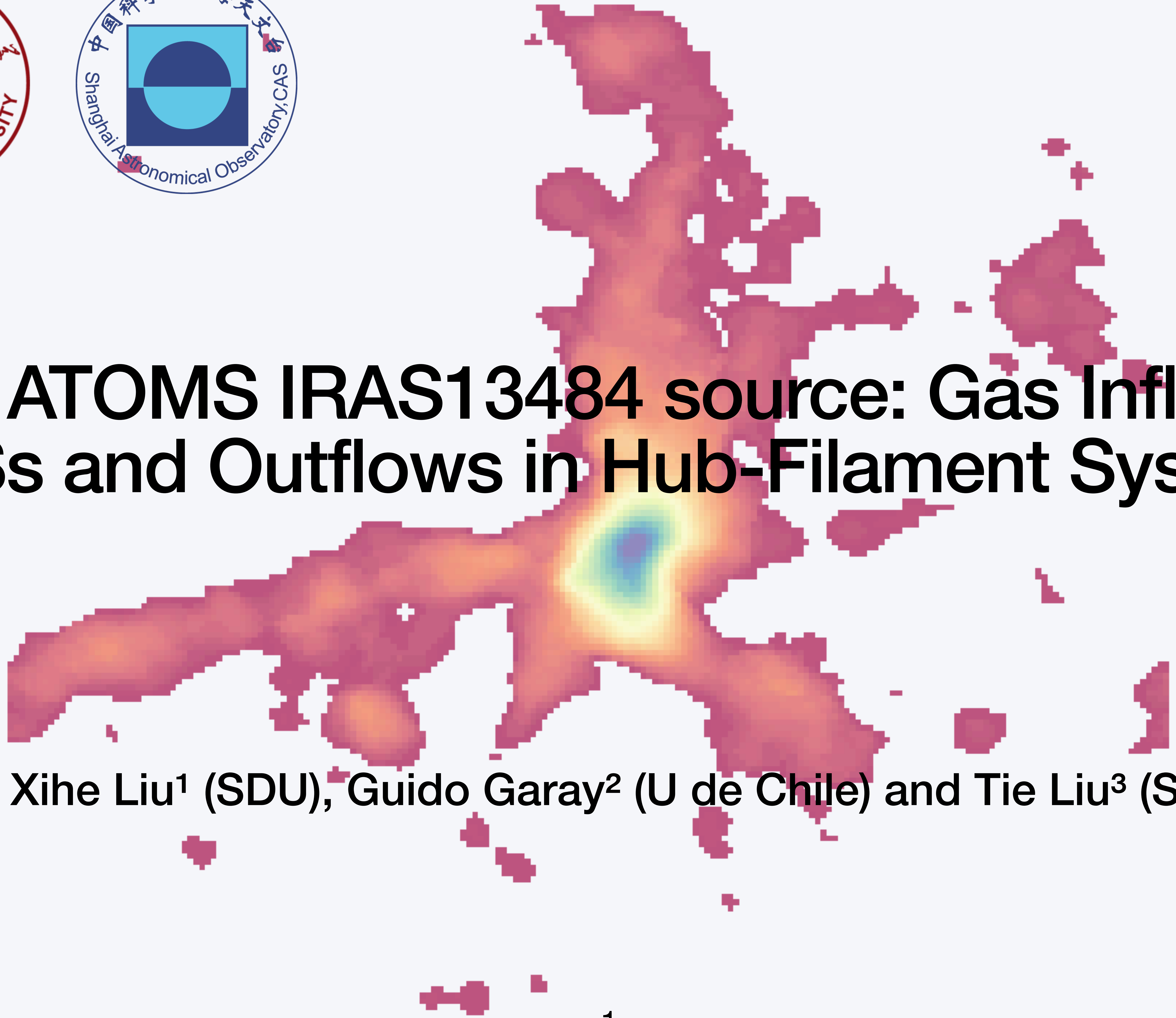
ALMA - ATOMS IRAS13484 source: Gas Inflow along HFSs and Outflows in Hub-Filament Systems



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Outline

1. Briefly Introduction about Previously Study of IRAS13484
2. Work Progress of IRAS13484 with QUARKS/ATOMS Data

   2.1 HFSs identified by $H^{13}CO^+$ and Gas Inflows

   2.2 High Velocity Outflows Identification

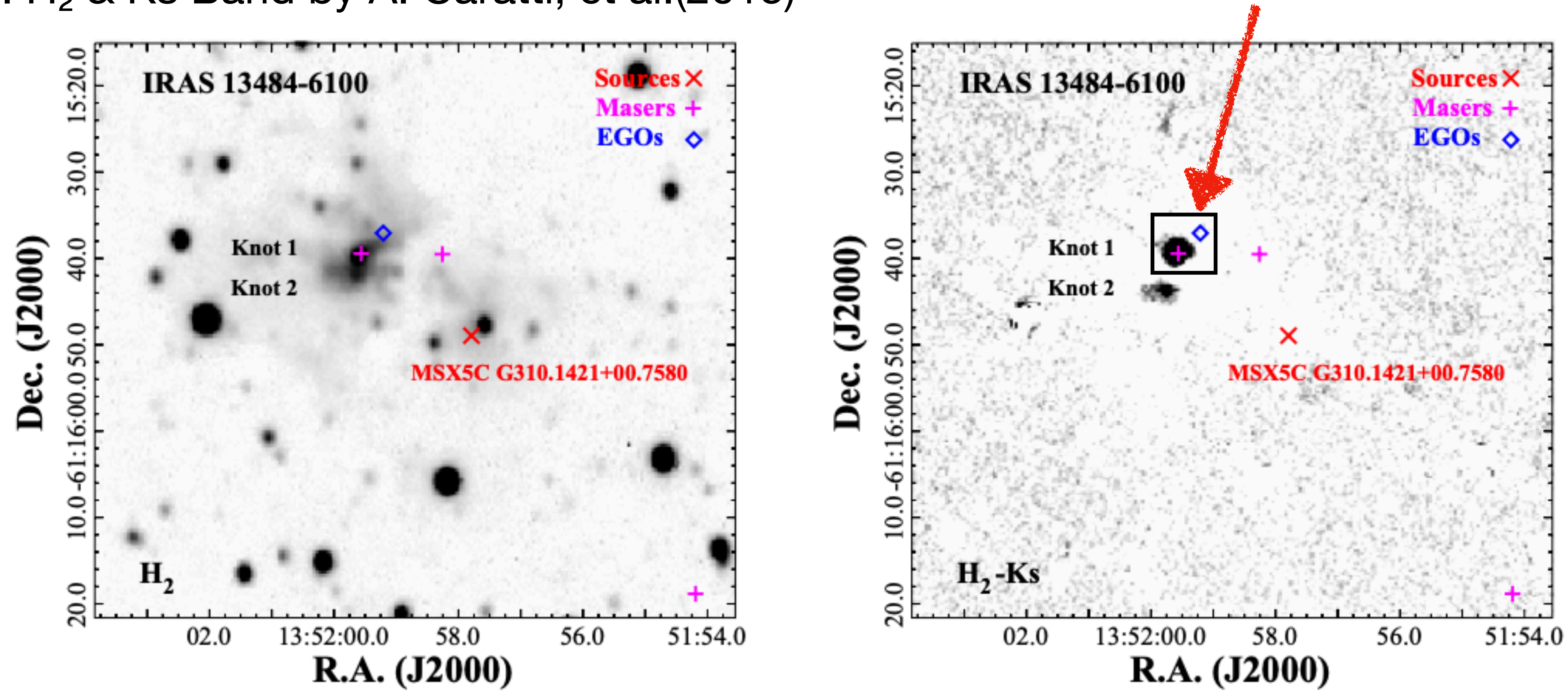
   2.3 Hot Core identified by CH_3OH

3. Future Work Plan

Briefly Introduction about Previously Study of IRAS13484

1. H_2 & Ks Band by A. Caratti, et al.(2015)

EGO emission partially overlaps with Knot 1



Species	Term	$\lambda(\mu m)$	$F \pm \Delta F (10^{-15}$ erg cm^{-2} s$^{-1})$ Knot 1	Knot 2	YSO**
[Fe II]	$a^4D_{5/2}-a^4F_{9/2}$	1.534	4 ± 1	···	···
[Fe II]	$a^4D_{3/2}-a^4F_{7/2}$	1.600	6 ± 1	···	···
[Fe II]	$a^4D_{7/2}-a^4F_{9/2}$	1.644	39 ± 1	9 ± 1	11 ± 1
[Fe II]	$a^4D_{1/2}-a^4F_{5/2}$	1.664	6 ± 1	···	2.6 ± 0.8
[Fe II]	$a^4D_{5/2}-a^4F_{7/2}$	1.677	8 ± 1	···	···
H_2	1–0 S(7)	1.748	11 ± 1	3 ± 1	3 ± 1
H_2	1–0 S(6)	1.788	5 ± 1	···	···
[Fe II]	$a^4D_{7/2}-a^4F_{7/2}$	1.810	7 ± 2*	···	···
	$+a^4P_{5/2}-a^4D_{7/2}$	1.811	14 ± 2	···	···
H_2	1–0 S(3)	1.958	19 ± 4	6 ± 3*	6 ± 3*
H_2	1–0 S(2)	2.034	23 ± 2	5 ± 2*	5 ± 2*
H_2	3–2 S(5)	2.066	3 ± 1	···	···
H_2	2–1 S(3)	2.073	8 ± 1	···	···
H_2	1–0 S(1)	2.122	64 ± 1	11 ± 1	12 ± 1
H I	Brγ	2.166	4 ± 1	···	···
H_2	3–2 S(3)	2.201	3 ± 1	···	···
H_2	1–0 S(0)	2.223	22 ± 1	5 ± 1	6 ± 1
H_2	2–1 S(1)	2.248	9 ± 1	···	···
H_2	2–1 S(0)	2.355	4 ± 2*	···	···
H_2	1–0 Q(1)	2.407	68 ± 5	11 ± 5*	15 ± 5
H_2	1–0 Q(2)	2.413	29 ± 5	···	···
H_2	1–0 Q(3)	2.424	65 ± 5	11 ± 5*	13 ± 5*
H_2	1–0 Q(4)	2.437	24 ± 5	···	···
H_2	1–0 Q(5)	2.455	48 ± 5	···	···
H_2	1–0 Q(6)	2.476	14 ± 6*	···	···
H_2	1–0 Q(7)	2.500	35 ± 10	···	···

A. Caratti, et al.(2015)

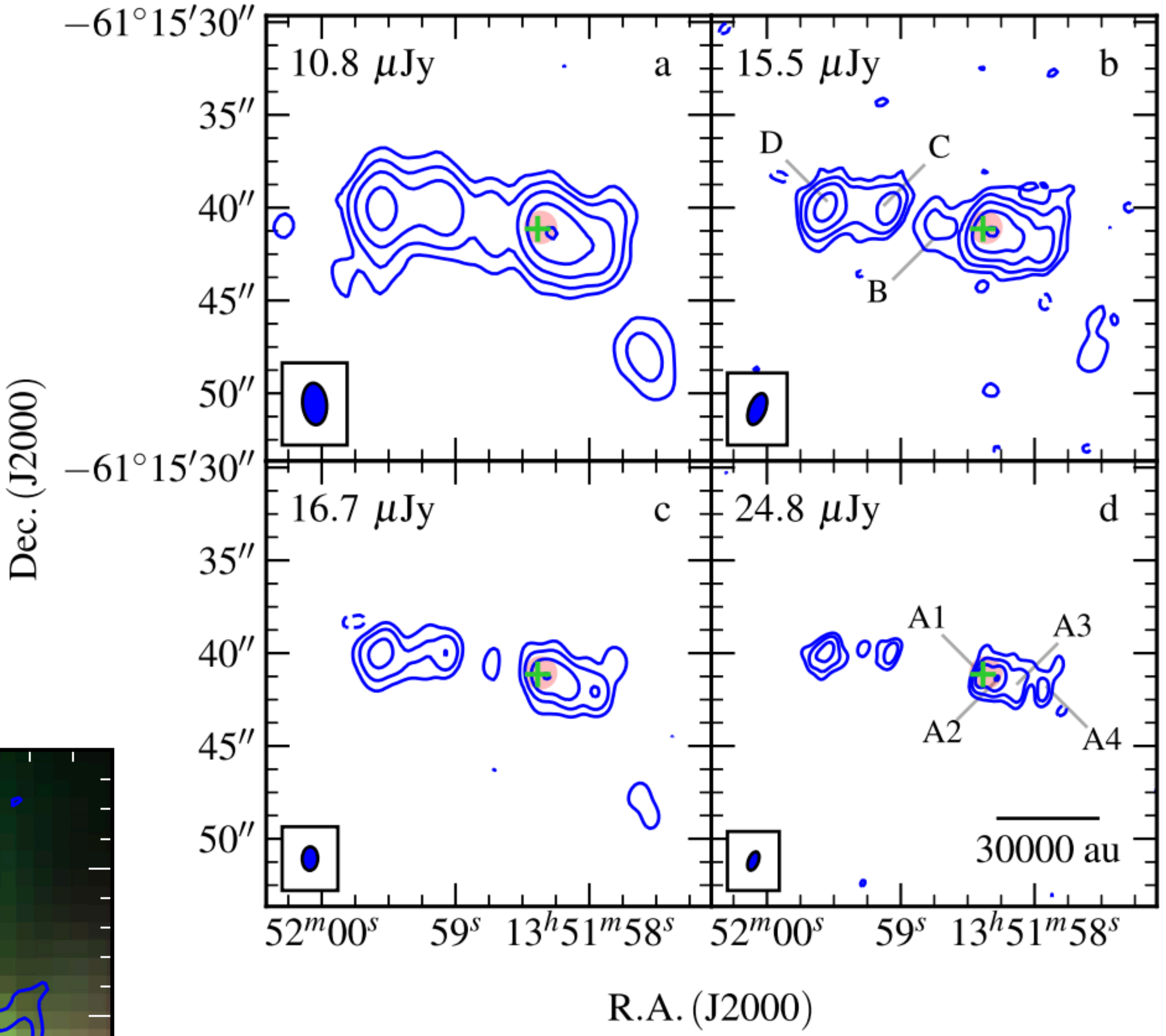
Distance: 5.4 Kpc; Bolometric luminosities : 4.3 solar luminosity

