A sub-arcsecond study of the disk-outflow system in the S255IR area of high mass star formation

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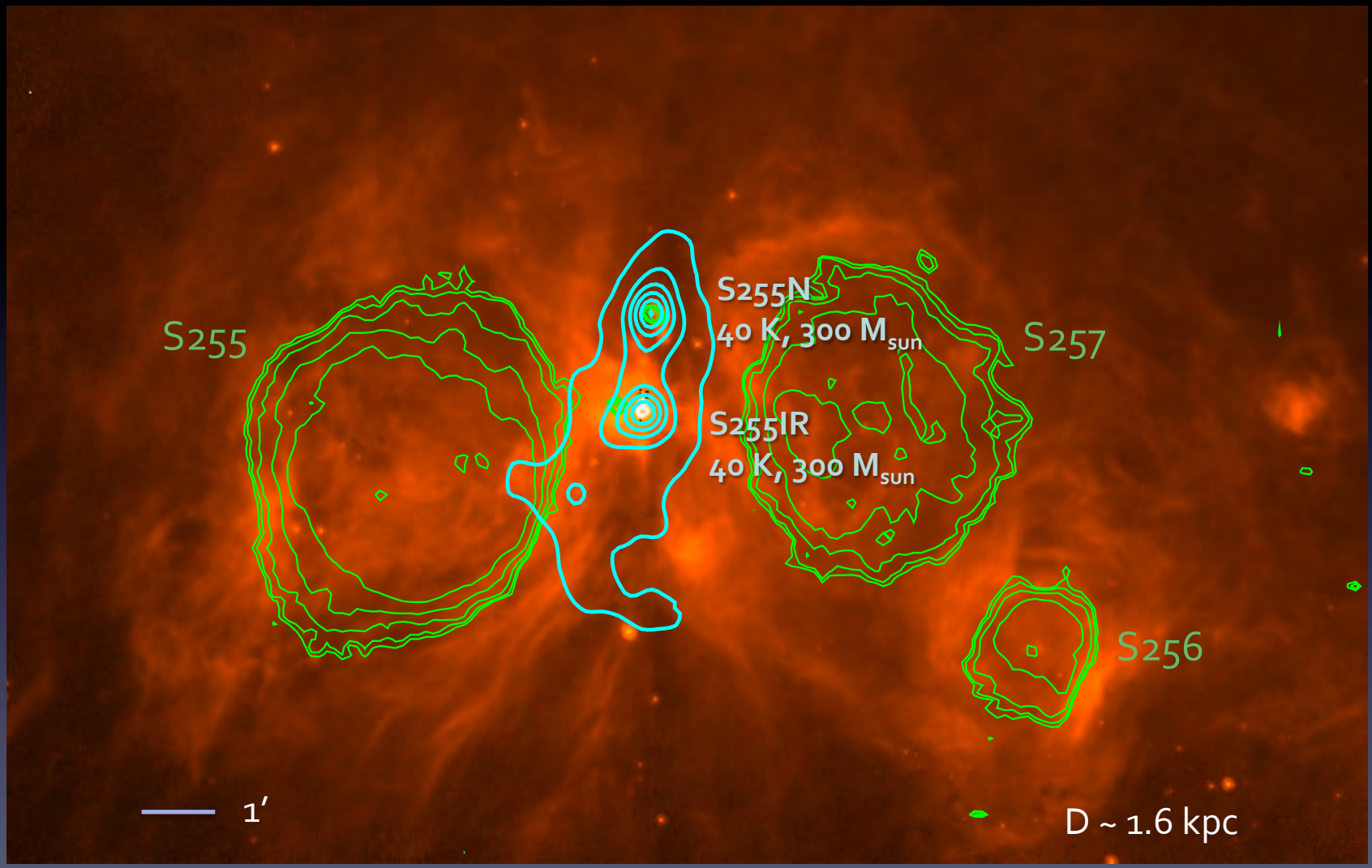
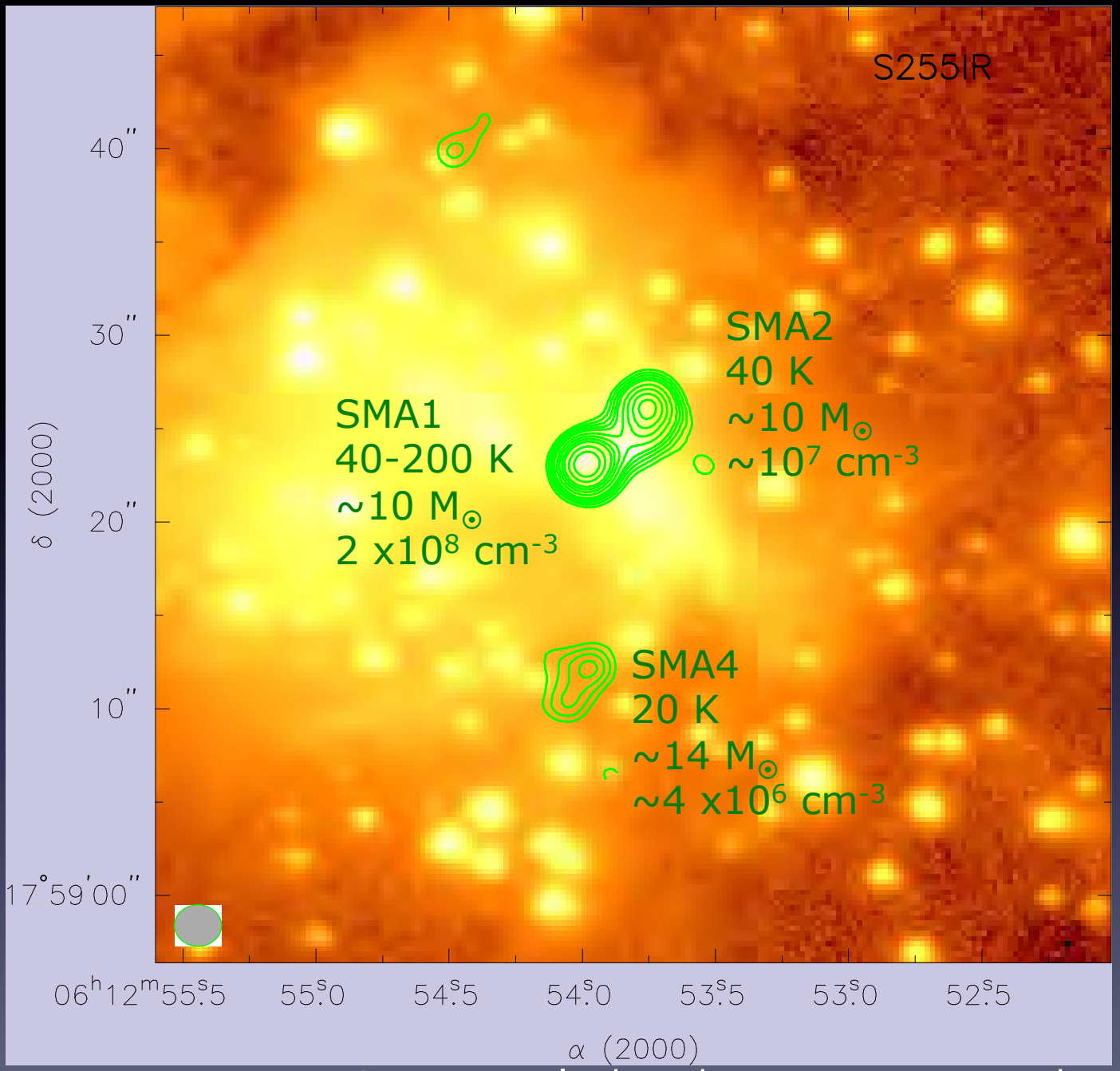
Outline

- General description of S255
- Observations
- Basic properties of the continuum and molecular emission
- S255IR-SMA1
  - Kinematics
  - Physical properties
- Morphology and properties of the outflows
- Surroundings

S255 star forming region



GMRT 610 MHz (green) and IRAM 30m 1.2 mm (cyan) contours overlaid on the Spitzer 8 μm image



1.1 mm continuum contours in S255IR overlaid on the 2 μm image (Zinchenko+, 2012)

New observations

SMA

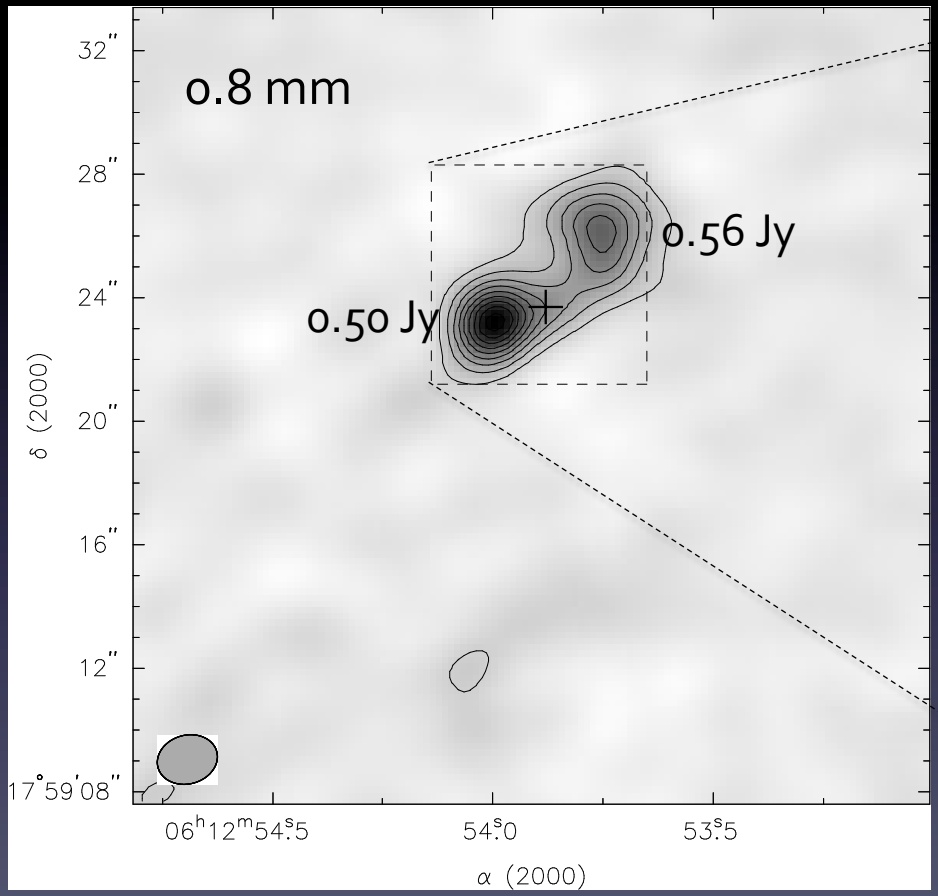
216.8-220.8 GHz θ ~ 0.4”
228.8-232.8 GHz
342.0-346.0 GHz θ ~ 2”
354.0-358.0 GHz

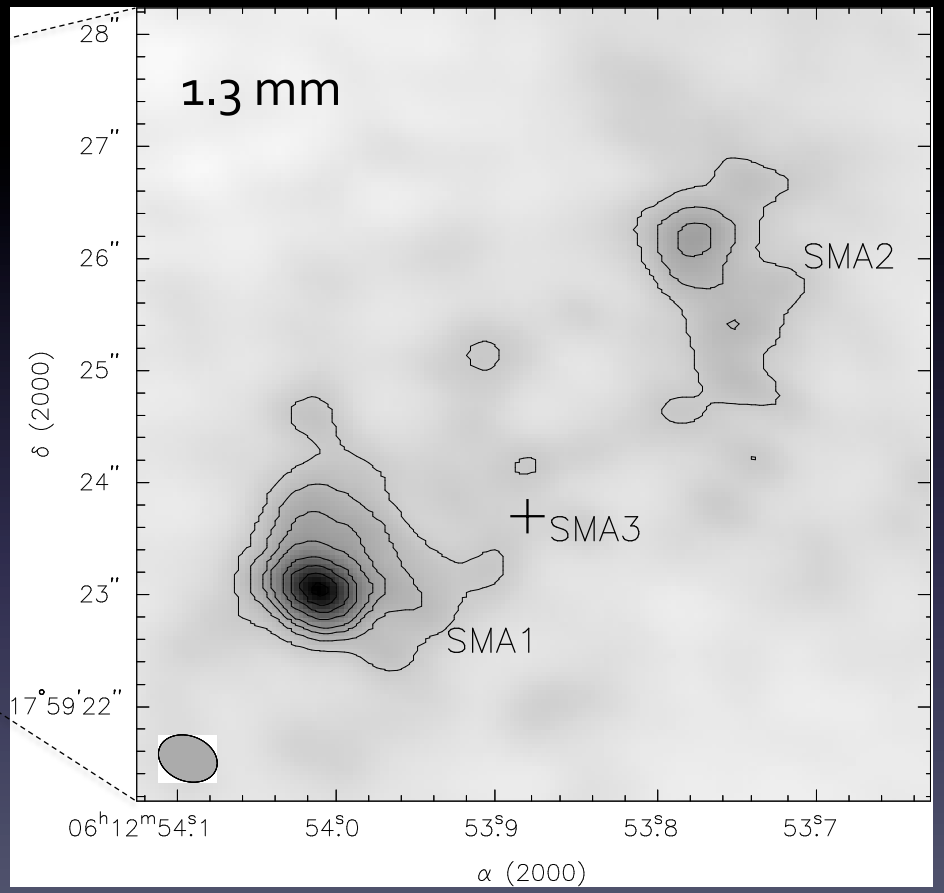
Continuum and multiple (several tens) spectral lines

