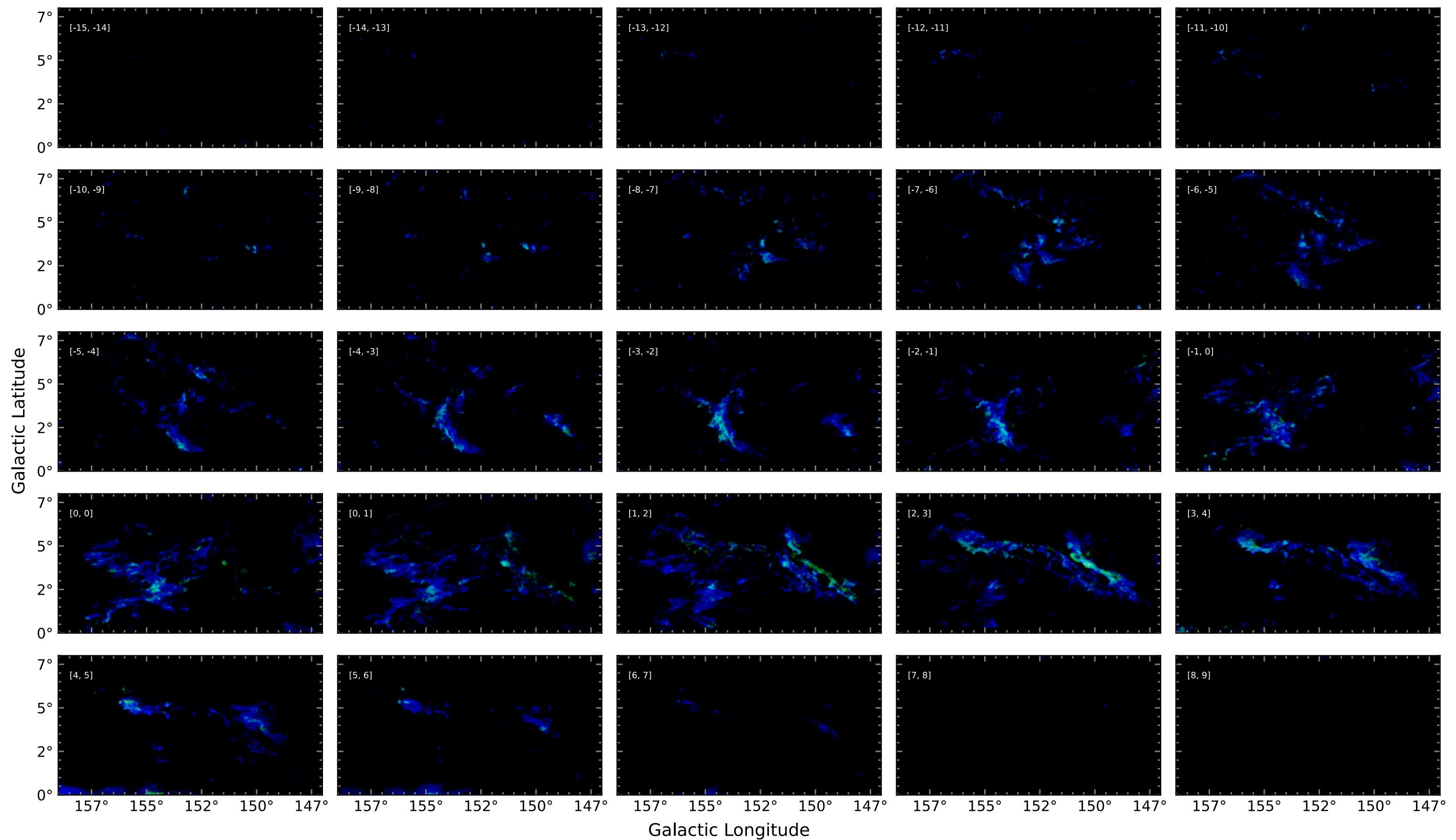


Properties and Distribution of Camelopardalis region Bow and Shell structures

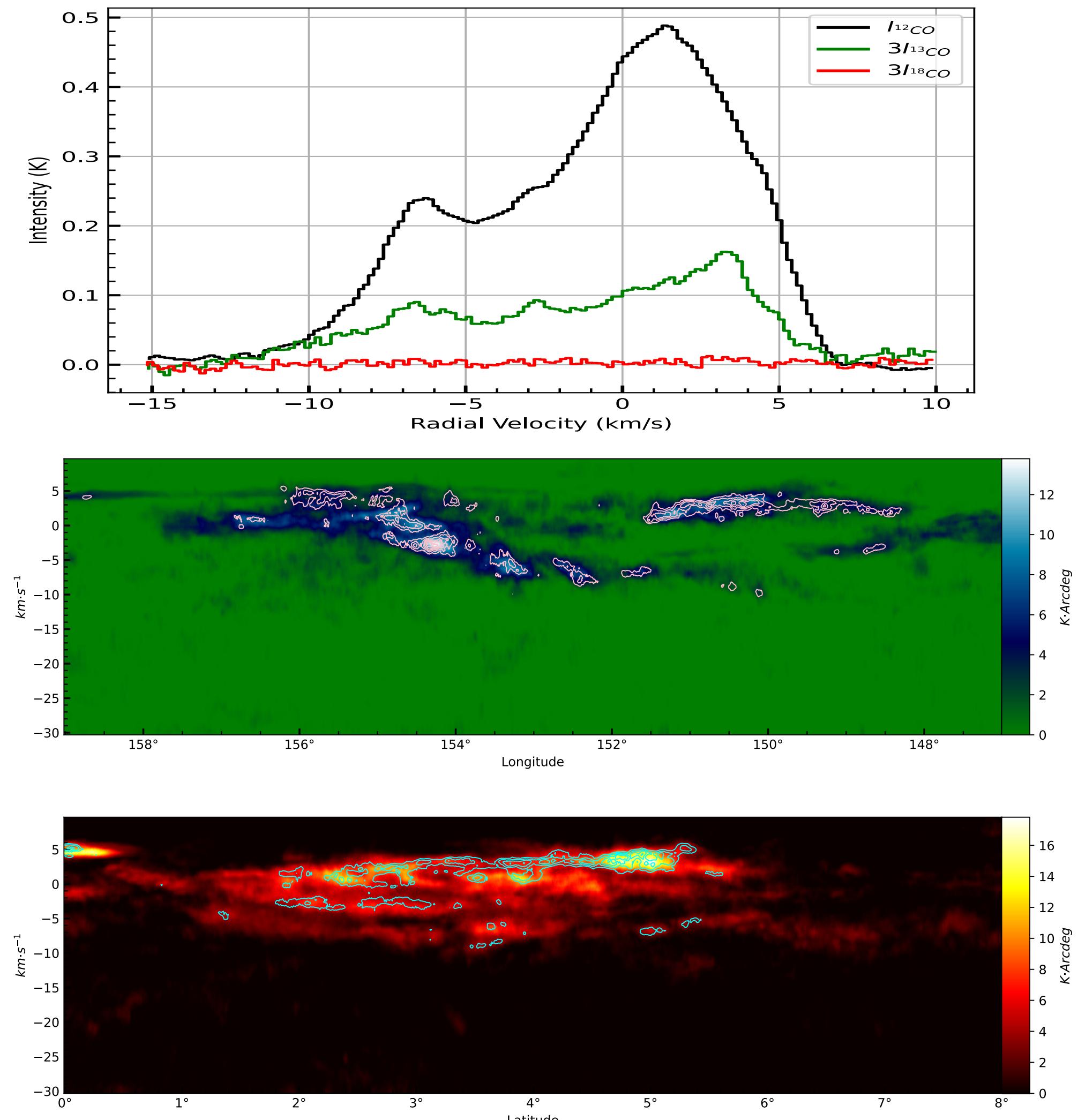
Wang Dong 2024.09.22

Overview of the region

CO Emissions and spectra



^{12}CO , ^{13}CO and C^{18}O emissions toward Camelopardalis direction



Identification of MCs

- Spectra decomposition
 - *GaussPy+*
 - A total of 228340 velocity components were decomposed
- Velocity Component Clustering
