

Master Thesis

**Exploring the existence of prebiotic species:  
ALMA observations of amine-containing  
organic molecule in star-forming regions.**

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# Abstract

A variety of complex organic molecules have been observed for decades in the interstellar medium. Some of them are considered to be delivered to the primordial Earth by comets, and contributed to the chemical evolution leading to terrestrial life. One example of such prebiotic species is amino acid. Glycine, the simplest amino acid, has been detected in comet 67P/C-G but its presence in molecular clouds is still uncertain.

In this work we analyze the ALMA archival data toward 3 star-forming regions, Orion Kleinmann-Low nebula (hereafter Orion-KL), IRAS 16293-2422 (IRAS 16293), and L483, to search methylamine ( $\text{CH}_3\text{NH}_2$ ), which is suggested as precursors to glycine.

As a result of analysis, we found 8 candidate emission at the hot core region in Orion-KL. By using the rotation diagram method, we evaluated its tentative column density and rotational temperature to be  $5.5 \times 10^{14} \text{ cm}^{-2}$  and 93.3 K, respectively. On the other hand,  $\text{CH}_3\text{NH}_2$  is not detected and stringent upper limit column densities are determined in IRAS 16293 and L483.

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# **Chapter 1**

## **Introduction**

### **1.1 Glycine and methylamine**

### **1.2 Star forming region**

#### **1.2.1 Orion Kleinmann-Low nebula**

#### **1.2.2 IRAS 16293-2422**

#### **1.2.3 L483**

### **1.3 Radio observation**

#### **1.3.1 Atacama Large Millimeter Array**

### **1.4 Purpose of this work**

# **Chapter 2**

## **Methylamine survey in Orion-KL**

### **2.1 Observation data**

### **2.2 Analysis**

#### **2.2.1 Continuum Subtraction of SV data**

#### **2.2.2 Line identification**

1. We drew methylamine emission maps using Common Astronomy Software Applications (CASA) software (McMullin et al. 2007). We used JPL Molecular Spectroscopy catalog to identify the transition lines. 8 spectral features exhibit a compact emission at the center of the Hot core . We extracted spectrum from this region.

2. We estimated the systemic velocity and the line width of 217.758 GHz line, reported by Pagani et al. (2017), which seem contaminated by other lines.
3. Using these value, we obtained the integrated intensity of 8 transitions described in Table 2.1 by Gaussian fitting.

## 2.3 Results

### 2.3.1 Transitions

Table 2.1: Observed rotational transitions of CH<sub>3</sub>NH<sub>2</sub> in Orion-KL

Frequency [GHz]	Sμ <sup>2</sup> [D <sup>2</sup> ]	E <sub>u</sub> [K]	Transition ( $J, K_a, \Gamma$ )	Comments
215.670	53.92	111.48	9, 2, $E_{1-1} \rightarrow 9, 1, E_{1+1}$	
245.202	37.84	168.31	12, 1, $B_2 \rightarrow 11, 2, B_1$	
217.758	129.88	182.05	12, 2, $B_2 \rightarrow 12, 1, B_1$	
221.755	35.06	133.11	10, 2, $A_2 \rightarrow 10, 1, A_1$	
229.908	27.37	92.71	8, 2, $A_2 \rightarrow 8, 1, A_1$	
235.735	82.06	92.76	8, 2, $B_2 \rightarrow 8, 1, B_1$	
242.262	60.23	60.86	6, 2, $B_2 \rightarrow 6, 1, B_1$	
244.887	49.54	48.09	5, 2, $B_1 \rightarrow 5, 1, B_2$	

### 2.3.2 Distribution

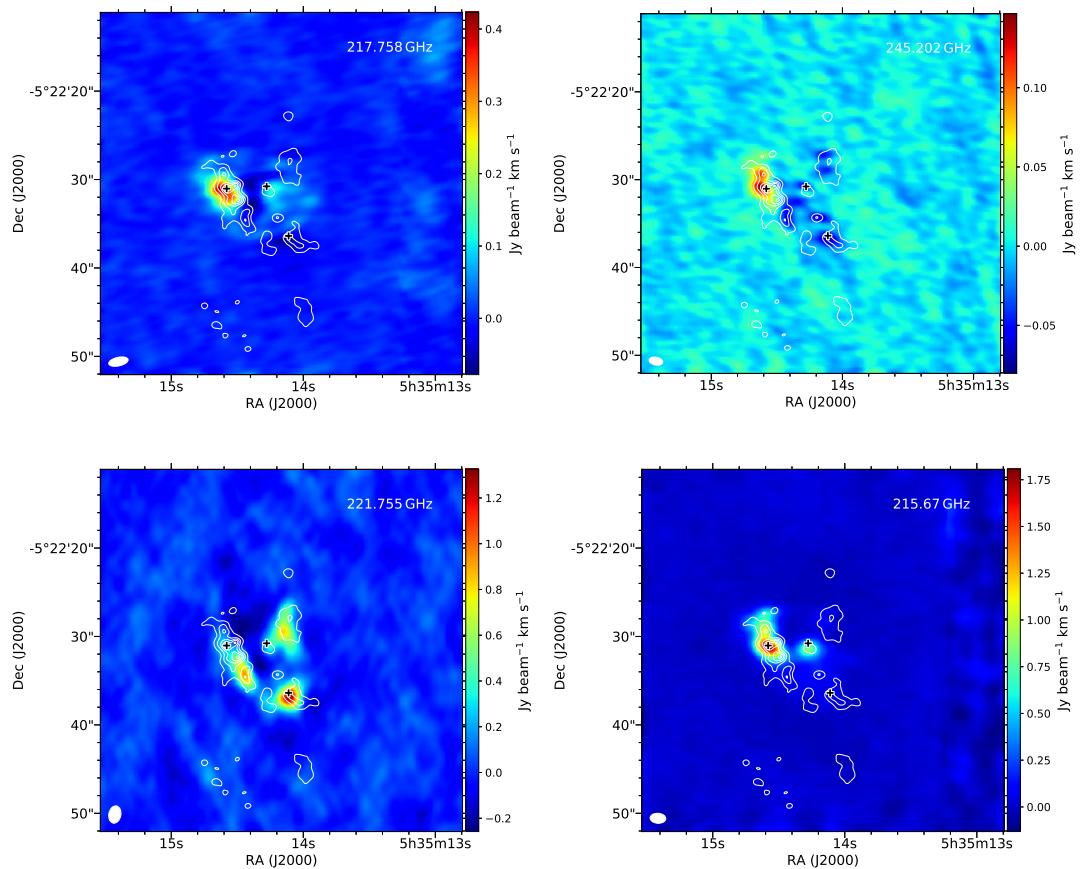


Figure 2.1: Integrated intensity map

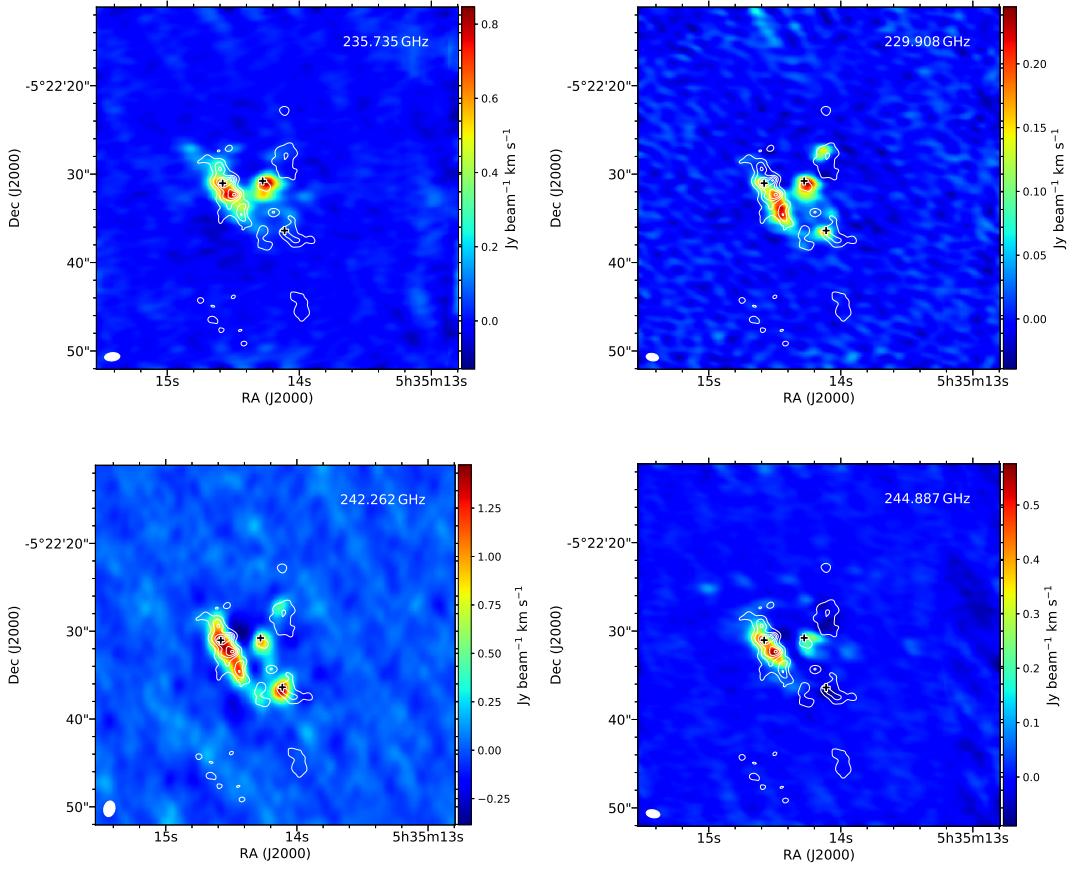


Figure 2.2: (Continued)

### 2.3.3 Spectrum

## 2.4 Disucssion

### 2.4.1 Column density and Rotation temperature

In this subsection we will describe the methodologies in deriving fractional abundances of COMs.