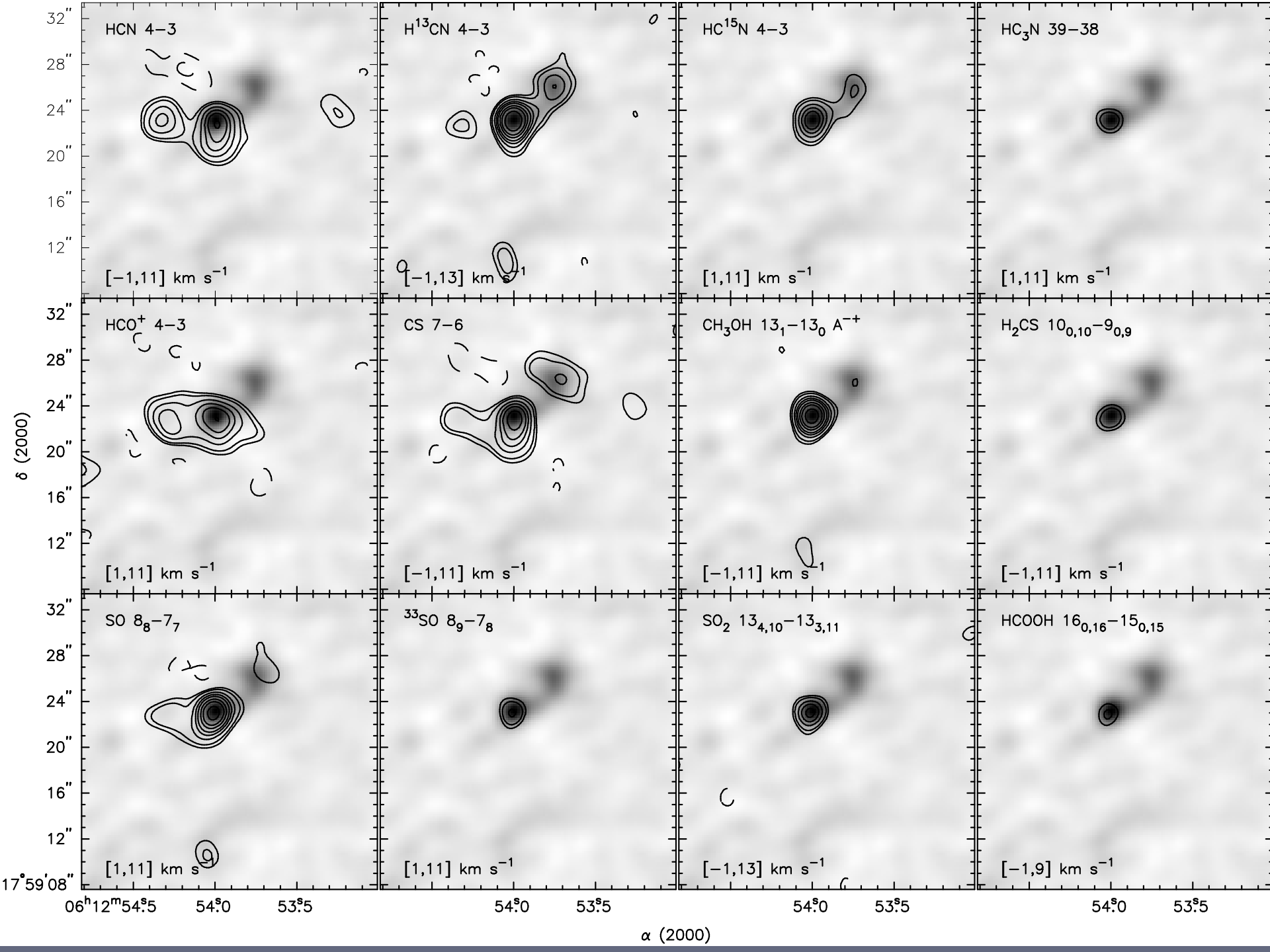
IRAM 30m

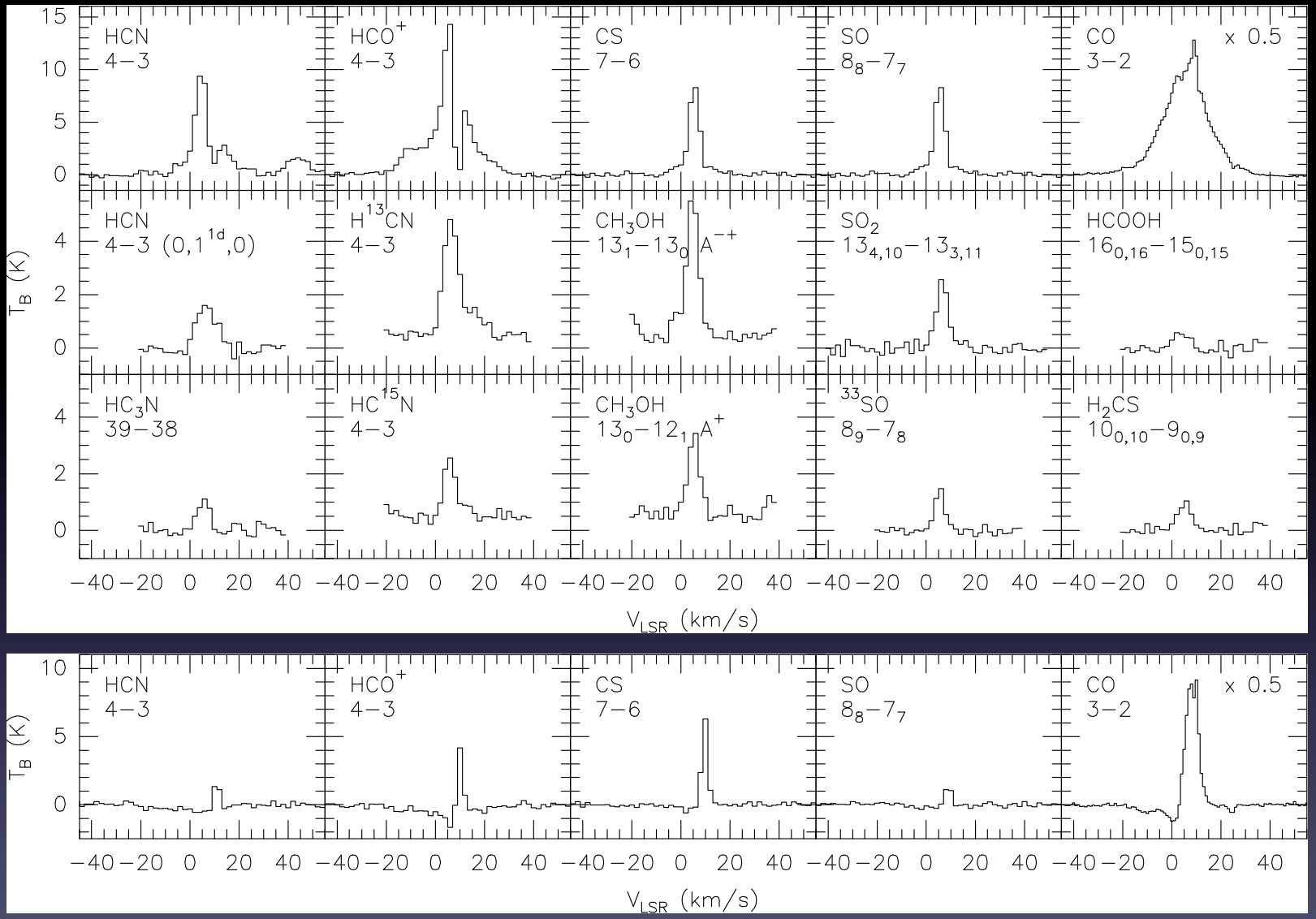
CO(3-2)
CS(7-6)
SiO(5-4)
N_2H^+(3-2)

Continuum

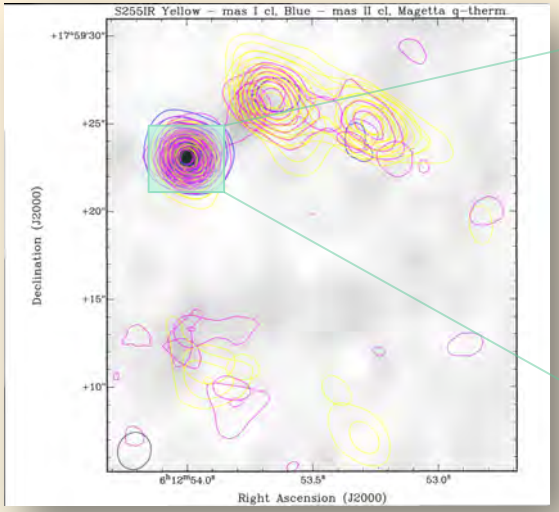

0.8 mm
0.56 Jy
0.50 Jy
32"
28"
24"
20"
16"
12"
17°59'08"
δ (2000)
06h12m54s.5
54s.0
53s.5
α (2000)

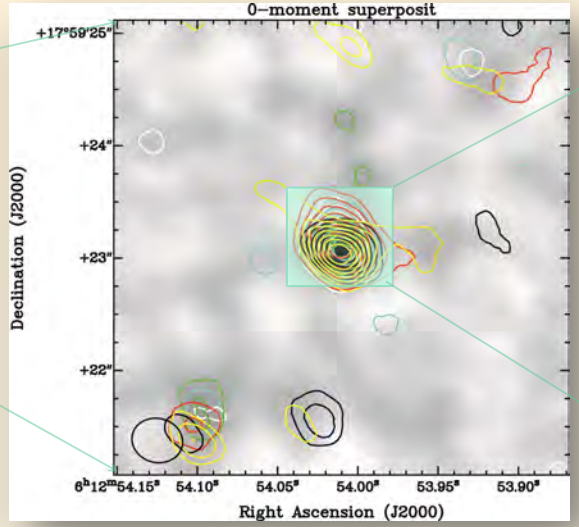

1.3 mm
SMA2
SMA3
SMA1
28"
27"
26"
25"
24"
23"
17°59'22"
δ (2000)
06h12m54s.1
54s.0
53s.9
53s.8
53s.7
α (2000)

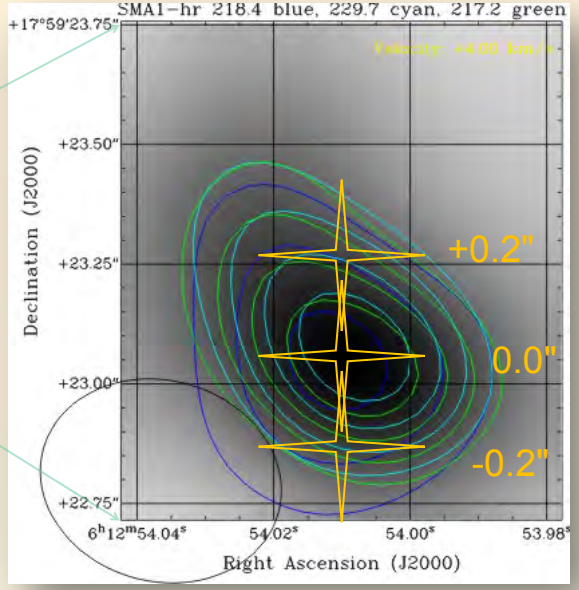

HCN 4–3
[−1,11] km s−1
H13CN 4–3
[−1,13] km s−1
HC15N 4–3
[1,11] km s−1
HC3N 39–38
[1,11] km s−1
HCO+ 4–3
[1,11] km s−1
CS 7–6
[−1,11] km s−1
CH3OH 131–130 A−+
[−1,11] km s−1
H2CS 100,10–90,9
[−1,11] km s−1
SO 88–77
[1,11] km s−1
33SO 89–78
[1,11] km s−1
SO2 134,10–133,11
[−1,13] km s−1
HCOOH 160,16–150,15
[−1,9] km s−1
32″
28″
24″
20″
16″
12″
δ (2000)
17°59′08″
06h12m54.s5
54.s0
53.s5
α (2000)