 - *Acrons* ($N_{min} = 25$)
 - A total of 99 molecular clouds with hierarchical structures were obtained
 - See Figure 1 for spatial distribution

Clustering

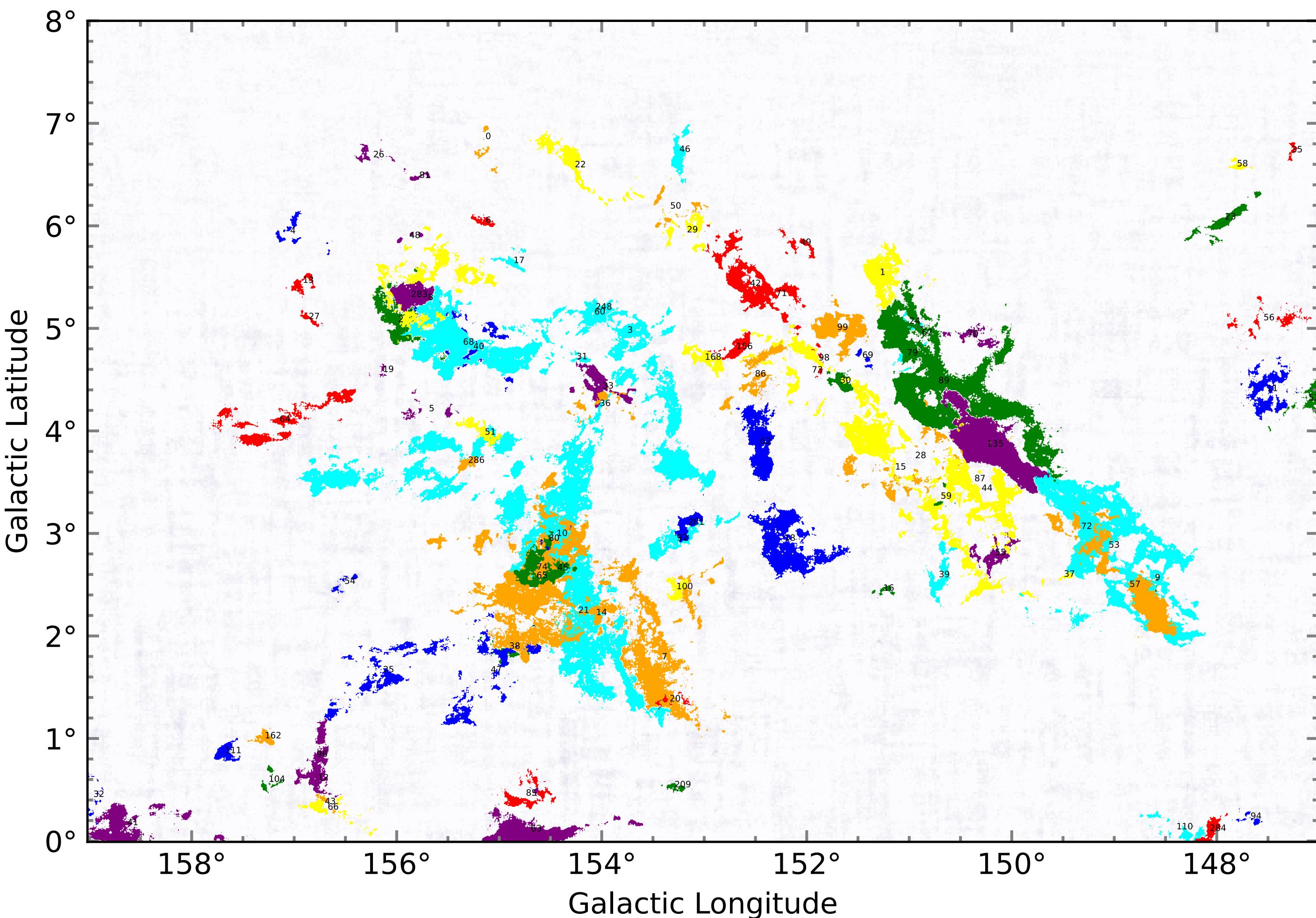


Figure 1

Distance and Properties

Distance Measurements and compiling of the Tables

- Distance

- Technique: BEEP (Figure 2)
- Number of measurable distances (approx. 40 % molecular cloud distance measurable)
- Distribution (Figure 3)

