

The $^{13}\text{CO}/\text{C}^{18}\text{O}$ ($J=3\rightarrow 2$)
Heterodyne Inner Milky Way
Plane Survey

Andrew J. Rigby

Toby J. T. Moore & David J. Eden

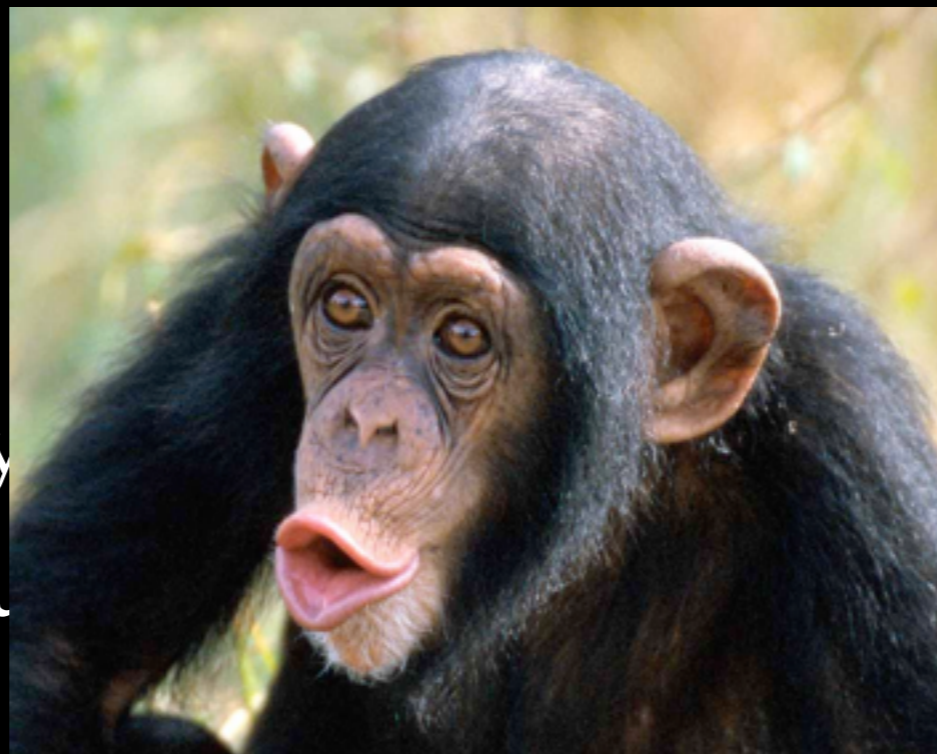
Puerto Varas, March 2015

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The $^{13}\text{C}\text{O}/\text{C}^{18}\text{O}$ ($J=3\rightarrow 2$)
Heterodyne Inner Milky Way
Plane Survey

CHIMPS



Toby
Pu

Eden
15

CHIMPS

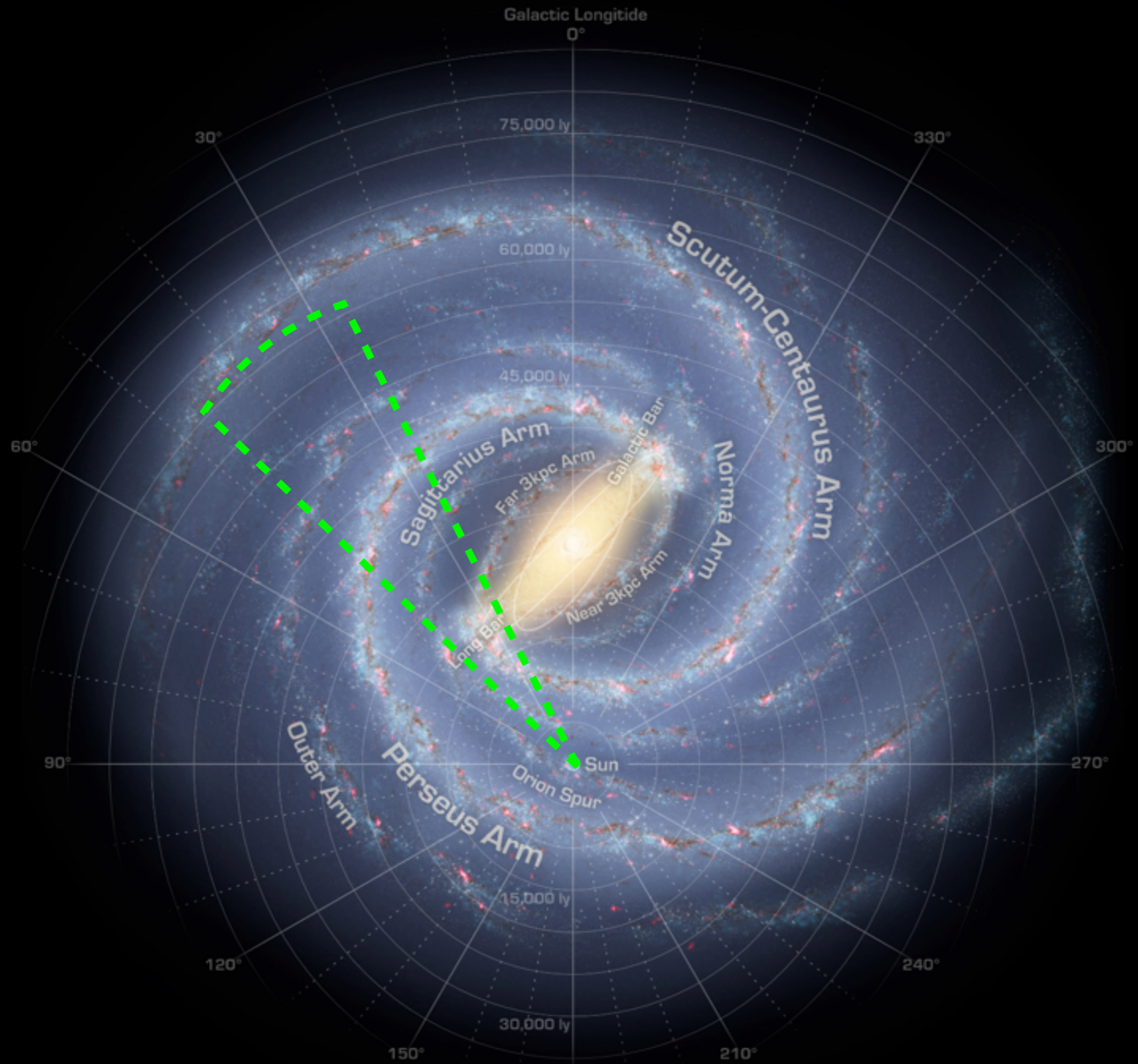
- 15m JCMT on Mauna Kea, Hawaii
- HARP: Heterodyne Array Receiver Program (Buckle +09)
- Two isotopologues: ^{13}CO and C^{18}O in the $J=3-2$ rotational transitions at 330.587 and 329.331 GHz.
- $^{12}\text{CO}/^{13}\text{CO}$ abundance ratio $\sim 60-100$ & $^{13}\text{CO}/\text{C}^{18}\text{O}$: ~ 10
 - > More optically thin
 - > Denser gas