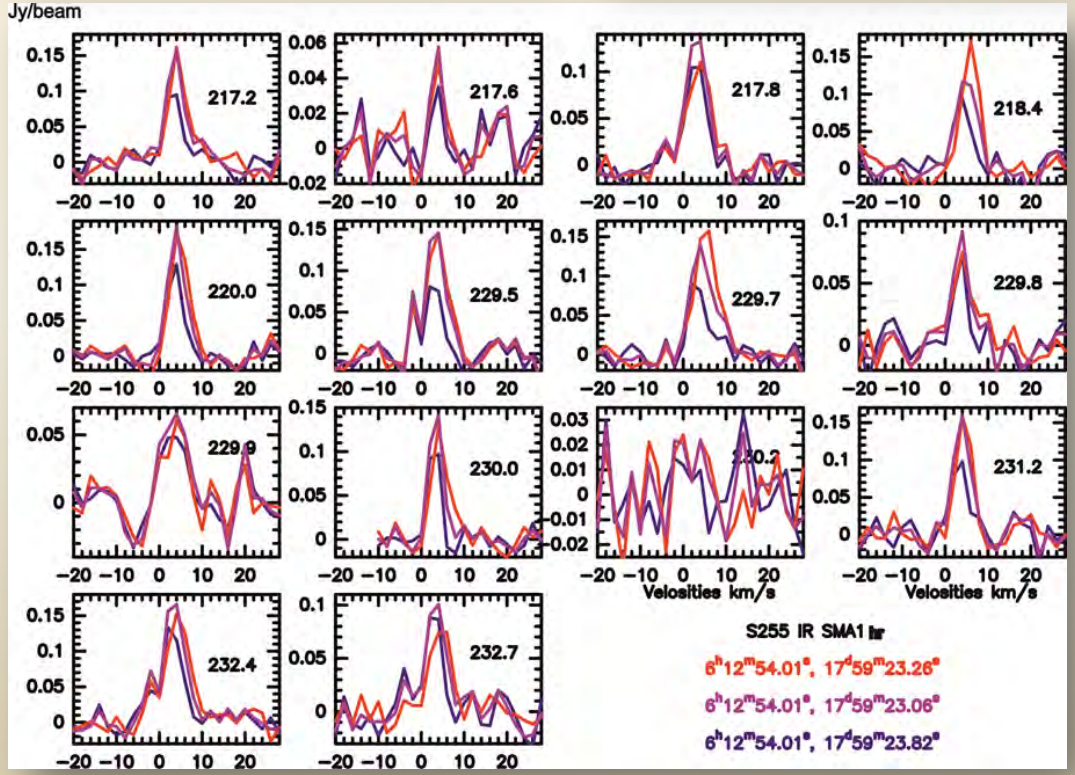


Spectra of several representative molecular transitions towards the SMA1 (upper panel) and SMA2 (lower panel) clump



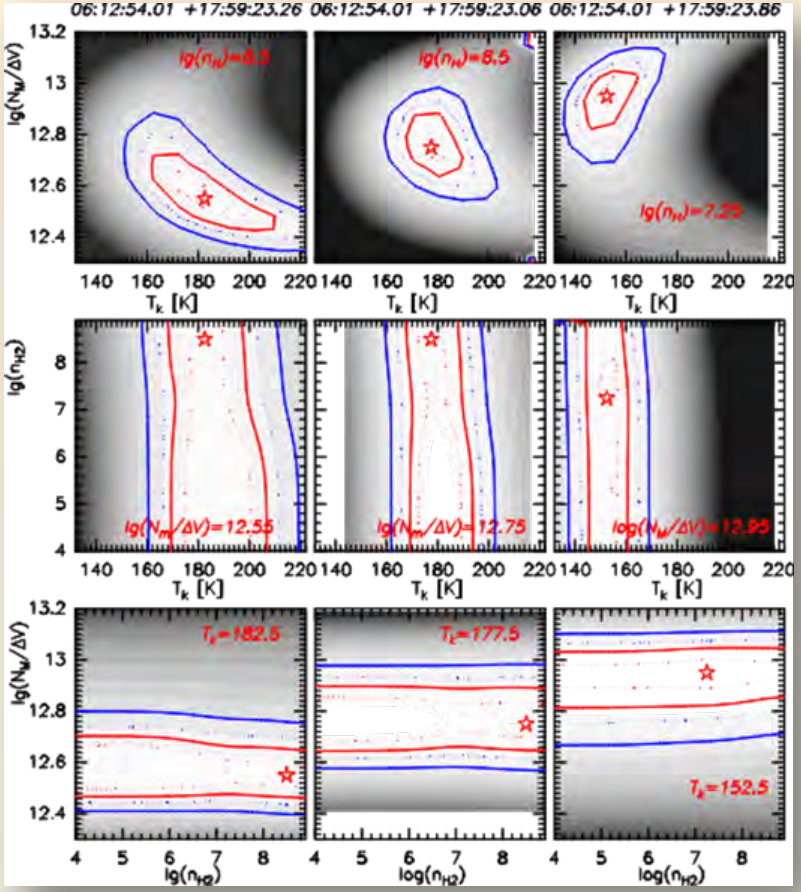


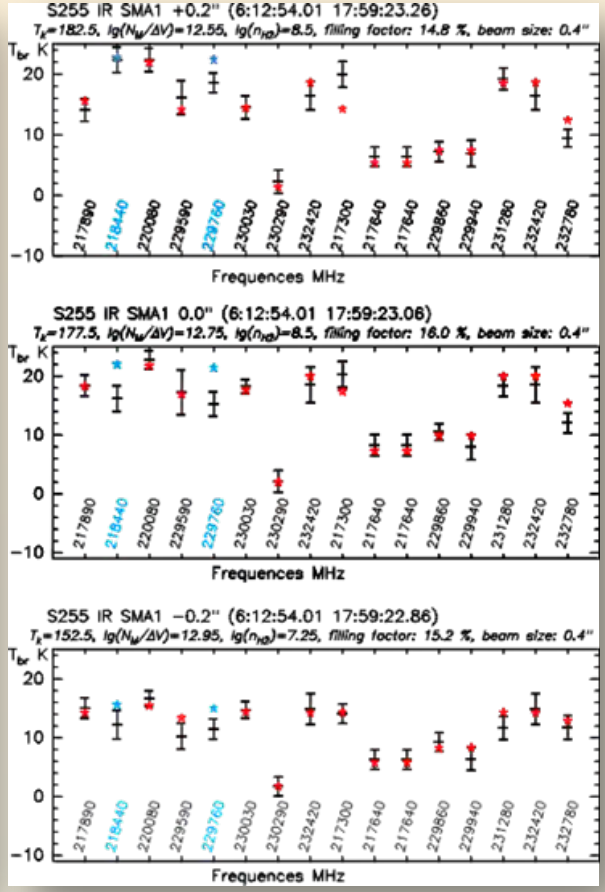




npos	α (2000)	δ (2000)
+0.2"	6:12:54.01	17:59:23.26
0.0"	6:12:54.01	17:59:23.06
-0.2"	6:12:54.01	17:59:22.86

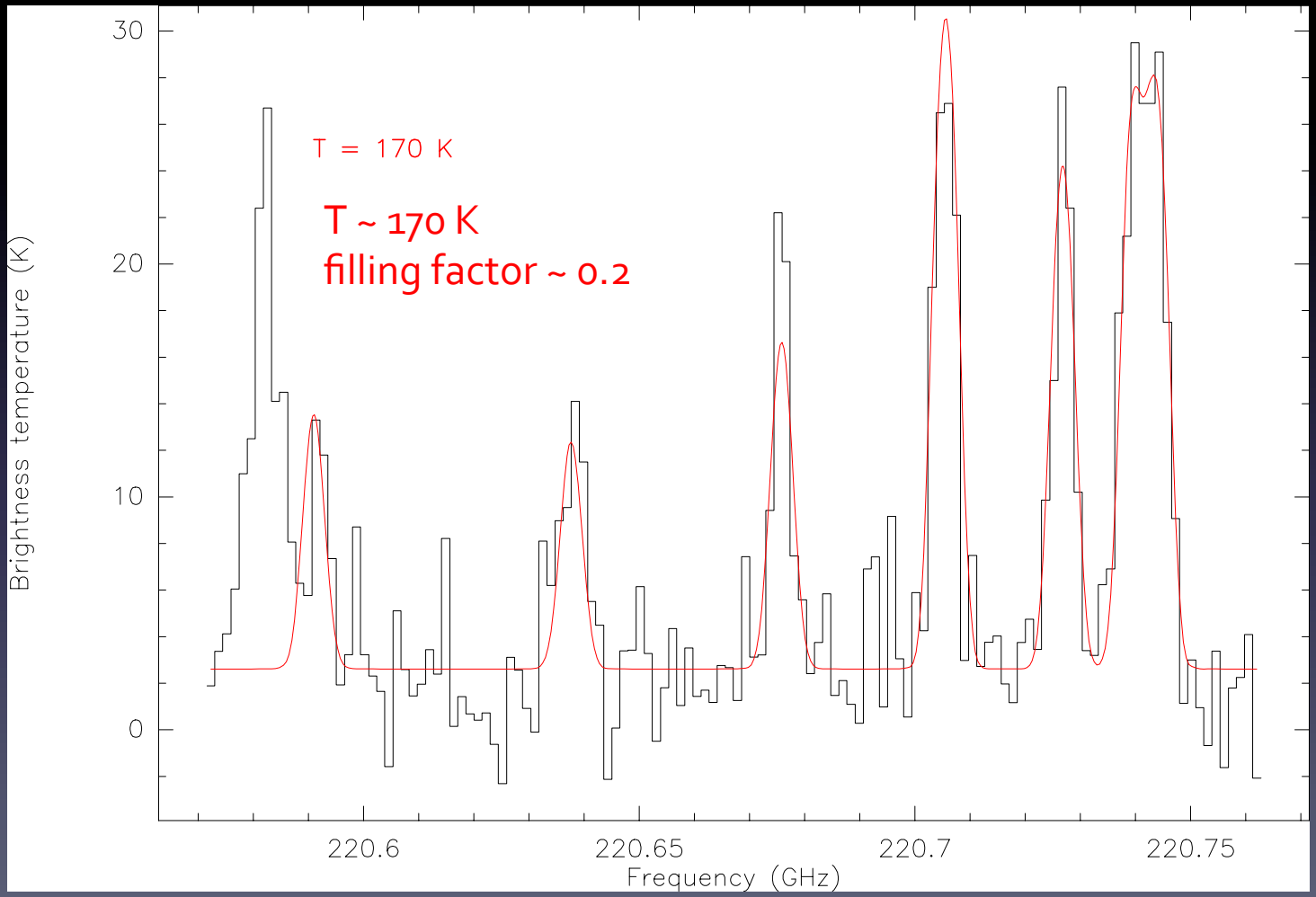
№	Freq. (MHz)	E_{up} (K)
1	217886.39	500.5
2	218440.05	37.6
3	220078.49	88.7
4	229589.07	366.5
5	229758.81	81.2
6	230027.00	31.9
7	230292.73	601.7
8	232419.50	649.2
9	217299.20	373.9
10	217642.86	745.6
11	229864.22	578.6
12	229939.18	578.6
13	231281.15	165.3
14	232418.57	165.4
15	232783.59	446.5