### 2.4.2 Blending

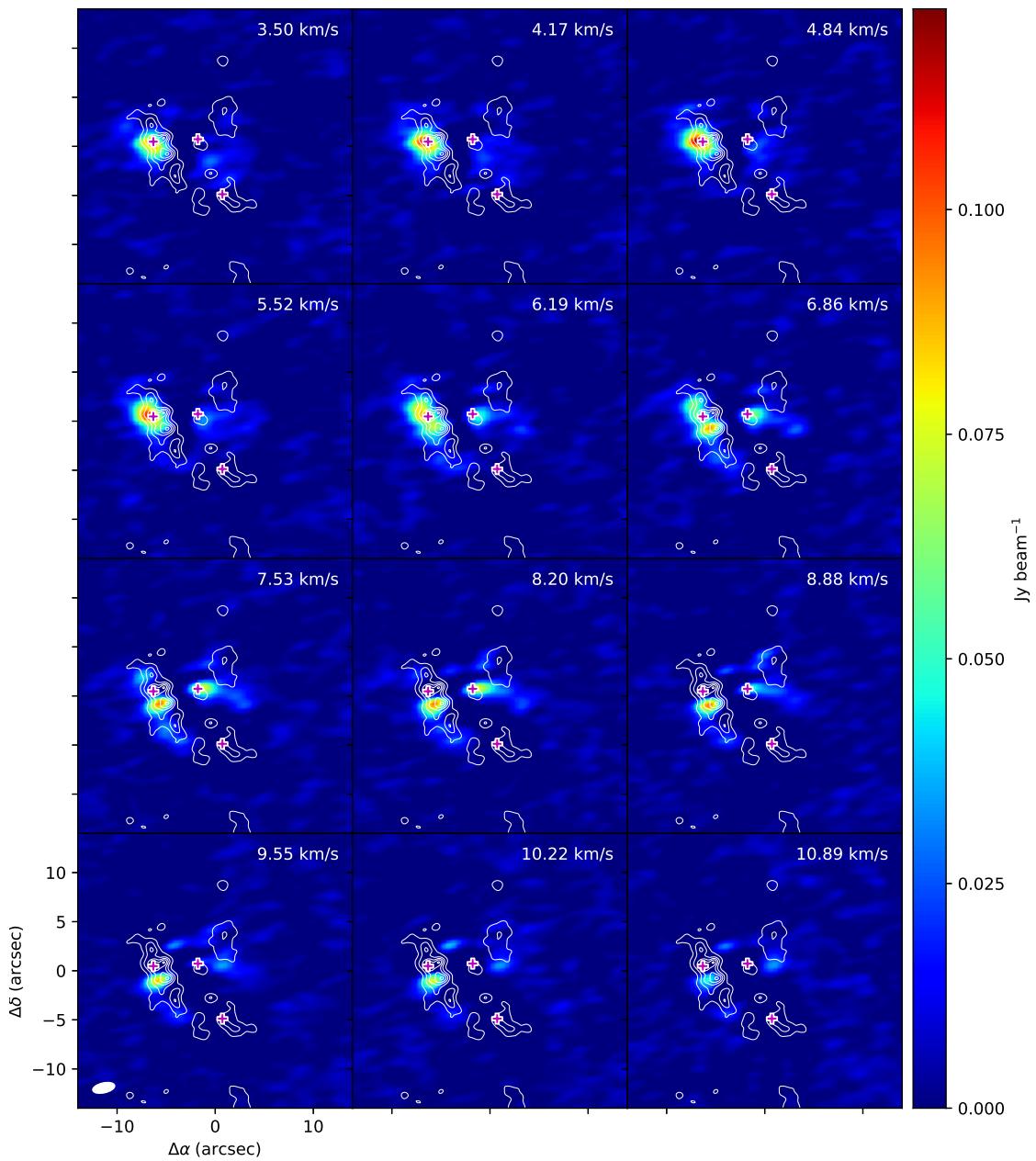


Figure 2.3: 217.758 GHz

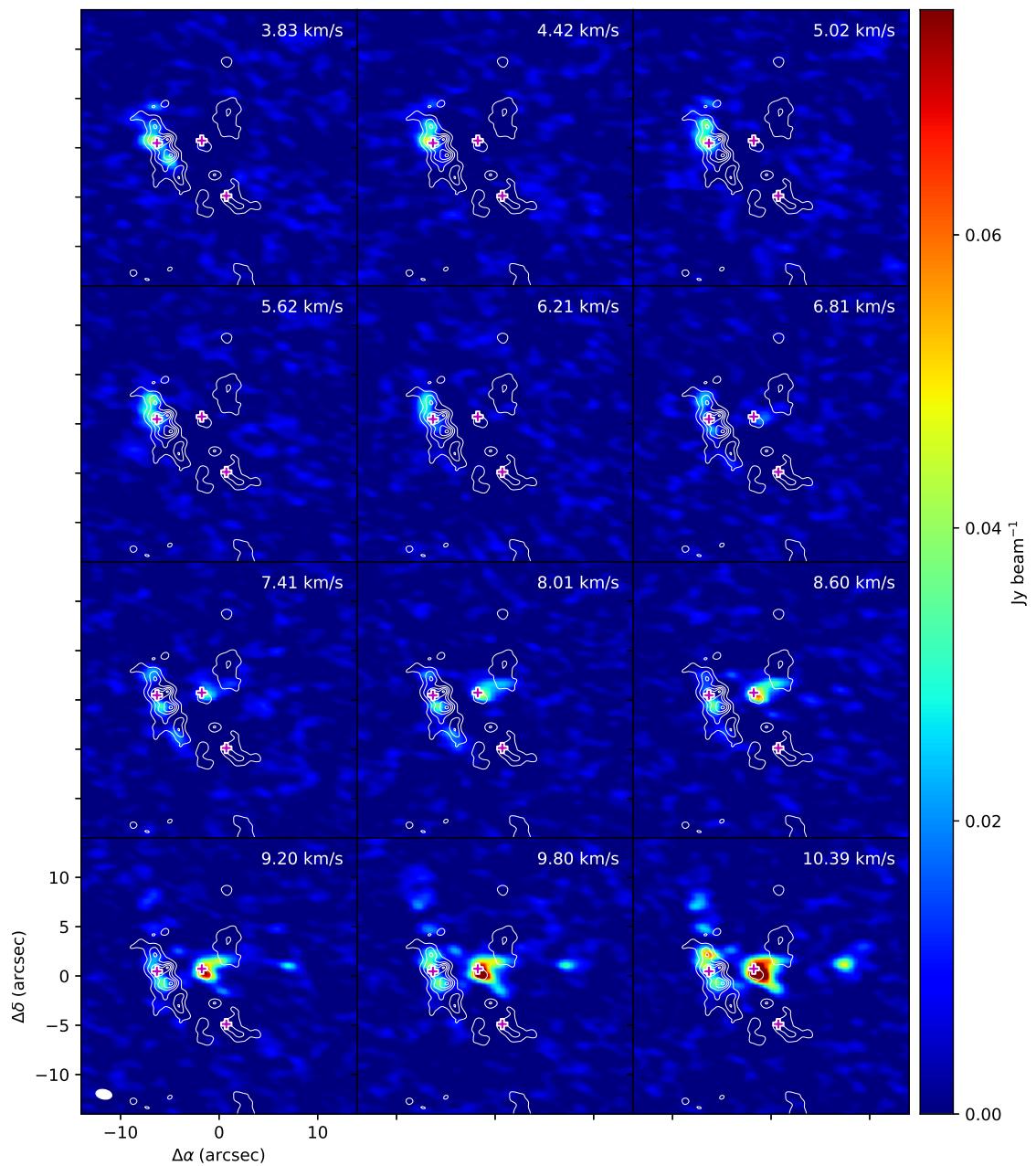


Figure 2.4: 245.202 GHz

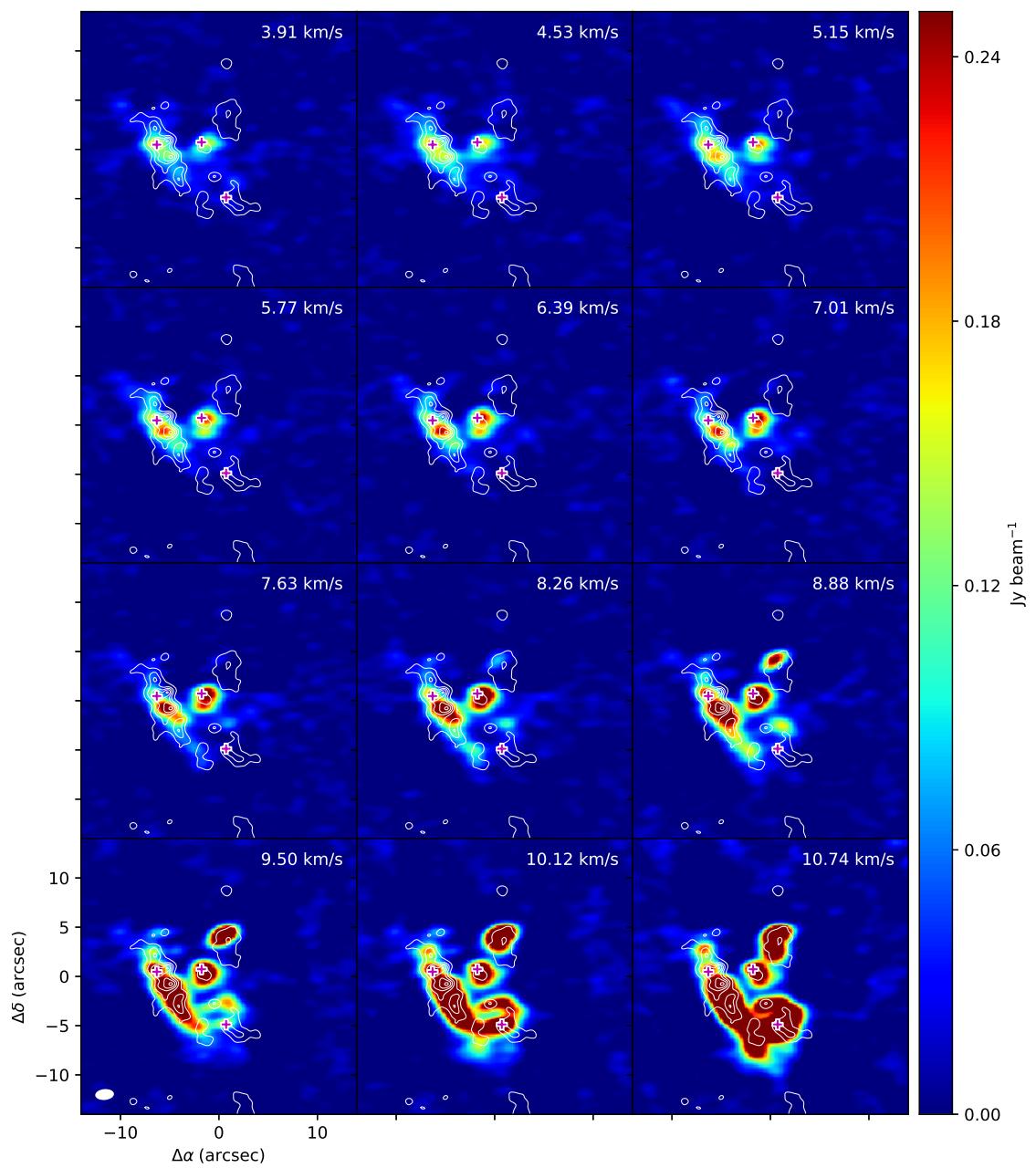


Figure 2.5: 235.735 GHz

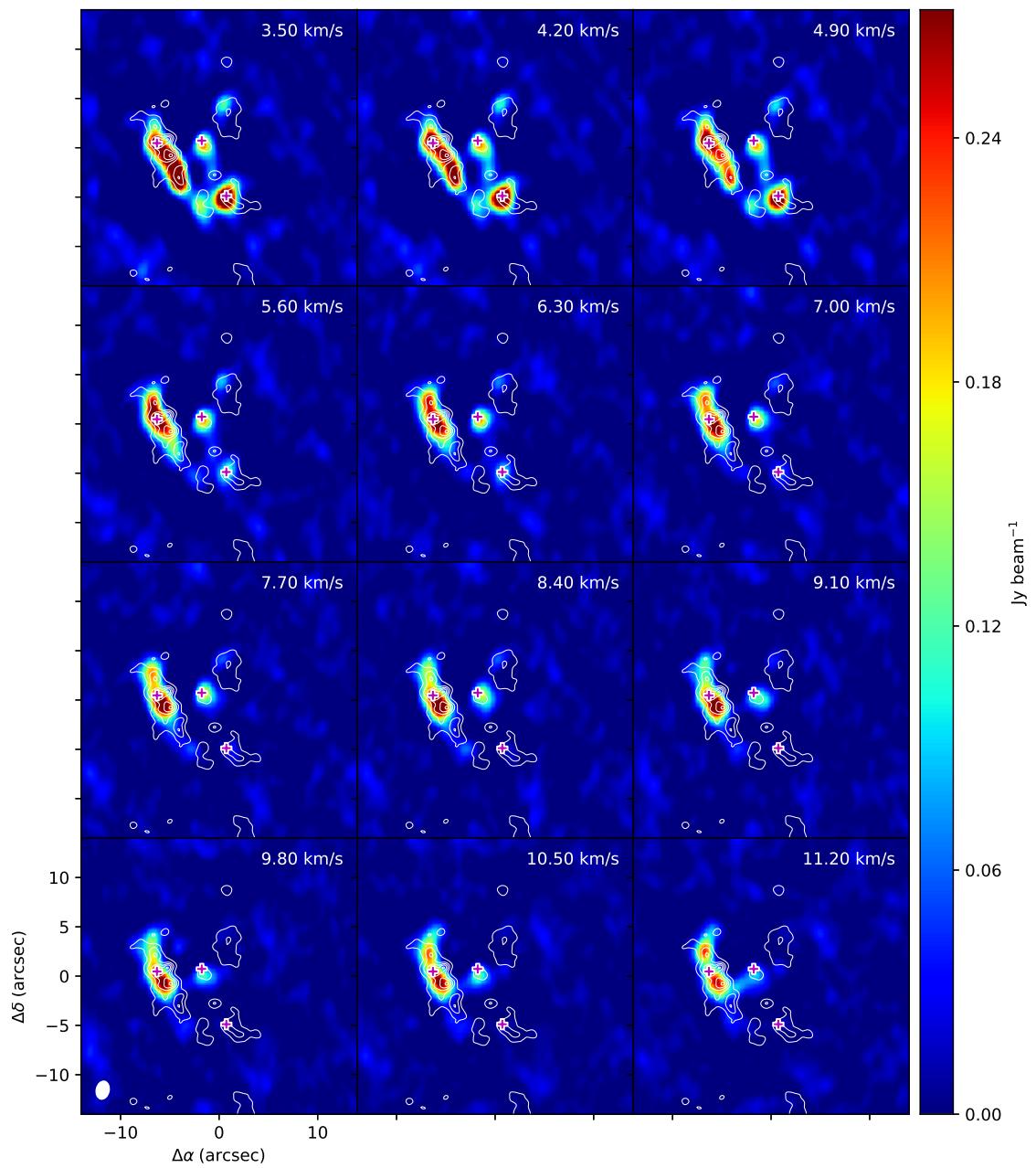


Figure 2.6: 242.262 GHz

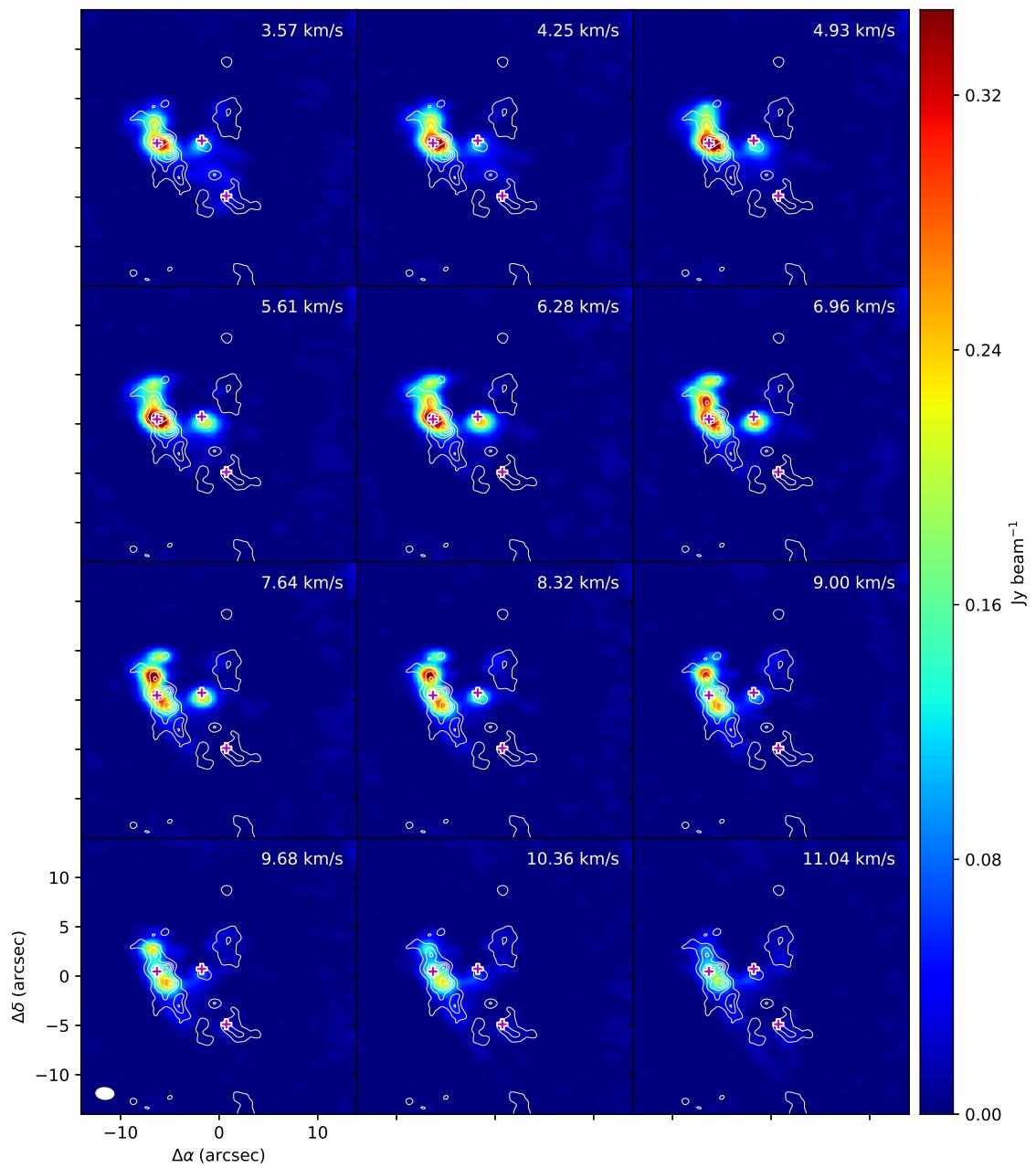


Figure 2.7: 215.670 GHz