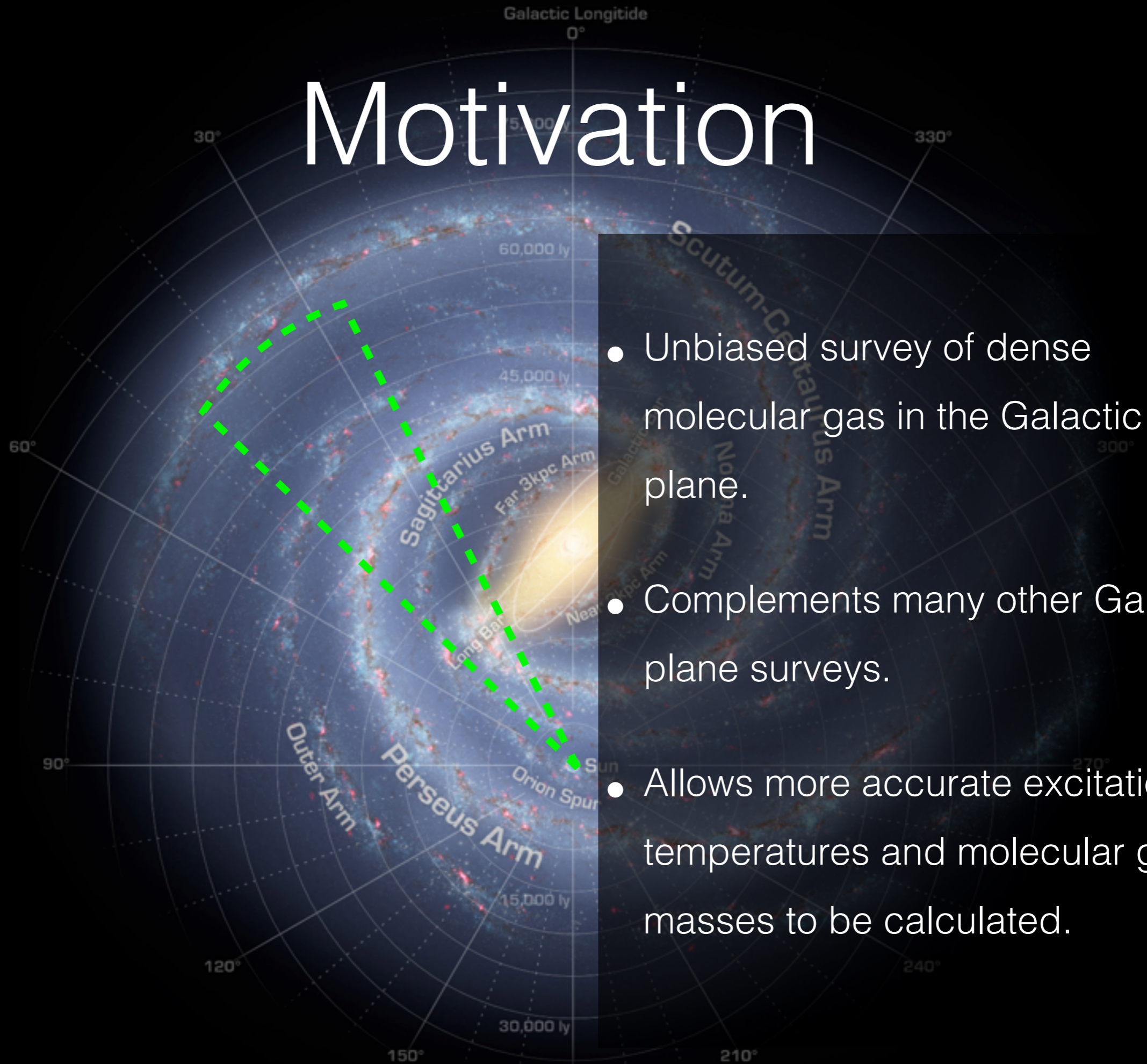
CHIMPS

- $28^\circ < l < 46^\circ$ and $|b| < 0.5^\circ$ (18 deg²) spectral survey
- Resolution $\sim 15''$ in l, b with effective resolution of $\sim 23''$ in the source catalogue after smoothing.
- Native velocity resolution of .055 km/s width re-binned to **0.5 km/s per channel** with 200 km/s bandwidth.
- **Sensitivity** rms ~ 1 K per channel, ~ 0.2 K after smoothing.