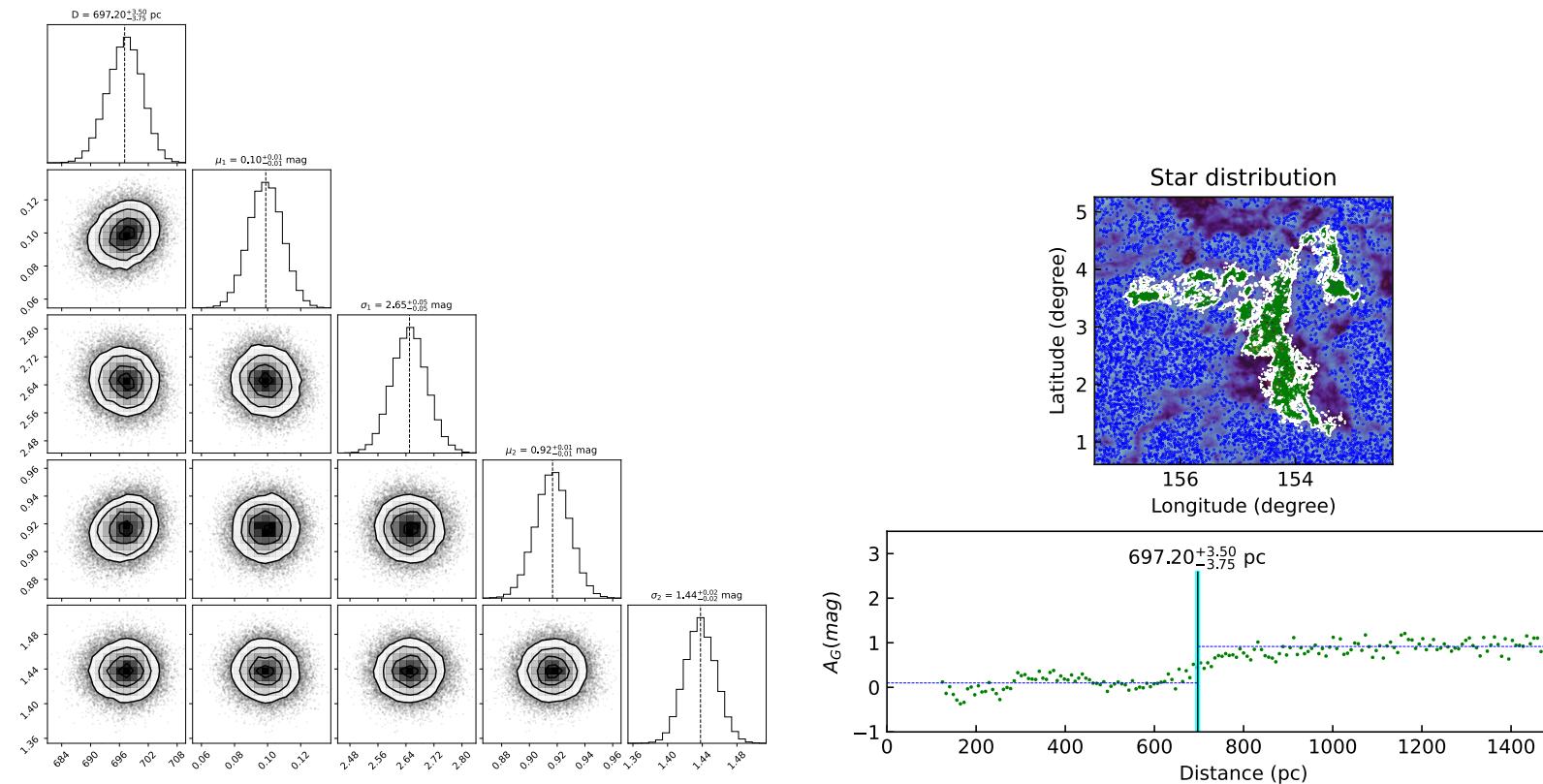


Figure 2

Table 2: Clouds Properties

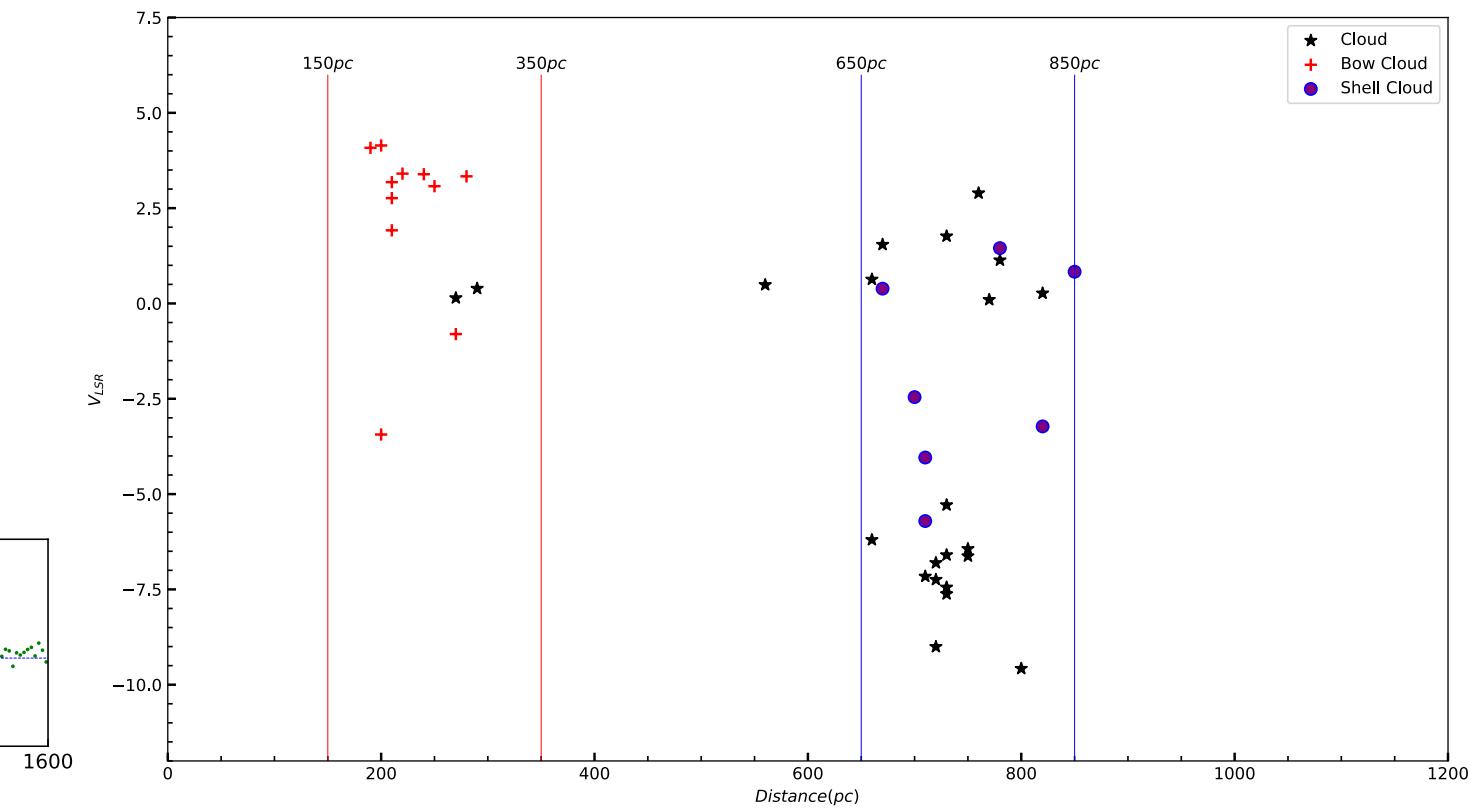


Figure 3

- Properties

- Size (Angular Area)
- Optical Depth (^{13}CO [LTE])
- Column Density (^{12}CO & ^{13}CO [LTE])
- Mass (^{12}CO & ^{13}CO [LTE])
 - $^{12}CO \rightarrow 40784M_{\odot}$
 - $^{13}CO \rightarrow 25269M_{\odot}$