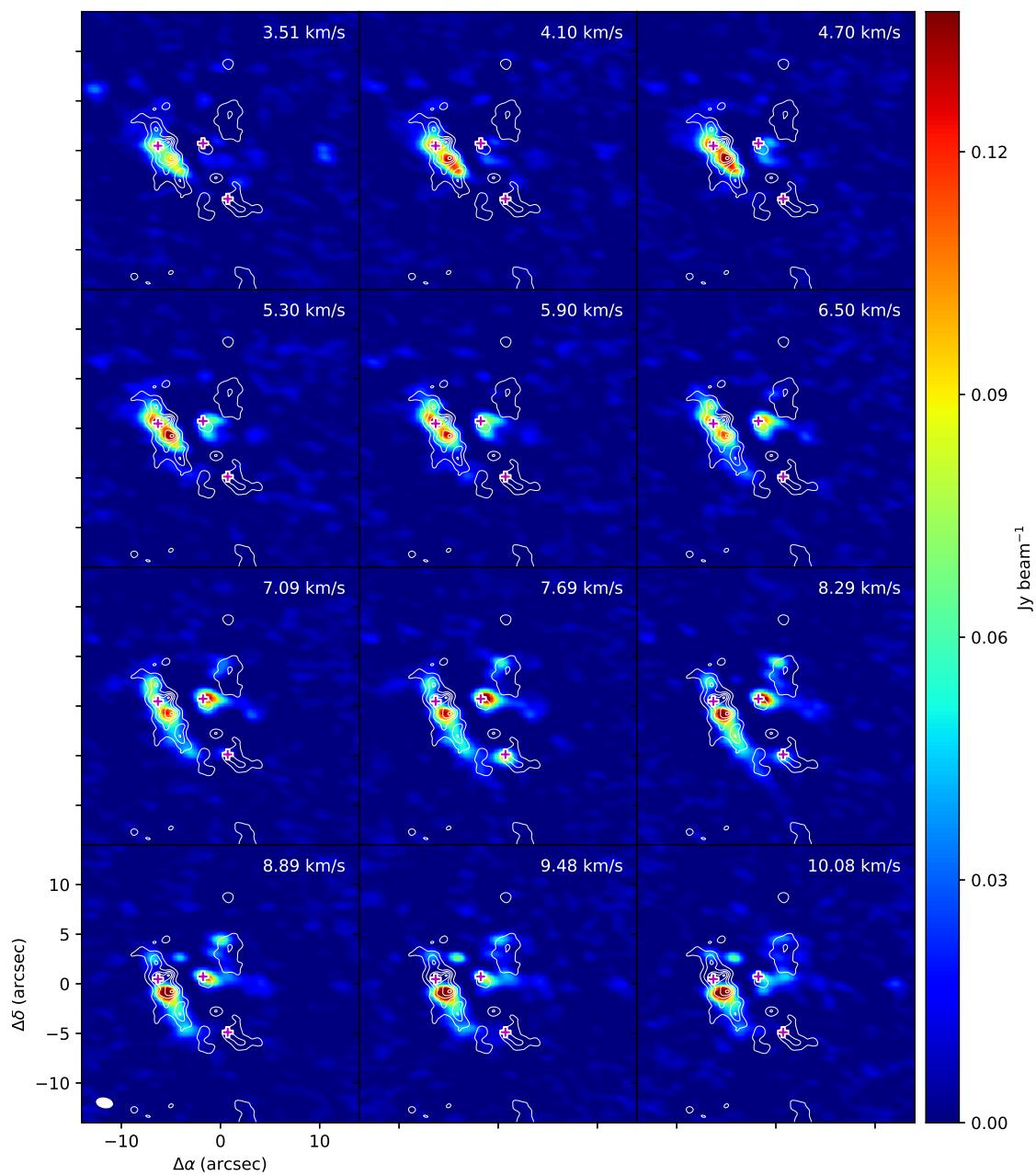


Figure 2.8: 244.887 GHz

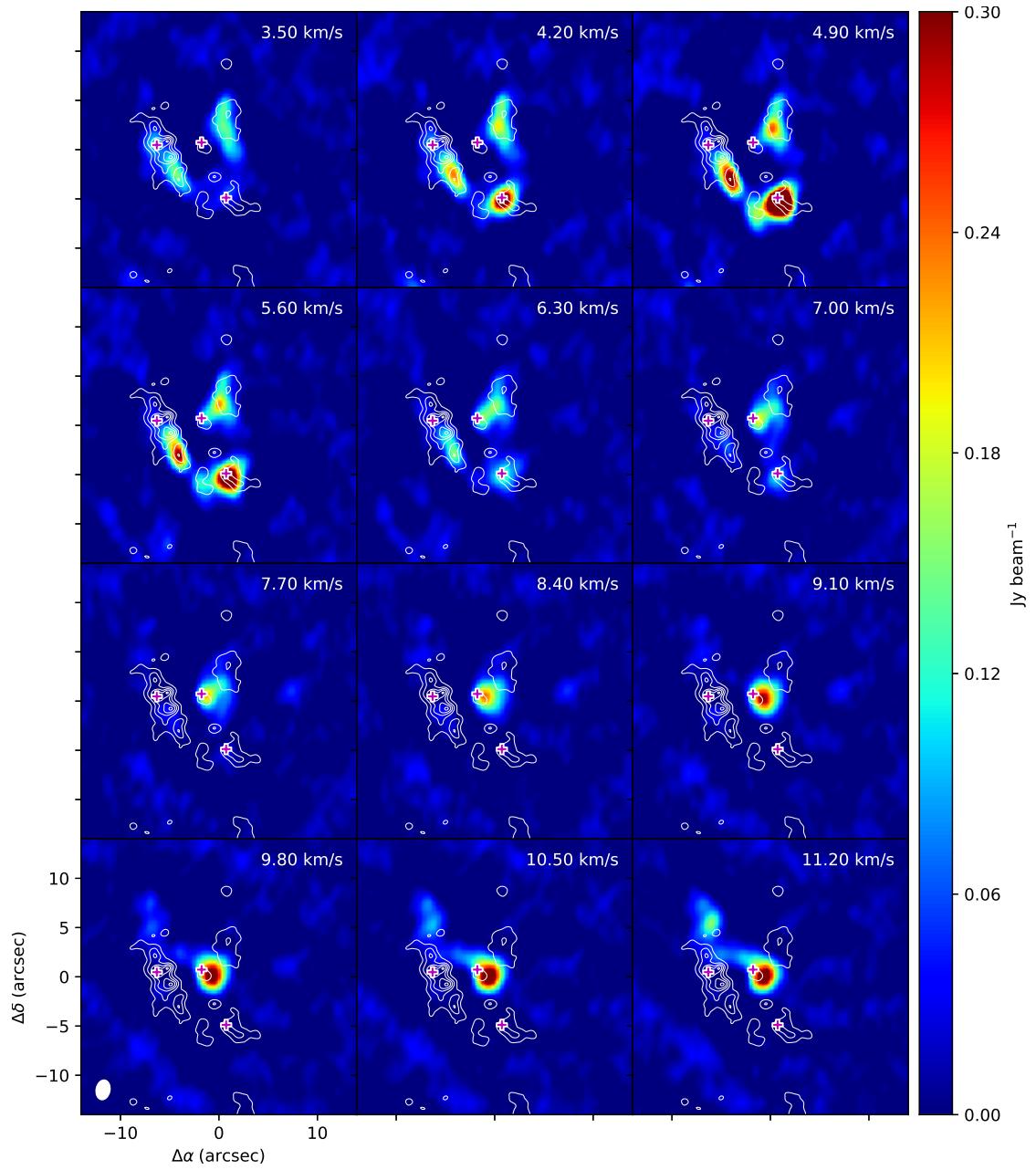


Figure 2.9: 221.755 GHz

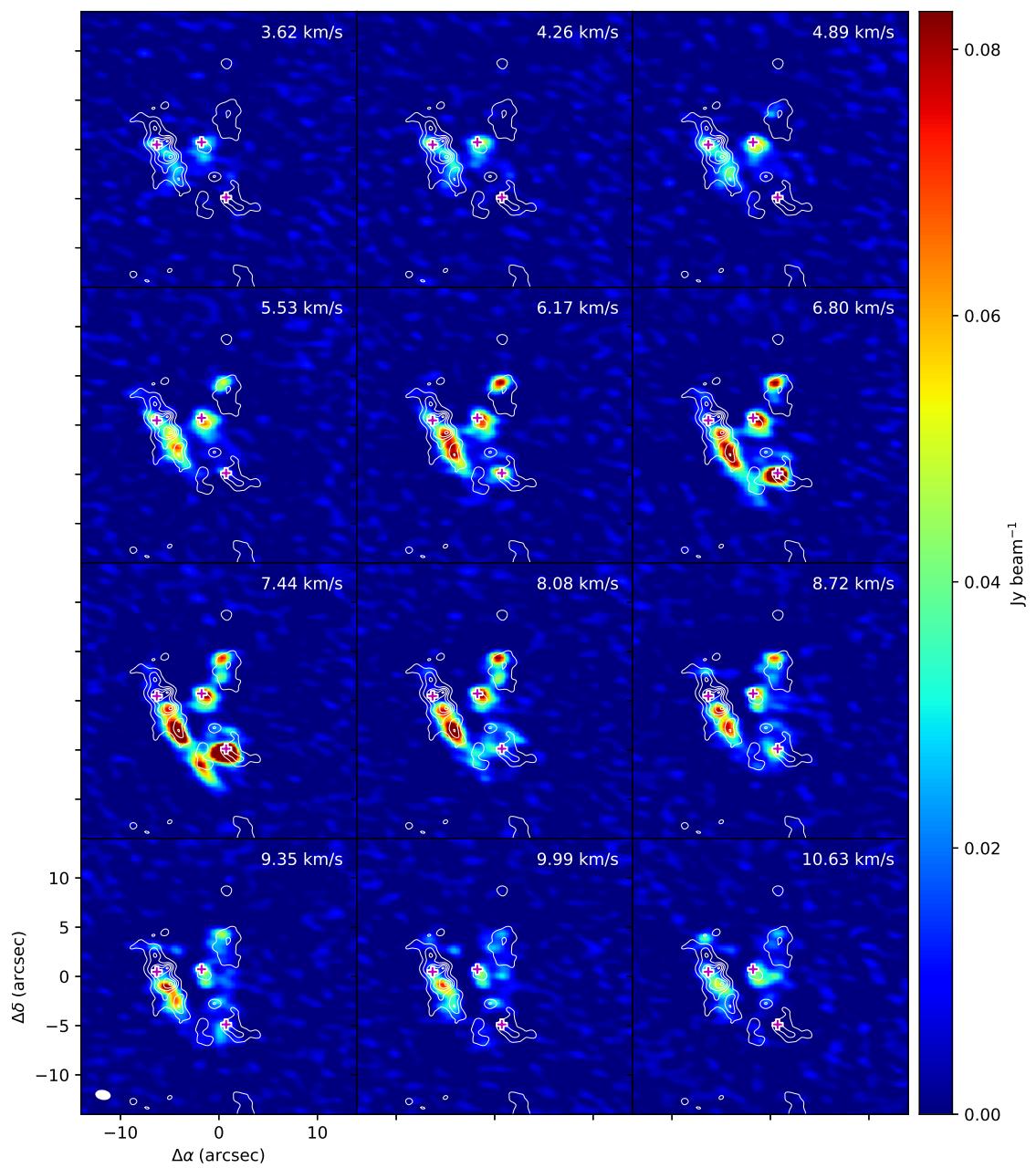
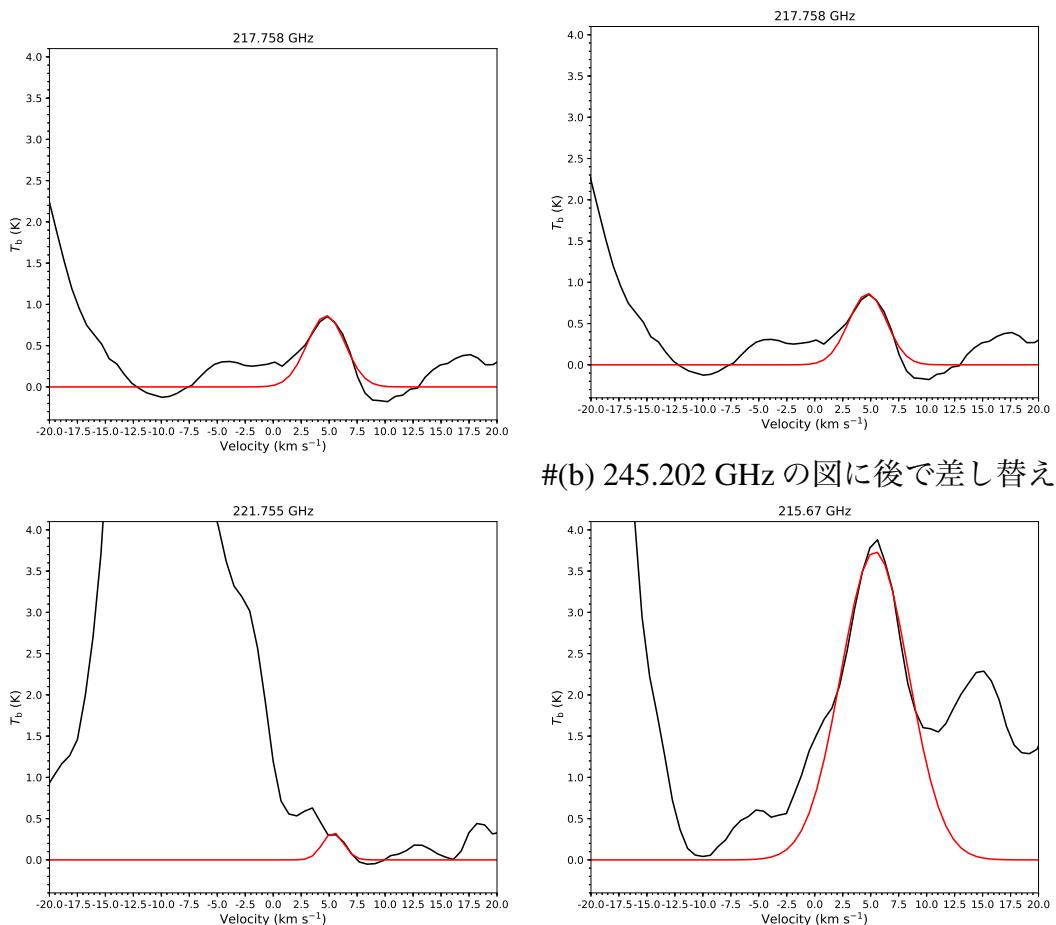


Figure 2.10: 229.908 GHz



#(b) 245.202 GHz の図に後で差し替え

Figure 2.11: Spectrum

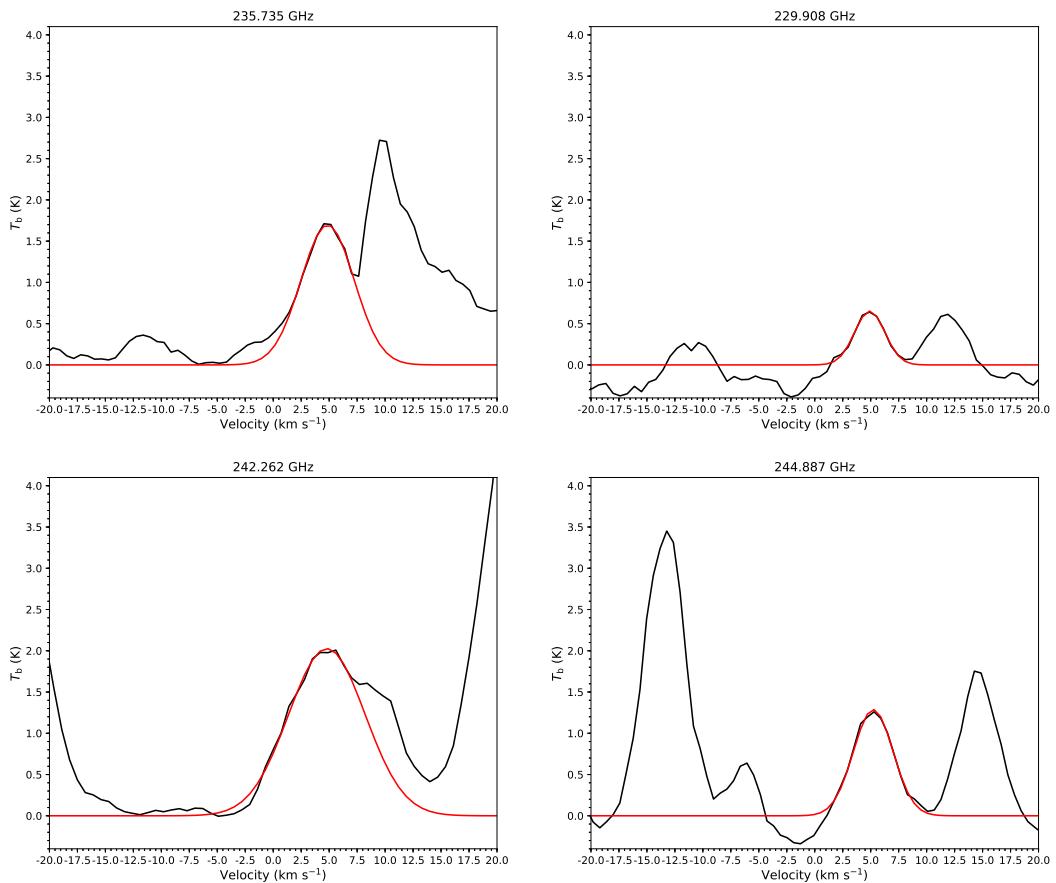


Figure 2.12: (Continued)