Motivation



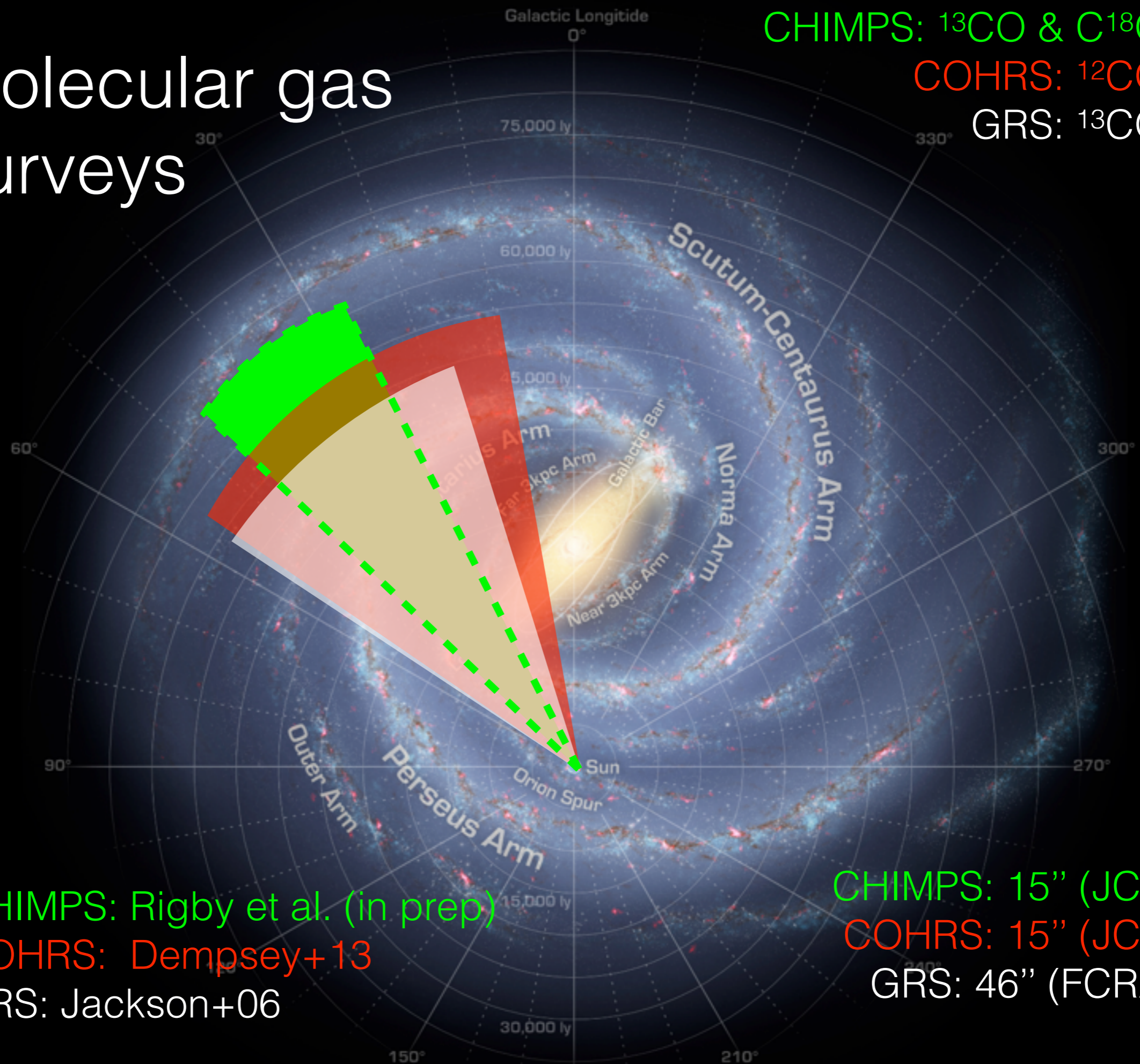
- Unbiased survey of dense molecular gas in the Galactic plane.
- Complements many other Galactic plane surveys.
- Allows more accurate excitation temperatures and molecular gas masses to be calculated.

Molecular gas surveys

CHIMPS: ^{13}CO & C^{18}O (3-2)

COHRS: ^{12}CO (3-2)

GRS: ^{13}CO (1-0)



CHIMPS: Rigby et al. (in prep)