Name	l	b	V	Area	d	M_{13}	M_{12}	\bar{N}_{12}	\hat{N}_{12}	τ	\bar{N}_{13}	\hat{N}_{13}	\hat{T}_{ex}	\hat{T}_{ex}
Cam 155.13+6.85	155.13	6.85	-7.93	70.25	-	-	-	13.43	22.88	0.28	5.64	20.37	7.33	9.25
Cam 151.29+5.52	151.29	5.52	1.54	534.25	670	443	786	17.08	29.61	0.30	9.63	39.22	9.60	12.52
Cam 155.99+5.06	155.99	5.06	4.14	512.75	200	79	100	25.40	46.29	0.38	19.94	69.18	10.49	13.58
Cam 153.75+4.96	153.75	4.96	2.89	568.50	760	719	1217	19.32	37.63	0.32	11.42	36.86	9.80	13.00
Cam 157.04+5.93	157.04	5.93	3.27	100.00	-	-	-	12.67	29.75	0.26	5.74	24.39	8.63	12.48
Cam 155.69+4.19	155.69	4.19	-8.78	90.75	-	-	-	24.04	54.08	0.29	10.69	41.04	8.57	11.64
Cam 155.13+6.03	155.13	6.03	-1.42	60.75	-	-	-	12.91	25.74	0.28	5.74	17.99	7.66	9.67
Cam 153.41+1.77	153.41	1.77	-5.71	1759.25	710	1843	3721	21.86	78.82	0.31	10.83	54.38	8.64	11.85
Cam 155.70+5.28	155.70	5.28	3.08	1130.25	250	144	261	19.28	57.07	0.28	10.63	67.80	9.47	12.96
Cam 148.60+2.54	148.60	2.54	-2.68	41.50	-	-	-	17.00	29.05	0.23	6.36	18.33	8.45	11.40
Cam 154.44+2.97	154.44	2.97	-2.46	7925.50	700	9906	16356	21.95	73.62	0.34	13.29	76.26	9.40	14.34
Cam 147.51+4.39	147.51	4.39	1.10	461.50	-999	447	606	6.85	15.96	0.47	5.06	23.57	7.16	9.96
Cam 156.77+0.59	156.77	0.59	1.46	138.75	-	-	-	13.47	34.21	0.25	6.29	37.22	9.40	12.83
Cam 156.92+5.44	156.92	5.44	-11.17	84.75	-	-	-	13.73	28.09	0.30	7.16	28.43	7.92	10.91
Cam 154.06+2.20	154.06	2.20	-4.04	125.50	710	230	269	22.12	62.70	0.42	18.94	75.01	9.37	12.40
Cam 151.14+3.62	151.14	3.62	1.92	1530.75	210	218	243	18.73	49.58	0.42	16.86	108.53	9.50	15.09
Cam 151.25+2.44	151.25	2.44	1.35	39.75	-	-	-	15.50	22.59	0.22	7.47	17.22	10.59	12.88

Identification of Clumps

Technique and Properties

- Technique
 - Search ^{13}CO clumps by *FacetClumps* ($N_{min} = 16$)
 - A total of 3128 non-boundary clumps were identified
- Distribution of Clumps
 - See Figure 4
- Properties of Clumps
 - See table in the right
- Statistical results
 - Clumps on MCs ($3128 \rightarrow 2109 \rightarrow 2022[d]$)
 - Radius ($R_{med} = 0.4 pc$)
 - Mass ($M_{med} = 5.85 M_{\odot}$)
 - Velocity Dispersion ($\sigma_{med} = 0.33 km/s$)
 - Virial Parameter ($\alpha_{med} = 0.78$)
 - In Bow ($613 \rightarrow 597[d]$)
 - In Shell ($682[d]$)