# **Chapter 3**

## **Methylamine survey in low mass star-forming regions**

### **3.1 Review of low mass star-forming region**

### **3.2 Analysis**

### **3.3 IRAS 16293**

#### **3.3.1 Observation data**

#### **3.3.2 Results**

### **3.4 L483**

#### **3.4.1 Observation data**

#### **3.4.2 Results**

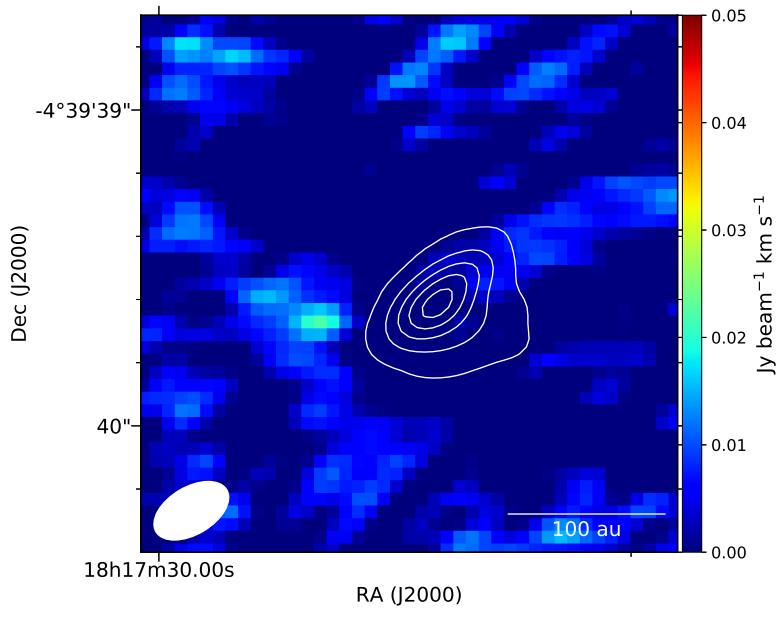


Figure 3.1: Integrated intensity map around 217.079 GHz. The white contours represent the 1.3 mm continuum map, where the contour levels are 10 %, 30 %, 50 %, 70 %, 90 % of the peak intensity.

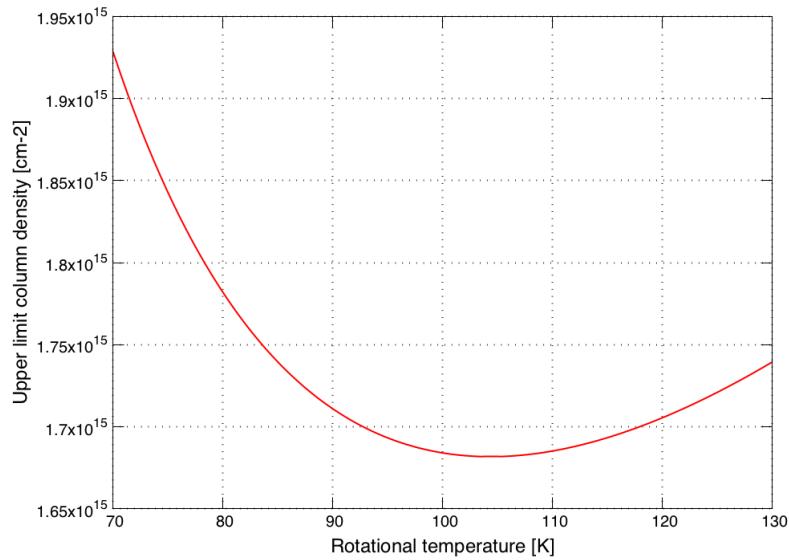


Figure 3.2: Upper limit column density for the strongest  $\text{CH}_3\text{NH}_2$  transition ( $11_2A_1 \rightarrow 11_2A_2$ ) as function of  $T_{\text{rot}}$ . A  $3\sigma$  value of 75  $\text{Jy km s}^{-1}$  is used.

# **Chapter 4**

## **Discussion**

# **Chapter 5**

## **Conclusions**

# **Appendix A**

## **Distribution of methylamine lines contaminated by other molecular line emission in Orion-KL**

### **A.1 Integrated intensity maps**

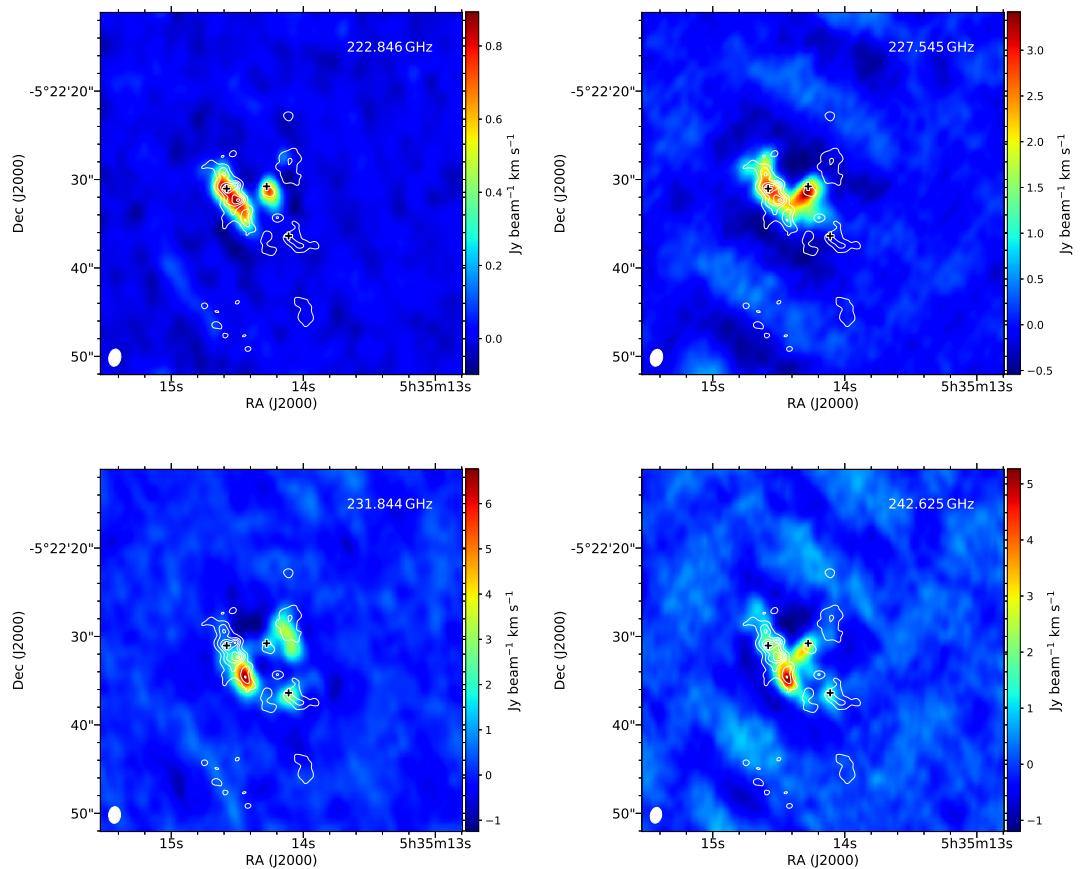


Figure A.1: Integrated intensity maps around methylamine line.

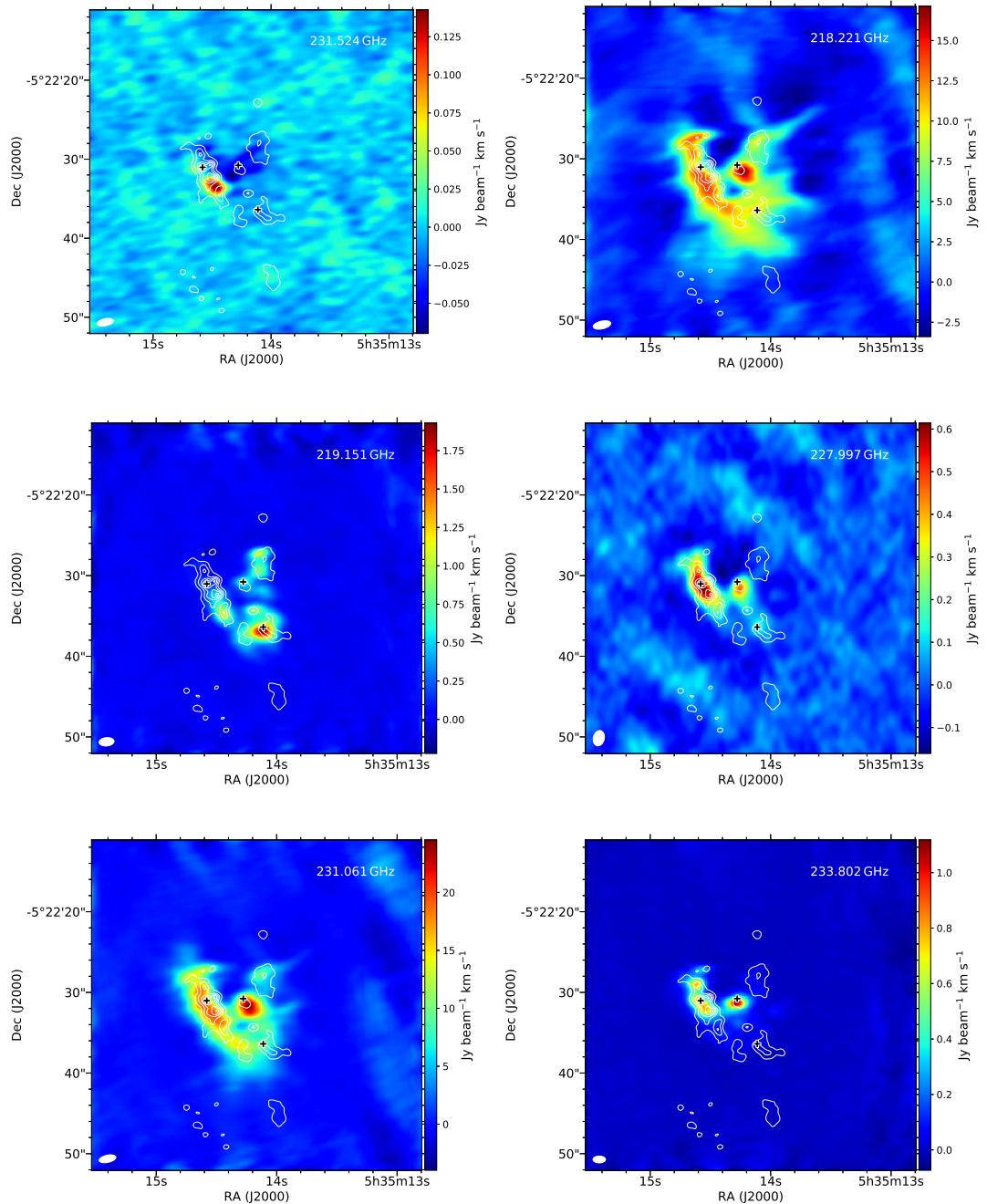


Figure A.2: (Continued)

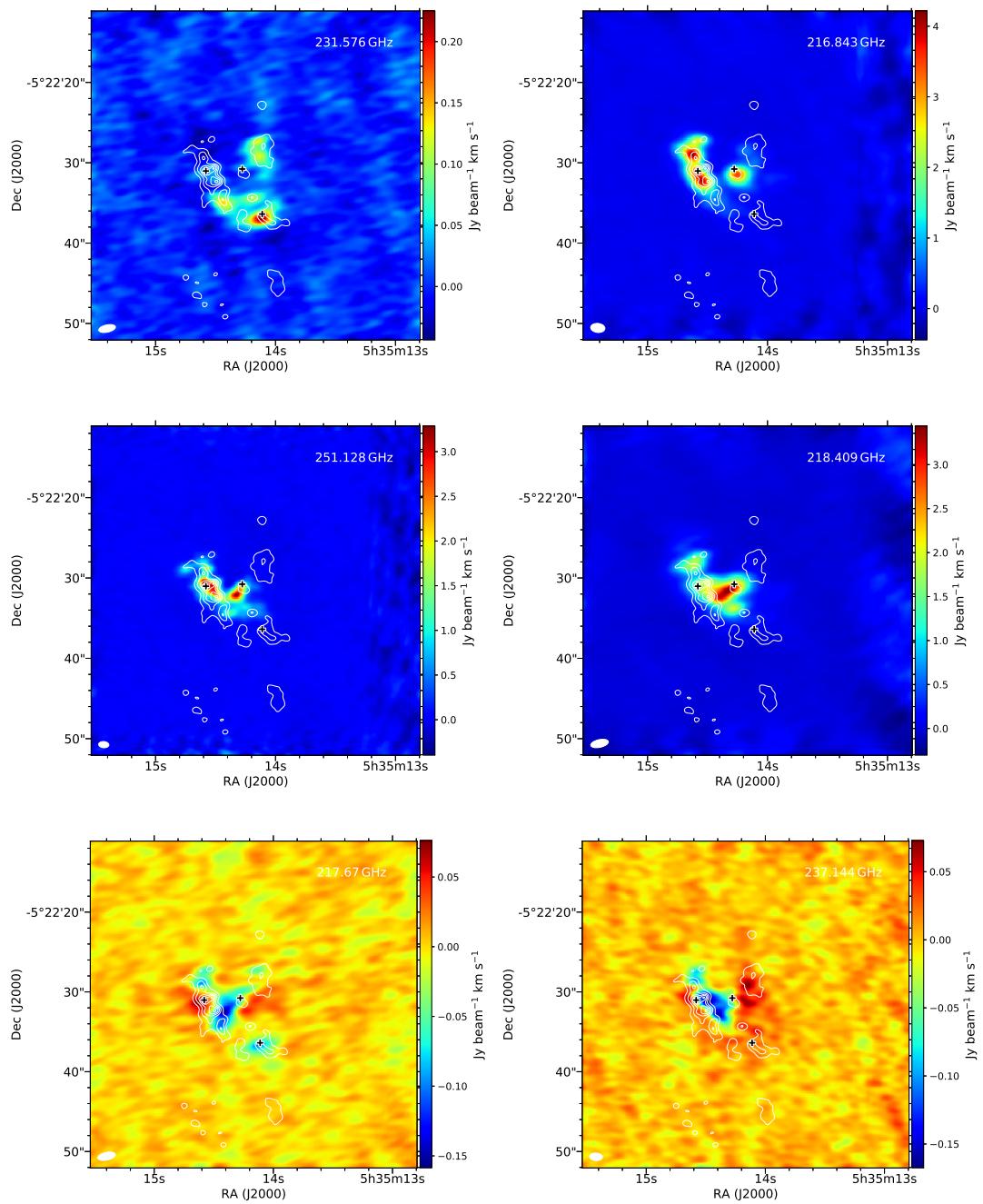


Figure A.3: (Continued)