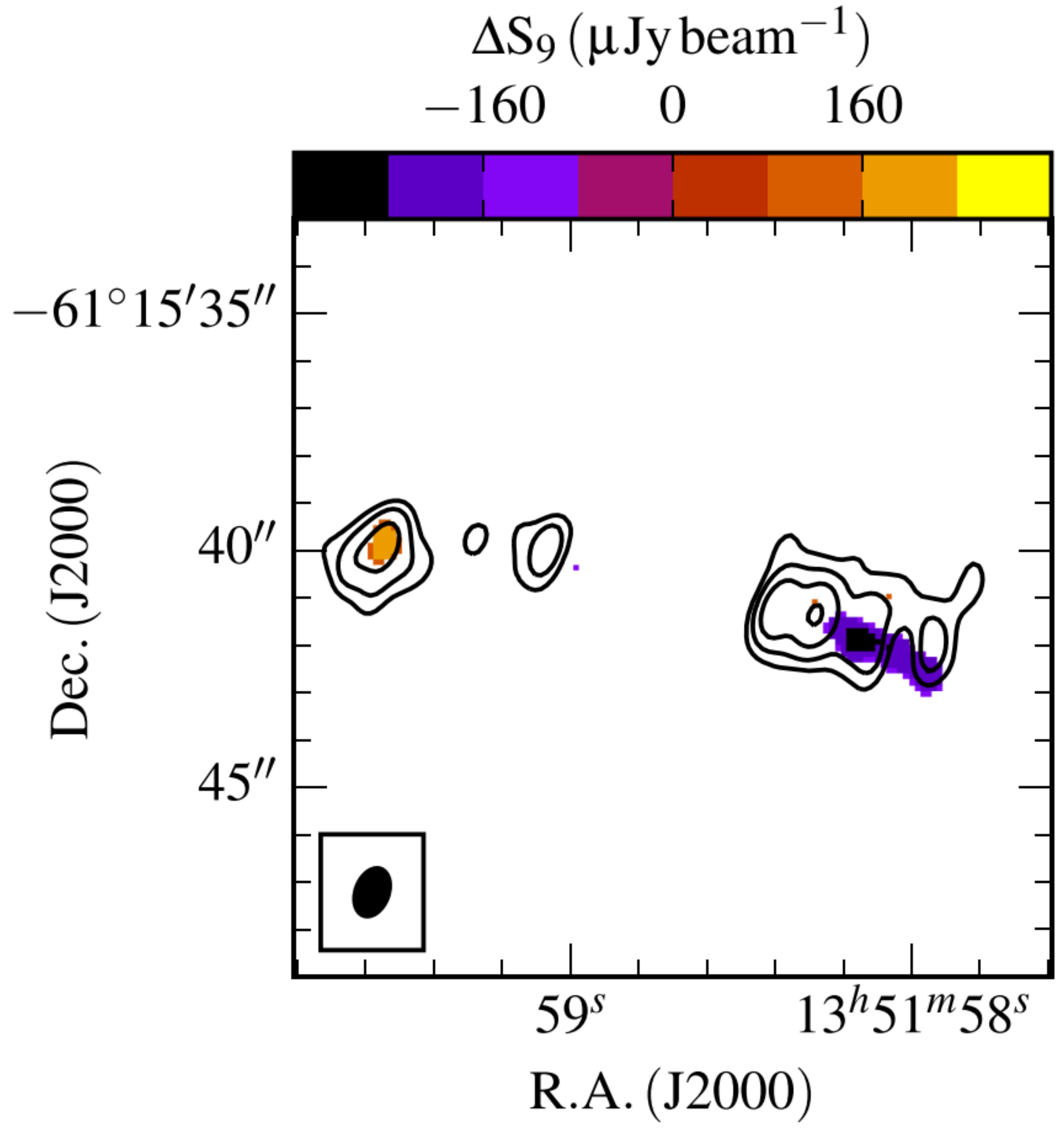
OUTFLOW	KNOT–ID	α(2000.0) ($^{h\ m\ s}$)	δ(2000.0) ($^{\circ\ \prime\ \prime\prime}$)	$F(2.12\ \mu m) \pm \Delta F$ $(10^{-15}$ erg s^{-1} cm$^{-2})$	Area $(10^{-10}$ sr)	A_V (mag)	$T(H_2)$ (K)	$N(H_2)$ (cm^{-2})	$M(H_2)$ $(M_\odot)$
IRAS 13484-6100	knot 1	13:51:59.6	−61:15:39.6	96 ± 2	7.74	15 ± 5	2580 ± 120	1.5×10^{19}	3.4
IRAS 13484-6100	knot 2	13:51:59.8	−61:15:44.0	11 ± 1	0.50	15 ± 5	2700 ± 500	3.1×10^{18}	0.04
IRAS 13484-6100	YSO	13:51:58.2	−61:15:42.3	5 ± 1	0.50	15 ± 5	2700 ± 400	3.3×10^{18}	0.05

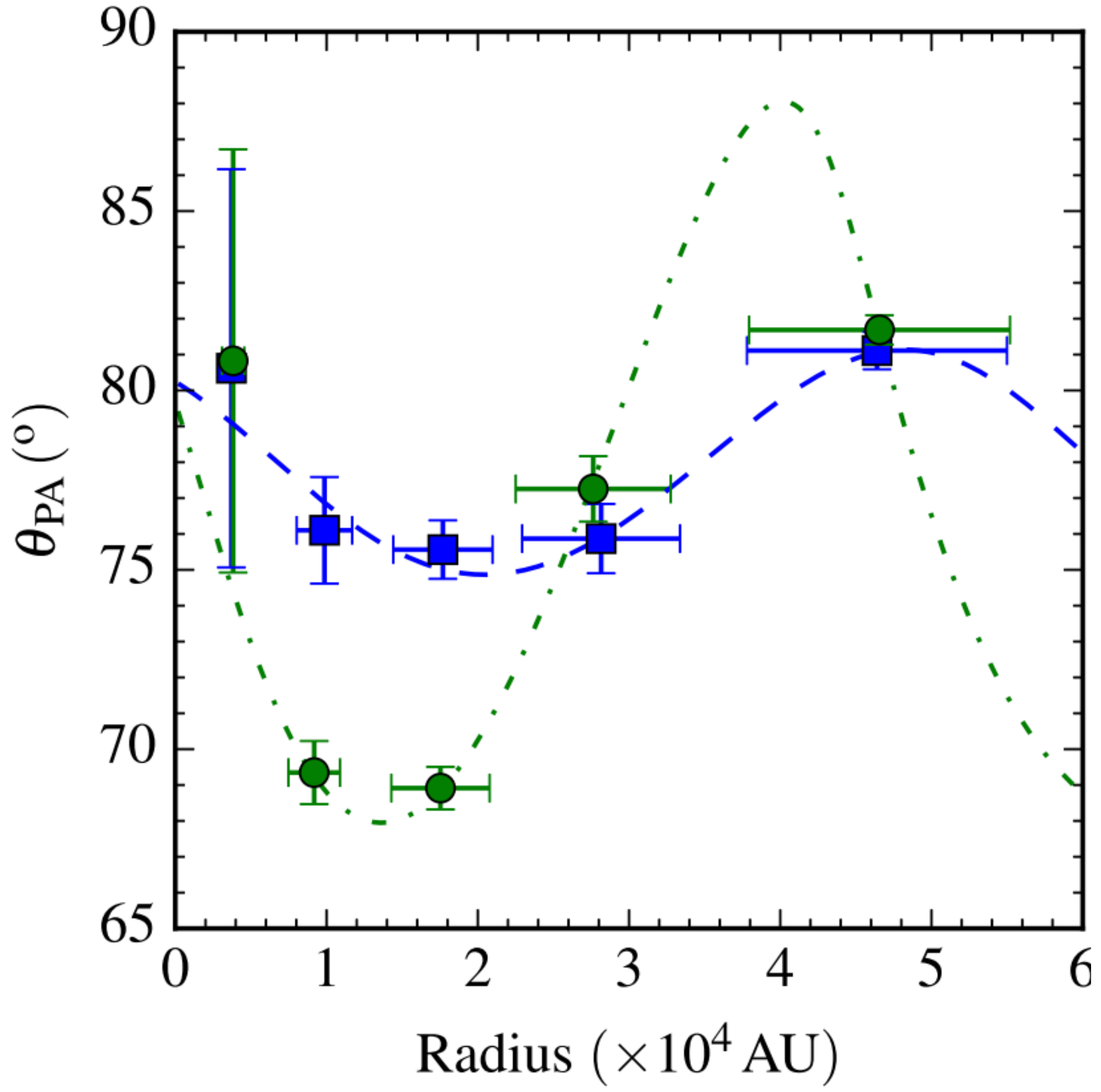
Not clear whether or not these emissions belong to the same flow.

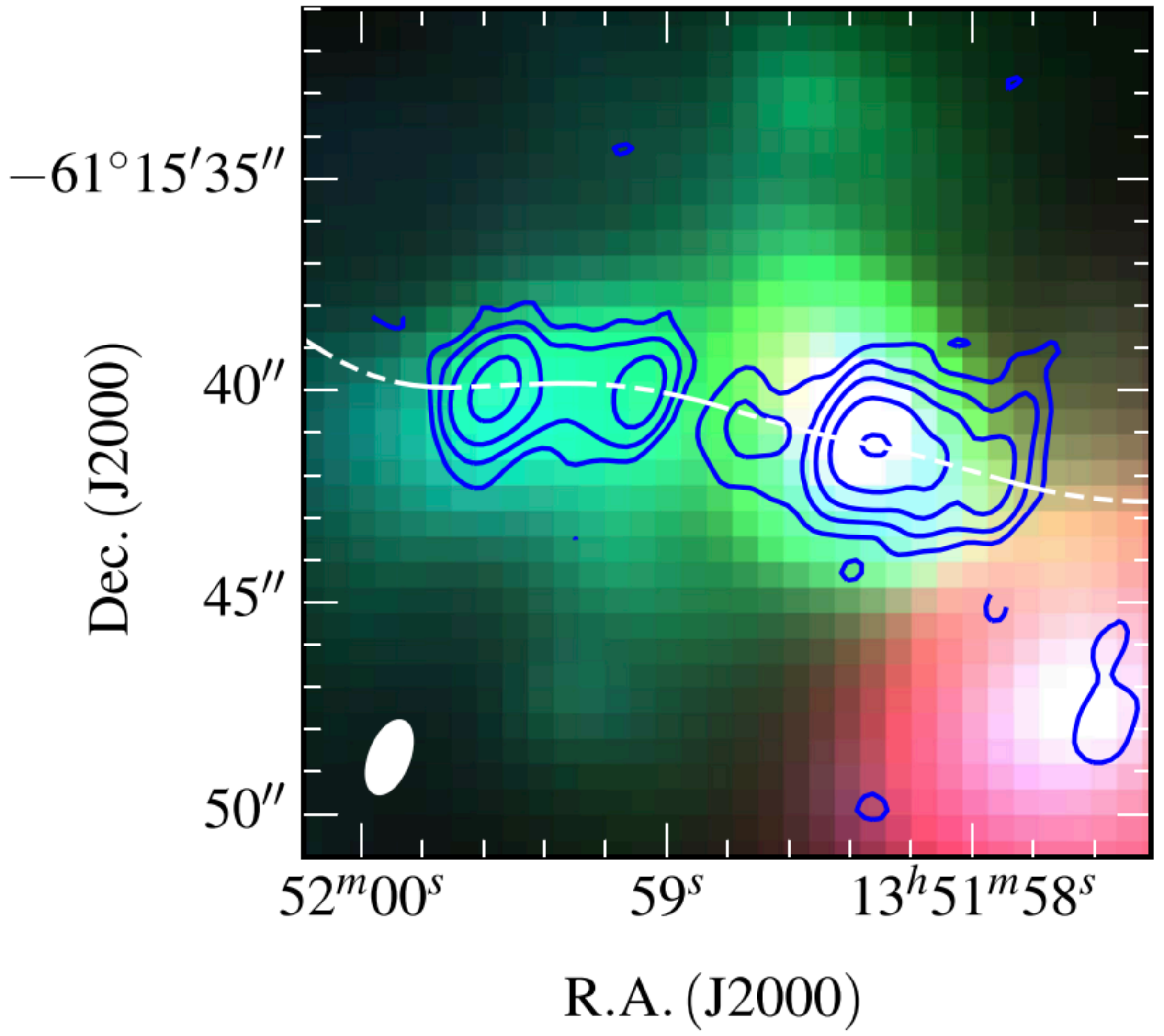
2. ACTA 6 GHz & 9 GHz by S. J. D. Purser, et al.(2018)

Name	Comp.	S_6 (μJy)	S_9 (μJy)	α	θ^6_{maj} (arcsec)	θ^9_{maj} (arcsec)	γ	R
G310.1420+00.7583A	A1	2744 ± 177 (A1, A2)	1459 ± 122	–	0.84 ± 0.03 (A1, A2)	0.66 ± 0.28	–	−1
	A2		1852 ± 147	–		0.62 ± 0.06	–	−1
	A3	2053 ± 144	1295 ± 160	−1.14 ± 0.35	1.09 ± 0.04	1.36 ± 0.14	0.53 ± 0.28	−1
	A4	888 ± 83	570 ± 94	−1.09 ± 0.47	0.93 ± 0.10	1.00 ± 0.22	0.18 ± 0.60	−1
	B	205 ± 65	117 ± 61	−1.38 ± 1.50	2.78 ± 0.94	–	–	−1
	C	568 ± 56	511 ± 74	−0.26 ± 0.43	<0.51	0.50 ± 0.17	> −0.03 ± 0.82	−1
	D	1896 ± 137	1684 ± 157	−0.29 ± 0.29	1.09 ± 0.05	0.98 ± 0.08	−0.25 ± 0.22	−1









Lobe C: Proper motion with a derived velocity of 1806 ± 596 km/s parallel to the jet's propagation axis

