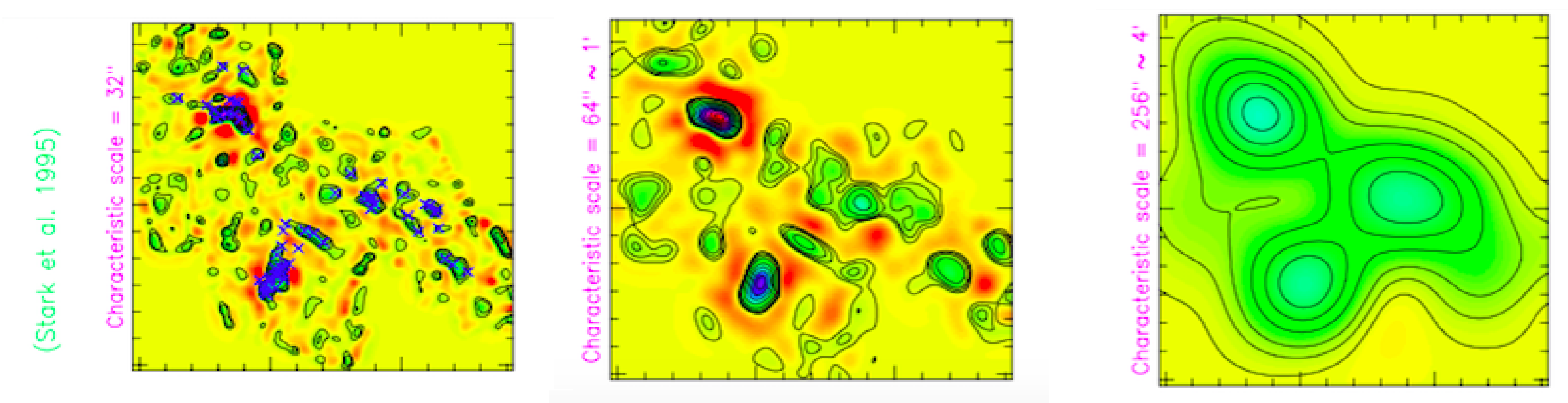
Pre- and proto-stellar cores extraction

Detection and characterization of compact sources with a multi-resolution program (G*etsources, Men'shchikov et al. 2012*)