COHRS: Dempsey+13

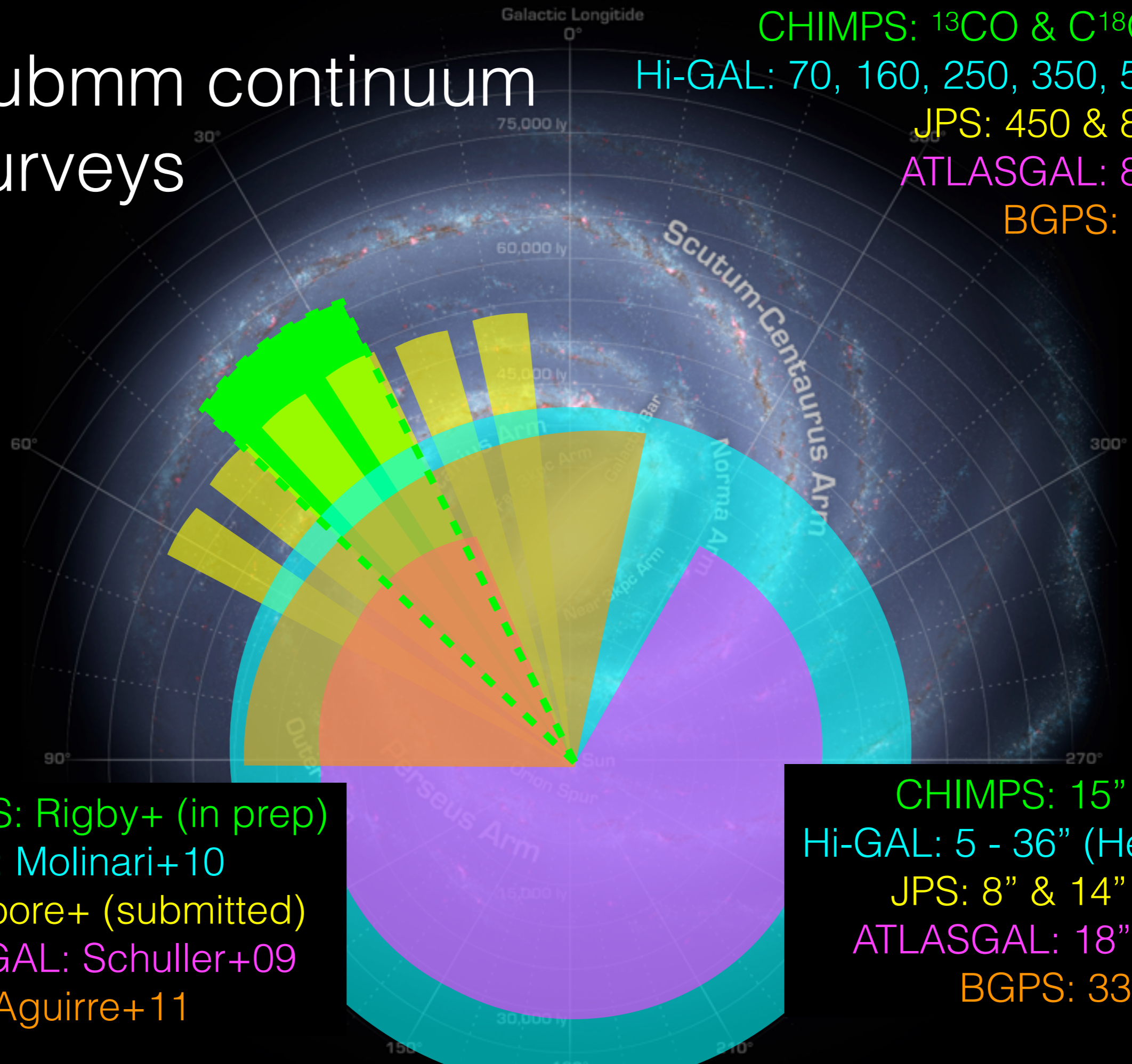
GRS: Jackson+06

CHIMPS: 15'' (JCMT)

COHRS: 15'' (JCMT)

GRS: 46'' (FCRAO)

Submm continuum surveys



CHIMPS: ^{13}CO & C^{18}O (3-2)
Hi-GAL: 70, 160, 250, 350, 500 μm
JPS: 450 & 850 μm
ATLASGAL: 870 μm
BGPS: 1.1mm

CHIMPS: Rigby+ (in prep)
Hi-GAL: Molinari+10
JPS: Moore+ (submitted)
ATLASGAL: Schuller+09
BGPS: Aguirre+11

CHIMPS: 15" (JCMT)
Hi-GAL: 5 - 36" (Herschel)
JPS: 8" & 14" (JCMT)
ATLASGAL: 18" (APEX)
BGPS: 33" (CSO)

Submm continuum surveys

CHIMPS: ^{13}CO & C^{18}O (3-2)
Hi-GAL: 70, 160, 250, 350, 500 μm
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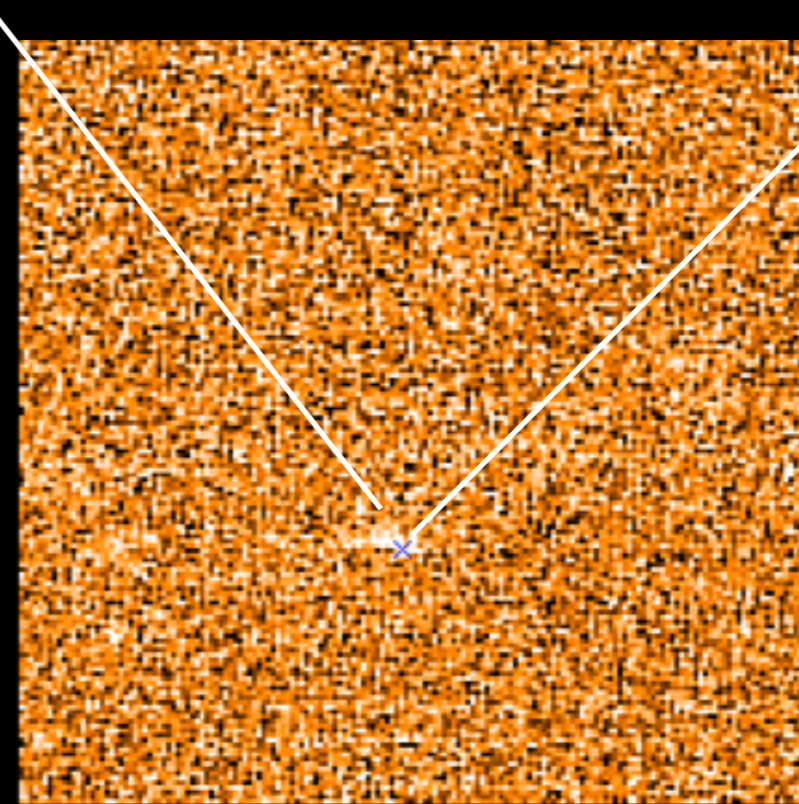
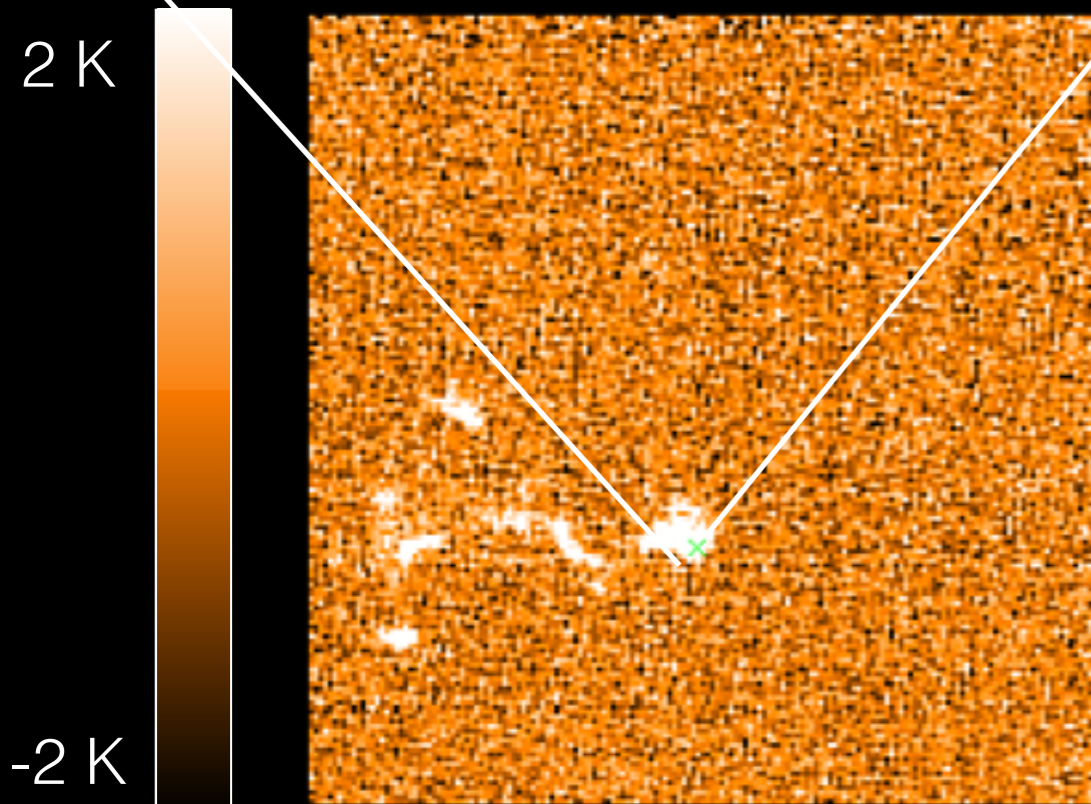
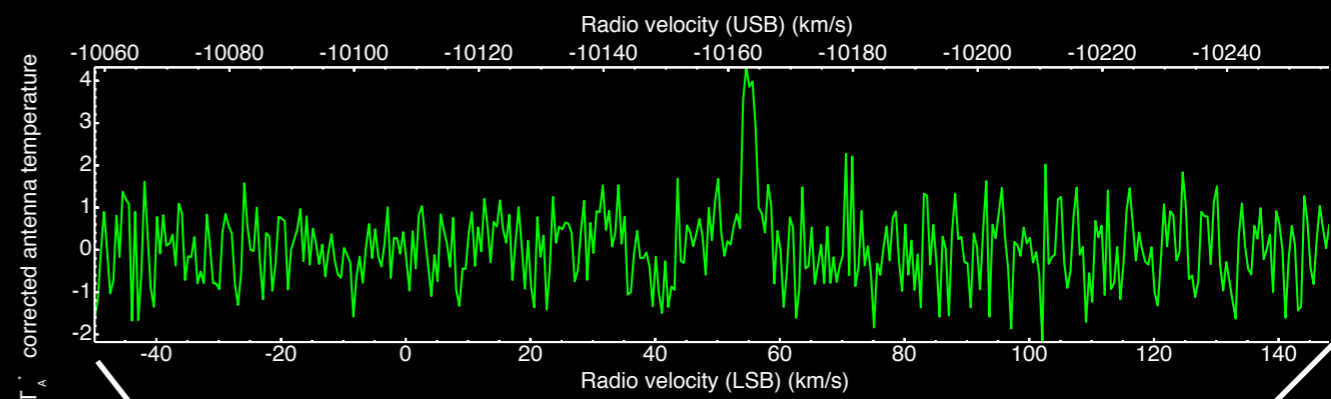
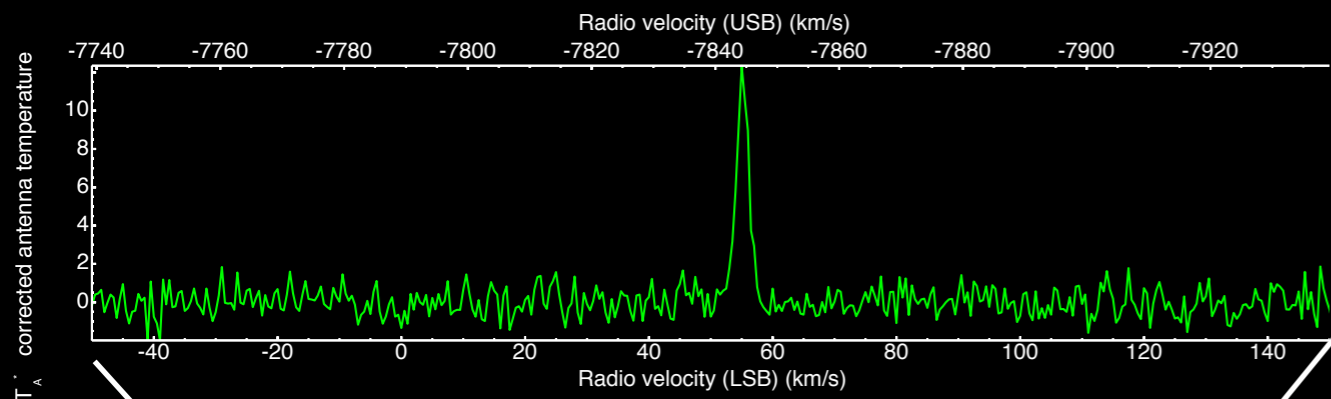