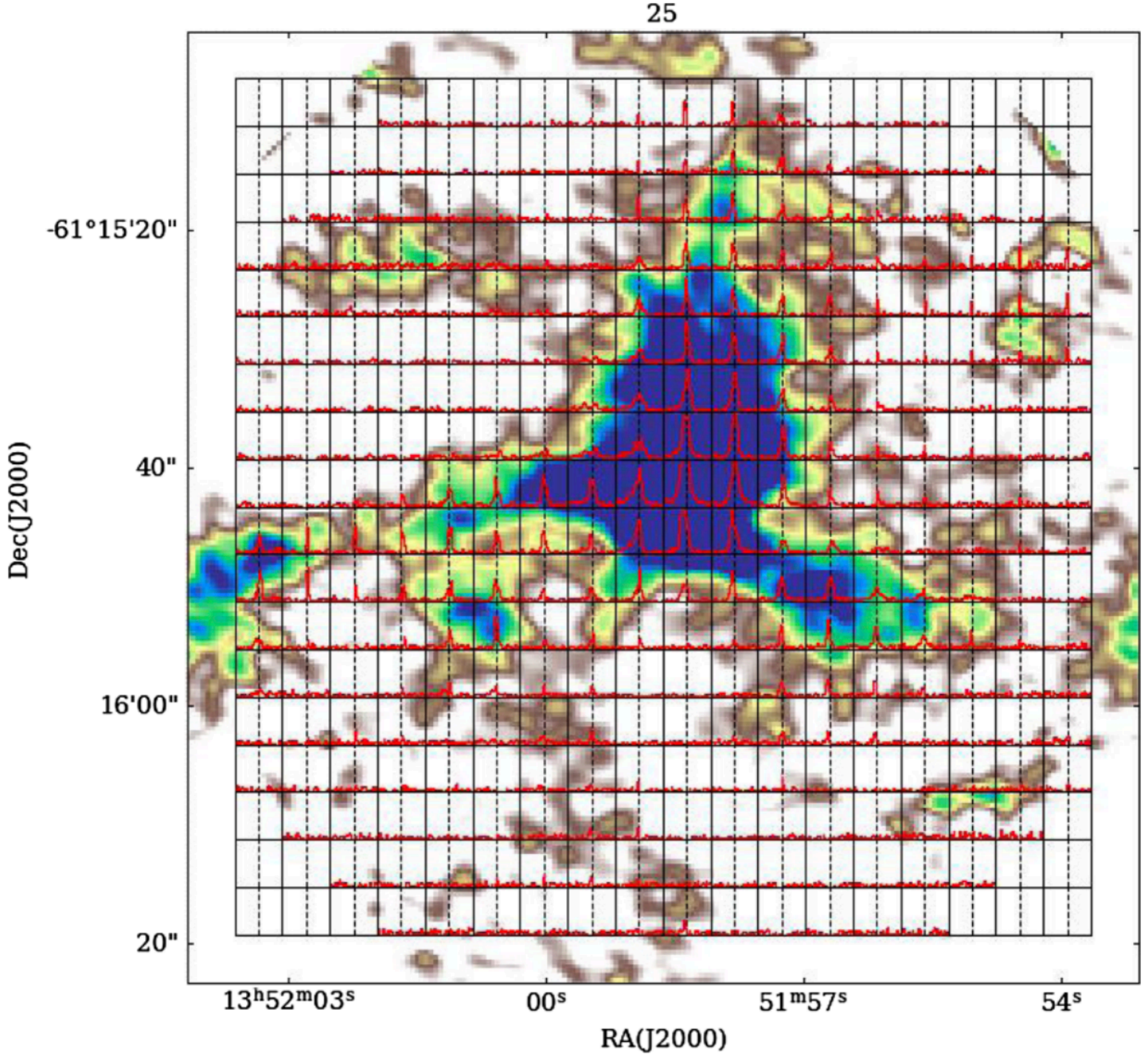
Lobe D: Change in the flux morphology support that the emission is the result of an evolving shock, rather than direct emission from the jet's stream

S. J. D. Purser, et al.(2018)

Find the evidence of precession

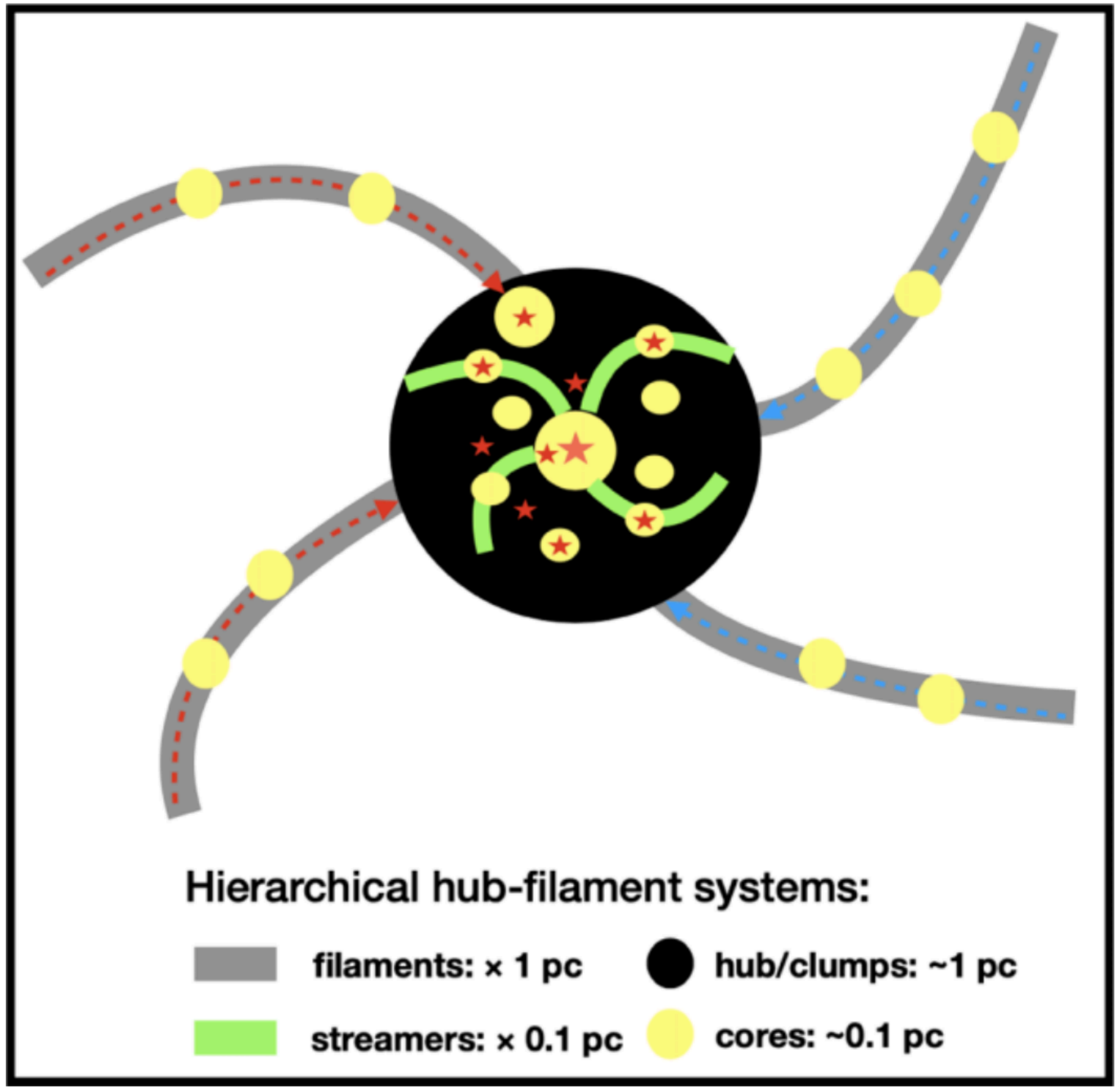
And then, Let's turn to the HFSs…

3. ALMA 12m & 7m Array by Jian-Wen Zhou, et al.(2022)



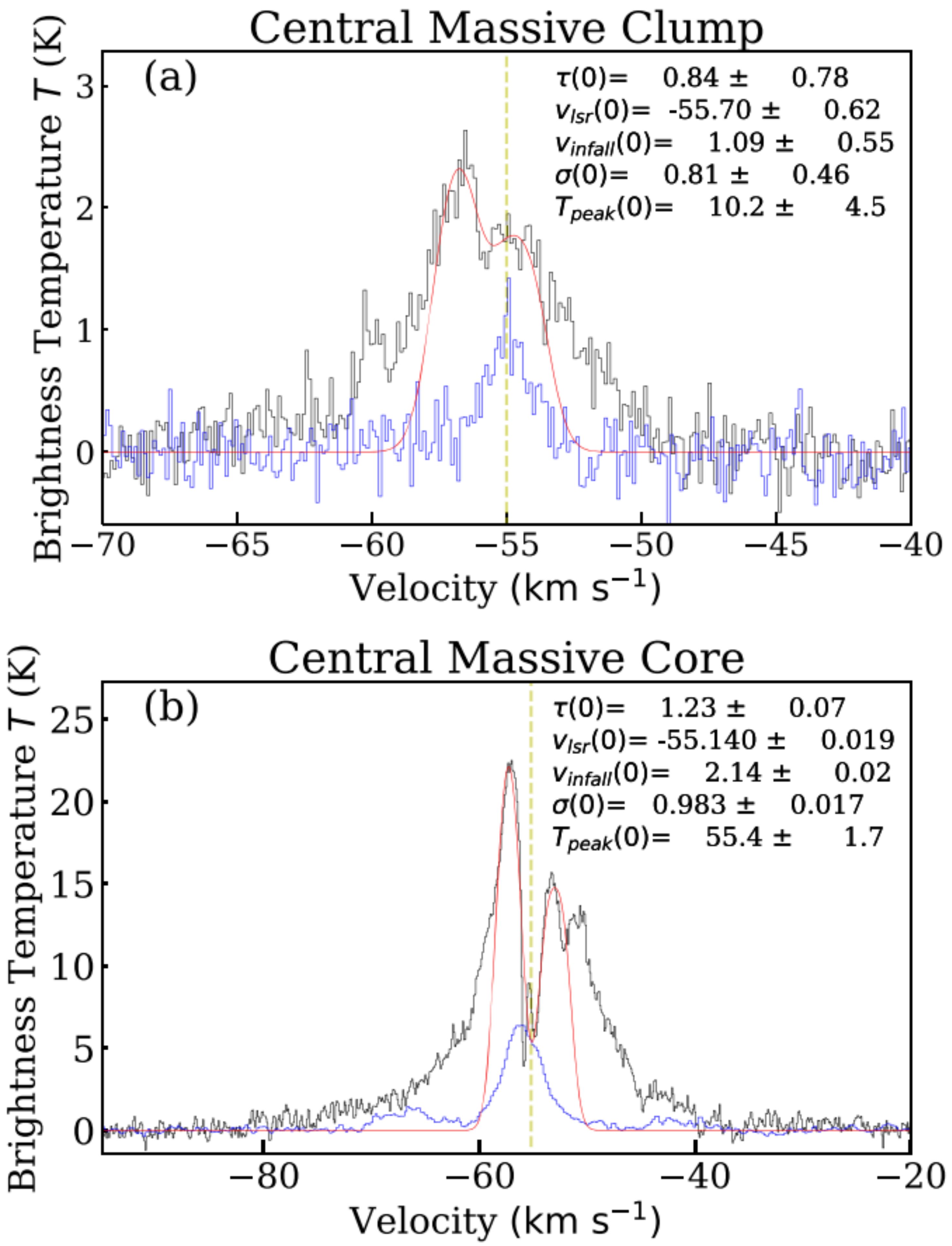
$H^{13}CO^{+}$ spectral grid map of ATOMS data

Jian-Wen Zhou, et al.(2022)



Schematic diagram of self-similar hierarchical HFS at different scales

4. ALMA 12m & 7m Array by Dongting Yang, et al.(2023)



Dongting Yang, et al.(2023)

Average spectra of J = 1–0 of HCO+ (in black) and H13CO+ (in blue) for the massive clump (panel (a)), and central massive core (panel (b)).

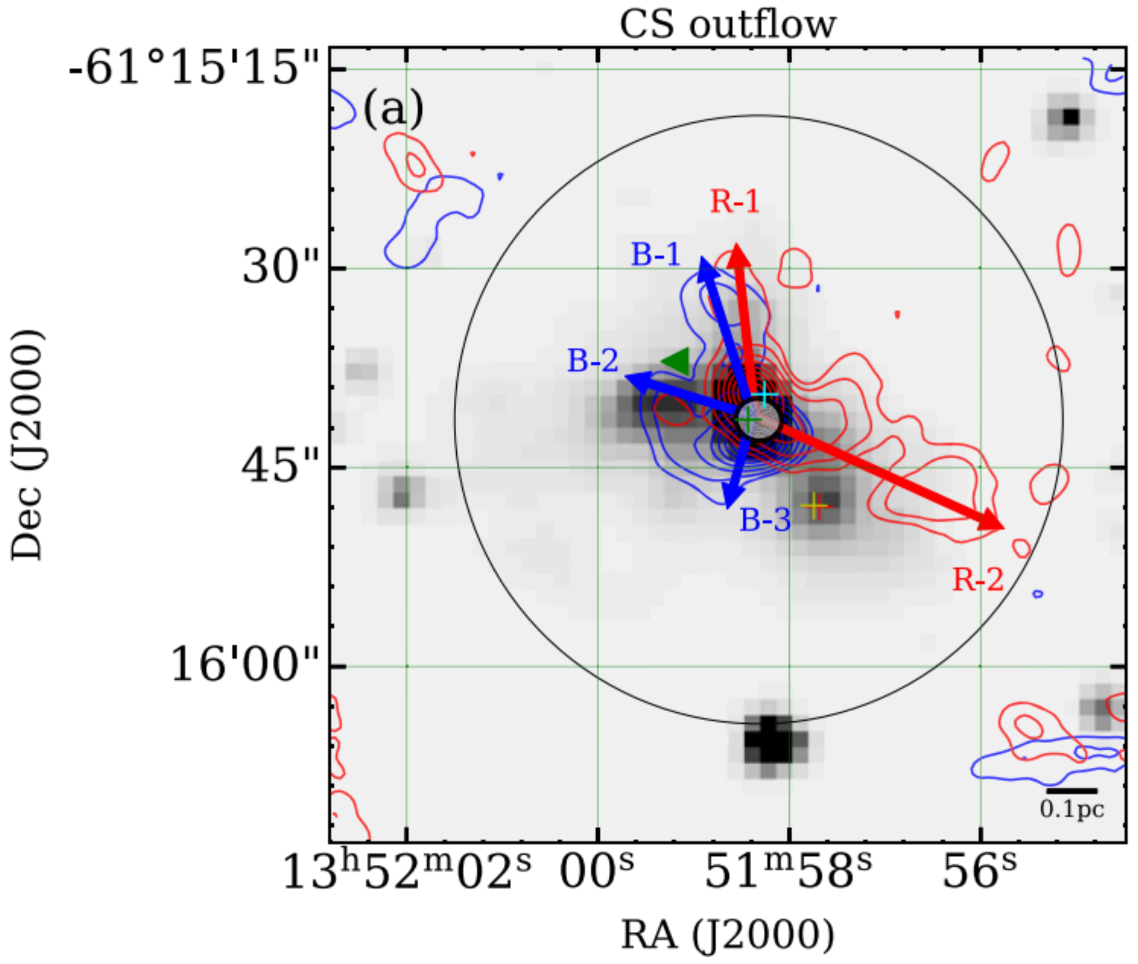
Physical Properties of the Central Clump and the Central Core in HFS G310

Name	R. A.	Decl.	Radius (pc)	T_{dust} K	Mass ($M_\odot$)	α_{vir}	V_{infall} (km s^{-1})	$\dot{M}_{infall}$ ($10^{-3} \times M_\odot$ yr^{-1})	Data Source
Central clump	13:51:57.76	−61:15:43.72	0.6	31.8	1280 ± 260	0.4 ± 0.1	1.1 ± 0.6	2.4 ± 1.7	Mopra
Central core	13:51:58.30	−61:15:41.40	0.036	100	106 ± 21	1.5 ± 0.6	2.1 ± 0.1	6.5 ± 1.3	ATOMS