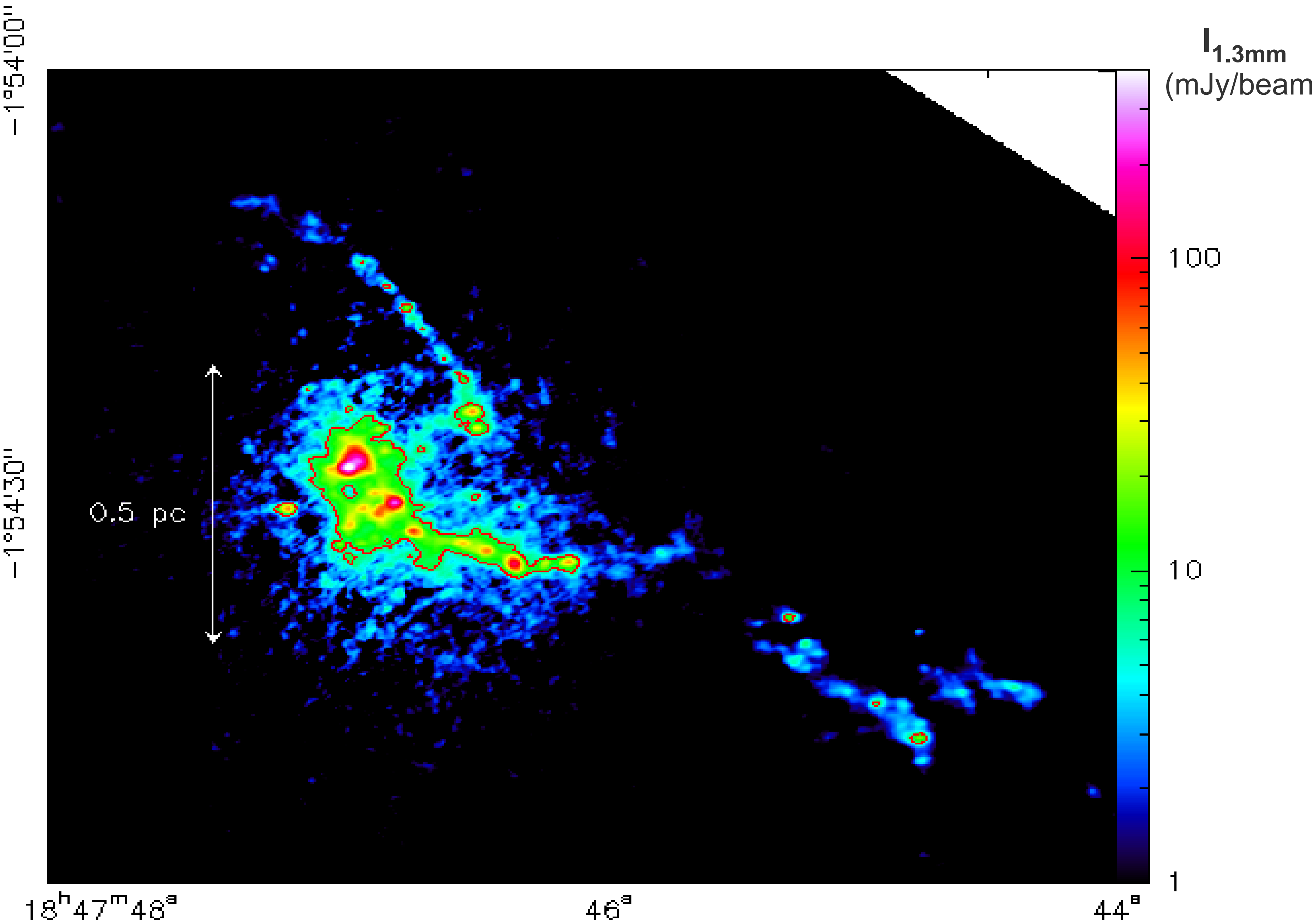
- On 12m selfcalibrated map → 174 sources detected
- 2 post selection criteria (size and ellipticity) + visual inspection

→ 134 cores (including 93 very reliable cores)