## A.2 Channel maps

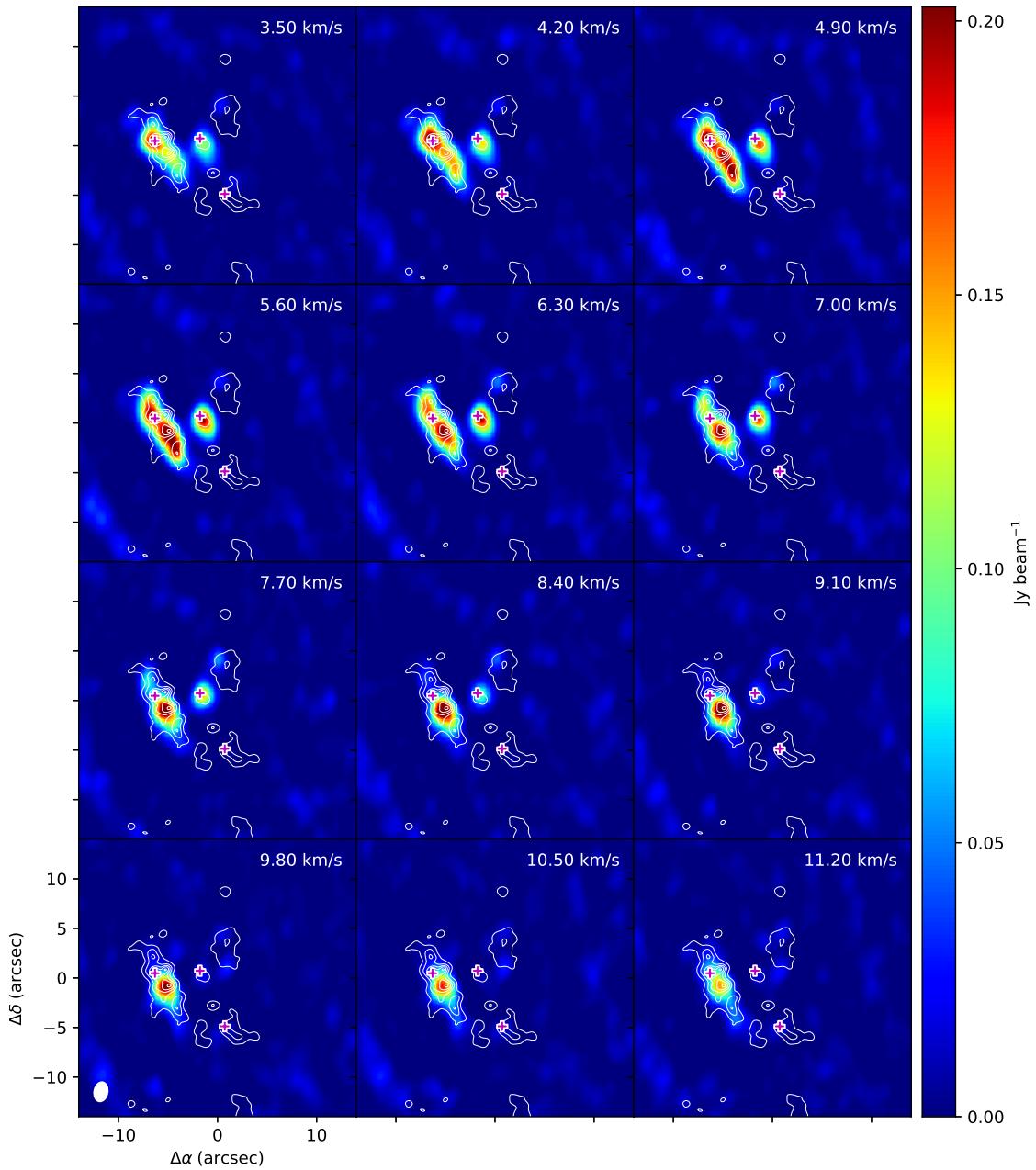


Figure A.4: 222.846GHz

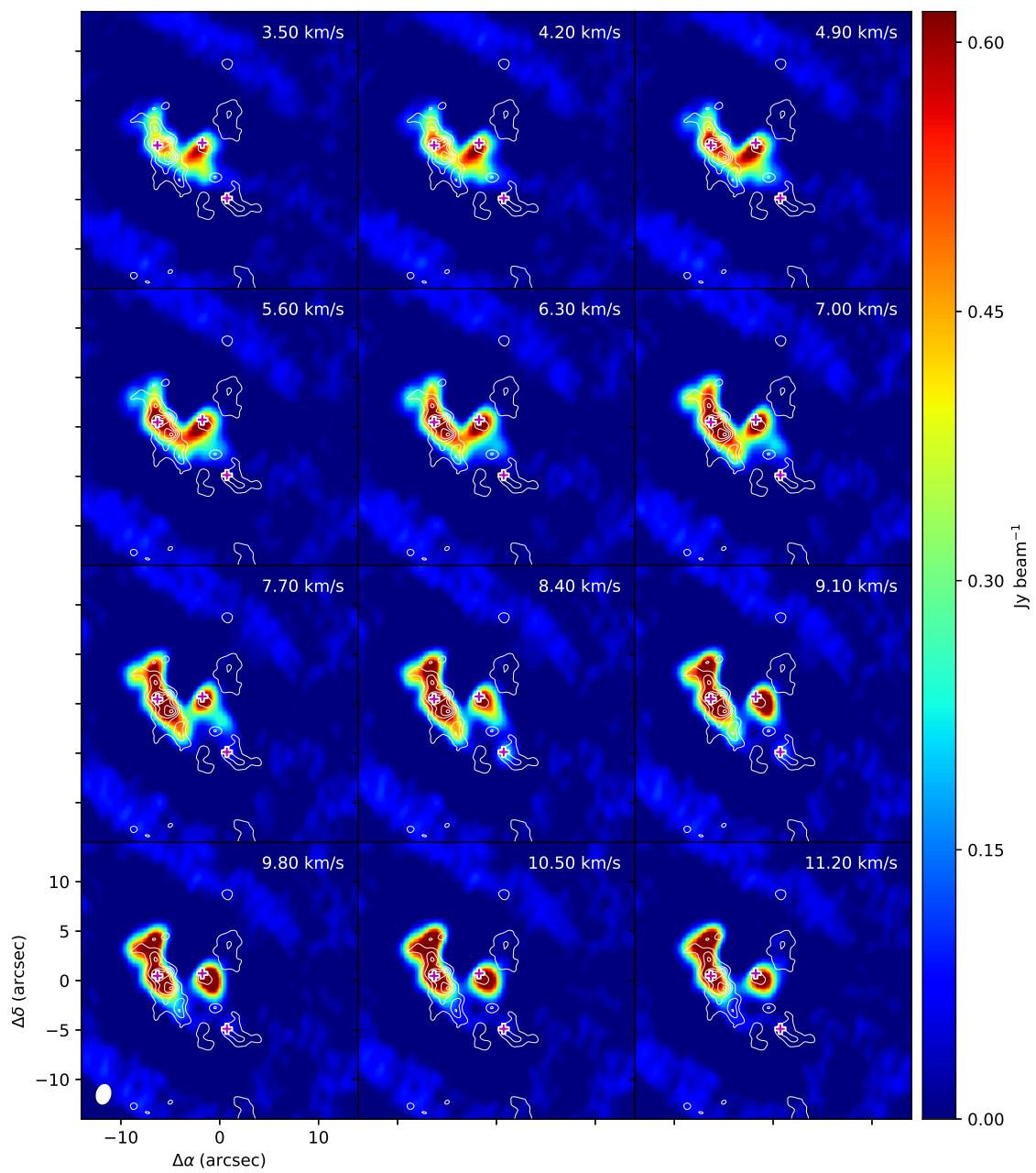


Figure A.5: 227.545GHz

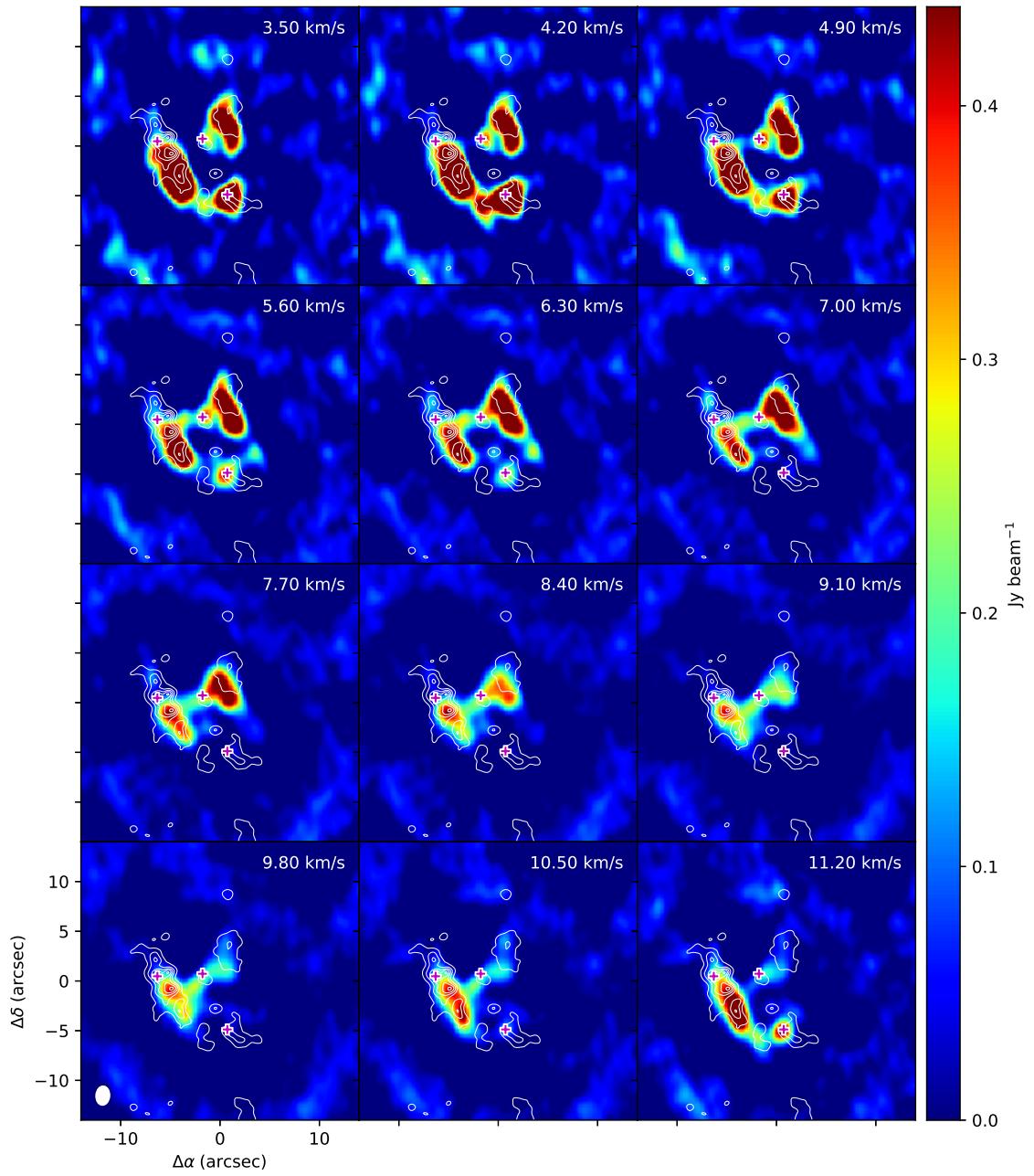


Figure A.6: 231.844GHz

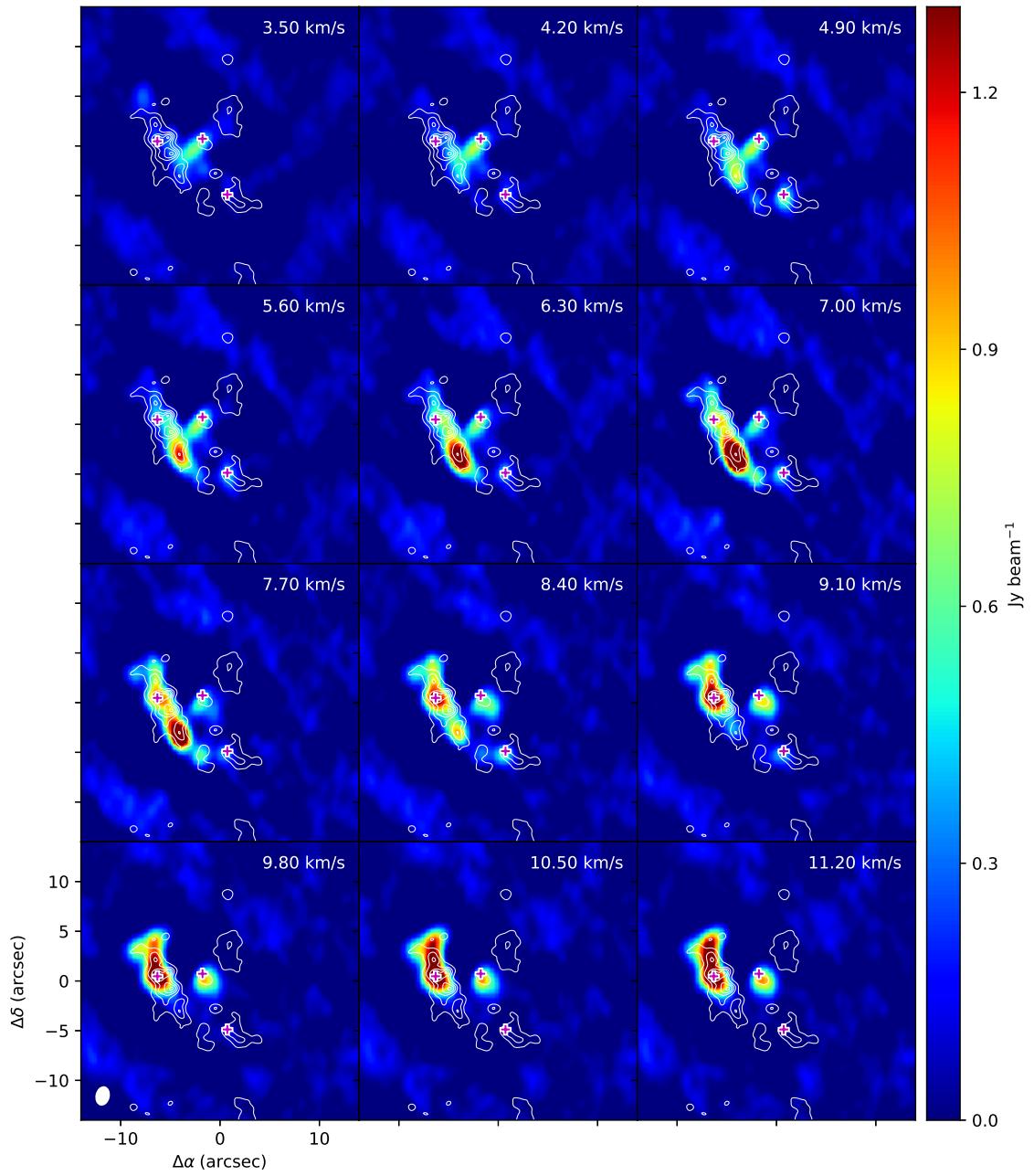


Figure A.7: 242.625GHz