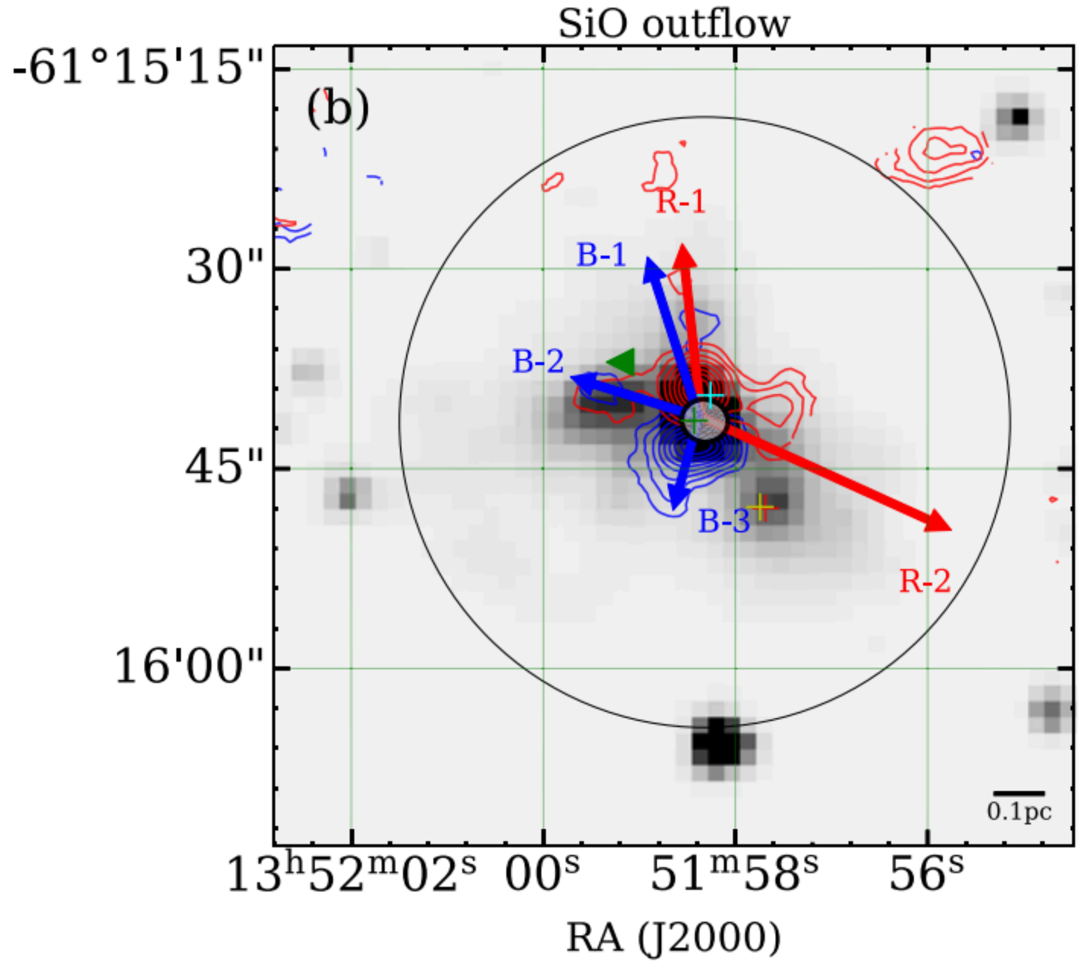
Physical Properties of Hub-composing Filaments in G310

Name	Area (pc^2)	Length (pc)	Width (pc)	M_{fil}^{a} ($M_\odot$)	M_{line} ($M_\odot$ pc^{-1})	∇_{fil}^{b} (km s^{-1} pc^{-1})	$\dot{M}_{\parallel}$ ($10^{-4} \times M_\odot$ yr^{-1})
Filament1	7.3	5.8	1.3	3566 ± 713	620 ± 124	0.10 ± 0.02	3.6 ± 1.5
Filament2	2.4	3.3	0.7	1353 ± 271	409 ± 82	0.17 ± 0.14	2.4 ± 2.4
Filament3	3.5	4.6	0.8	777 ± 155	167 ± 34	0.18 ± 0.04	1.4 ± 0.6

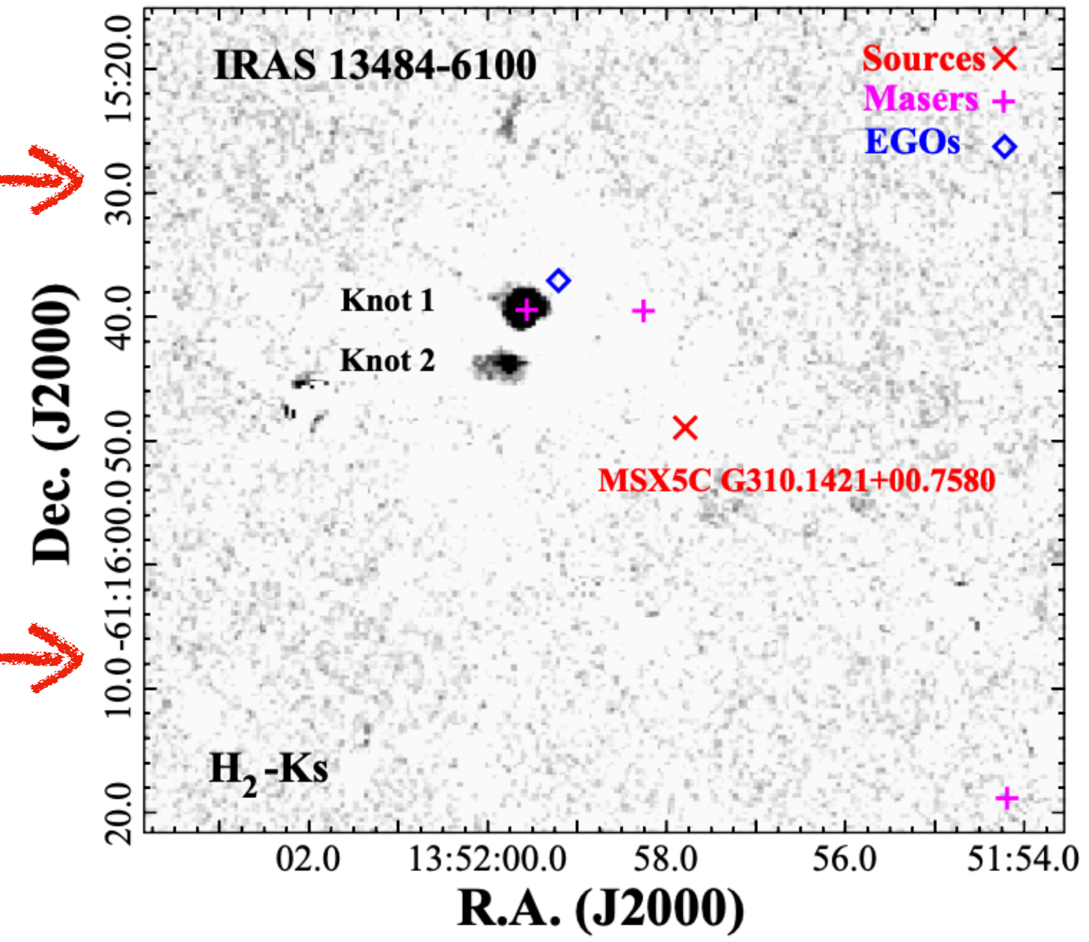
Outflows compare ALMA ATOMS with ESO/NTT



Dongting Yang, et al.(2023)



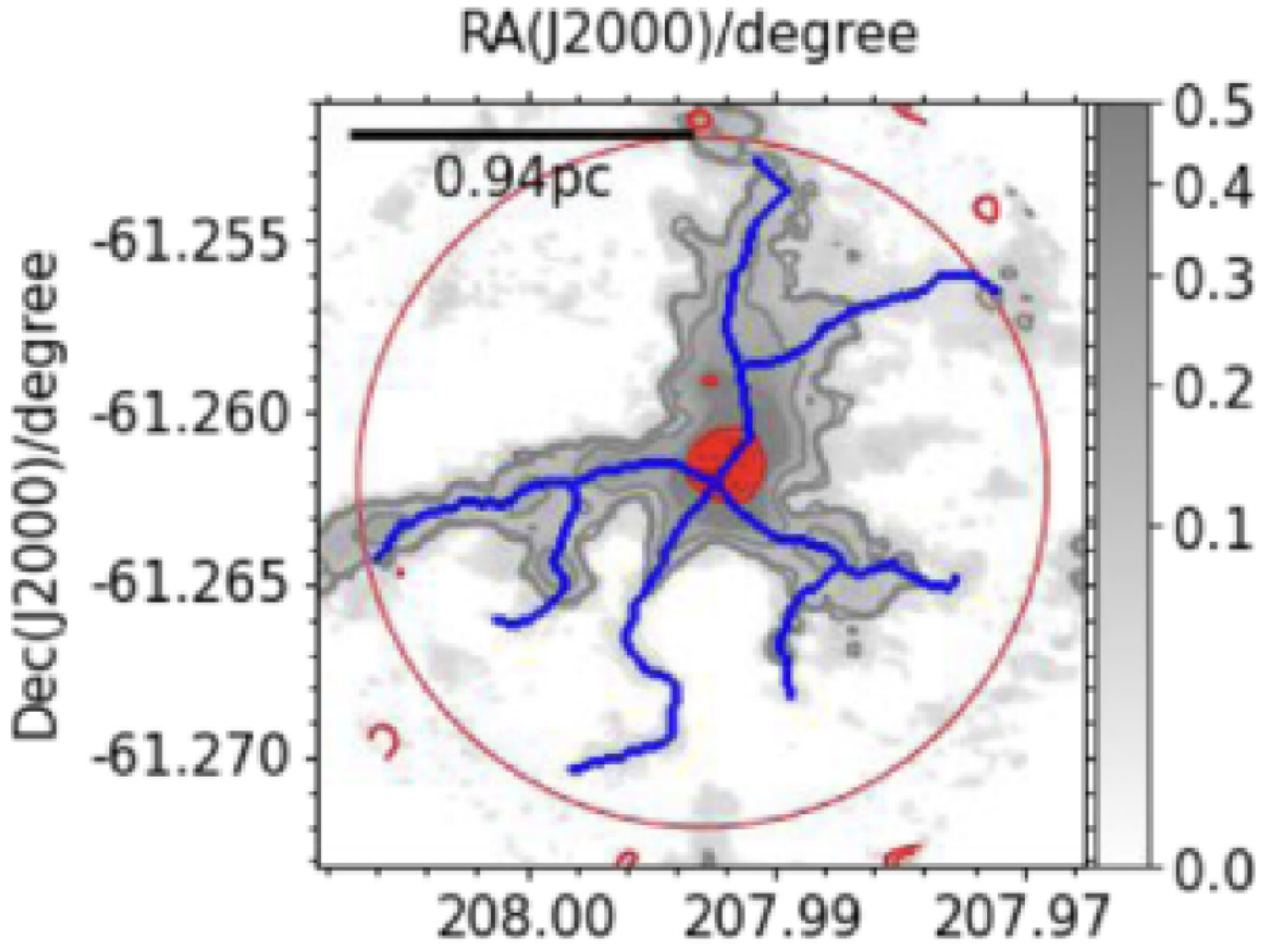
Dongting Yang, et al.(2023)



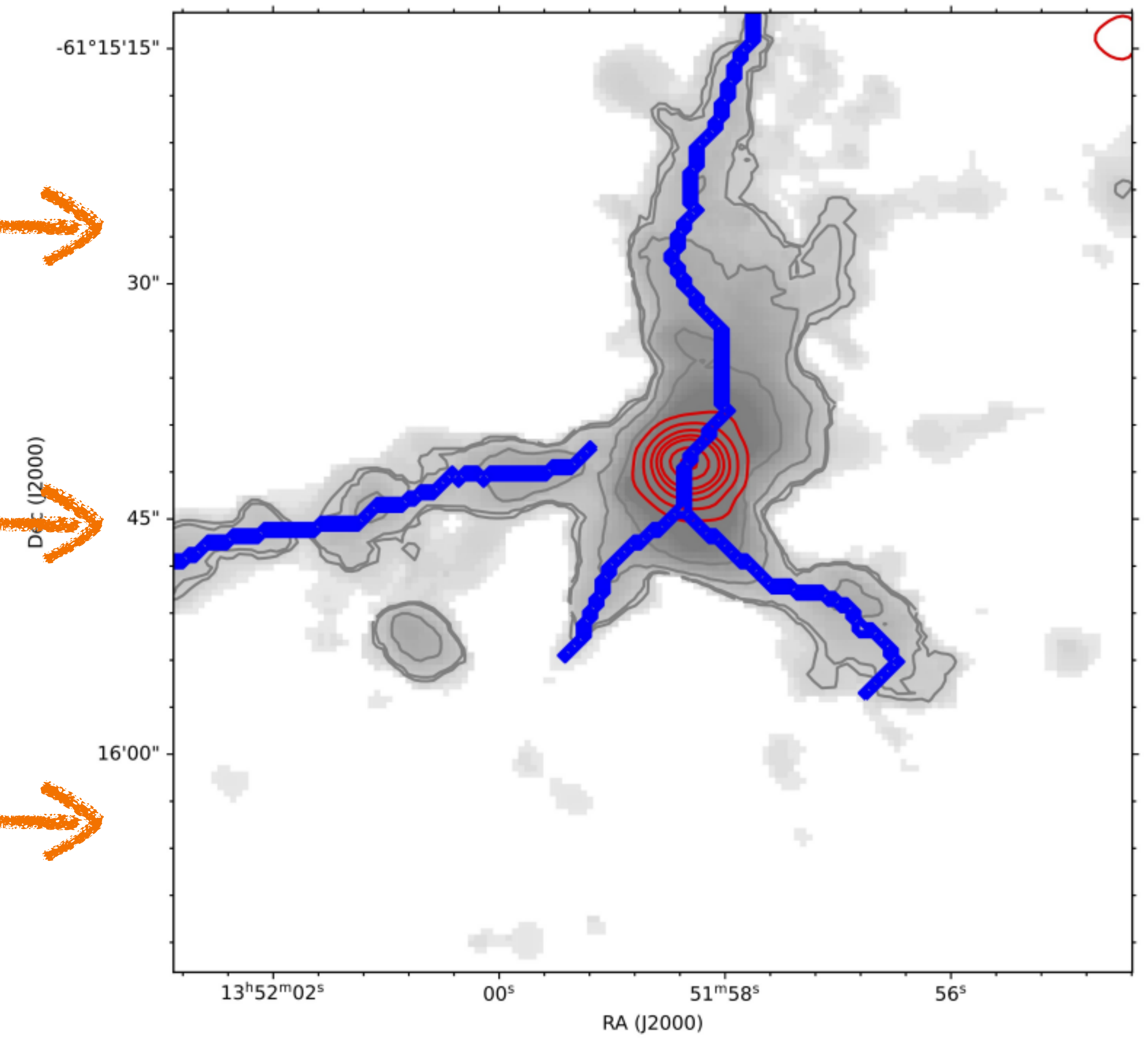
A. Caratti, et al.(2015)