Separation of cloud emission at different spatial scales



Continuum map



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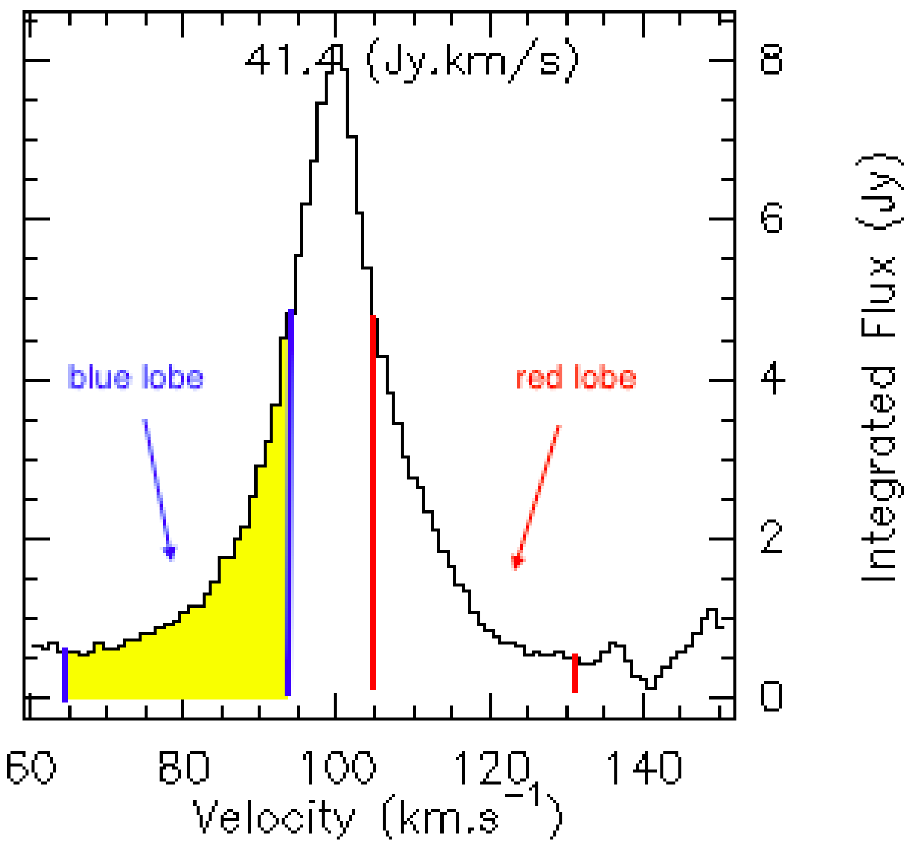
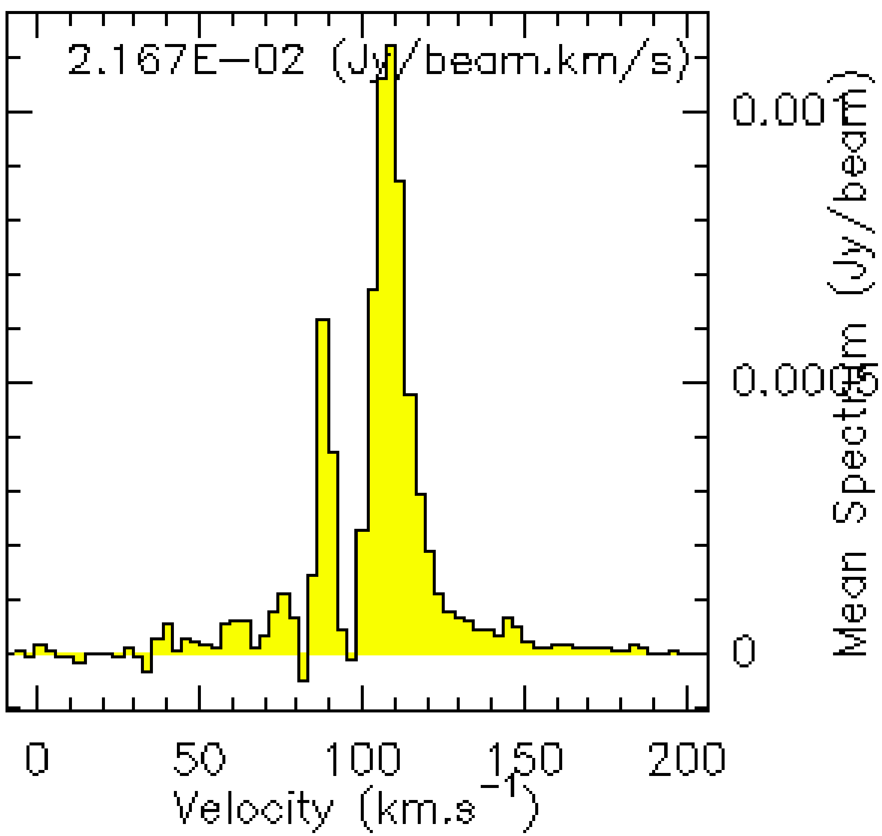
Molecular lines used to trace outflows

SiO(5-4)