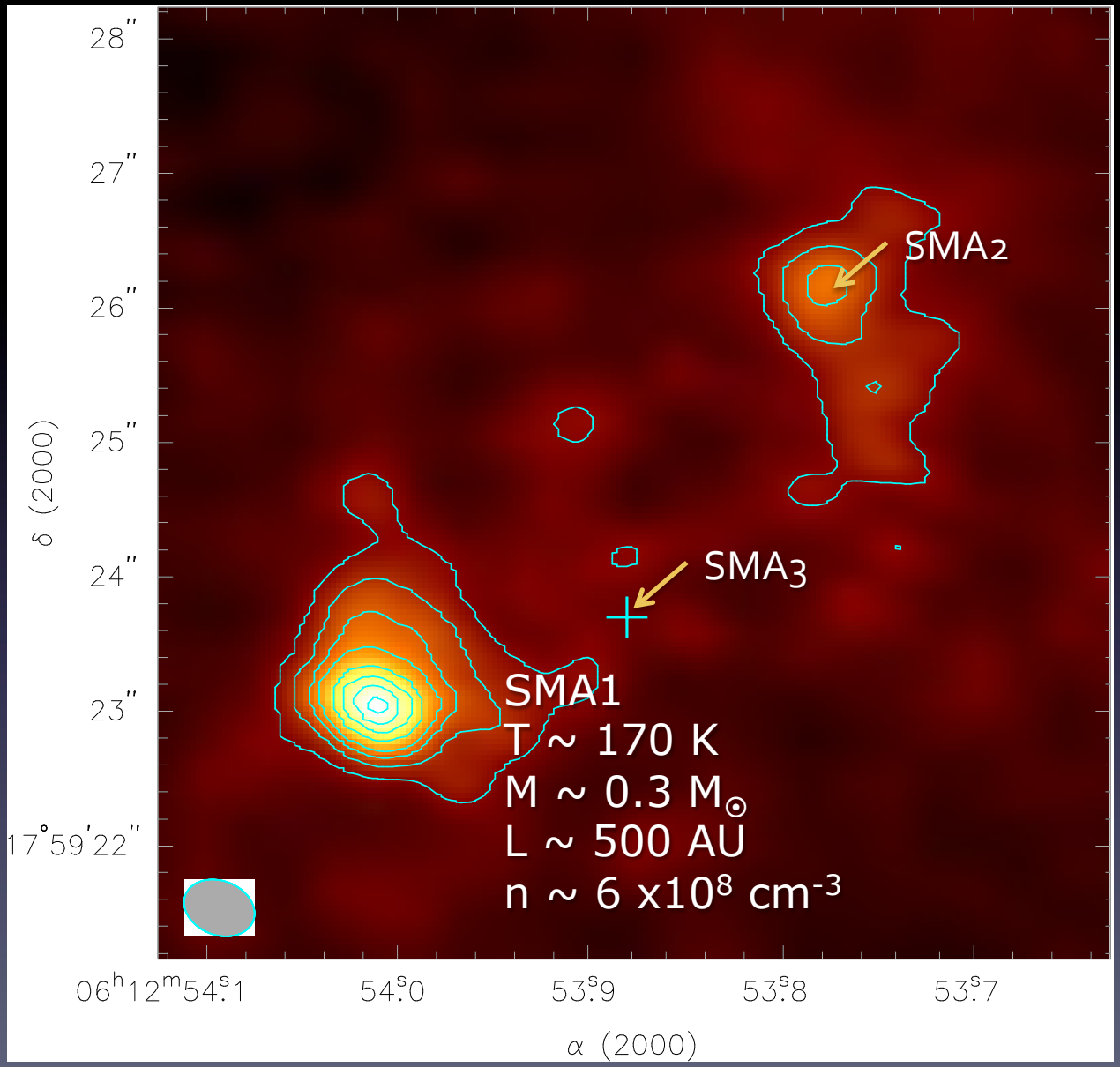
npos	T_k (K)	lg(N_{CH3OH}/ΔV)	lg(n_{H2})	fil. fac. (%)
+0.2"	182.5 (170-200)	12.55 (12.45-12.70)	(3.5-9.0)	14.8
0.0"	177.5 (165-195)	12.75 (12.60-12.98)	(3.5-9.0)	16.0
-0.2"	152.5 (140-165)	12.95 (12.70-13.10)	7.25 (3.5-9.0)	15.2

Hot core temperature from CH_3CN

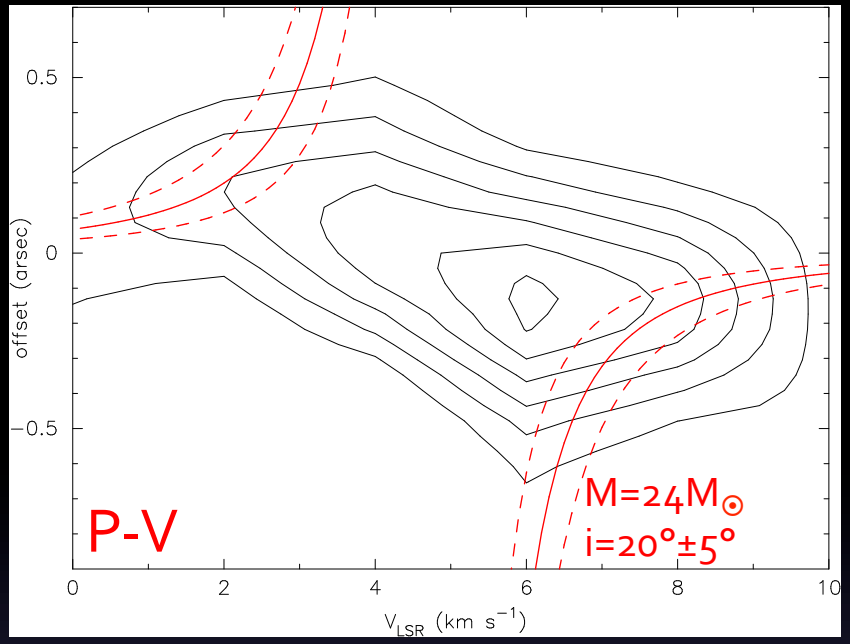


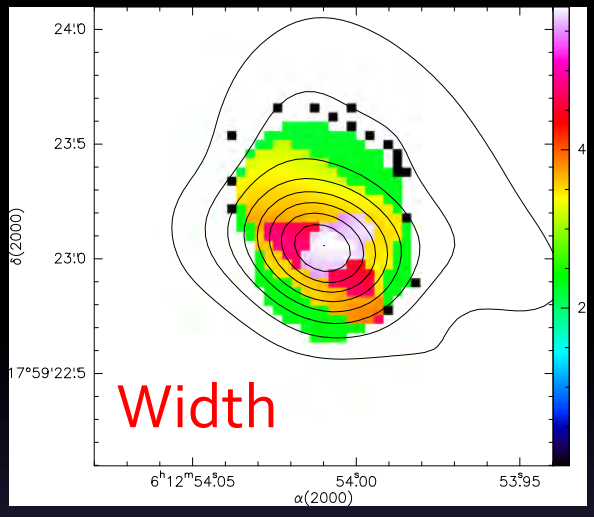
Physical properties

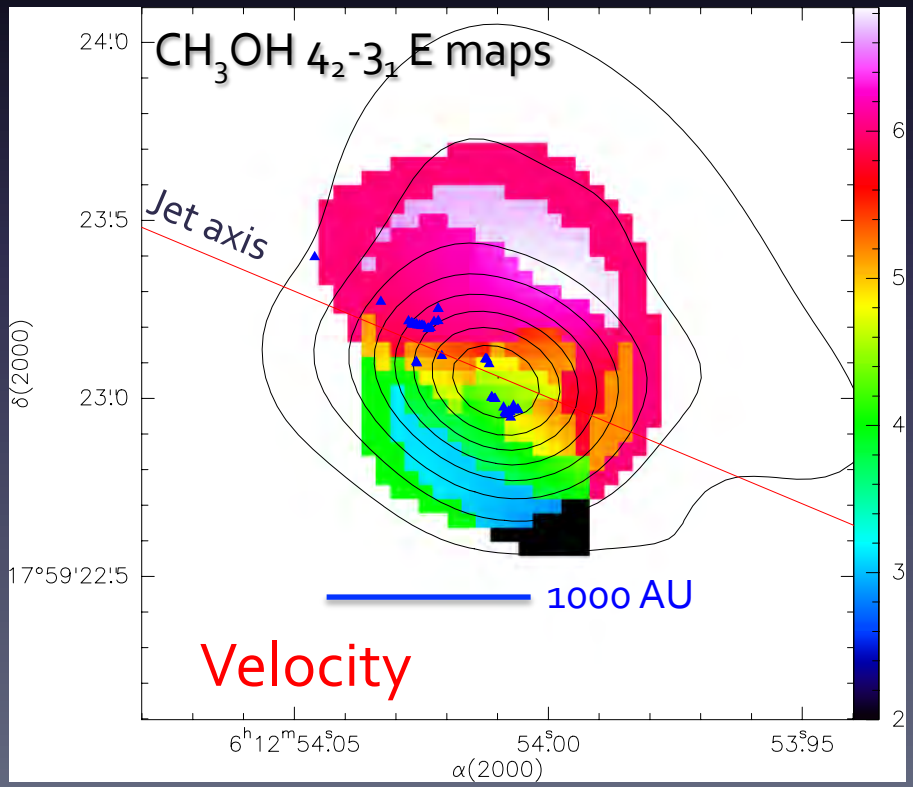
The virial mass of the hot core derived from the line widths is ~ 10 $M_\odot$, which is consistent with the estimated mass of the central star (24 $M_\odot$).