CHIMPS:
Hi-GAL:
JPS: Moo
ATLASGAL: Schuller+09
BGPS:

" (JCMT)
Herschel)
" (JCMT)
" (APEX)
ATLASGAL: 18"
BGPS: 33" (CSO)



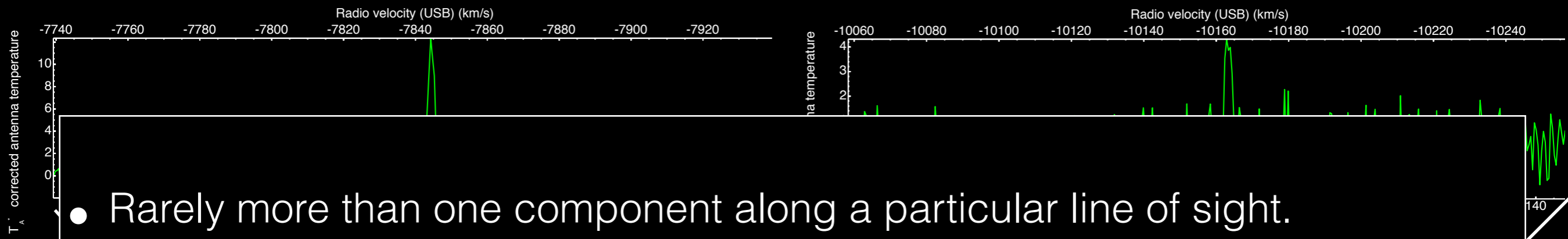
- Observations are l,b,v cubes $\sim 20' \times 20' \times 200$ km/s
- Every pixel is a spectrum $\sim 26,000$ spectra per cube, 178 cubes in each isotopologue.
- 4.5 million spectra in the survey, ~ 850 million voxels