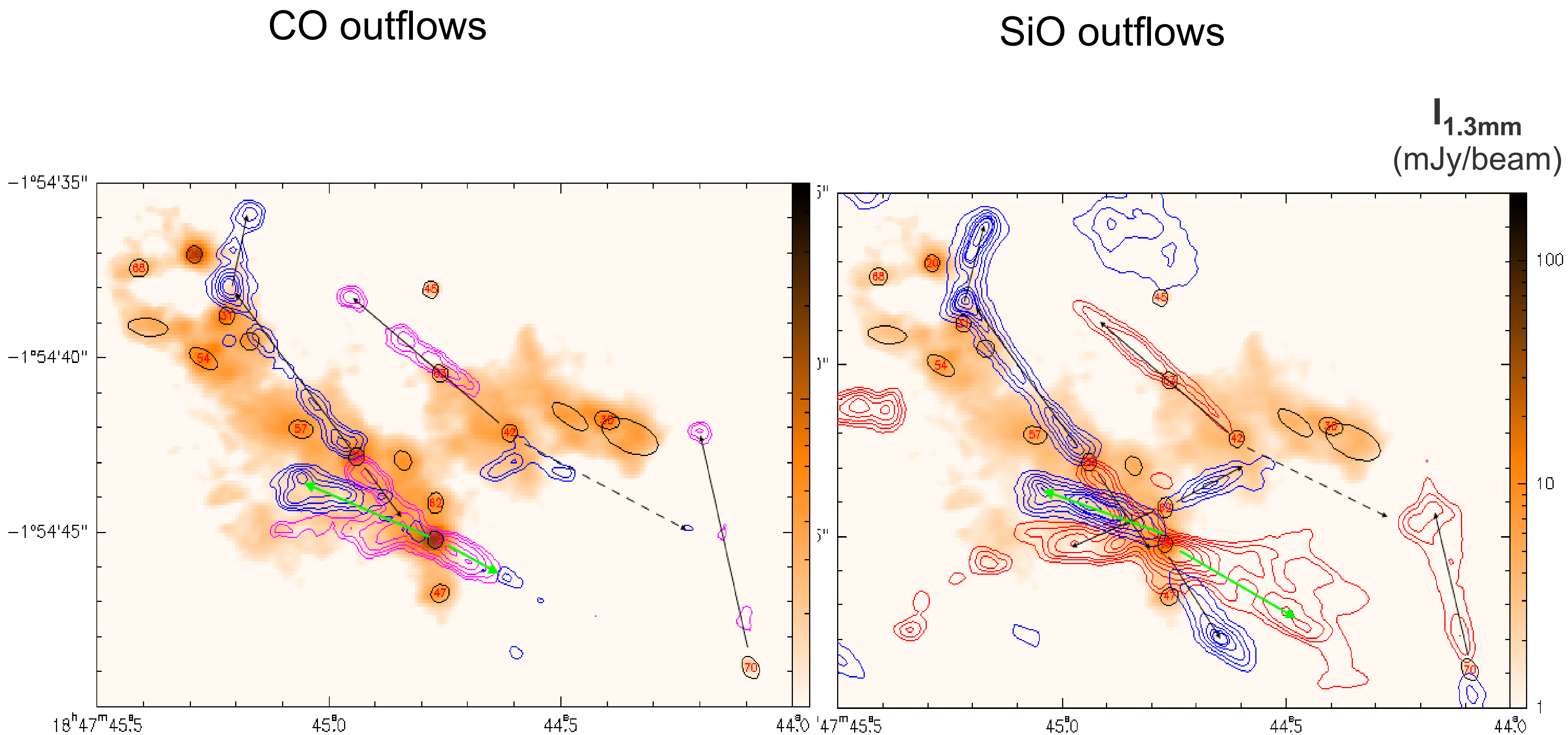
CO(2-1)