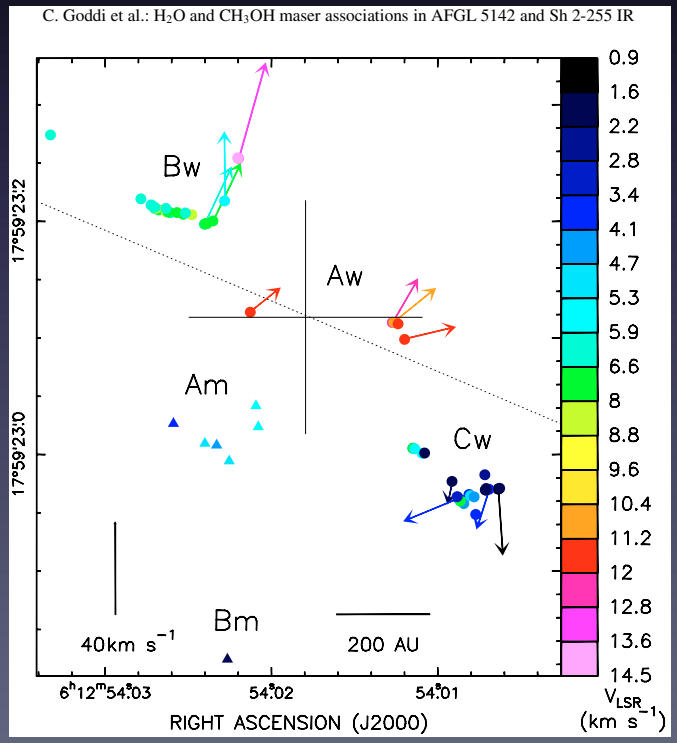


Core rotation



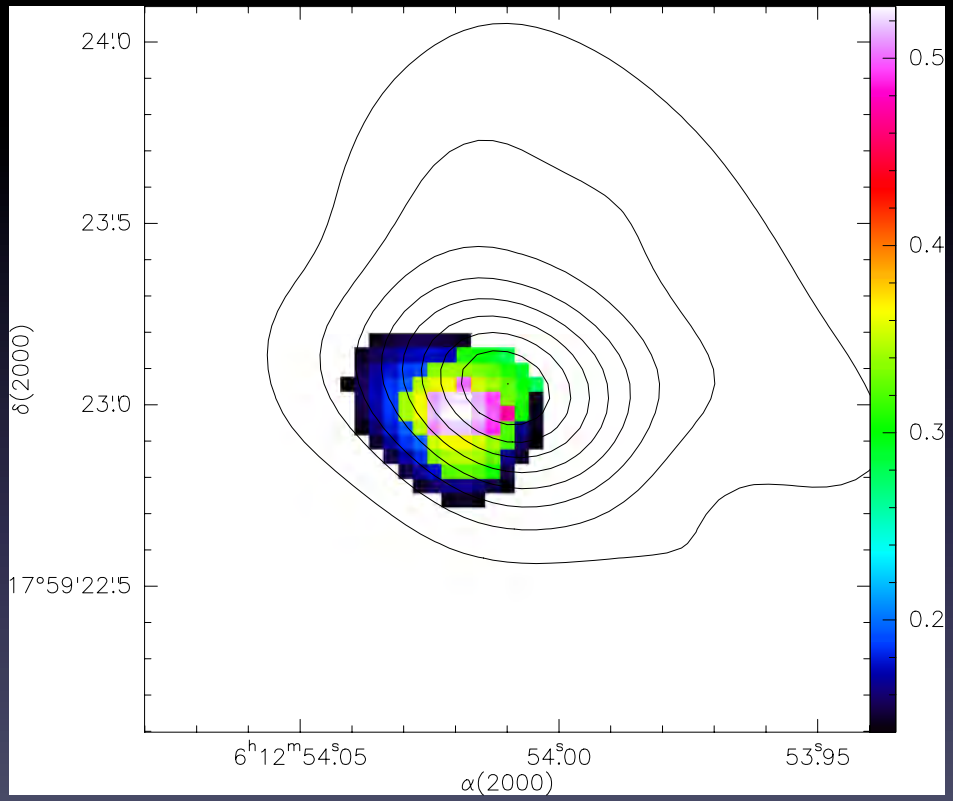




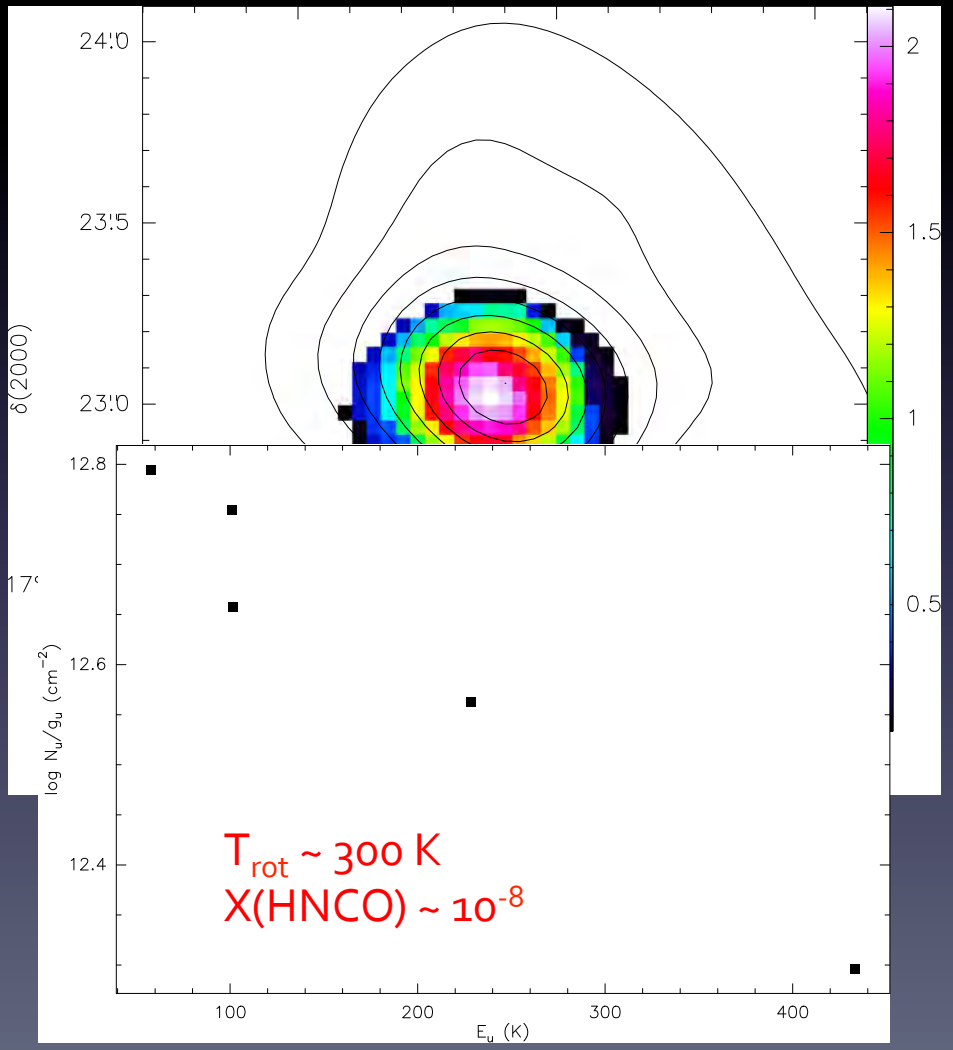


DCN in the hot core

DCN (3-2)

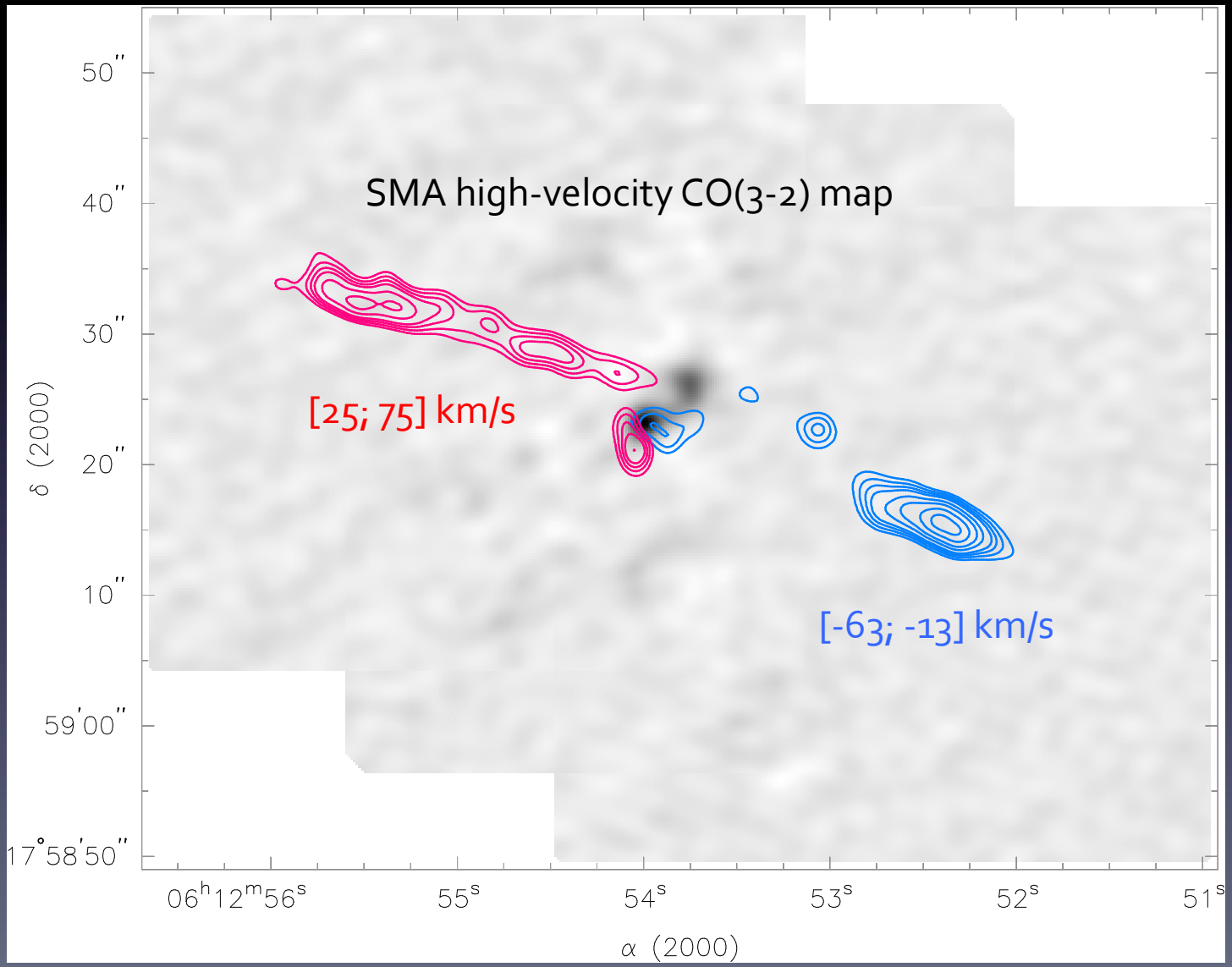


HNCO (10_2-9_2)

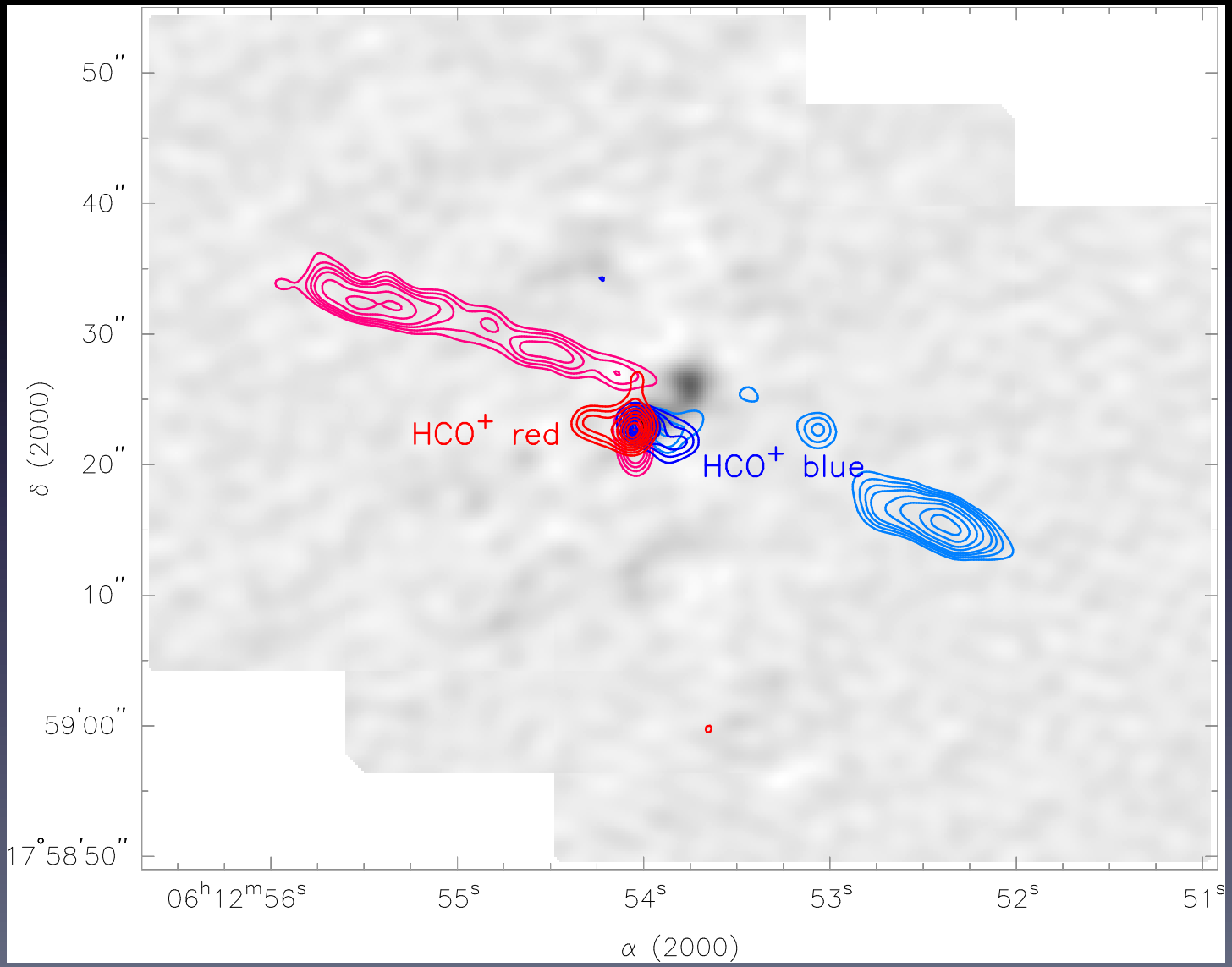


X(DCN) > 10^{-11}.
A low temperature or a very young age are implied.