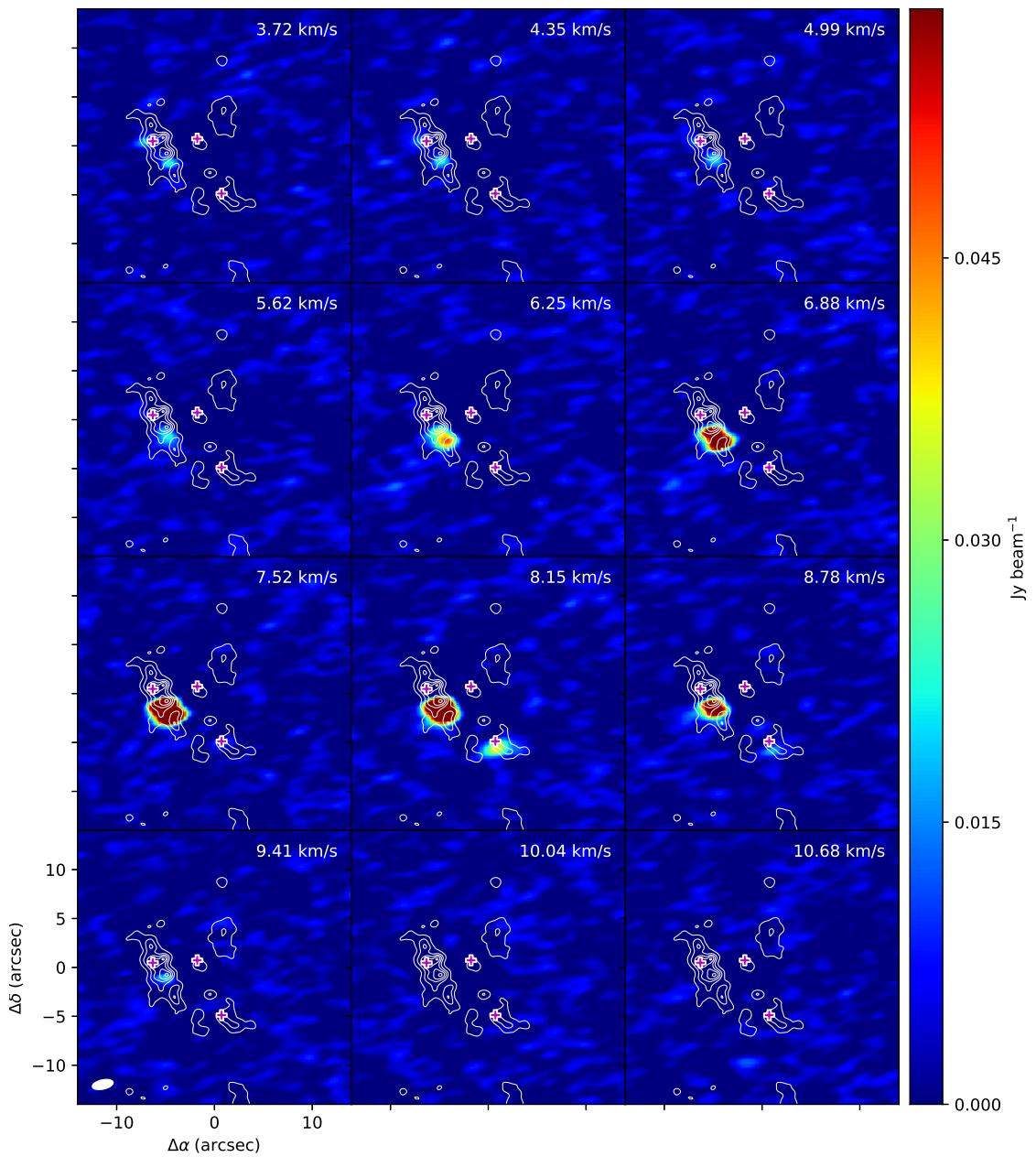


Figure A.8: 231.524GHz

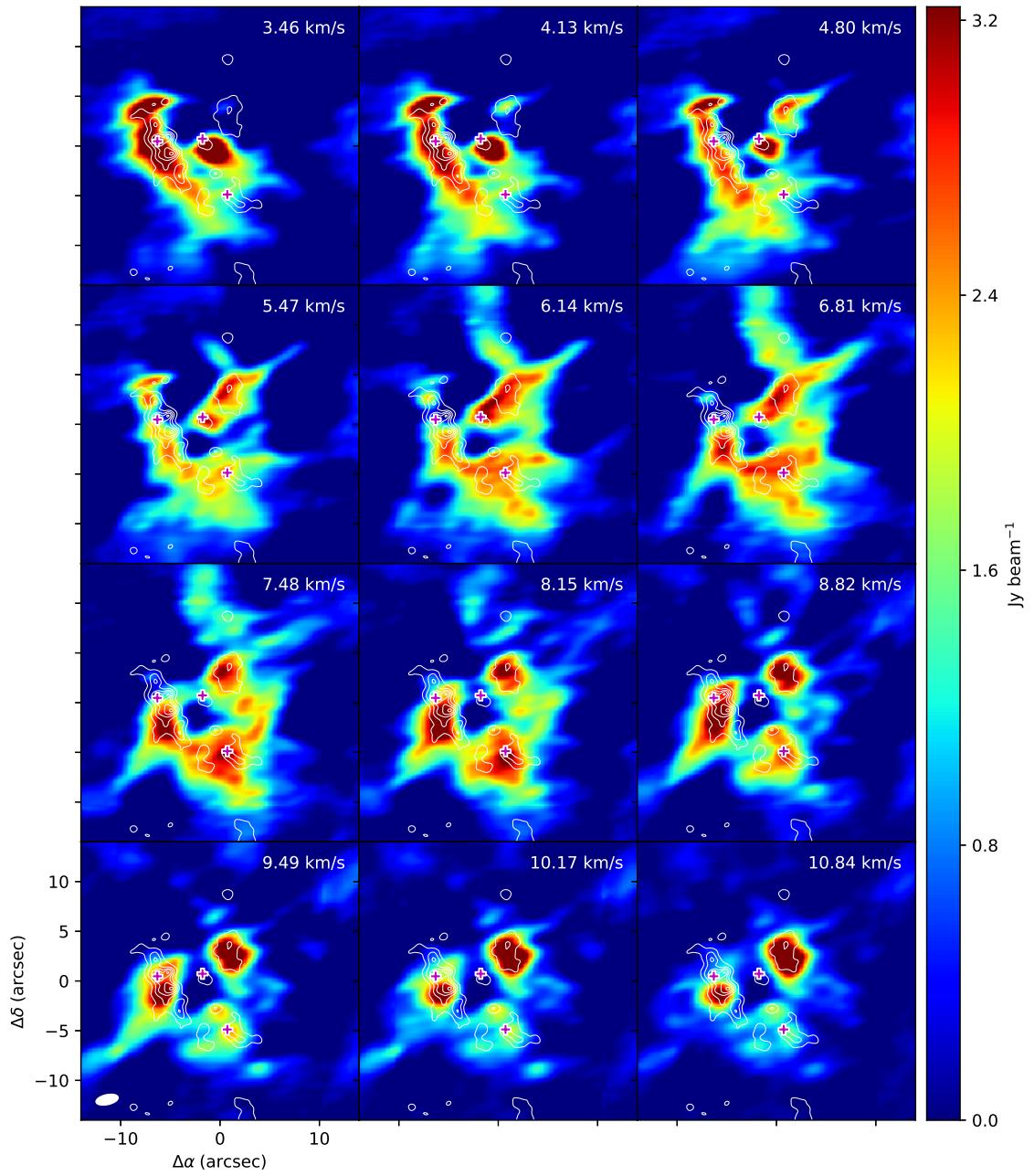


Figure A.9: 218.221GHz

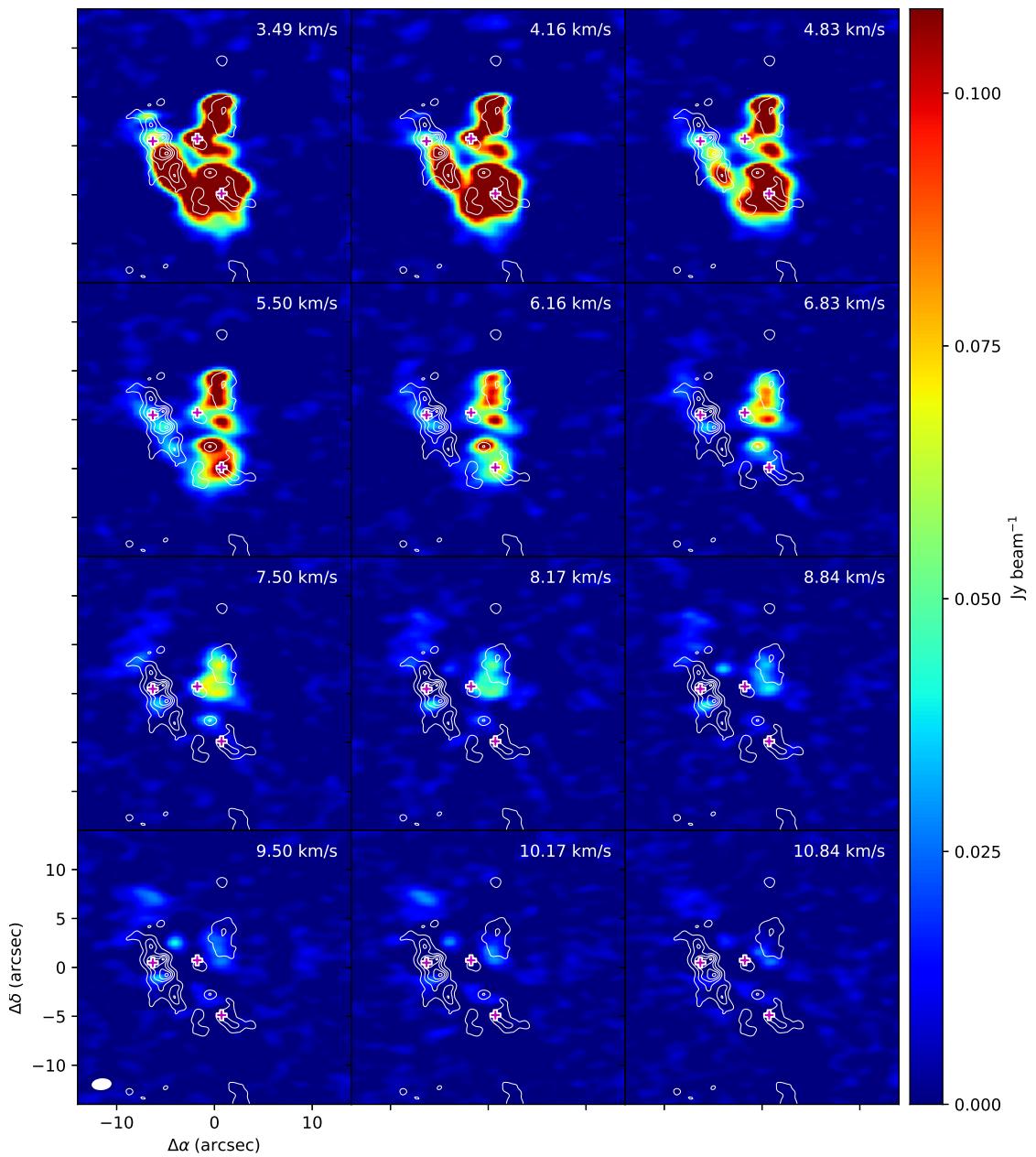


Figure A.10: 219.151GHz

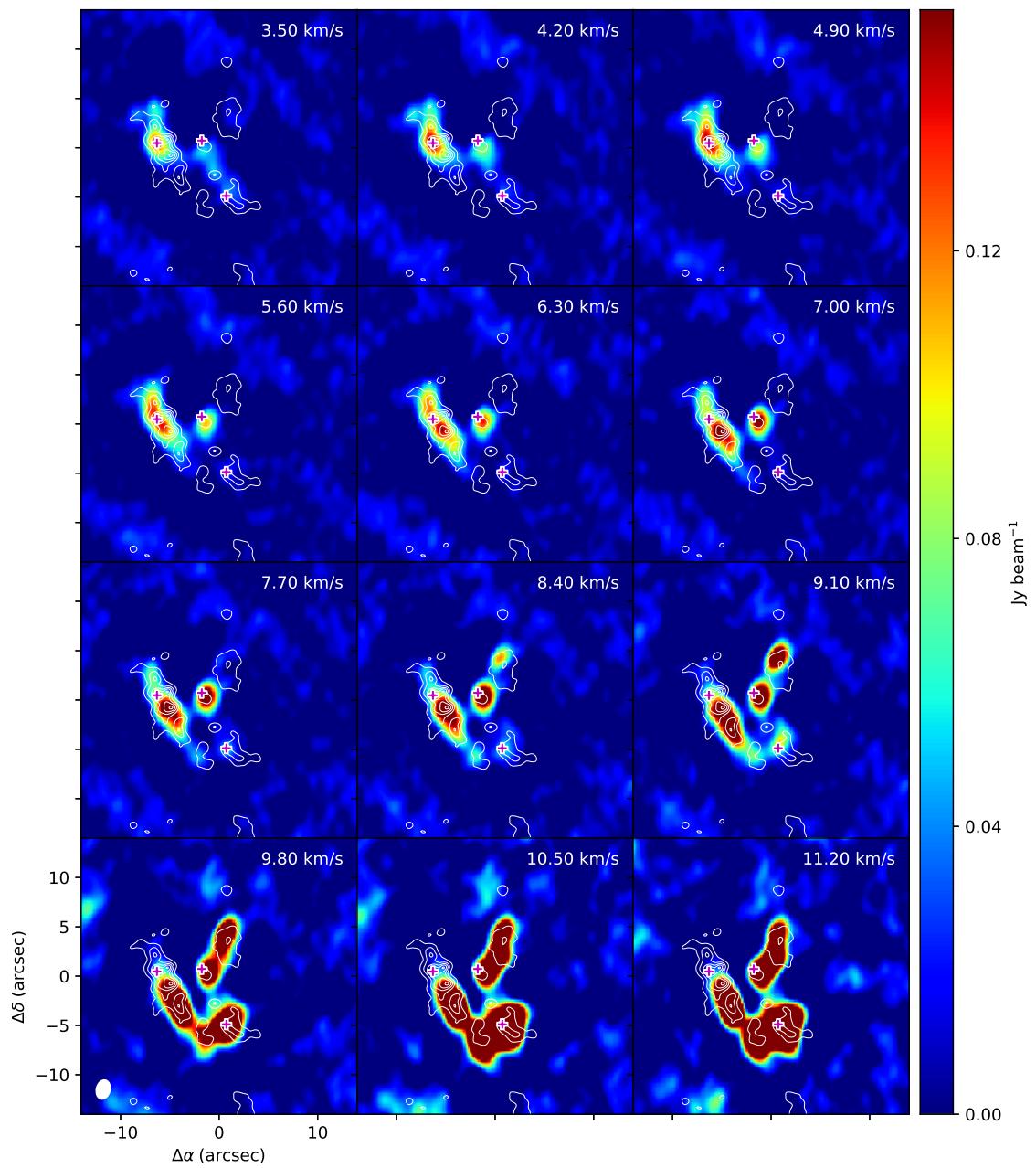


Figure A.11: 227.997GHz