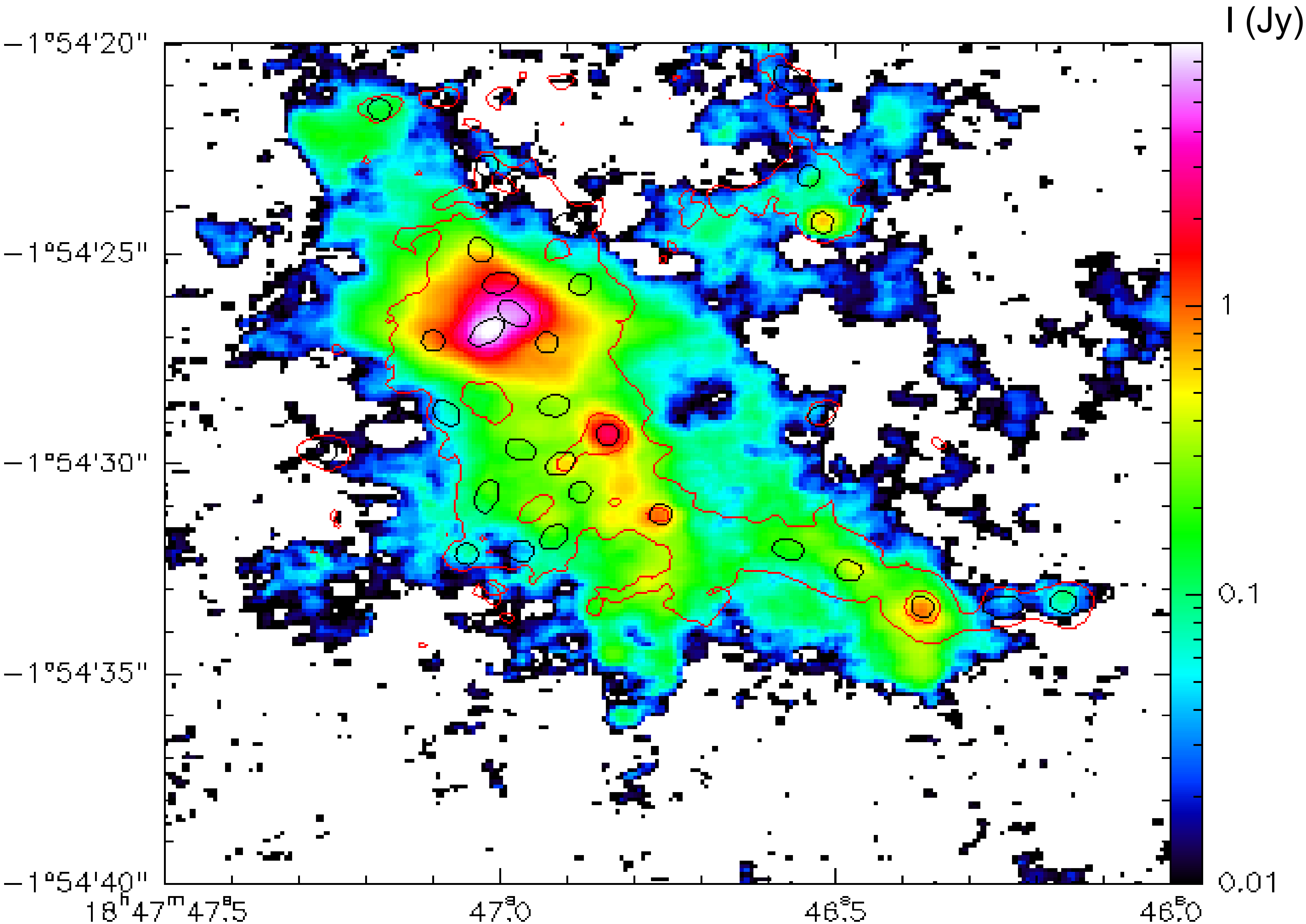
Integration:
Δv = 65 - 92 km/s → blue lobe
Δv = 105-132 km/s → red lobe