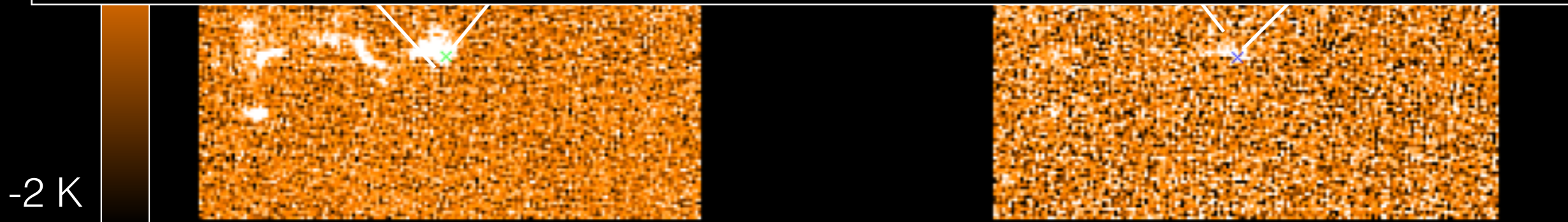
^{13}CO : 55.6 km/s channel

C^{18}O : 55.6 km/s channel

- Observations are l,b,v cubes ~ 20' x 20' x 200 km/s
- Every pixel is a spectrum ~ 26,000 spectra per cube, 178 cubes in each isotopologue.
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- Rarely more than one component along a particular line of sight.
- Ideal for assigning source velocities -> kinematic distances.
- Data features in Eden+12, Eden+13, Urquhart+13

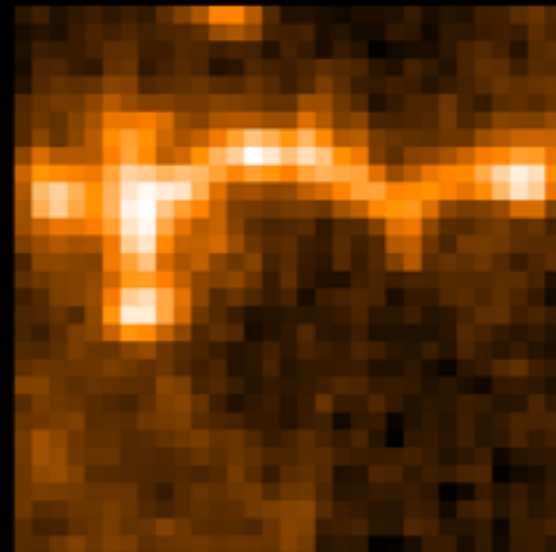


^{13}CO : 55.6 km/s channel

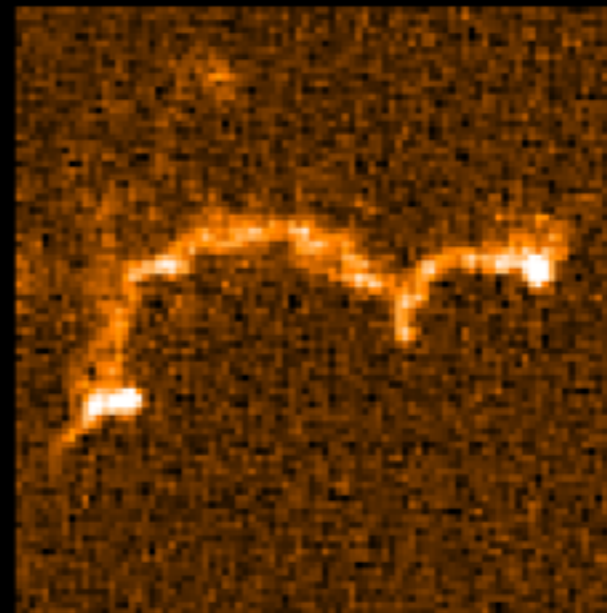
C^{18}O : 55.6 km/s channel

If you're interested in masses...