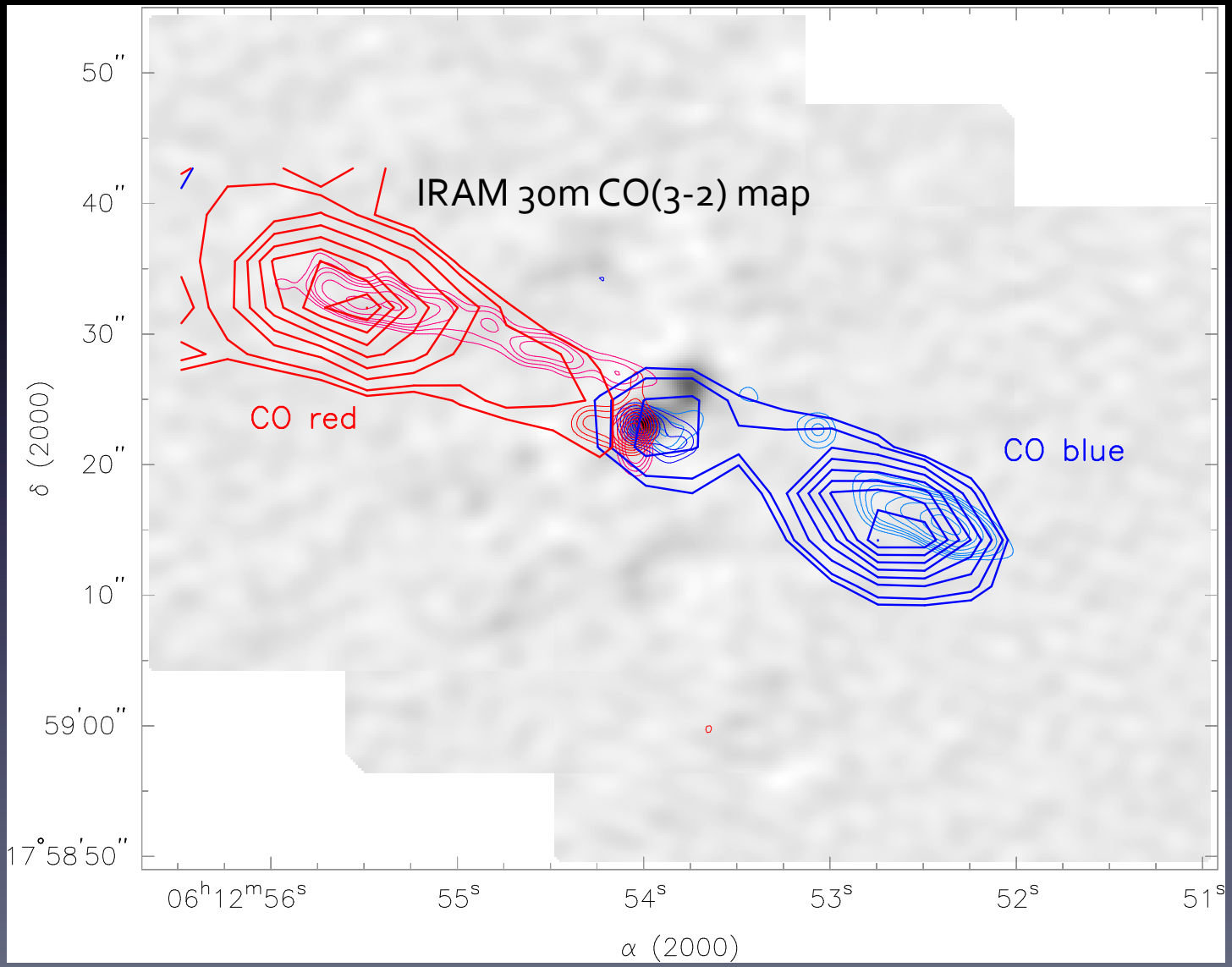
High velocity outflow in S255IR



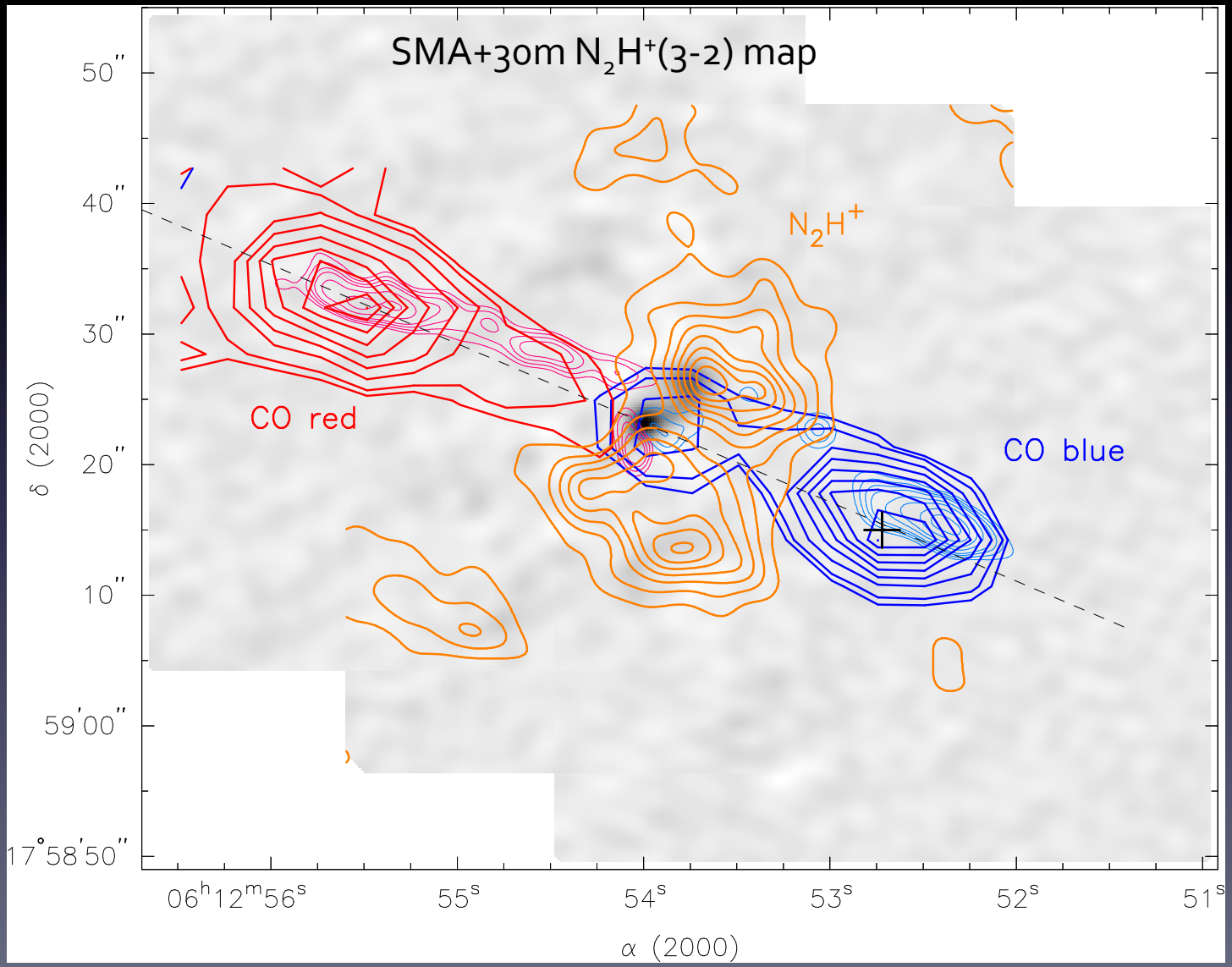
High velocity outflow in S255IR



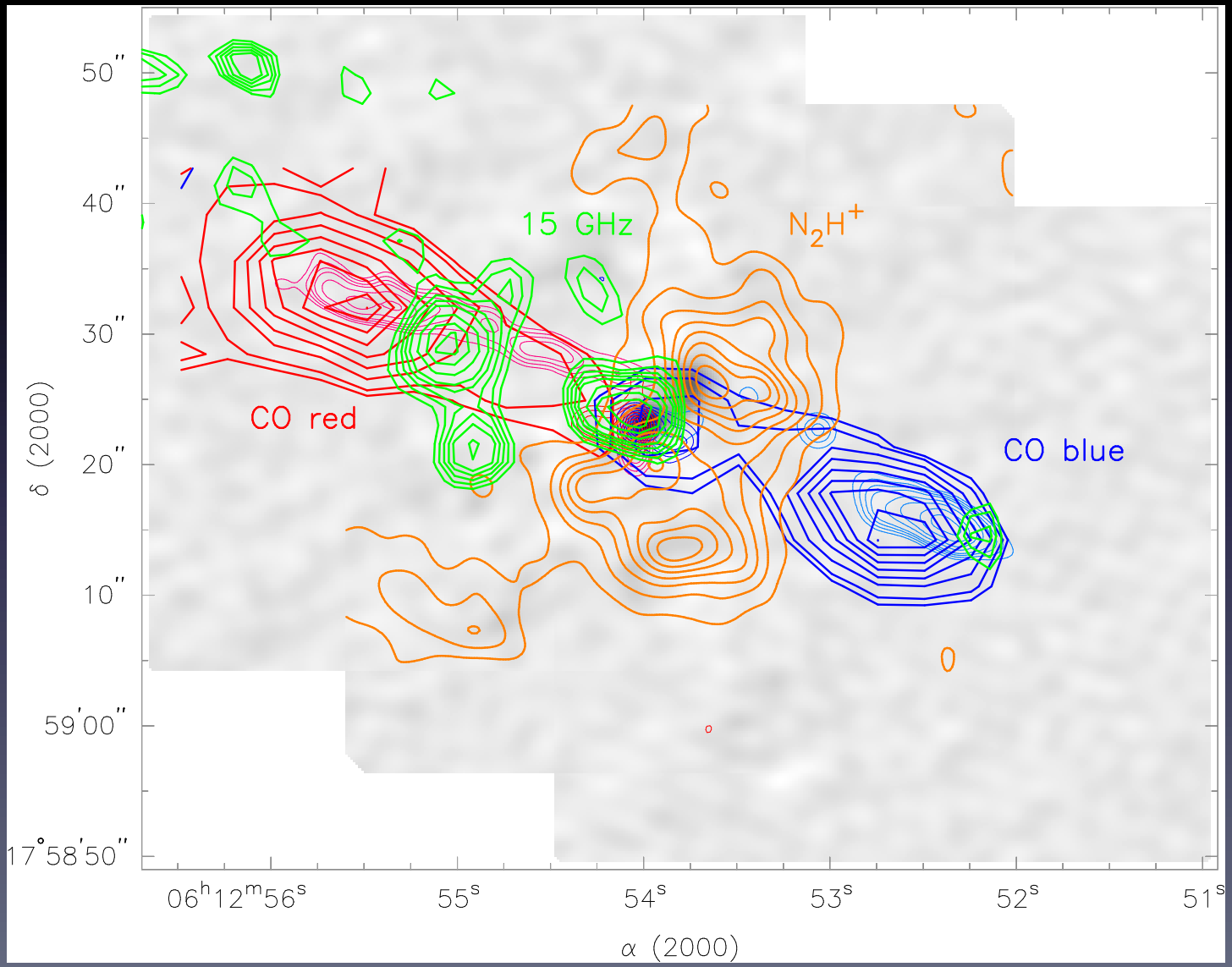
High velocity outflow in S255IR



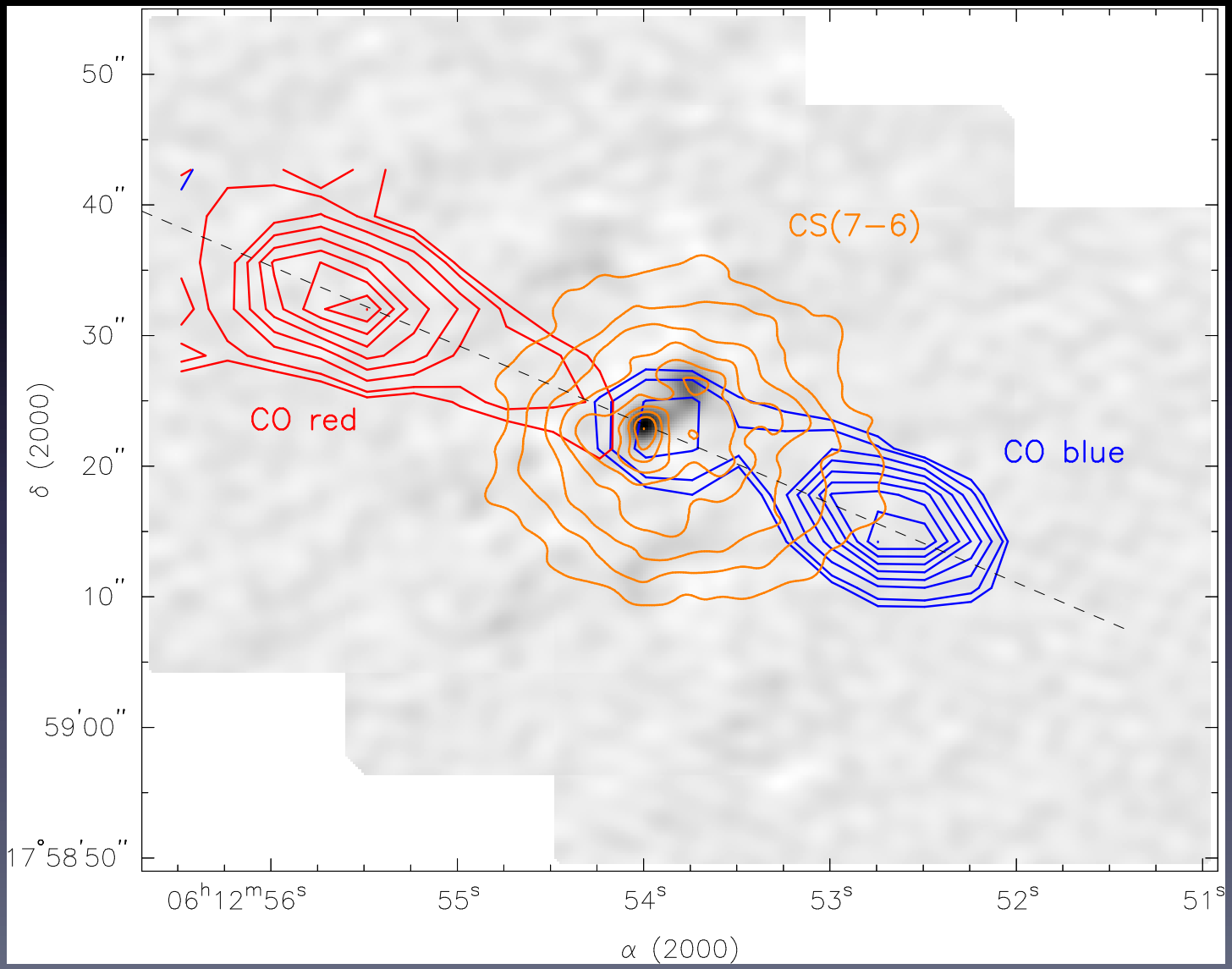
High velocity outflow in S255IR



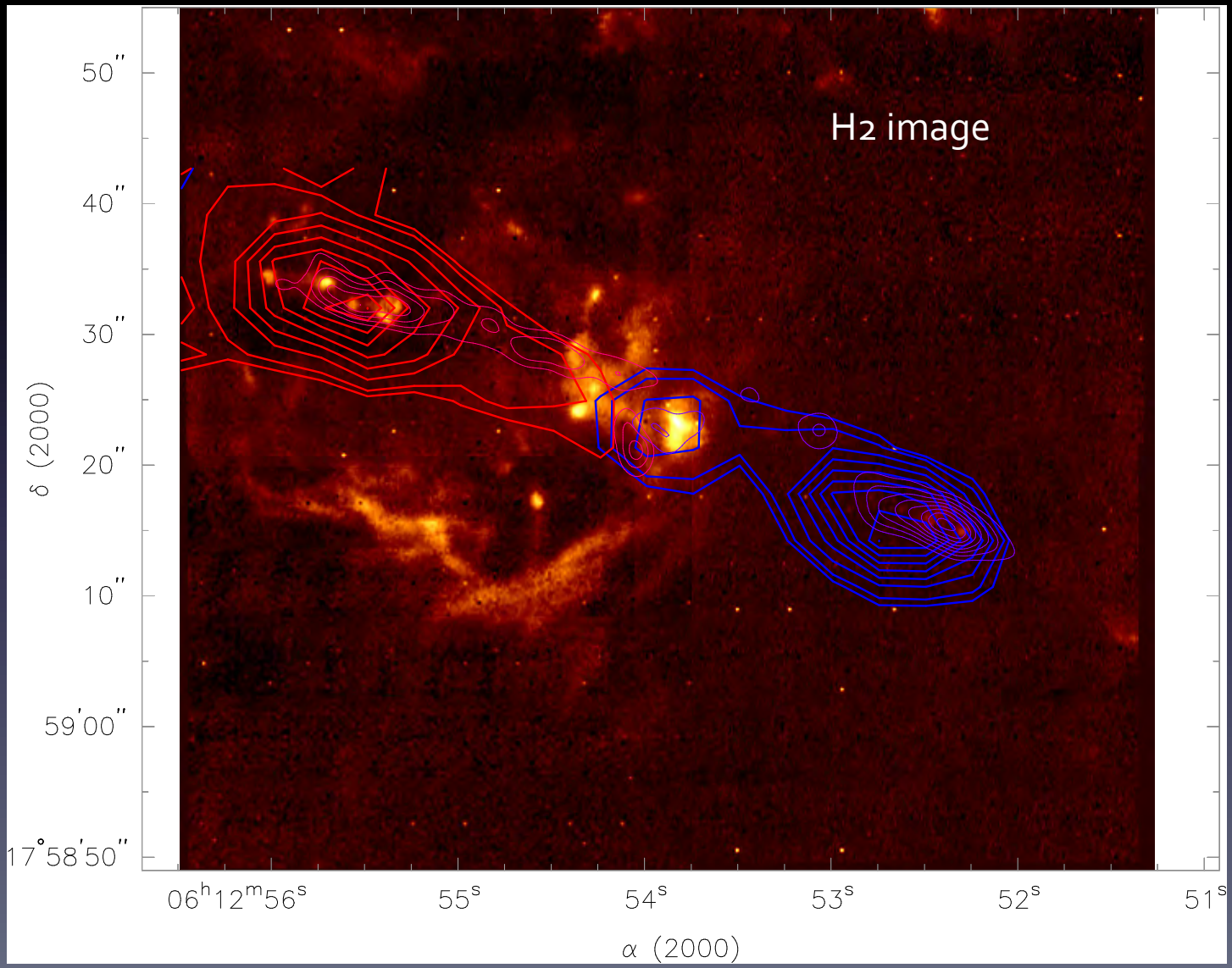
High velocity outflow in S255IR



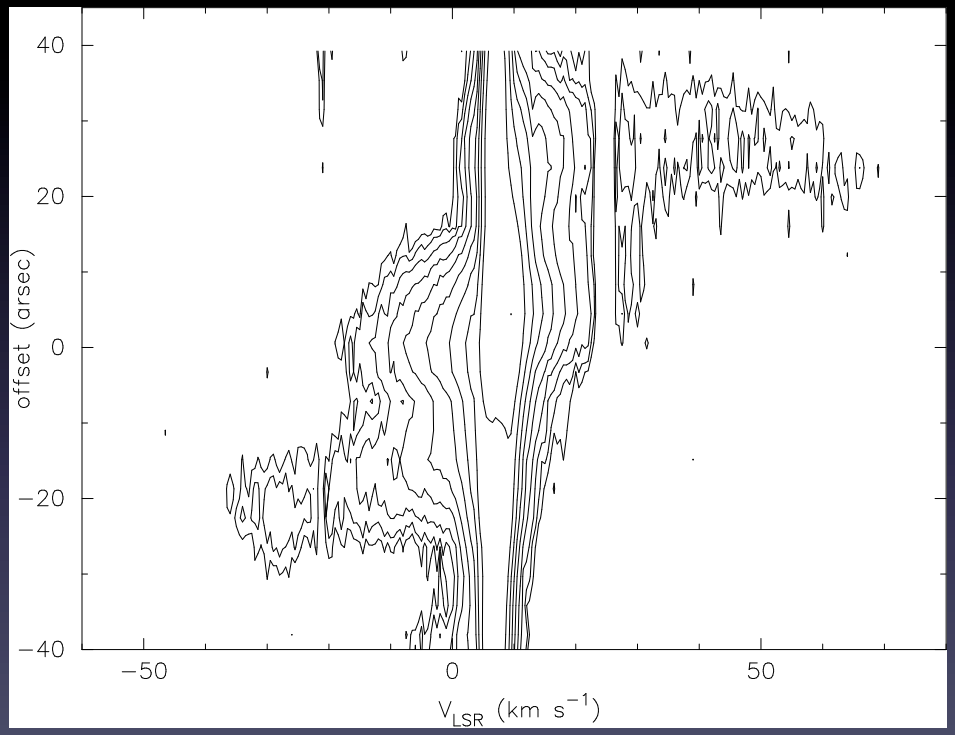
High velocity outflow in S255IR



High velocity outflow in S255IR



The position velocity diagram for the IRAM-30m CO data

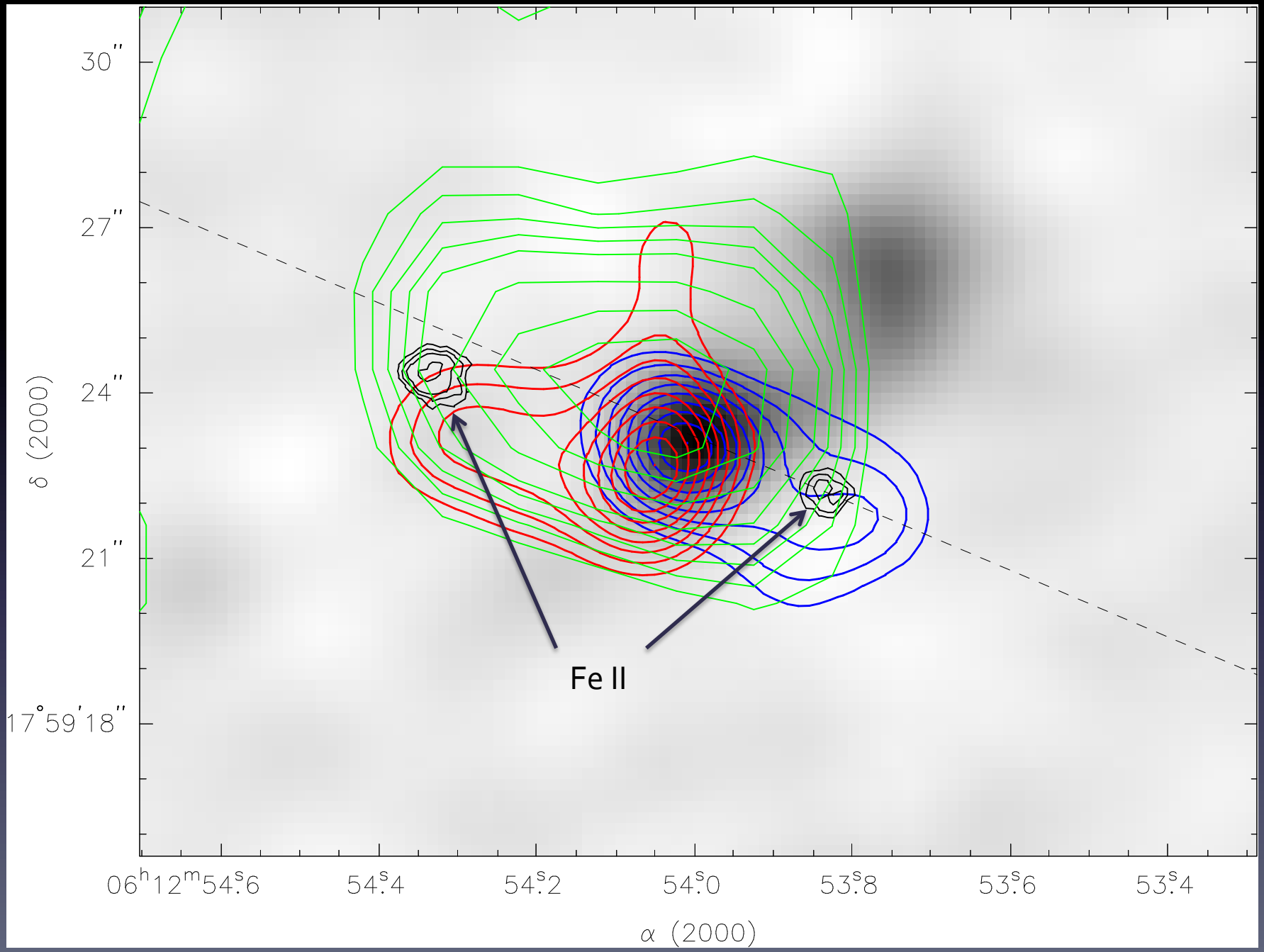


Molecular outflow properties predicted by different models

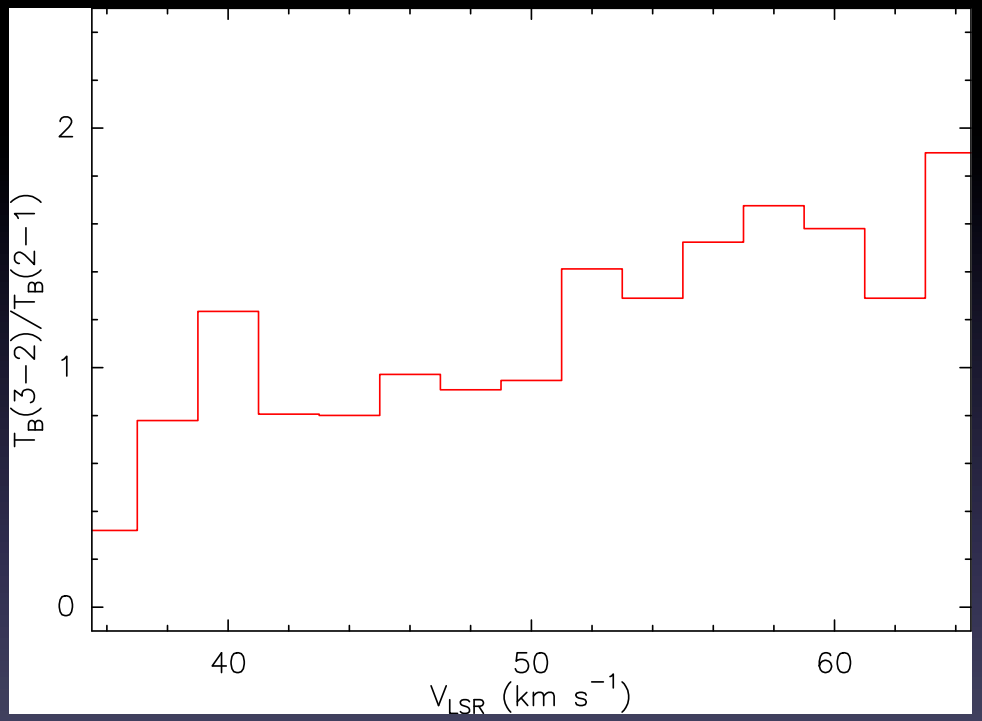
Model	Wind	Predicted property of molecular outflow along axis: Morphology	Velocity (v →)	Temperature (T →)	Momentum[a] (P →)
Turbulent Jet					
Jet Bow Shock					
Wide-angle Wind					
Circulation					