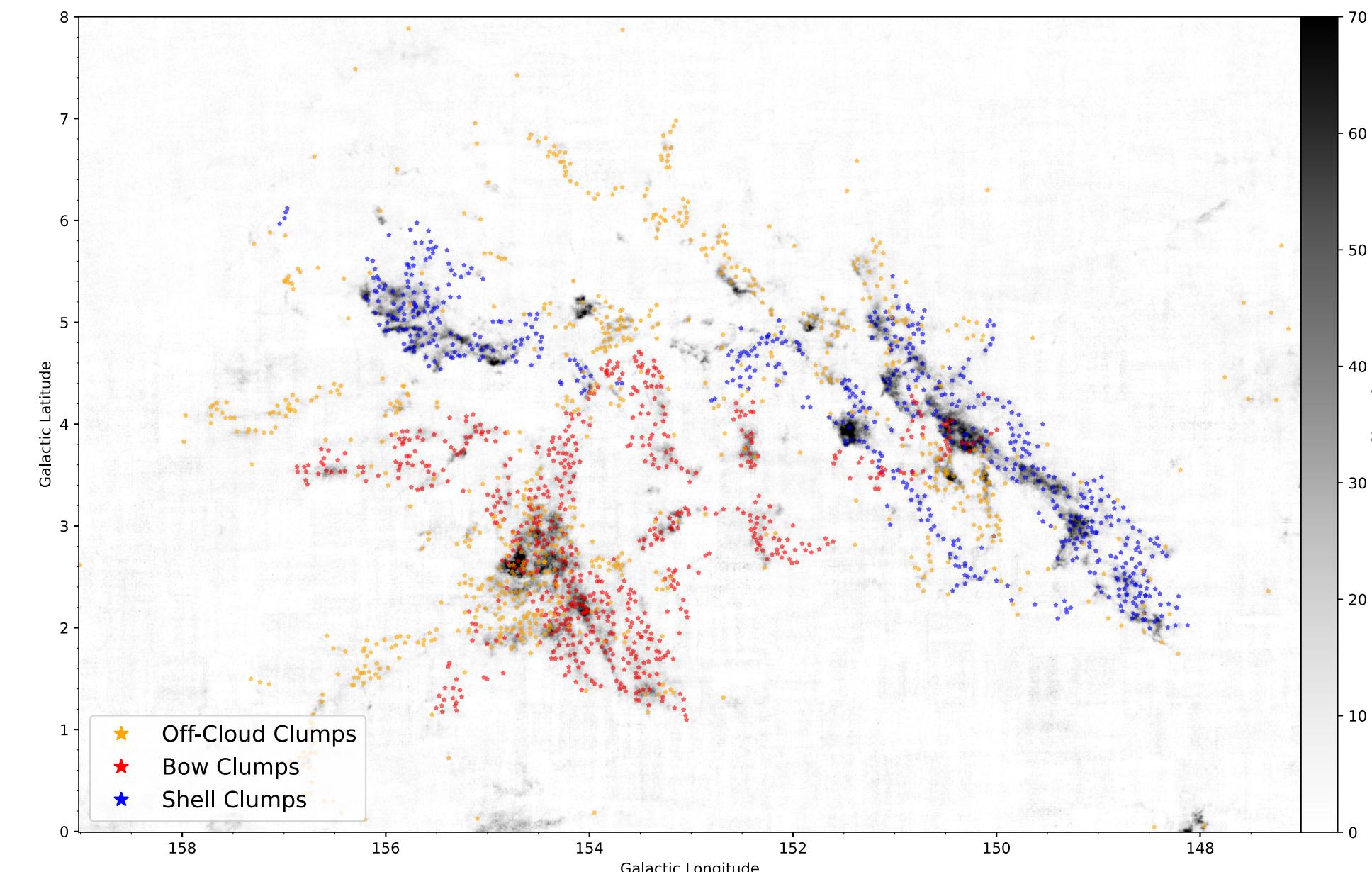
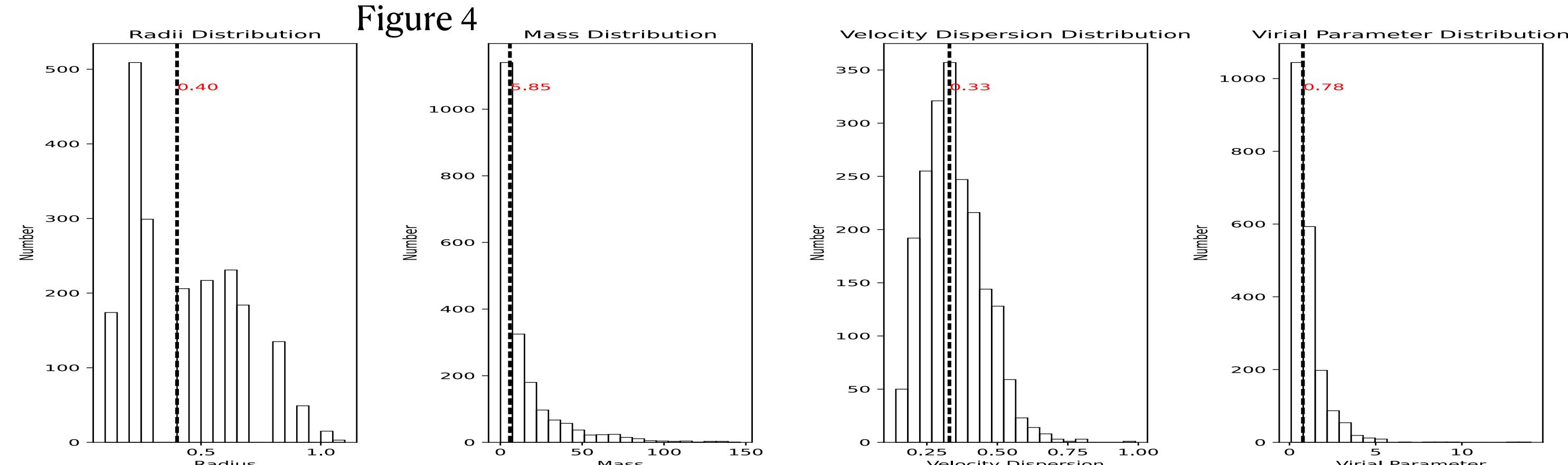


Table 3: Clumps Properties								
Name	l	b	V_{lsr}	M	\hat{T}	σ_V	R	α
Clumps 150.09+3.23	150.089	3.228	-10.128	12.00	3.05	0.28	0.5	0.38
Clumps 150.10+3.27	150.102	3.273	-9.882	46.20	3.49	0.33	0.8	0.23
Clumps 150.15+3.25	150.151	3.253	-9.603	21.80	3.11	0.31	0.6	0.30
Clumps 150.17+3.30	150.174	3.299	-9.73	5.50	2.04	0.28	0.4	0.64
Clumps 150.12+3.52	150.125	3.52	-9.56	104.10	4.86	0.45	0.8	0.18
Clumps 150.13+3.48	150.13	3.478	-9.36	57.50	4.26	0.43	0.7	0.26
Clumps 150.07+3.43	150.075	3.431	-9.492	39.30	3.37	0.49	0.7	0.49
Clumps 150.09+3.57	150.085	3.574	-9.448	44.10	3.57	0.46	0.8	0.44
Clumps 150.19+3.54	150.187	3.539	-8.737	5.50	2.39	0.30	0.4	0.75
Clumps 150.21+3.51	150.207	3.513	-9.031	3.50	1.86	0.22	0.4	0.66
Clumps 156.41+5.43	156.412	5.427	-11.345	2.50	1.54	0.17	0.4	0.56
Clumps 153.26+6.71	153.256	6.713	-9.511	36.00	3.05	0.43	0.7	0.41
Clumps 153.20+6.71	153.199	6.713	-9.569	29.40	3.80	0.45	0.6	0.48
Clumps 153.27+6.83	153.273	6.833	-9.847	20.60	2.39	0.41	0.7	0.67
Clumps 153.23+6.64	153.226	6.639	-9.273	19.10	2.32	0.54	0.6	1.07
Clumps 153.23+6.58	153.233	6.585	-8.61	28.90	2.63	0.47	0.7	0.62
Clumps 153.29+6.60	153.288	6.597	-9.566	10.80	1.81	0.42	0.5	0.93
Clumps 153.30+6.63	153.296	6.633	-9.91	4.60	1.38	0.29	0.4	0.85
Clumps 153.24+6.52	153.242	6.519	-9.507	2.90	1.52	0.22	0.4	0.79
Clumps 153.17+6.93	153.173	6.929	-9.962	13.50	1.92	0.32	0.6	0.51
Clumps 153.15+6.98	153.148	6.98	-10.06	3.40	1.60	0.22	0.4	0.68