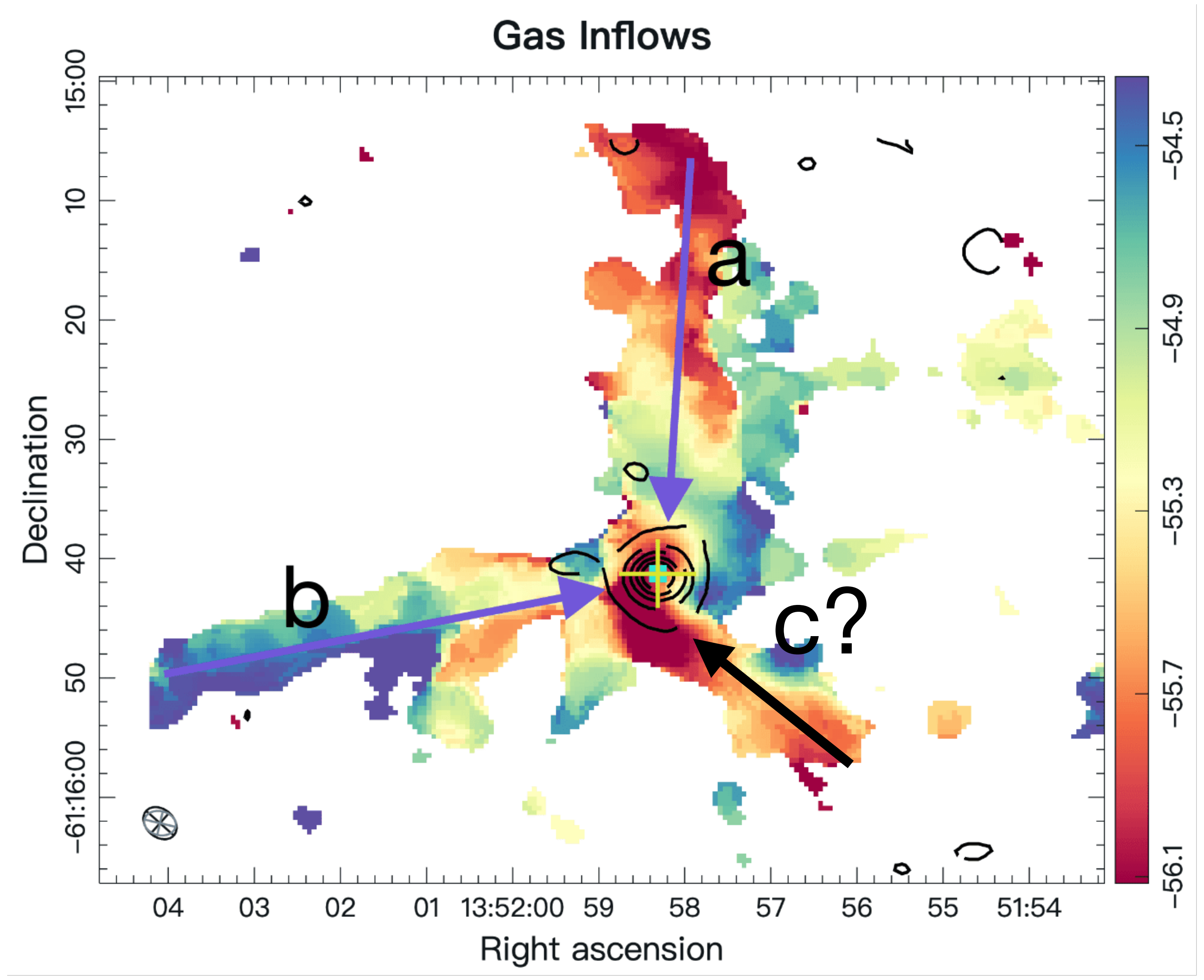
Work Progress of IRAS13484 with QUARKS/ATOMS Data

1. HFSs identified by $H^{13}CO^+$ and Gas Inflows



Jian-Wen Zhou, et al.(2022)





By selecting higher skeleton and branch threshold,
we redraw the filament structure.

We mainly identified the obvious gas inflow in the two main filament structures of IRAS13484 in Fig 4, and calculated that the global velocity gradient of gas inflow along filament(a) is 1.79 km/s/pc, and filament(b) is 0.98 km/s/pc.

Channel Map of $H^{13}CO^+$

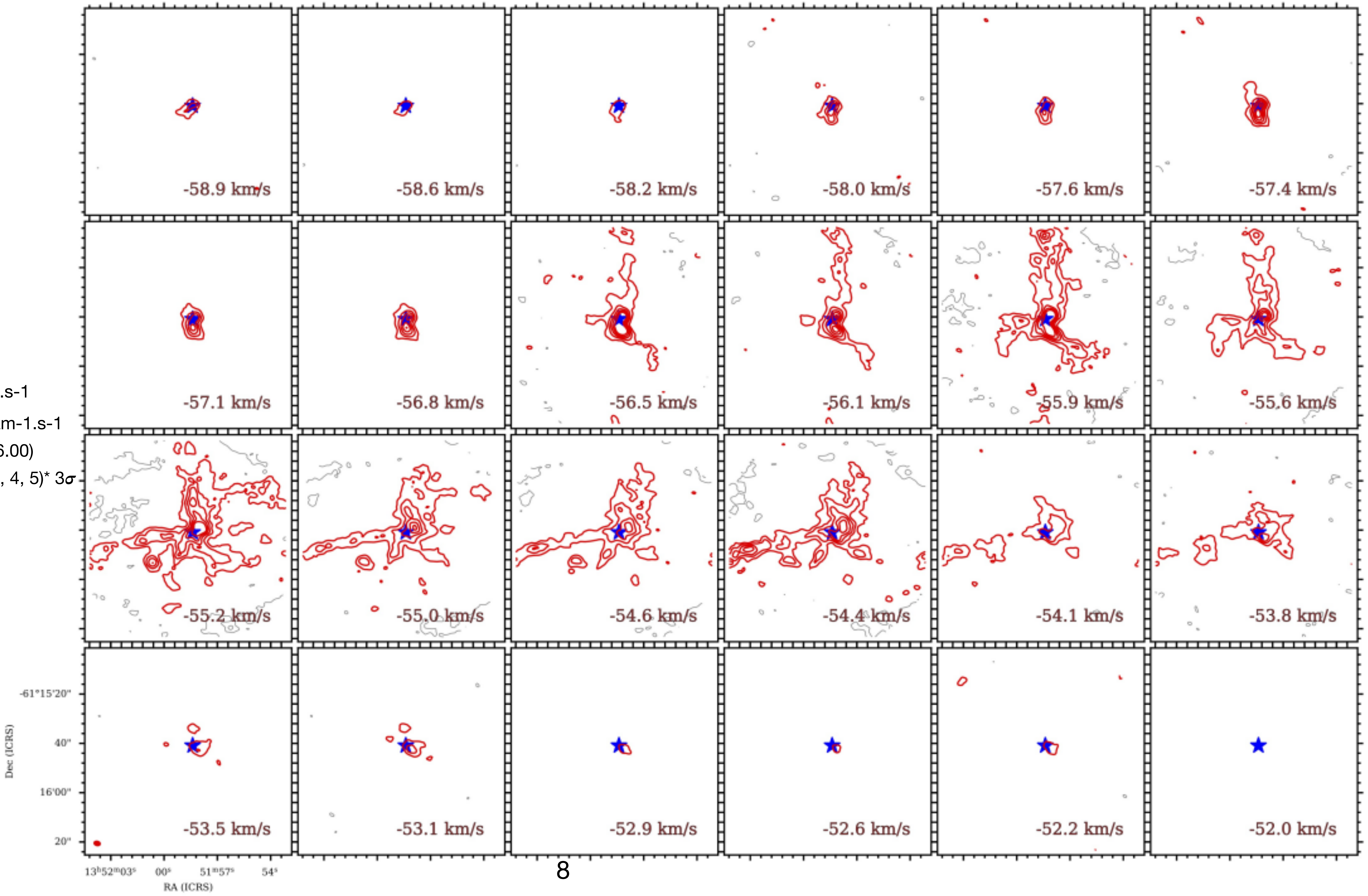
σ = 9.8* 10^-3 Jy.km.beam-1.s-1

Max = 1.64* 10^-1 Jy.km.beam-1.s-1

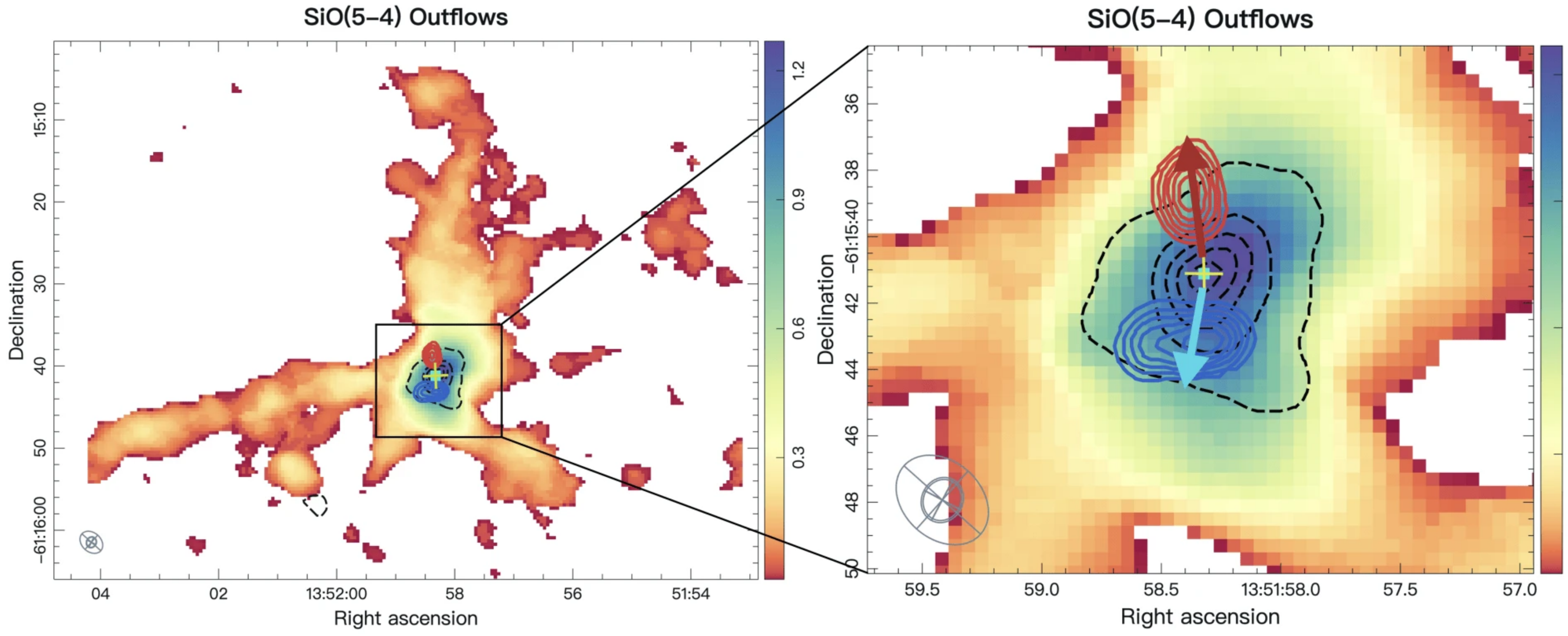
Gaussian center: (104.45, 106.00)

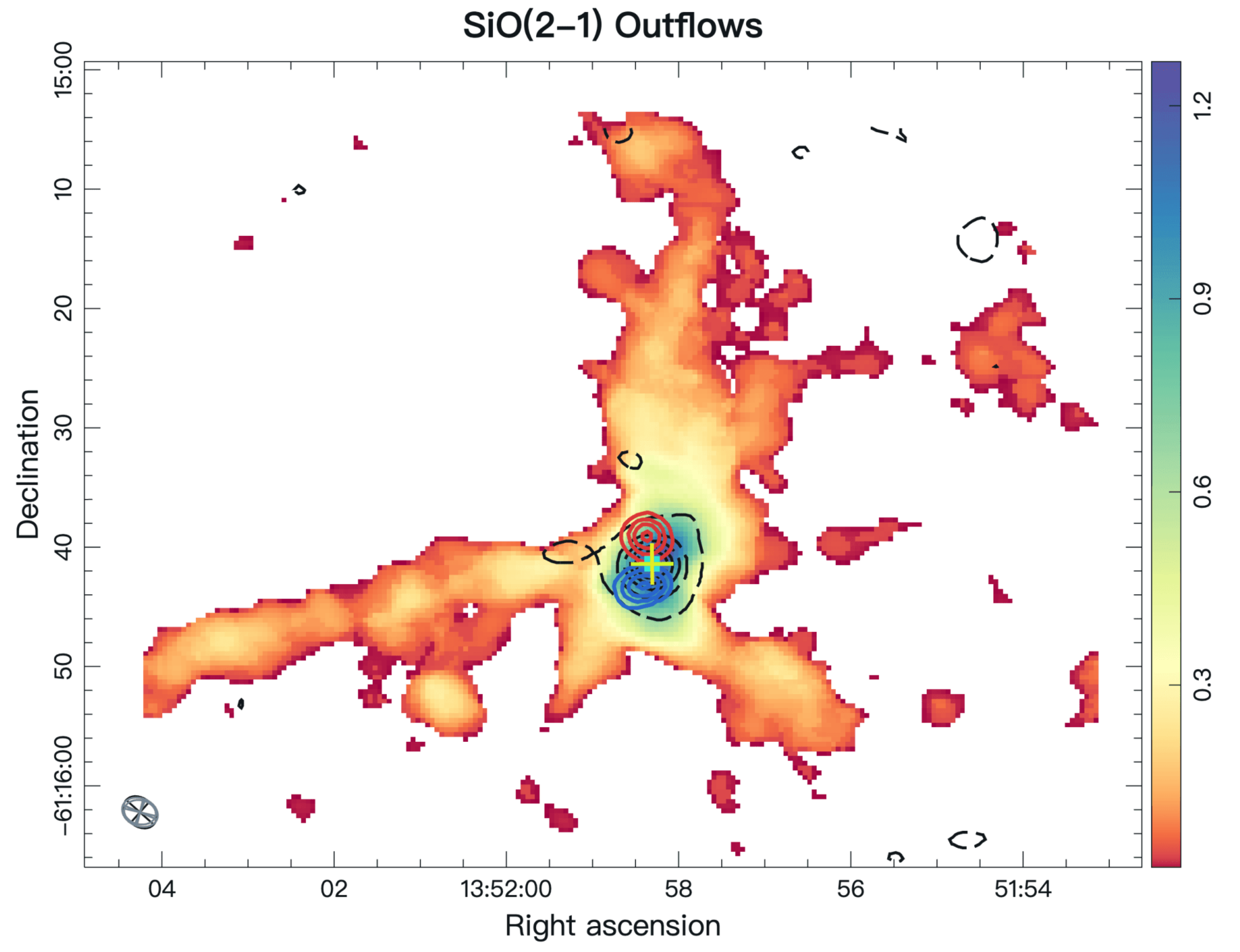
Red contour: emission(1, 2, 3, 4, 5)* 3σ