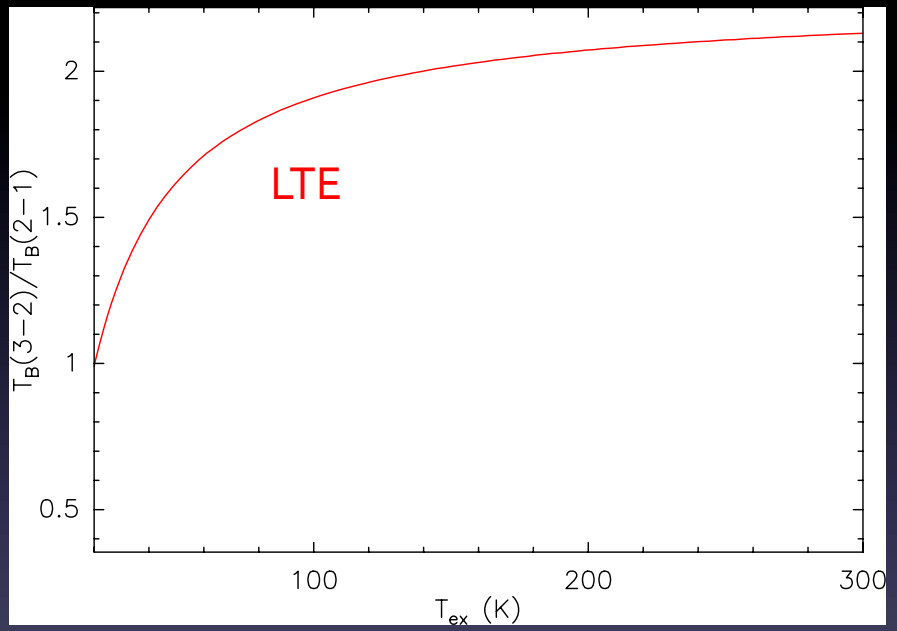
[a] Assuming an underlying density distribution of r^{-1} to r^{-2}.

Arce et al. 2007


30''
27''
24''
21''
δ (2000)
17°59'18''
06h12m54s.6
54s.4
54s.2
54s.0
53s.8
53s.6
53s.4
α (2000)
Fe II

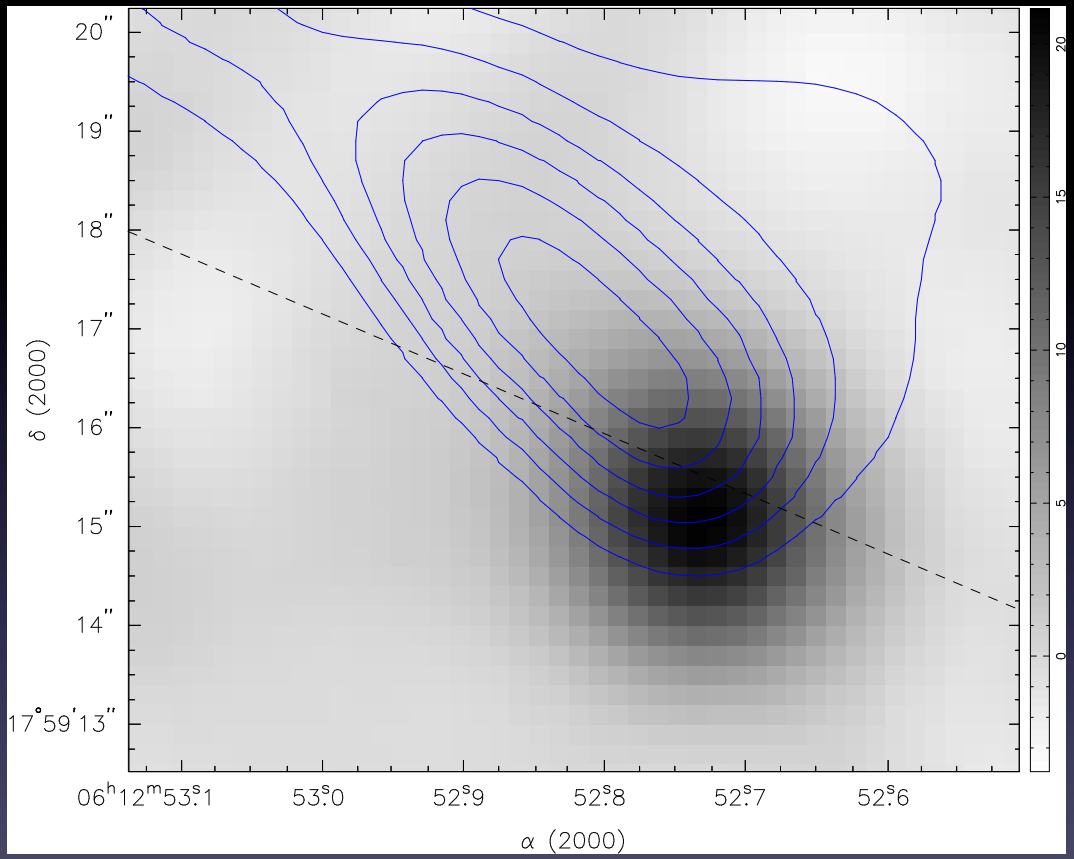
Outflow parameters from the CO(3-2)/CO(2-1) intensity ratio





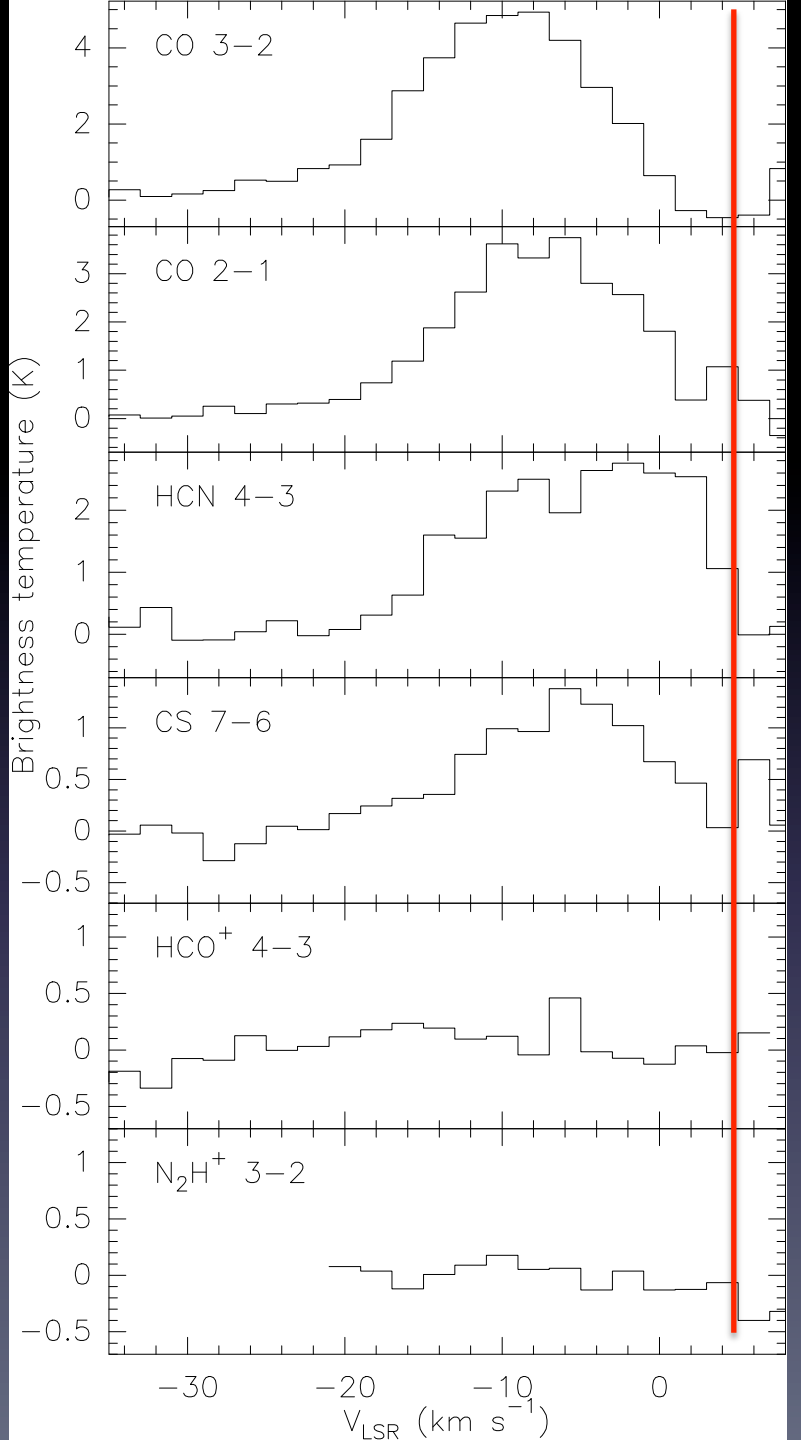
The CO emission is apparently optically thin. High temperature and density are implied. The excitation increases with velocity.

Dense high velocity clump



Grey-scale image – CS(7-6)
Contours – CO(3-2)

$n > 3 \times 10^6$ cm^{-3}, gravitationally unbound



Summary

- The hot (T ~ 200 K) dense (n > 6 10^8 cm^{-3}) core in S255IR-SMA1 probably represents a fragmented (the filling factor ~ 0.2) protostellar disk around the massive (24 $M_\odot$) star with a size of ~500 AU. The mass of the clump is significantly lower than the mass of the central star.
- A strong DCN emission very close to the center of the hot core most probably indicates a presence of a rather large amount (≥ 1 $M_\odot$) of dense cold (T < 80 K) material here.
- The CO outflow morphology obtained from combination of the SMA and IRAM-30m data is significantly different from that derived from the SMA data alone. The CO emission detected with the SMA traces only one boundary of the outflow and leads to a rather distorted picture.
- The outflow is most probably driven by jet bow shock. There are signs of episodic ejections.
- The proper motions of the water masers excited along the jet imply some misalignment of the jet and rotation axis of the material in the outer parts of the clump.
- The outflow strongly affects the chemical composition of the surrounding medium. The N_2H^+ molecules are destroyed.

THANK YOU!