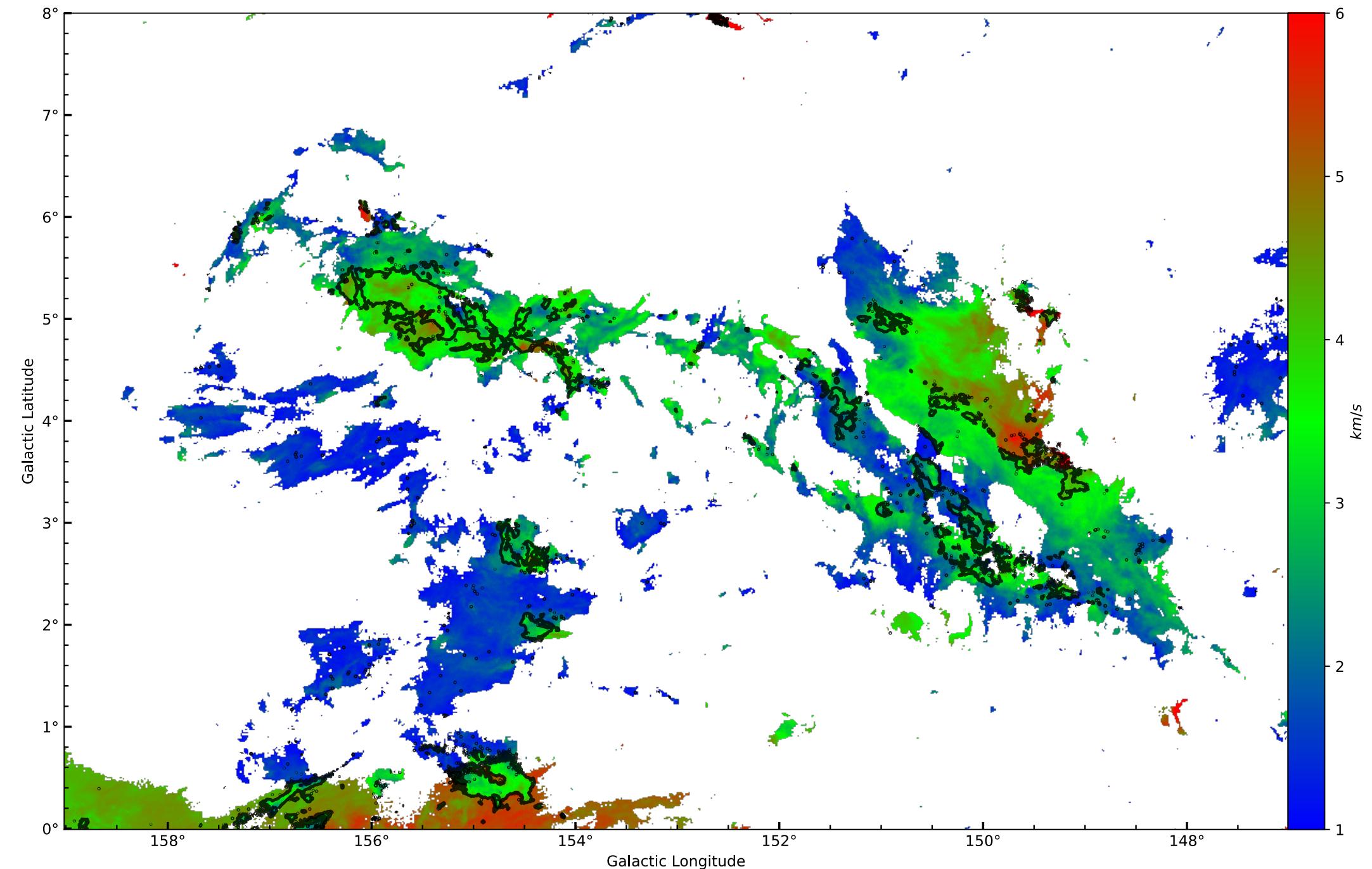
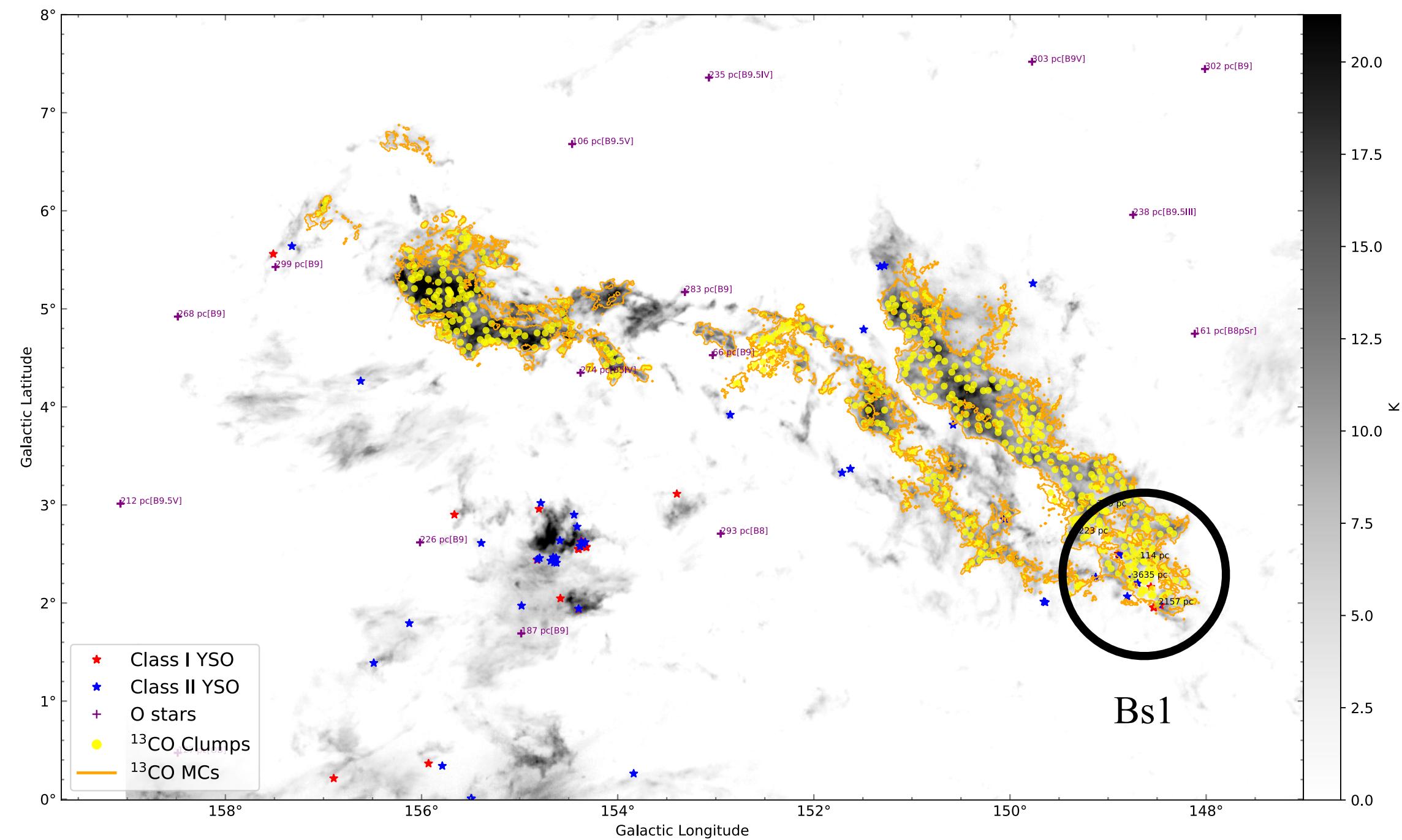
Two Major Structures