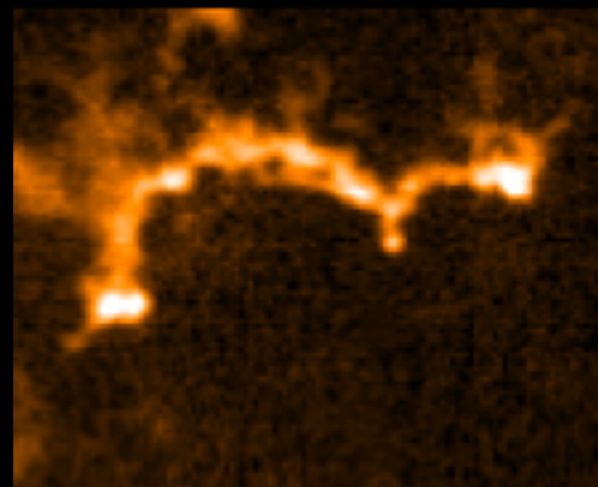
^{13}CO (1-0)
GRS



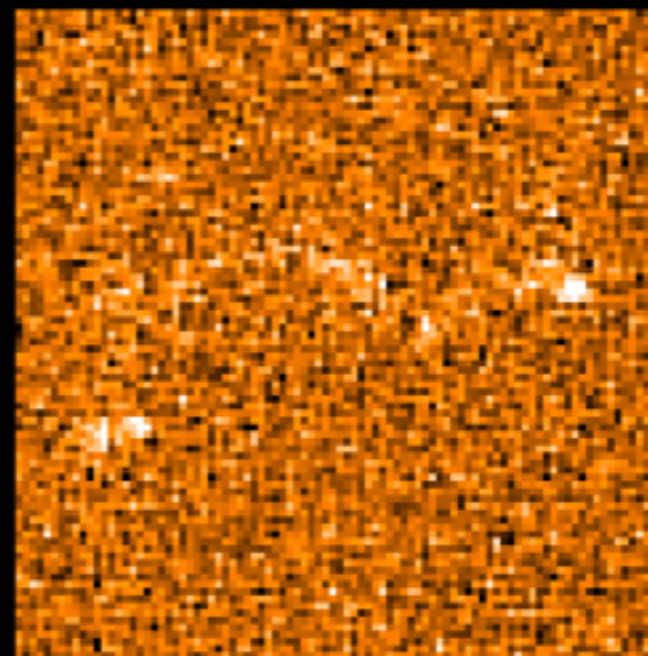
^{13}CO (3-2)
CHIMPS



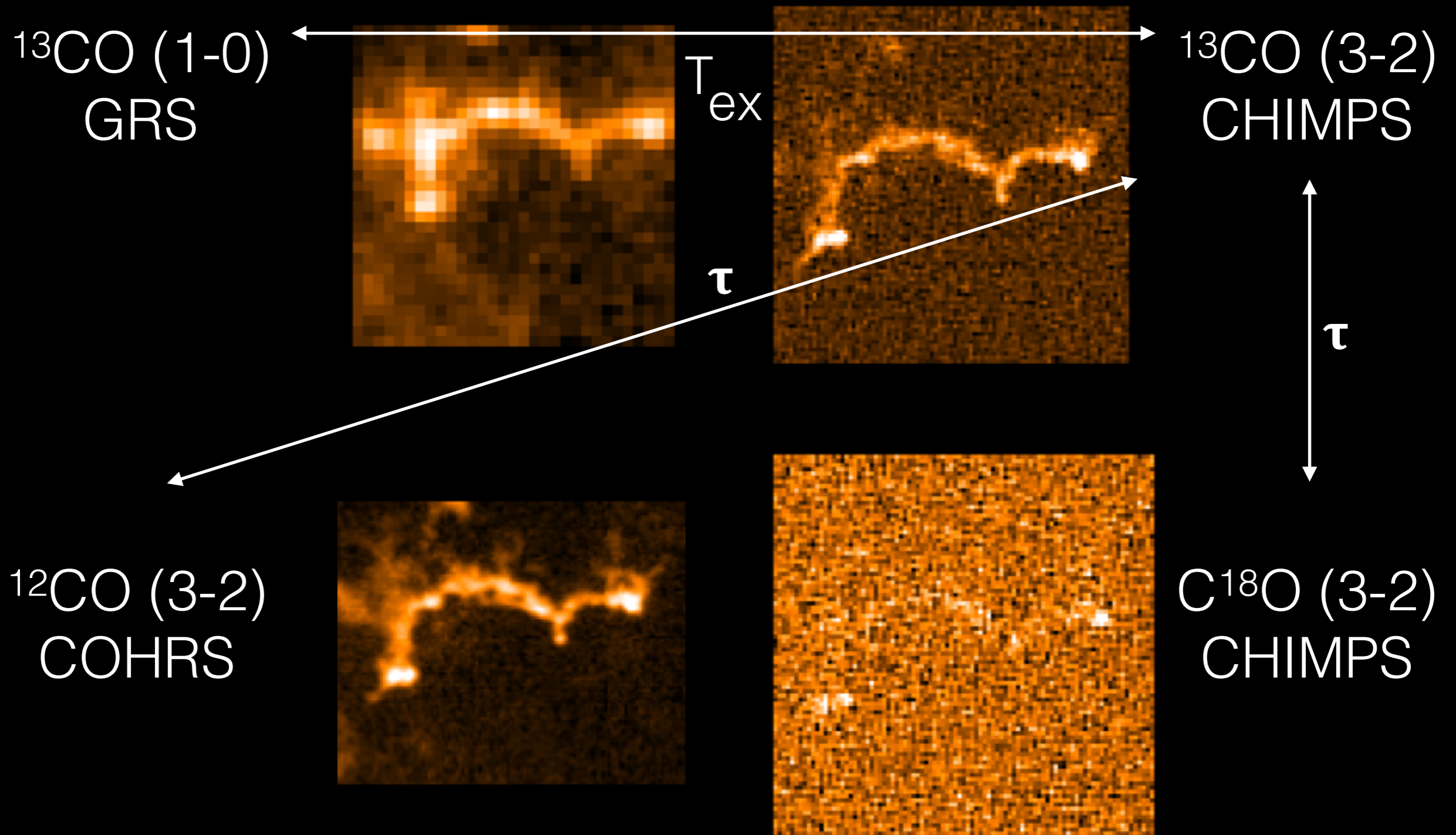
^{12}CO (3-2)
COHRS



C^{18}O (3-2)
CHIMPS



Different isotopologues + different transitions = masses



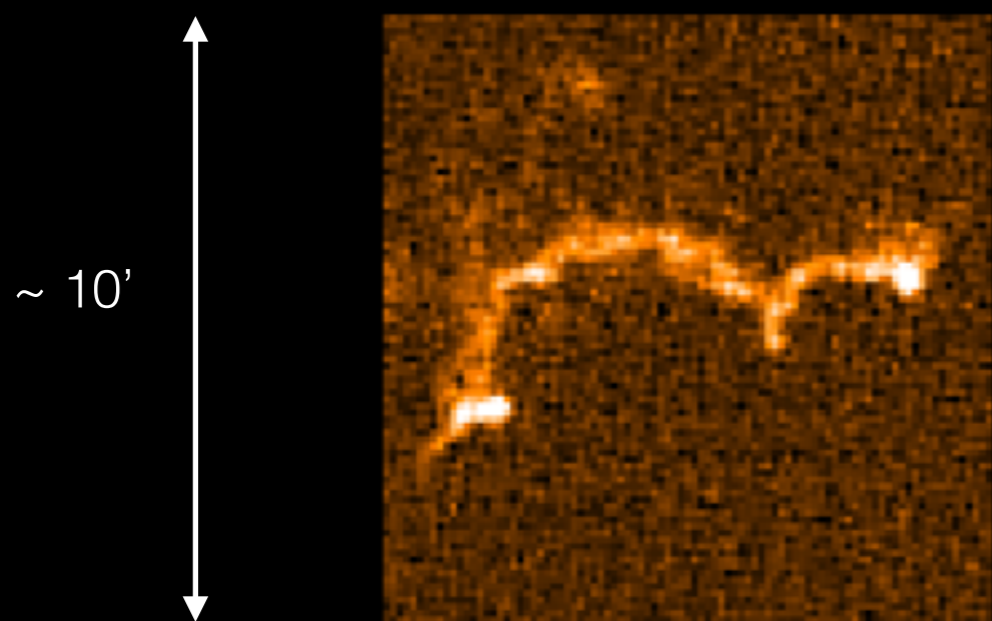
For the future: ^{12}CO , ^{13}CO & C^{18}O (1-0) - NRO 45m

Source extraction

- Smoothed spatially using a Gaussian kernel.
- Sources extracted from SNR cubes - lose less due to variable weather conditions.
- All sources with $\text{SNR} > 5$
- Using the 'FellWalker' algorithm of David Berry (arXiv:1411.6267)