Integration:
Δv = 49 - 89 km/s → blue lobe
Δv = 117-157 km/s → red lobe

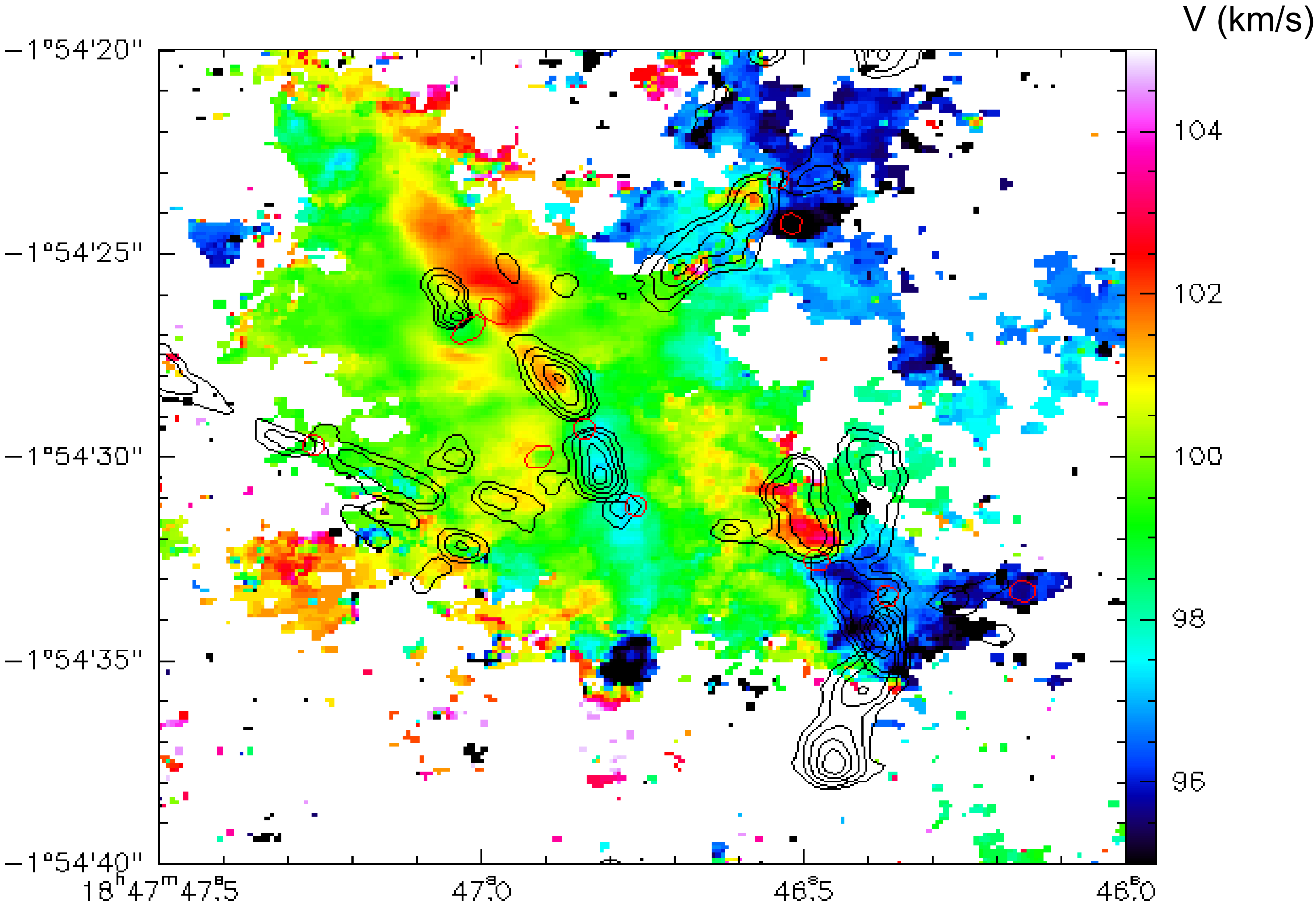
Outflows driven by the most massive cores