Bow

- Velocity Range
 - $v \in [1 \sim 8] \text{ km/s}$
 - Projection Area
 - $^{13}\text{CO} \rightarrow 70 \text{ pc}^2 \text{ or } 4.8 \text{ deg}^2$
 - Distance
 - $d \approx 220 \text{ pc}$
 - H_2 Column Density
 - $N_{Peak}^{12} \approx 5.7 \times 10^{21} \text{ cm}^{-2} \text{ or } N_{Peak}^{13} \approx 1.1 \times 10^{22} \text{ cm}^{-2}$
 - $N_{Mean}^{12} \approx 1.7 \times 10^{21} \text{ cm}^{-2} \text{ or } N_{Mean}^{13} \approx 1.3 \times 10^{21} \text{ cm}^{-2}$
 - Mass
 - $^{12}\text{CO} \rightarrow 2878 M_\odot$
 - $^{13}\text{CO} \rightarrow 2467 M_\odot$
 - Outflow——Require further investigation
 - A total of XX outflow sources ($N_{Single} = XX, N_{Bipolar} = XX$)
 - Clumps
 - Mass ($M_{med} = 2.3 M_\odot$)
 - Velocity Dispersion ($\sigma_{med} = 0.34 \text{ km/s}$)
 - Virial Parameter ($\alpha_{med} = 1.19$)
- How to determine the ^{13}CO boundary?
 - MCs whose distances are within 300 pc and projected spatially to form a Bow shape
 - $v \in [1, 8] \text{ km/s}$, not measurable in distance and form a Bow in projected space
 - How to search for outflow?
 - Spurs in *PV – diagram* , locate (l, b, v)
 - Integrated over (l, b, v) 's line wings
 - Properties of outflow?
 - Kinematic energy
 - Momentum

Two Major Structures

Bow

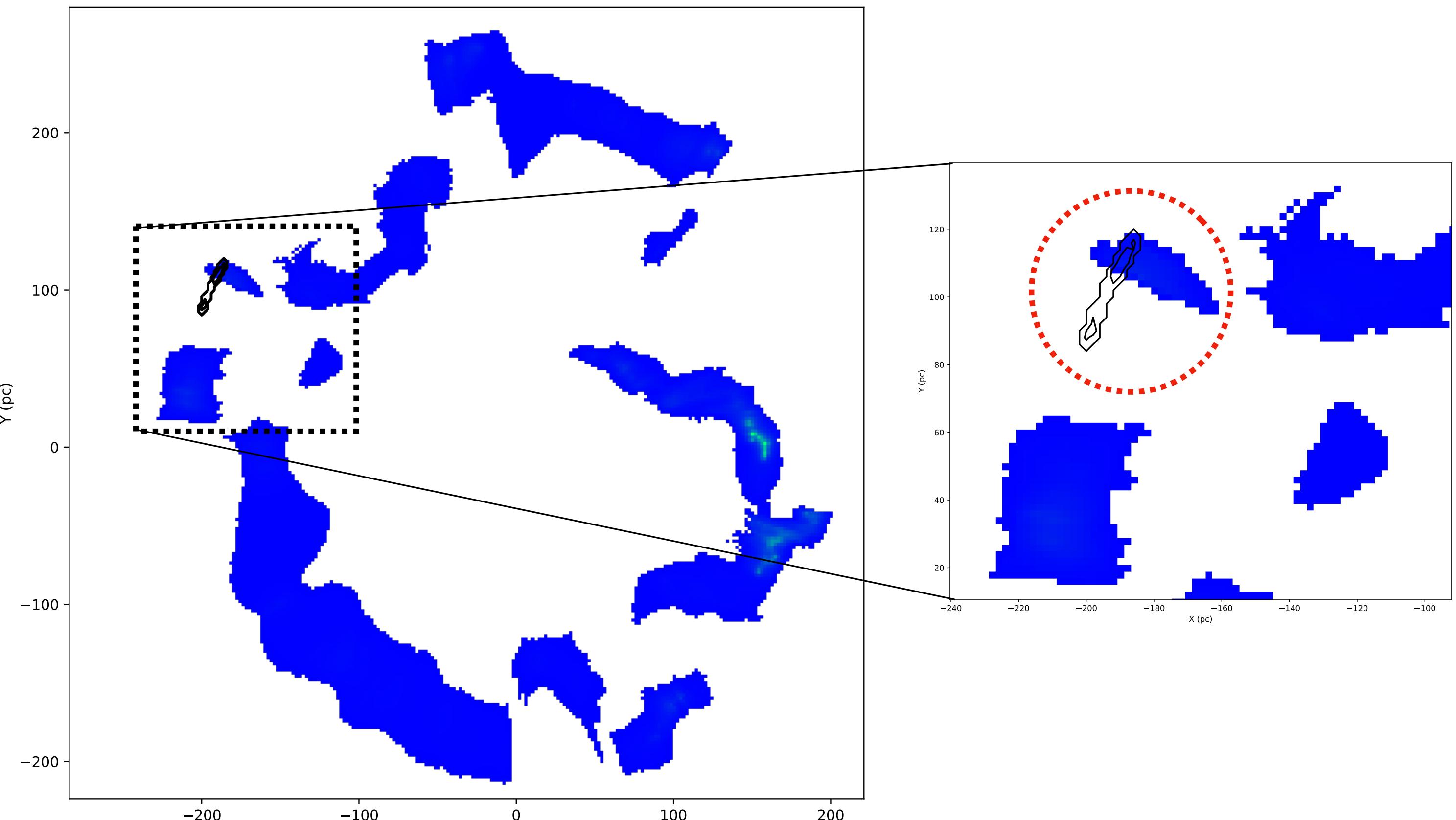


- Left: Distribution of MCs, Clumps, YSOs and OB stars
 - YSOs gather in Bs1, only B stars have been found \Rightarrow Early stage of Star Formation (Starless MCs)
- Right: Distribution of Central Velocity and Velocity Dispersion
 - The Bow MCs have similar velocities and relative larger velocity dispersion than ambient MCs \Rightarrow More Turbulent than ambient MCs \Rightarrow Under Stellar Feedback?