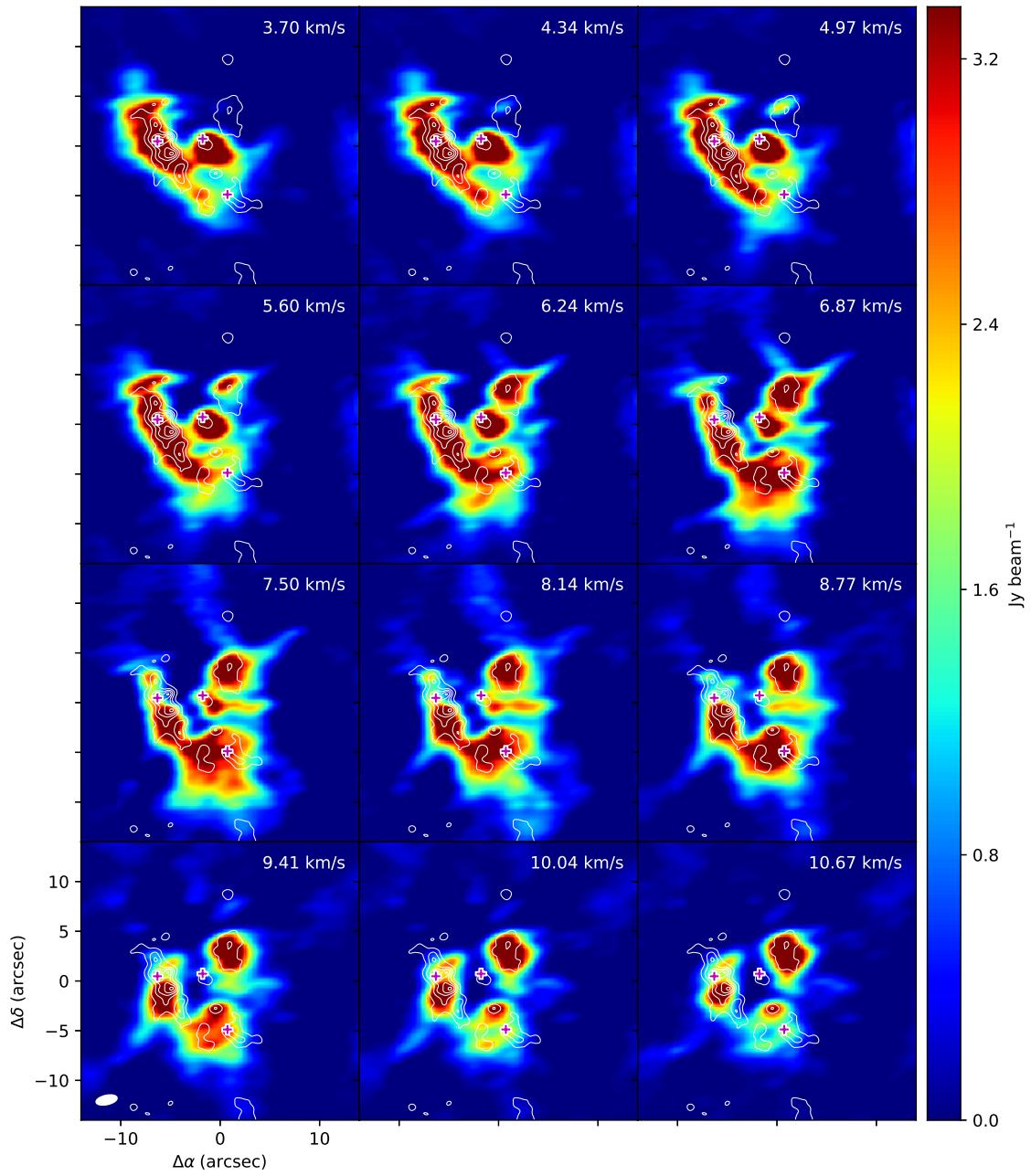


Figure A.12: 231.061GHz

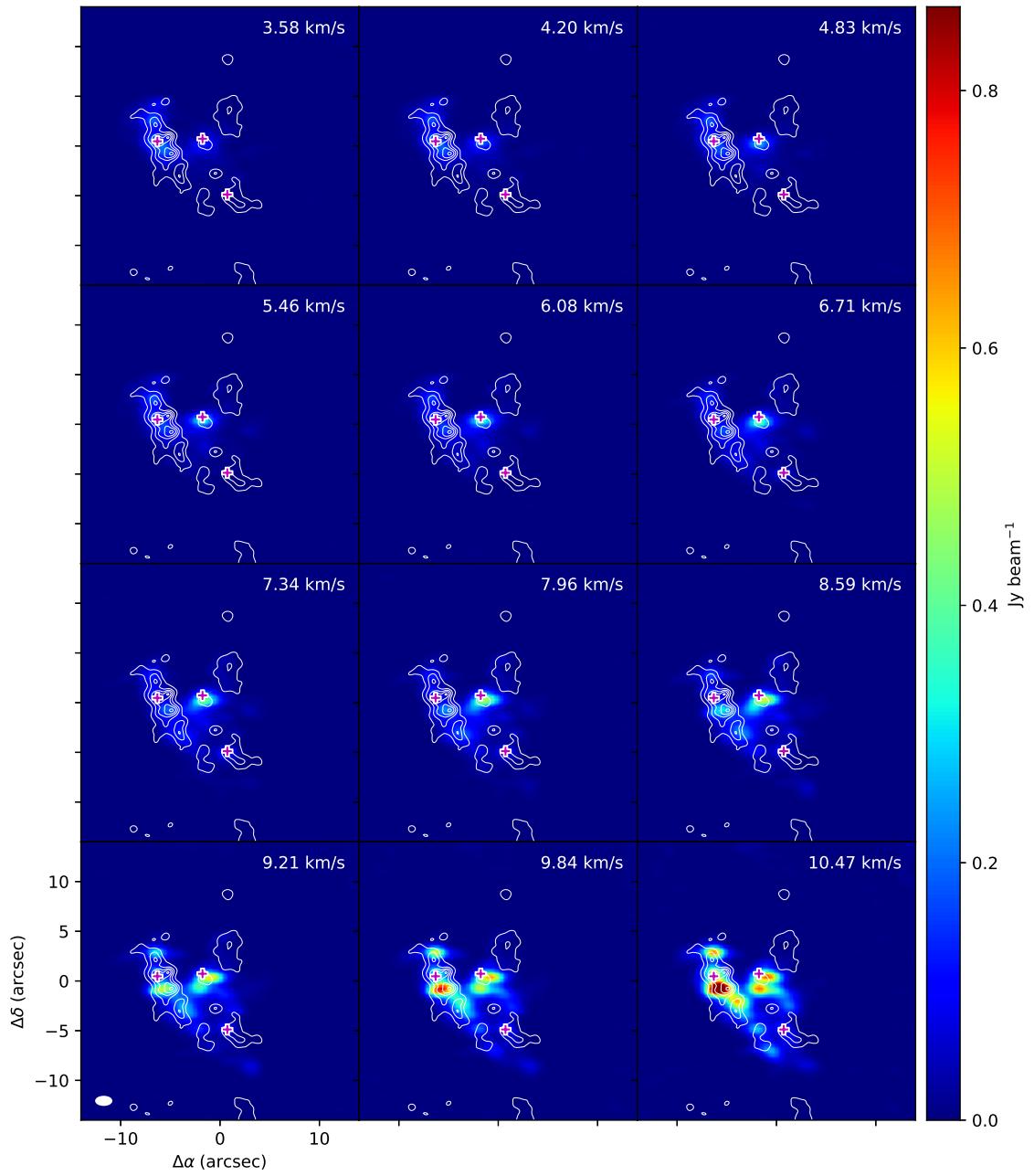


Figure A.13: 233.802GHz

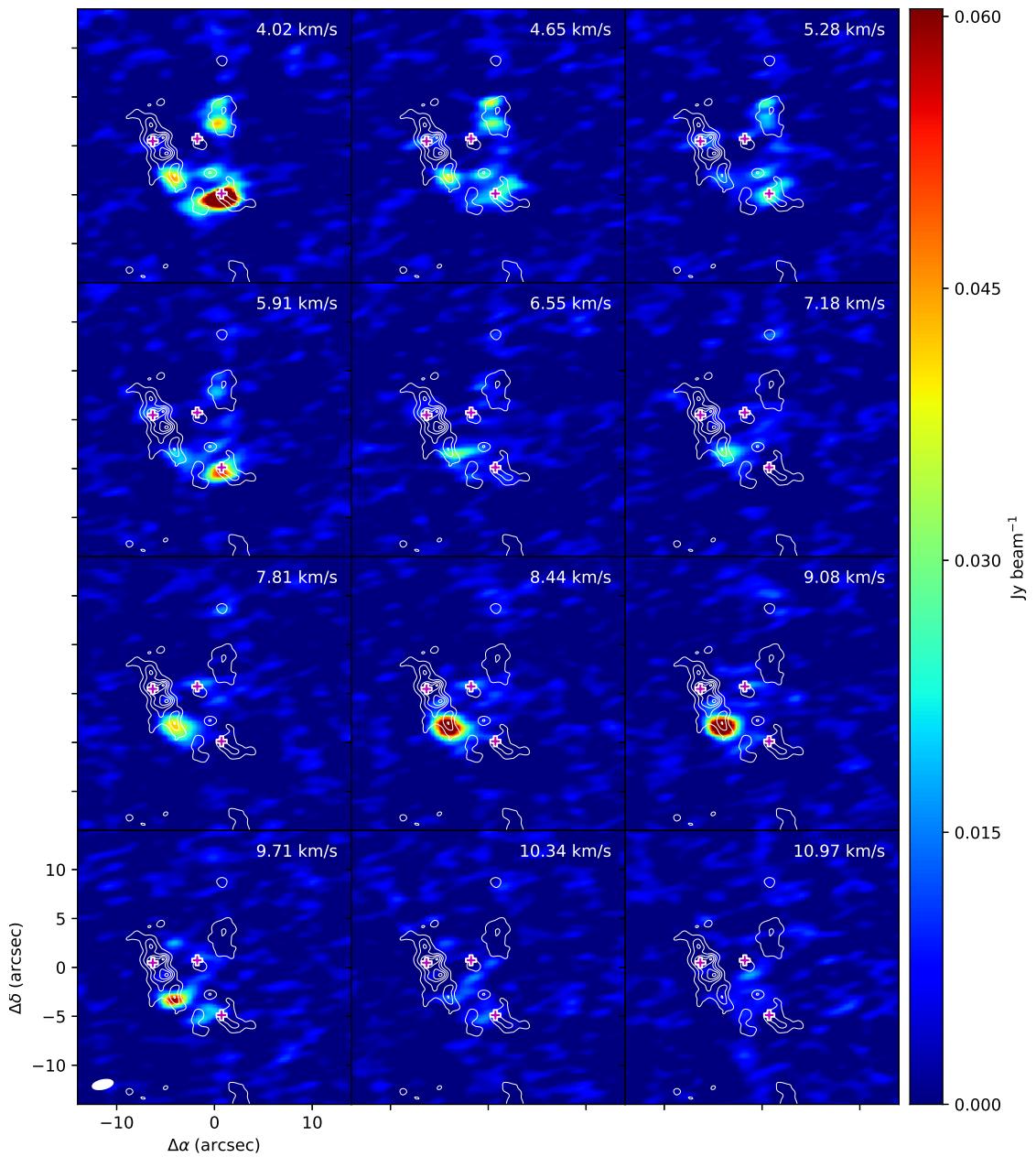


Figure A.14: 231.576GHz

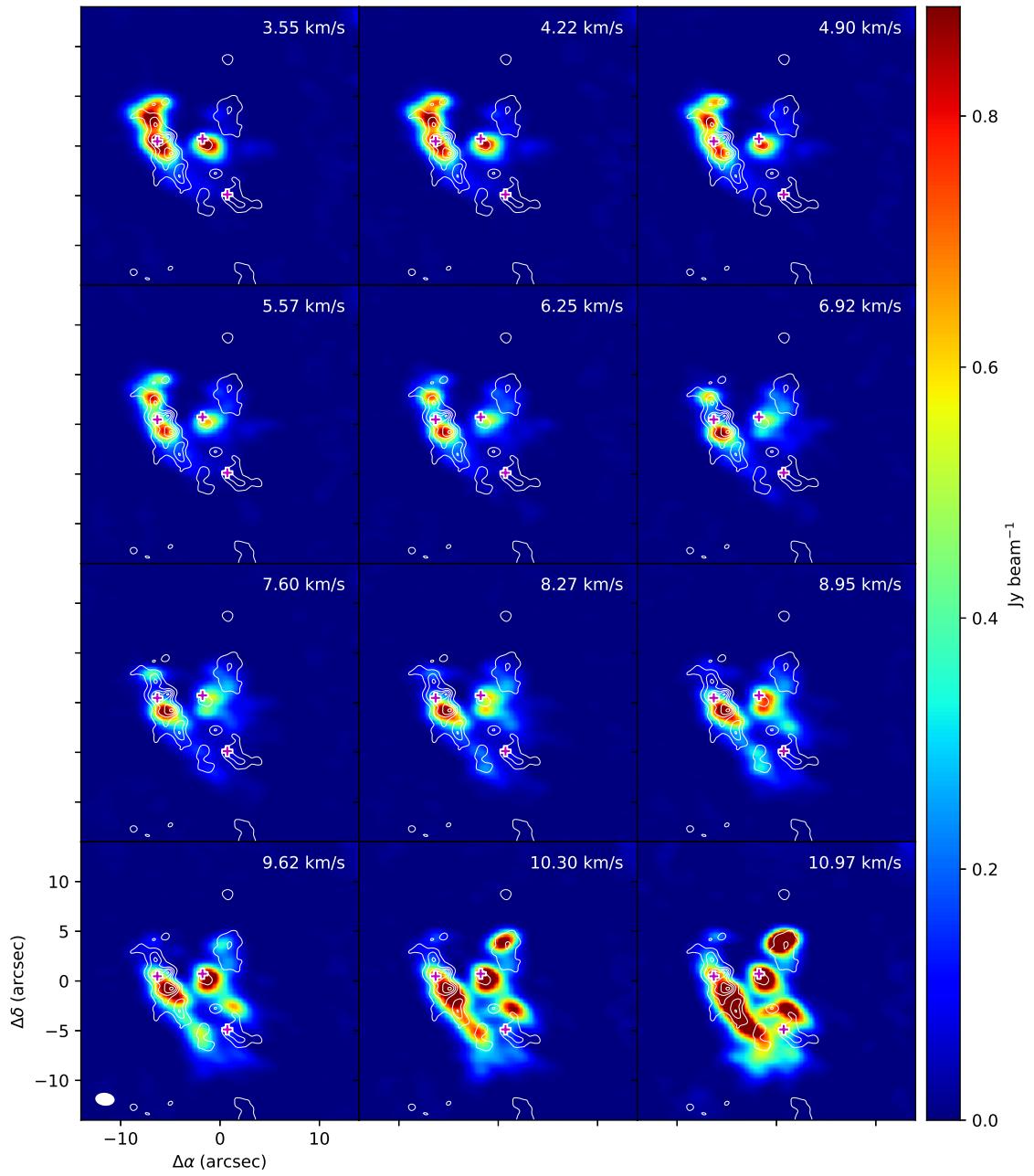


Figure A.15: 216.843GHz

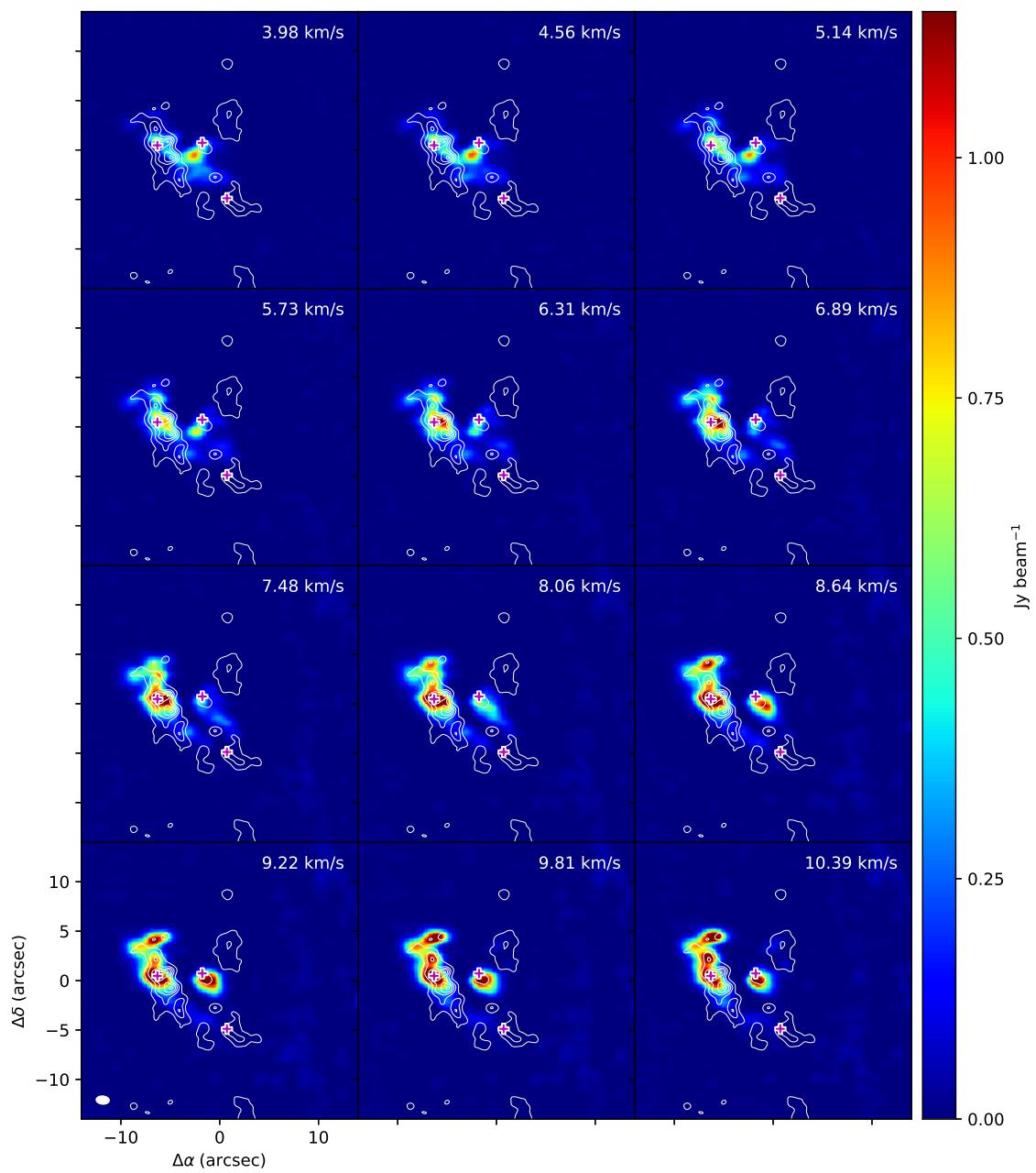