Grey contour: (-1)* 3σ

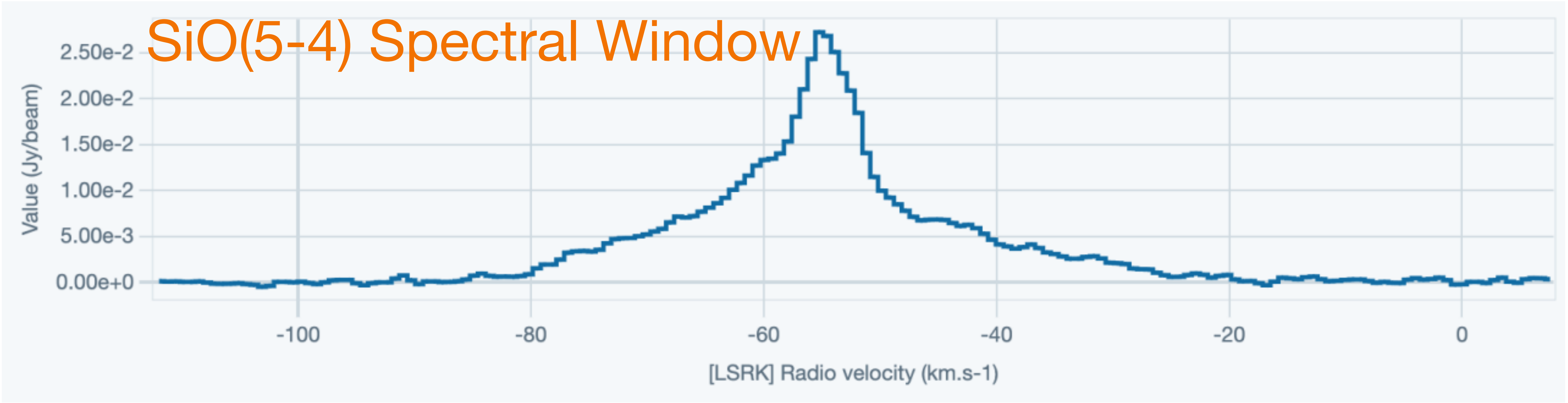


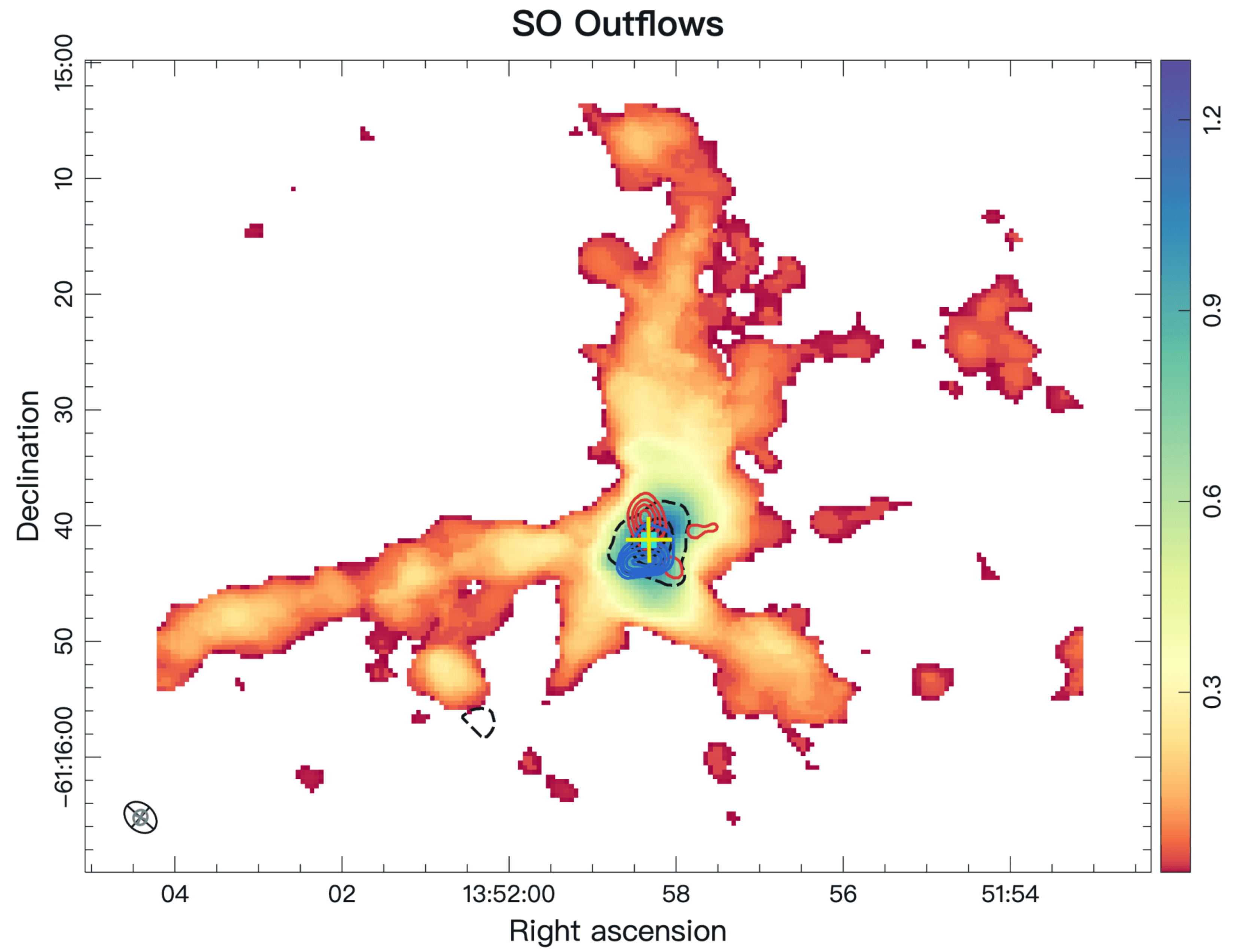
2. High Velocity Outflows Identification





Very distinct gas outflows in the center of the IRAS13484. SiO (J=5-4) has higher energy, thus providing the most reliable tracing of the outflow. We propose that the gas is feeding the central region of the HSF by filaments and part of the accreted gas is ejected shown as the outflow.





Channel Map of SiO(5-4)

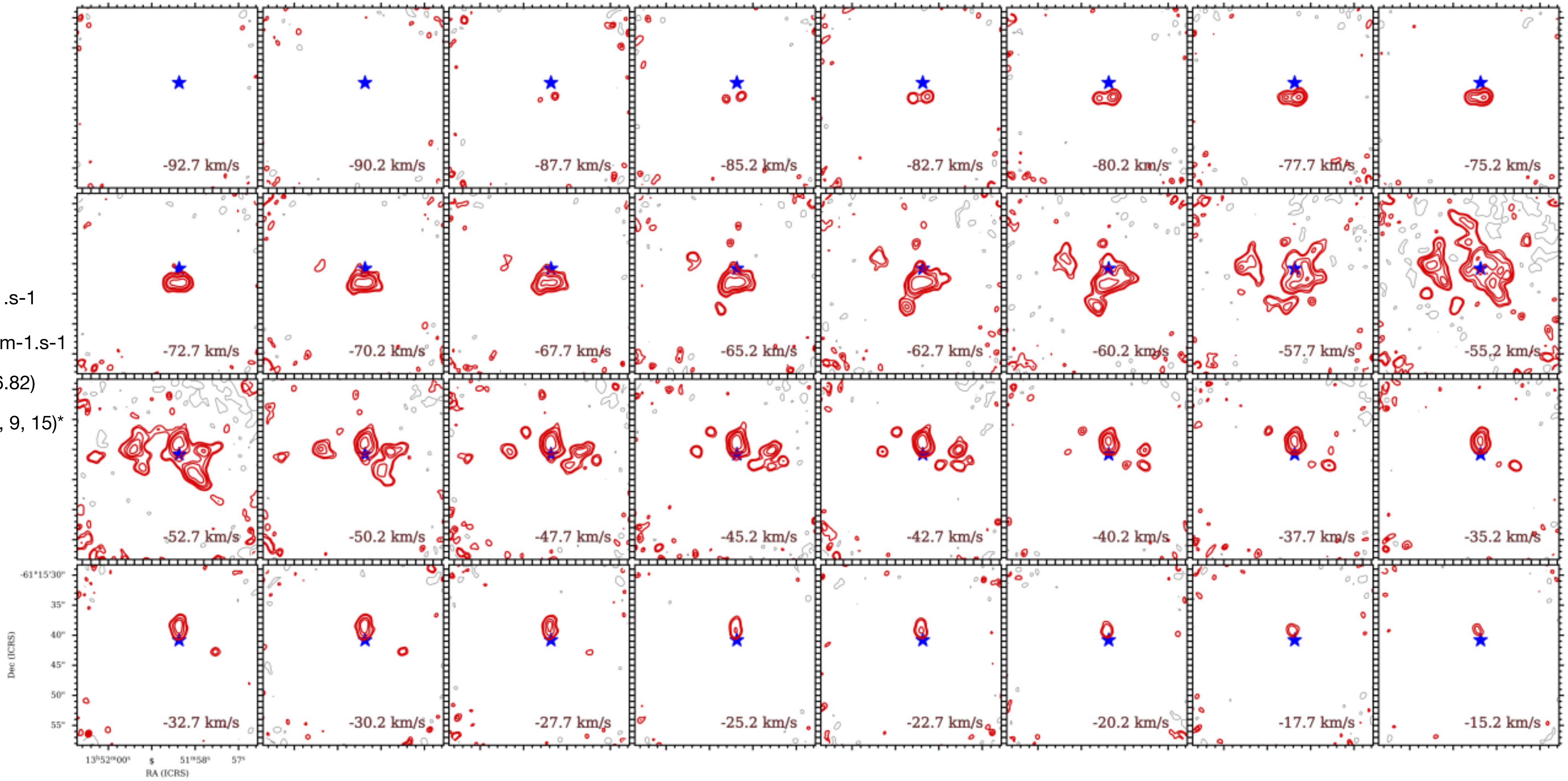
σ = 1.6* 10^-2 Jy.km.beam-1.s-1

Max = 7.61* 10^-1 Jy.km.beam-1.s-1

Gaussian center: (104.49, 106.82)

Red contour: emission(2, 3, 6, 9, 15)* 3σ

Grey contour: noise(-2)* 3σ



PV Diagram of Outflows

SiO(5-4)

-94.2 ~ -13.7 km.s-1

σ = 7e-3 Jy.beam-1

Green contour: emission(1, 2, 3, 5, 8, 12)* 3σ

SiO(2-1)

-86.5 ~ -1.8 km.s-1

σ = 5.5e-3 Jy.beam-1

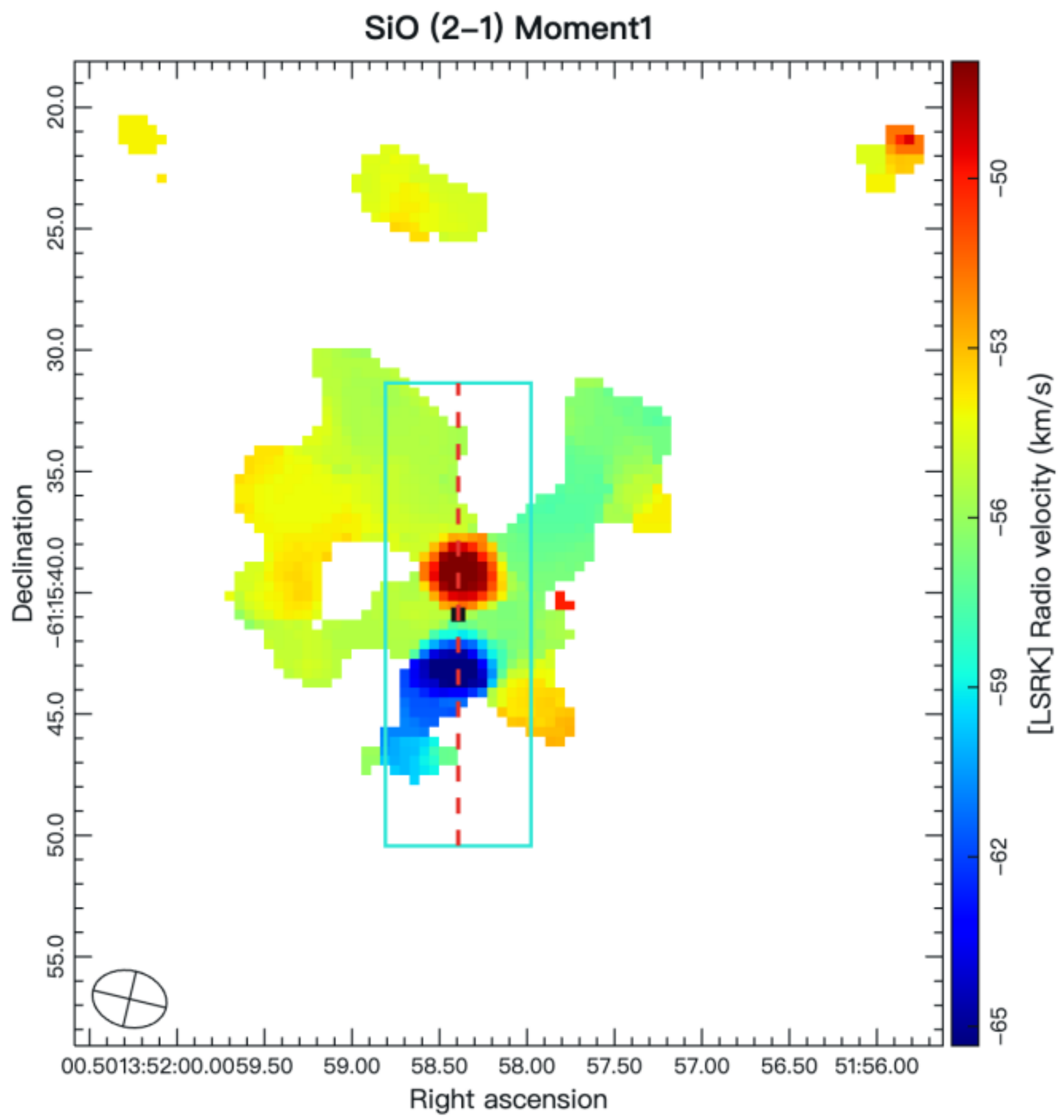
Green contour: emission(1, 2, 3, 5, 7)* 3σ