Two Major Structures

Bow

- MCs on the Shell of the Local Bubble
 - Local Bubble model from O'Neil (2024)
 - $Z \in [10, 24] pc$
- Are these MCs fragmenting?
 - Need further investigation



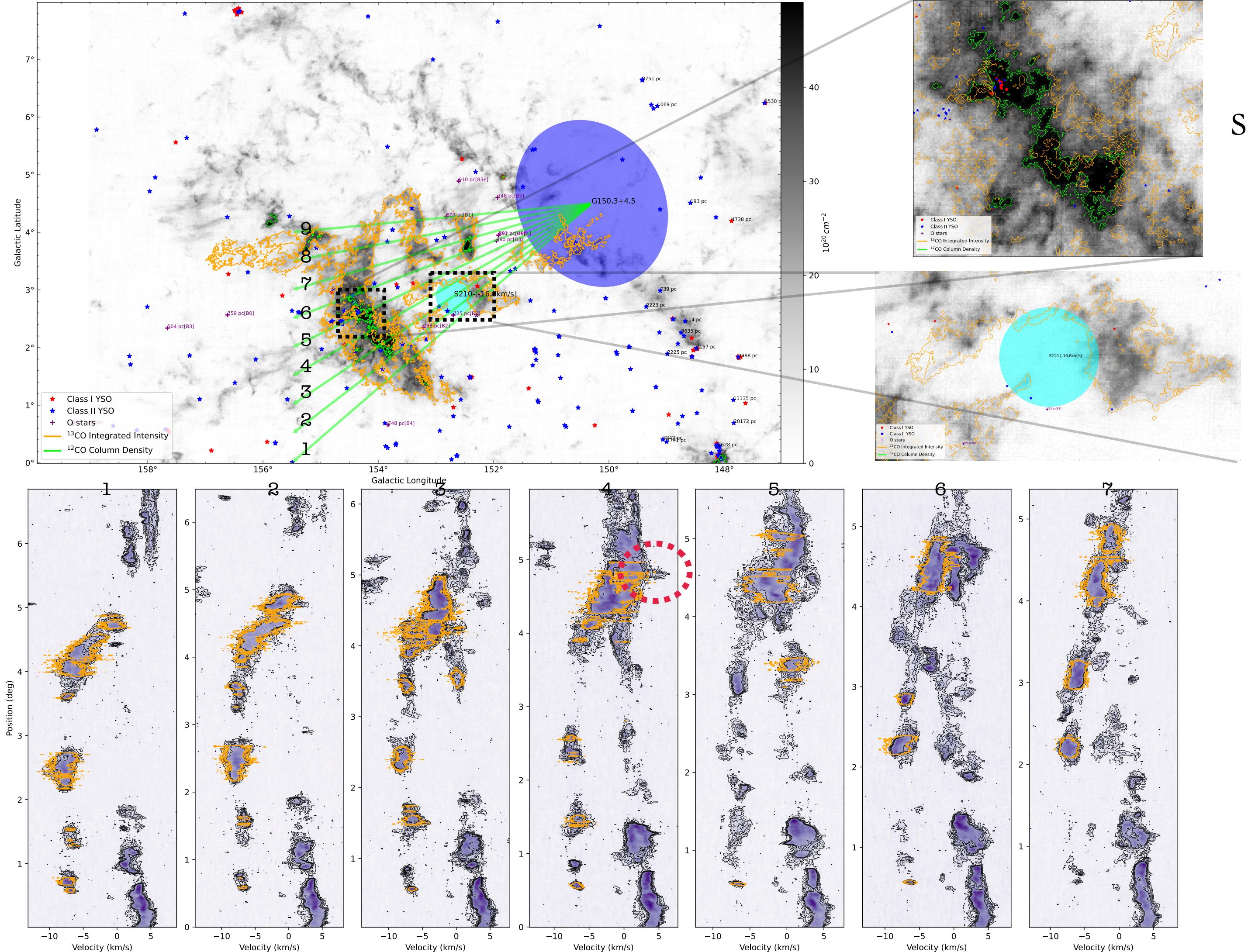
Two Major Structures

Shell

- Velocity Range
 - $v \in [-10 \sim -1] \text{ km/s}$
 - Projection Area (A)
 - $^{13}\text{CO} \rightarrow 598 \text{ pc}^2 \text{ or } 3.7 \text{ deg}^2$
 - Distance
 - Bulk $d \approx 710 \text{ pc}$, some $d \sim 800 \text{ pc}$
 - H_2 Column Density
 - $N_{Peak}^{12} \approx 7.9 \times 10^{21} \text{ cm}^{-2} \text{ or } N_{Peak}^{13} \approx 7.6 \times 10^{21} \text{ cm}^{-2}$
 - $N_{Mean}^{12} \approx 1.8 \times 10^{21} \text{ cm}^{-2} \text{ or } N_{Mean}^{13} \approx 1.1 \times 10^{21} \text{ cm}^{-2}$
 - Mass (M)
 - $^{12}\text{CO} \rightarrow 27743 M_\odot$
 - $^{13}\text{CO} \rightarrow 16181 M_\odot$
 - Shell Properties
 - $R_{sh} \approx 55 \text{ pc}$
 - $V_{sh} \approx 7.5 \text{ km/s}$
- How to determine the ^{13}CO boundary?
 - MCs whose distances are within $[650, 850] \text{ pc}$ and projected spatially to form a Shell shape
 - $v \in [-10, -1] \text{ km/s}$ not measurable in distance and form a Shell in projected space
 - How to determine the expanding velocity?
 - From *PV – diagram*
 - How to estimate properties?
 - Timescale ($t_{sh} = R_{sh}/V_{sh}$)
 - Kinetic Energy ($E_{sh} = \frac{1}{2}MV_{sh}^2$)
 - Total Energy ($E_{Total} = E_{sh} \times \frac{4\pi R_{sh}^2}{A}$)

Two Major Structures

Shell



- Expanding Velocity
 - $V_{sh} \approx 7.5 \text{ km/s}$
 - Timescale
 - $t_{sh} \approx 7.2 \text{ Myr}$
 - Mass
 - $M = 16181 M_{\odot}$
 - Total energy of the Shell
 - $E_{sh} \approx 9.1 \times 10^{48} \text{ erg}$
 - Energy required from Stars
 - $E_{Total} \approx 5.6 \times 10^{50} \text{ erg}$
 - How much energy can star offer?
 - $E_{cluster} \in [10^{50} \text{ erg} \sim 10^{52} \text{ erg}] \Rightarrow E_{Total} \in E_{cluster}$
 - Distribution of YSOs
 - There are some YSOs in Ss2 region
 - ClassI ($t_{typical,I} \approx [0.1 \text{ Myr} \sim 1 \text{ Myr}]$)
 - ClassII ($t_{typical,II} \approx [1 \text{ Myr} \sim 10 \text{ Myr}]$) $\Rightarrow t_{sh} \in t_{typical,II}$
 - Properties of Clumps
 - Mass ($M_{med} = 15.4 M_{\odot}$)
 - Velocity Dispersion ($\sigma_{med} = 0.36 \text{ km/s}$)
 - Virial Parameter ($\alpha_{med} = 0.56$)
- Haven't been confirmed