Figure A.16: 251.128GHz

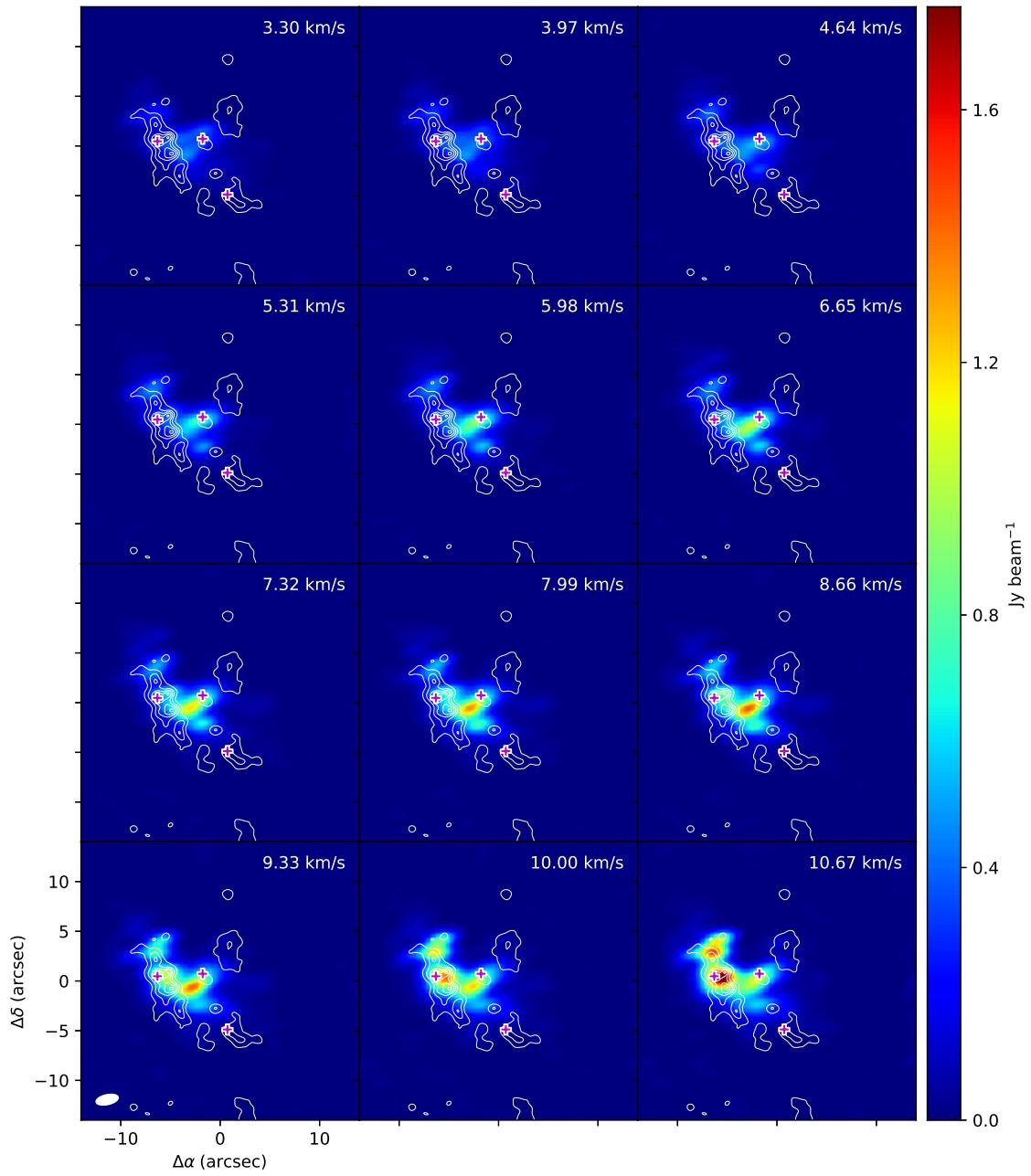


Figure A.17: 218.409GHz

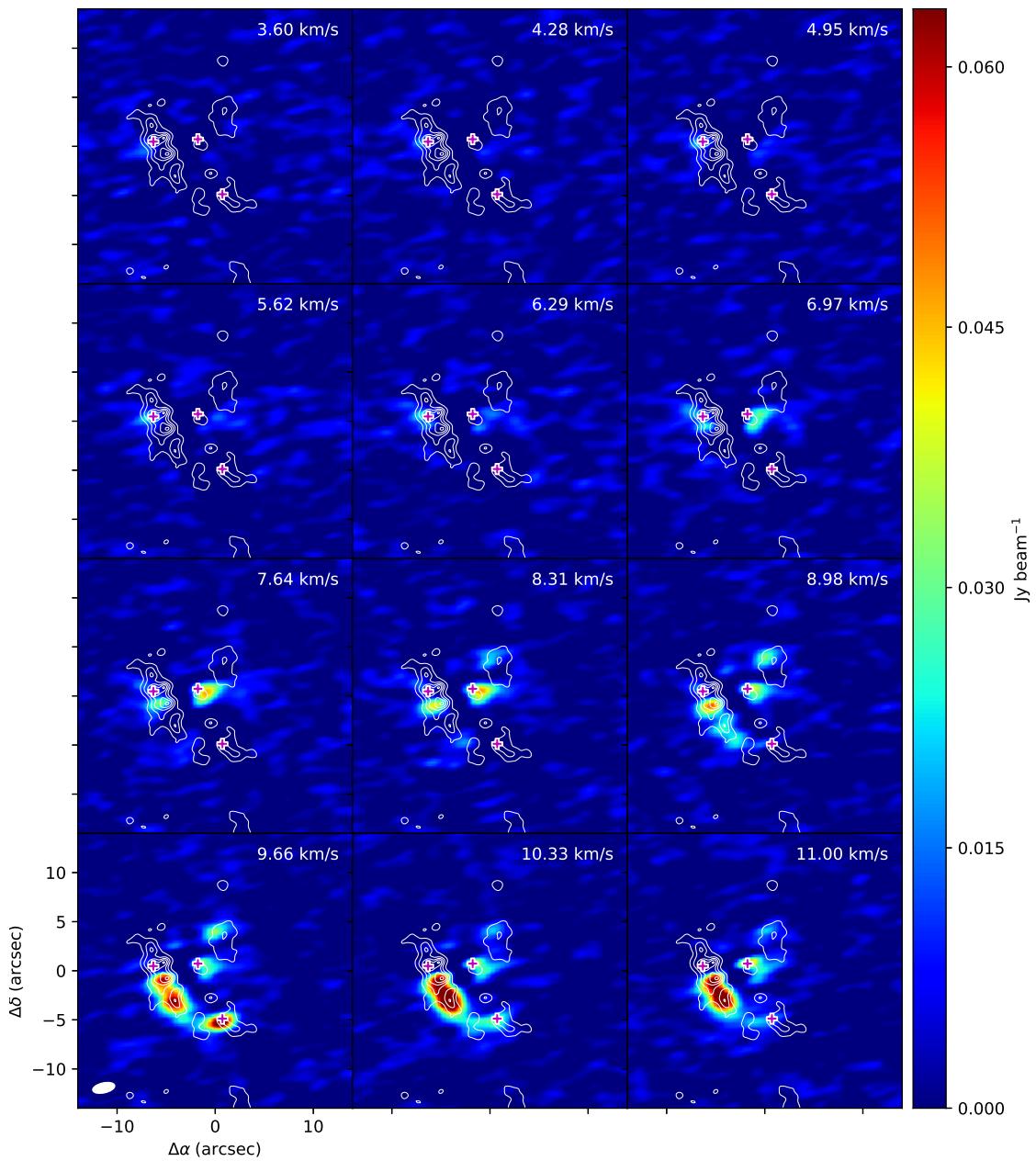


Figure A.18: 217.670GHz

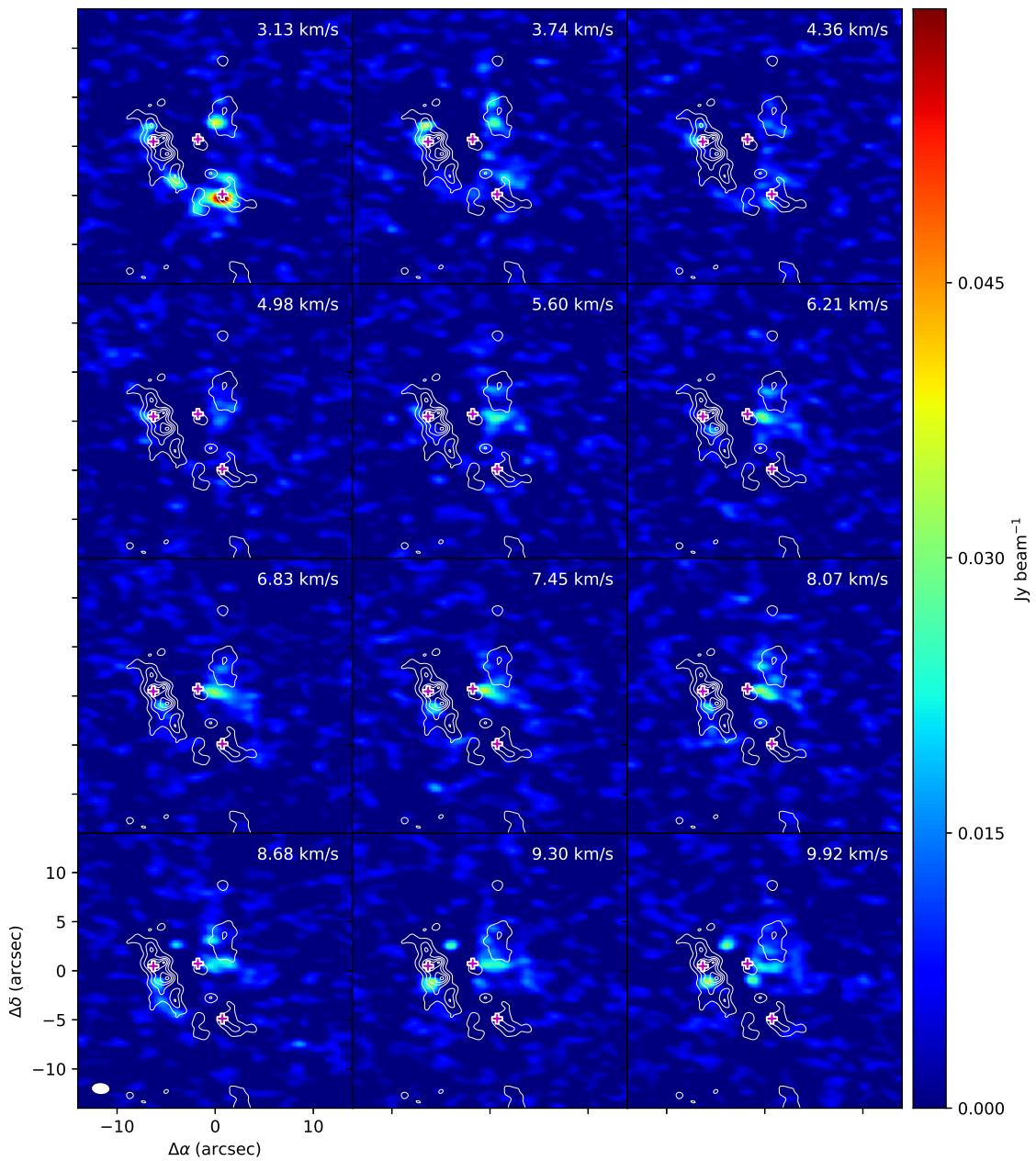


Figure A.19: 237.144GHz

# **Acknowledgments**

# **References**