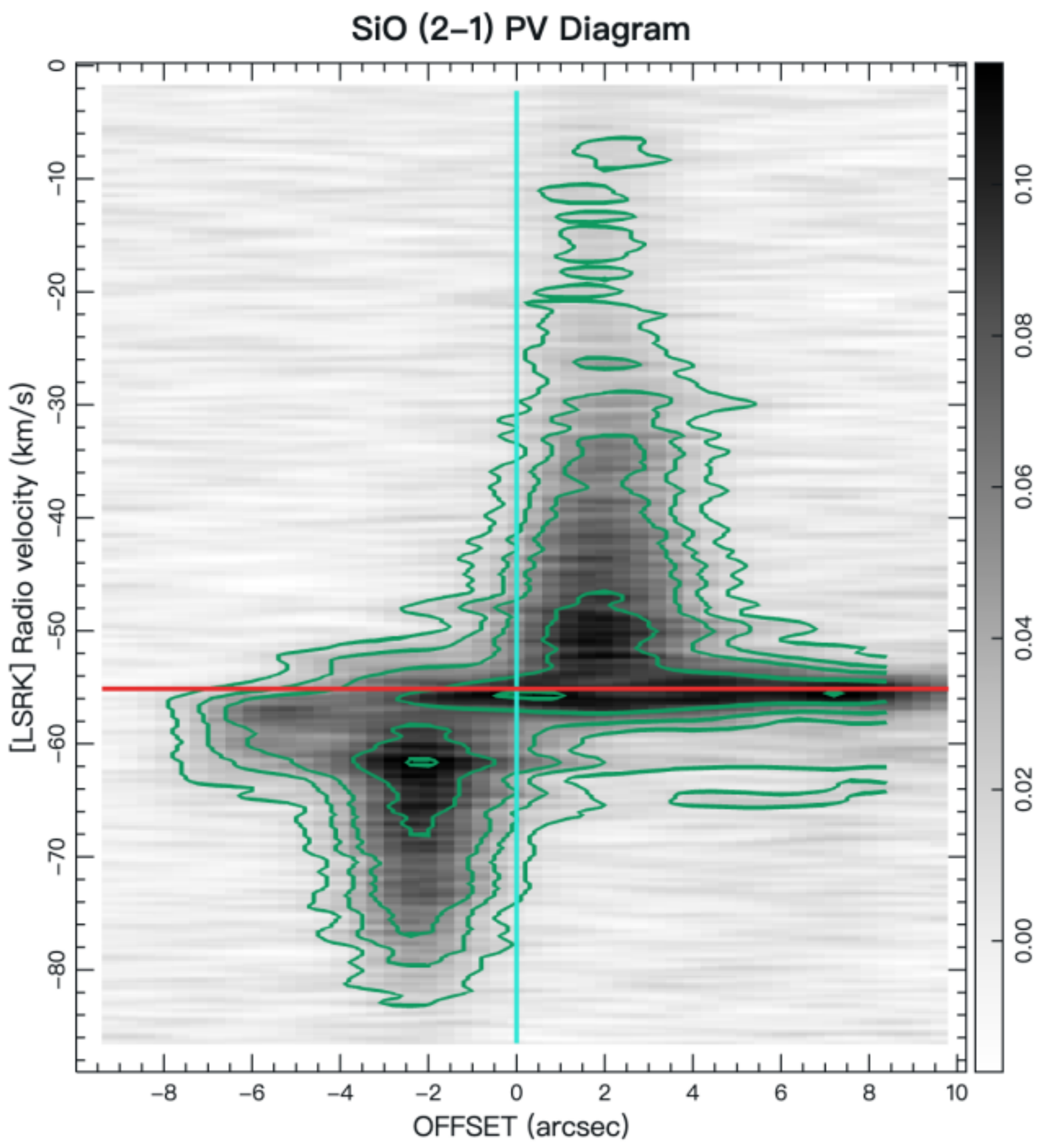
SO

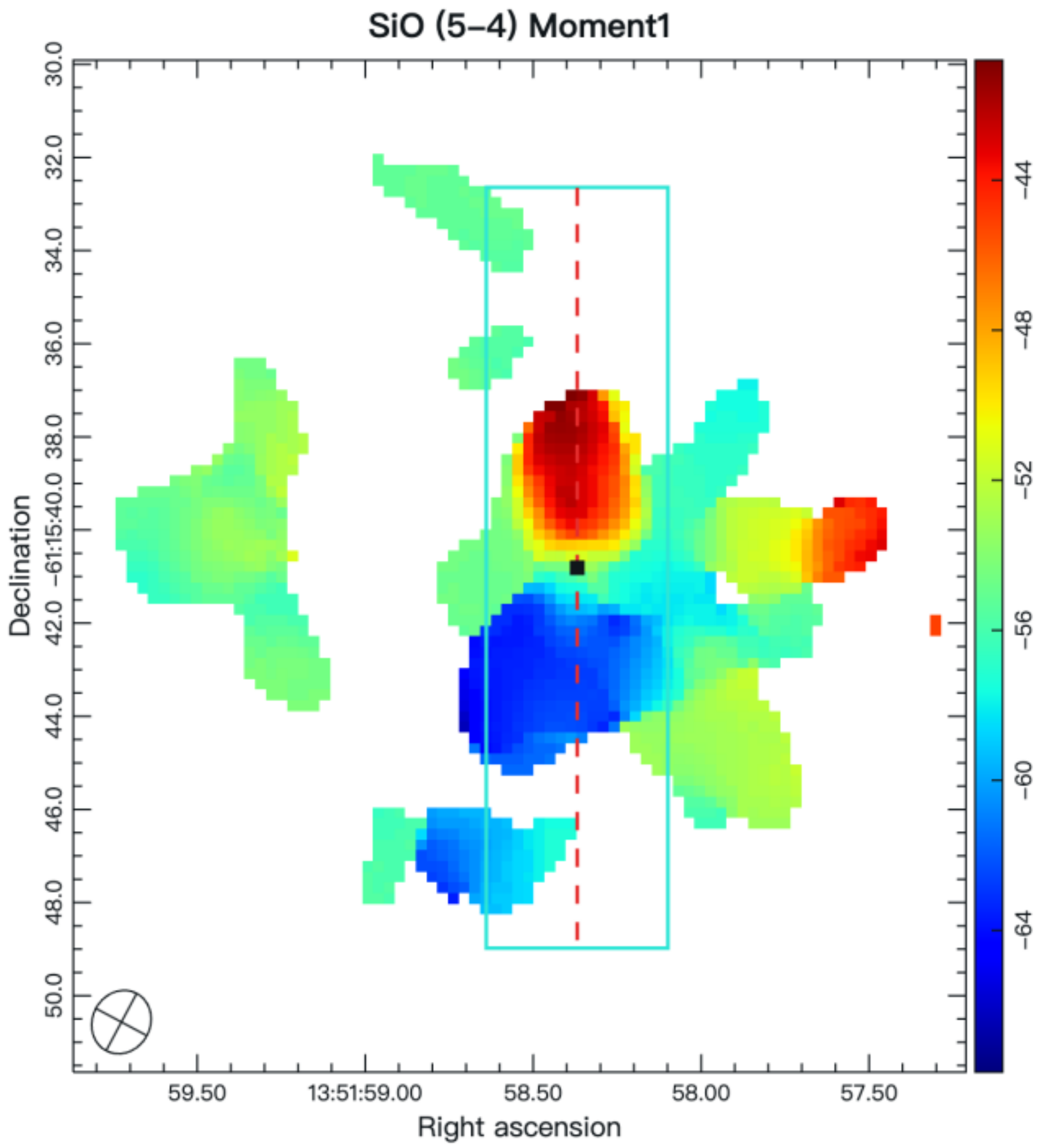
-86.37 ~ -13.16 km.s-1

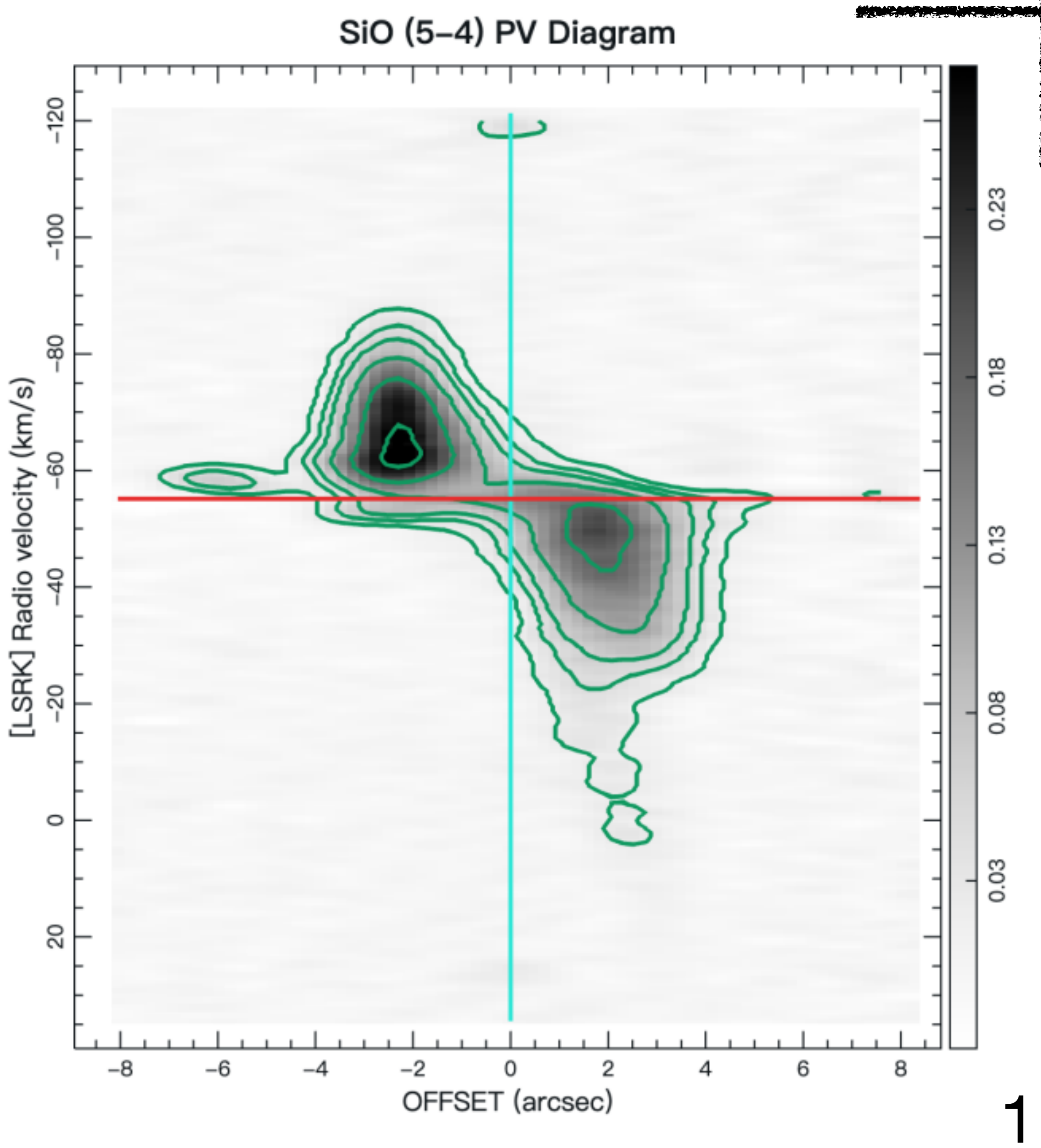
σ = 7.8e-3 Jy.beam-1

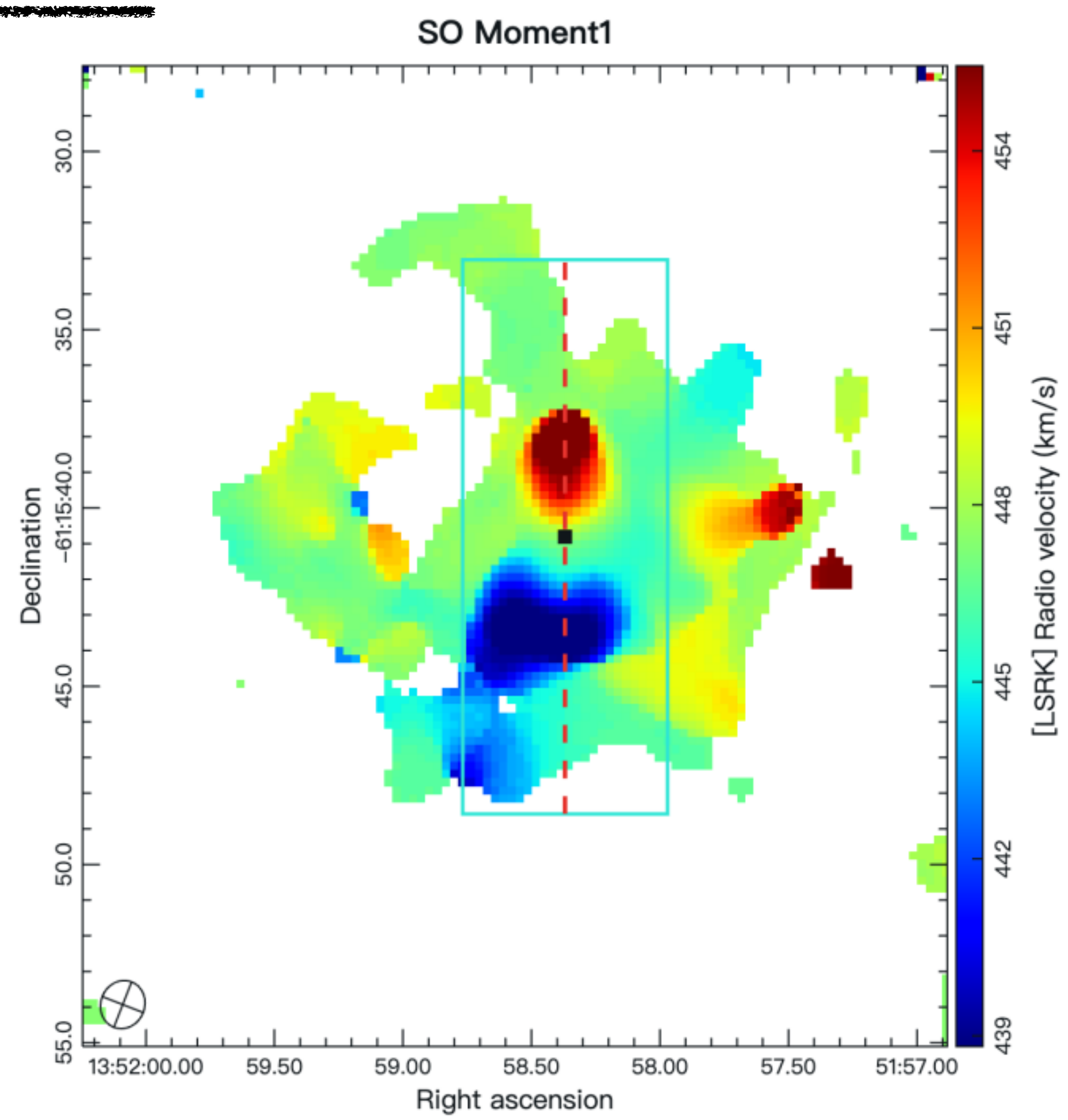
Green contour: emission(1, 3, 5, 9, 14, 20, 28, 41)* 3σ