^{13}CS Mean map



^{13}CS Velocity map



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Estimate cores mass

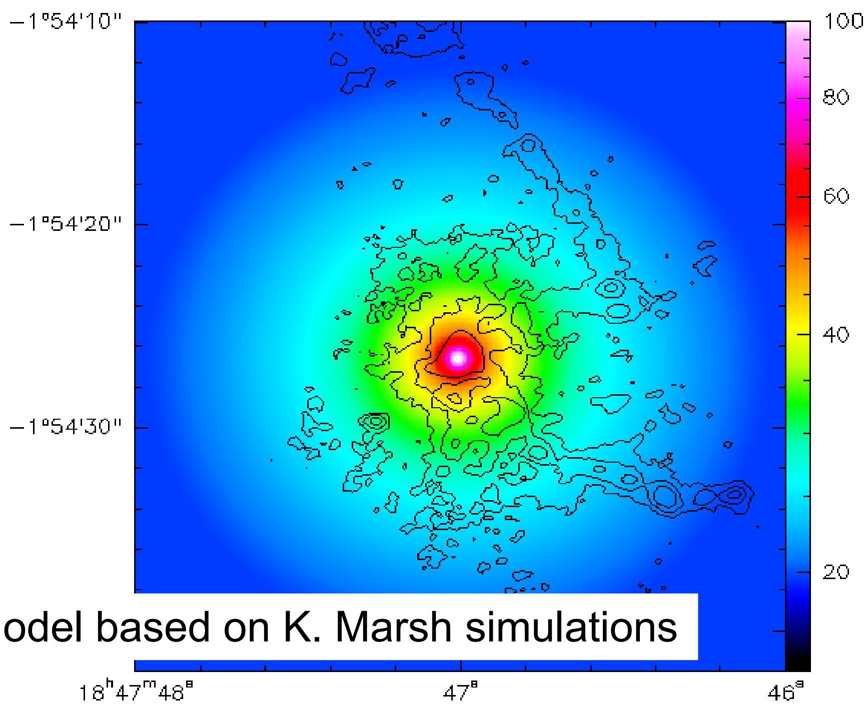
Mass calculation from dust thermal emission:

flux distance

$$M_{smm} = \frac{S_\lambda . d^2}{\kappa_\lambda . B_\lambda(T_d)} . C_\tau(T_d, T_b)$$

dust emissivity Planck function

with optically thin emission hypothesis



Model based on K. Marsh simulations

T_b : brightness temperature

T_d : dust temperature

<u>heating model:</u>

N1a = hot core and $\langle T_d \rangle$ = 20 K

$$\rho \propto r^{-2} \rightarrow T_d = 20\left(\frac{r}{14.2''}\right)^{-0.4}$$

Mass from 0.3 to 180 M_{sun}

Cores able to form massive stars

Table 1: Massive cores (M > 16 $M_\odot$) in W43-MM1

Source	Mass ($M_\odot$)	CO	SiO outflow	Hot core	Nature
#1	162	Y	Y	Y	protostars
#2	182	Y	Y	Y	
#3	184	Y	Y	Y	
#7	55	Y	Y	N	
#8 (S)	72	Y	Y	N	
#9	71	Y	Y	Y	
#16	23	Y	Y		
#4	49	N?	N?	Y	protostars?
#5	42	N	N	Y	
#10	33	Y?(l)	Y? (B)	Y	
#12	66	N	Y? (R)		prestellar cores?
#24	16	Y? (B)	N?	N	
#6	147 ?	N	N	N	prestellar cores
#18	27	N	N ?		

→ ≤ 4 massive pre-stellar cores / 10 massive proto-stellar cores

Different from ratio 10 to 1 for low mass cores (André+ 2010)

CMF of W43-MM1 proto-cluster

→ CMF for cores forming up to 70 M_{sun} !
→ excess of massive cores

Conclusions and future work

- A massive protocluster studied at high resolution with ALMA:

➢ First measure of CMF in high mass area

→ top-heavy CMF or evolution with time ? (Motte *et al.* in prep, ALMA LP)

➢ Good correlation between massive cores and outflows

→ few high-mass prestellar cores / 13-20 proto-stellar cores detected with CO and SiO outflows

→ still one candidate high mass prestellar core (Nony *et al*. in prep.)

- Collaboration with Jordan Molet (PhD Bordeaux) on lines survey and Fabien Louvet on filaments formation, shocks

- Comparison with simulations within *StarFormMapper* ?