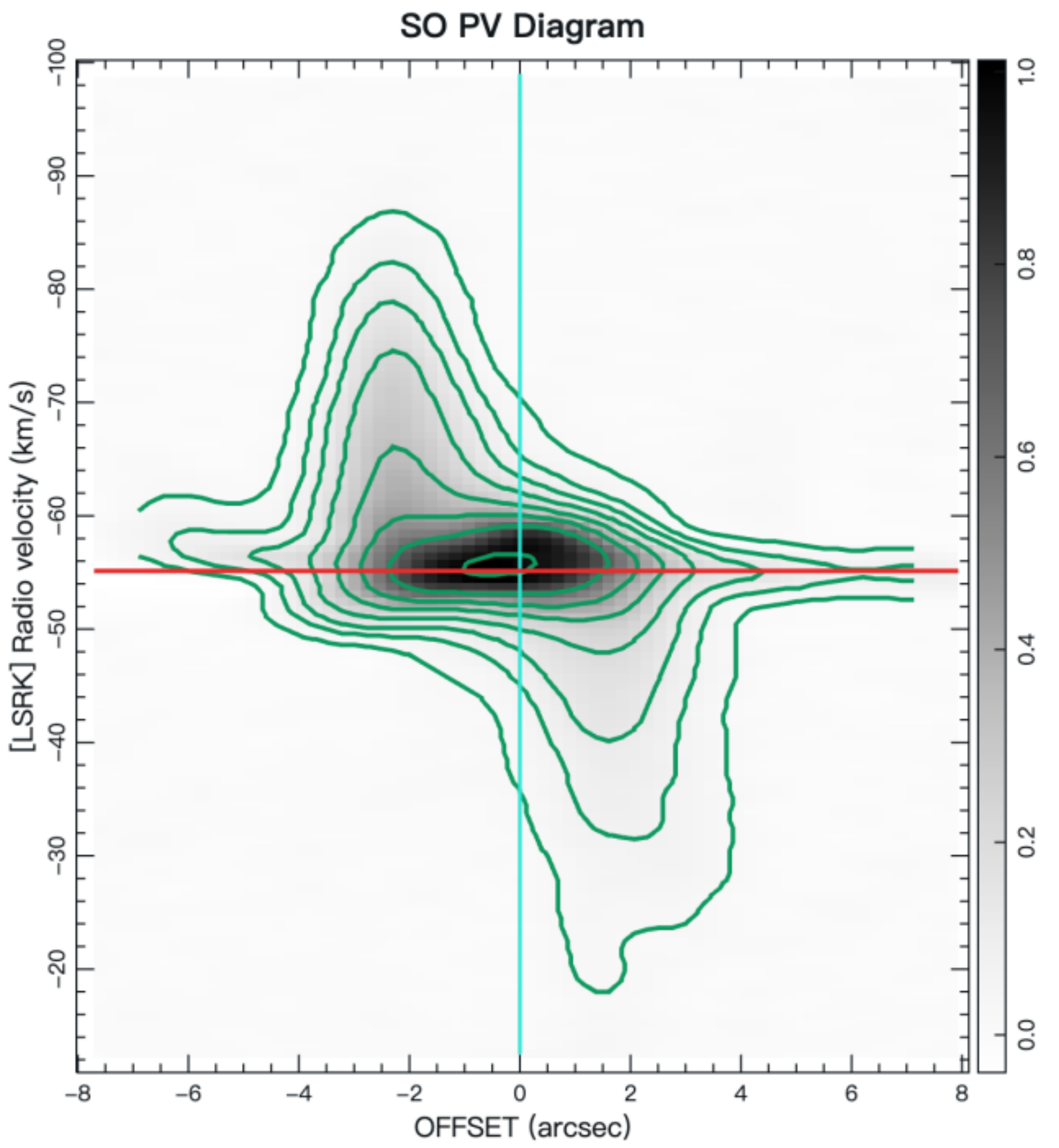






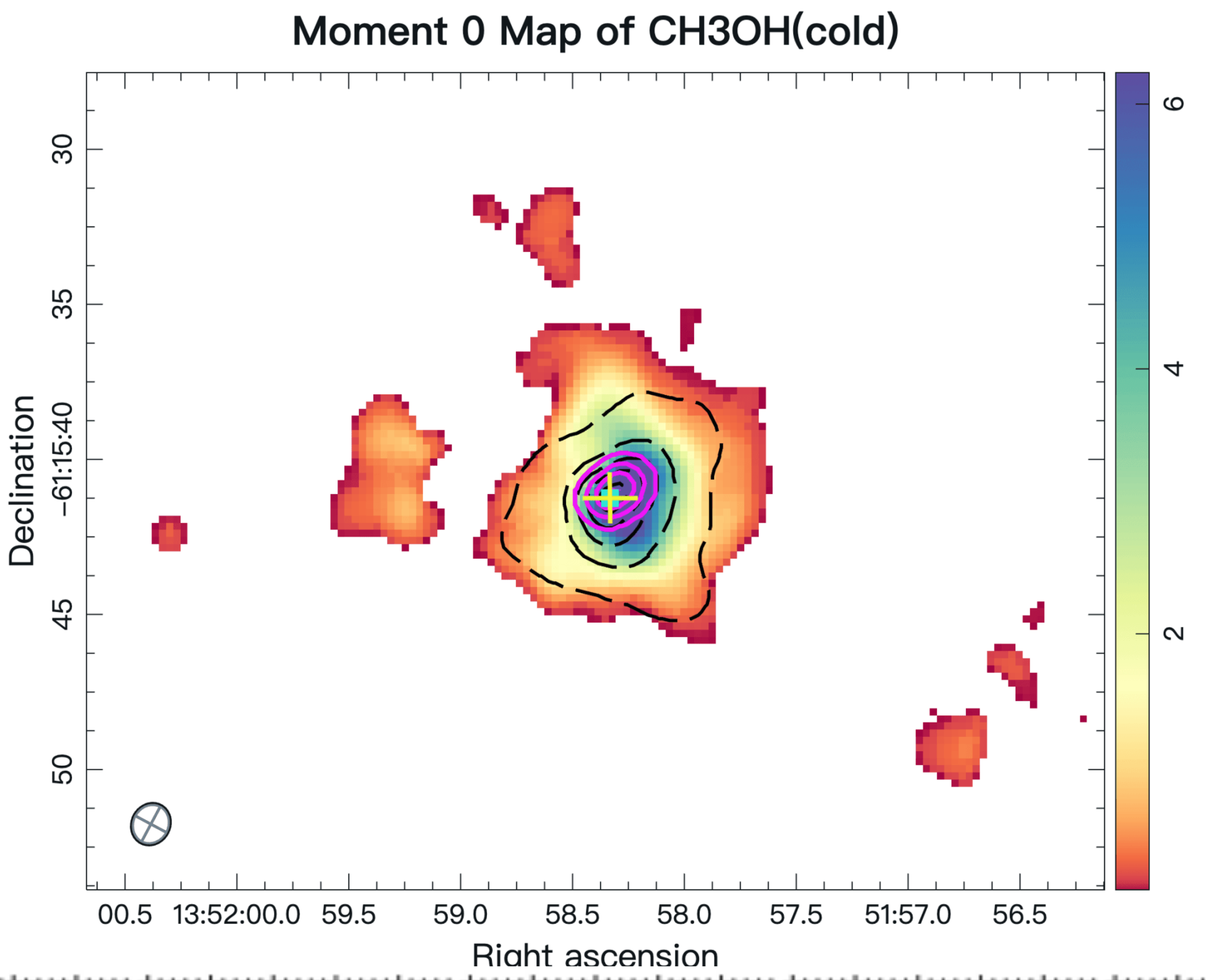


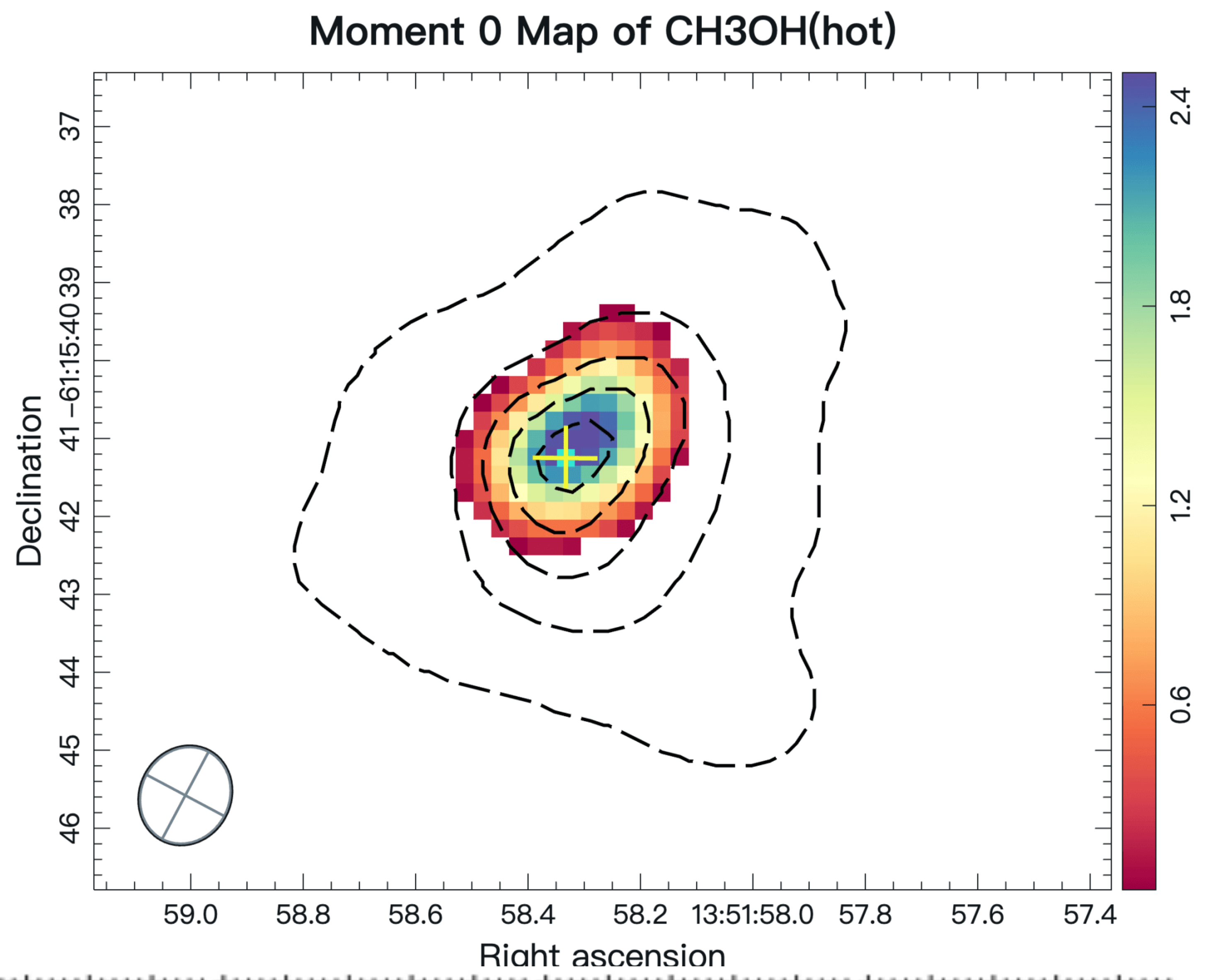




3. Hot Core identified by CH_3OH

From the synthesis of CH3OH data of low temperature(J=4(-2,3)-3(-1,2)) and high temperature(J=10(-3)-11(-2)), we find the central temperature of IRAS13484 is high, while the extended structure of the center outward has a lower temperature. This shows that protostar heating the core from inside, resulting the temperature of core higher than high-speed dispersion structure traced by CH3OH.





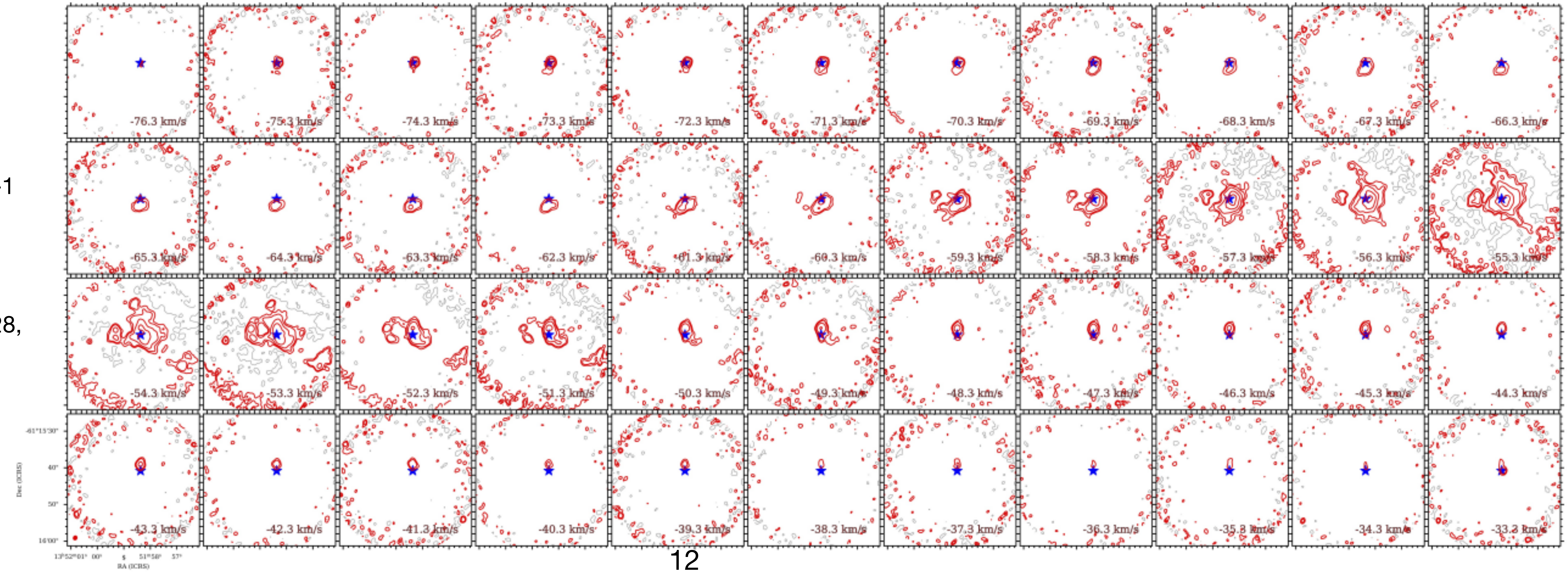
CH3OH Cold Channel Map: Extension Structure?

-76.8 ~ -32.8 km.s-1

σ = 8* 10^-3 Jy.km.beam-1.s-1

Red contour: emission(2, 4, 10, 28, 74, 155)* 3σ

Grey contour: noise(-2)* 3σ



Future Work Plan

1. Draw the rotation temperature diagram about the center region with emission of both two CH3OH lines
2. Quantitative analysis of outflows, calculate velocity, momentum and kinetic energy
3. Conduct a more precise analysis of the PV diagram to study the possible precession at the center
4. Calculate the mass and velocity along the filament from four HFSs sources(IRAS13484, IRAS16272, IRAS18182, IRAS18264), then plot statistical charts to study their relationship
5. Analyze the evolution stage by studying the outflows

Many Thanks!