Example source extraction

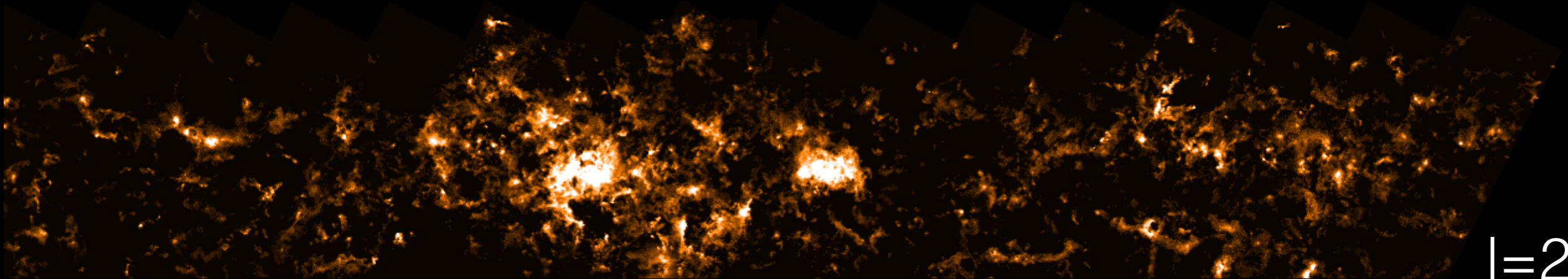
- Filaments ($l=37.4$, $b=-0.05$) tend to split into many sources.
- Separated into 6 sources by FellWalker.
- Advantages over ClumpFind and GaussClumps:



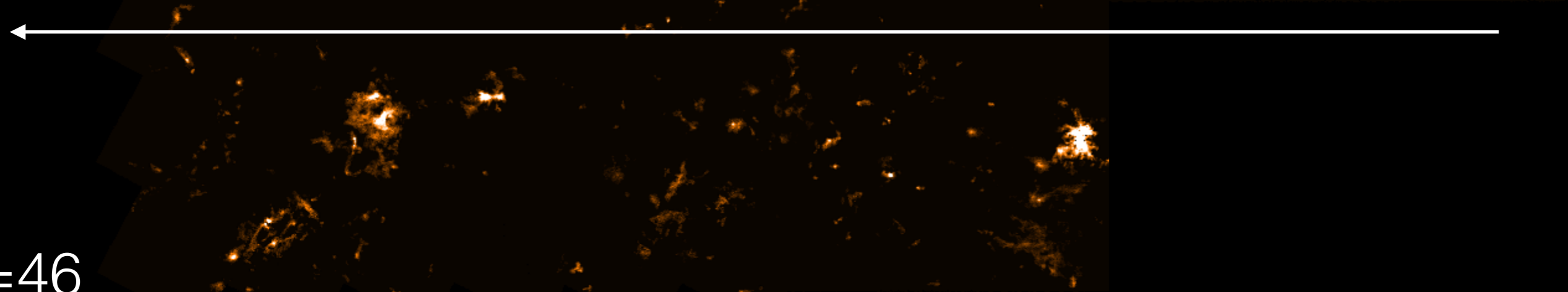
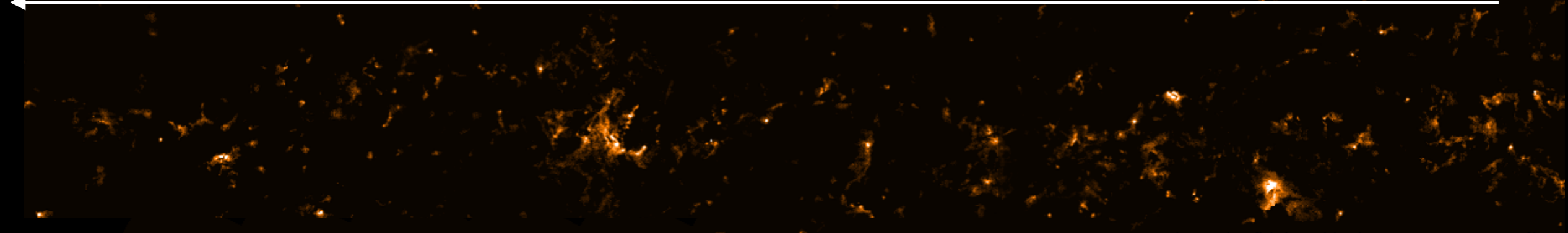
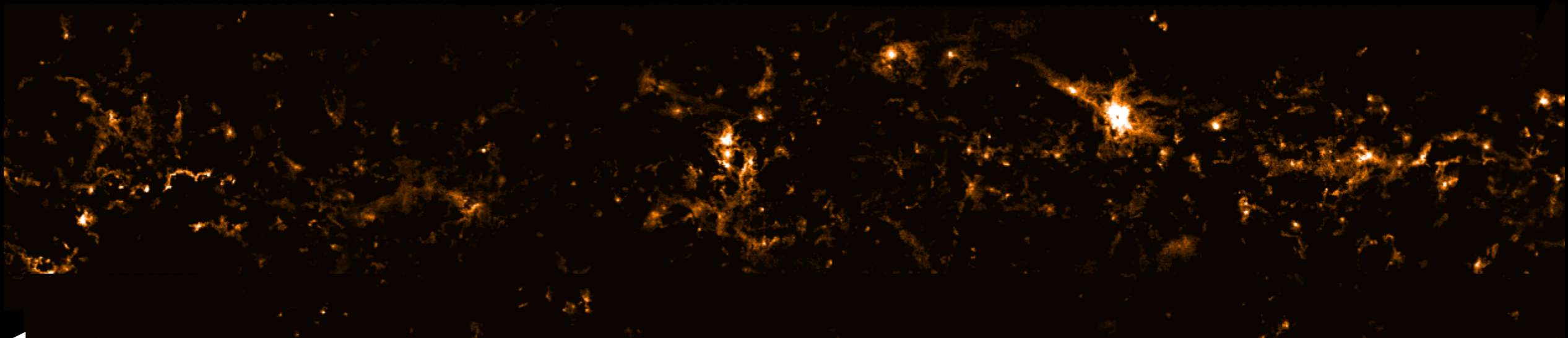
Integrated over 63 - 51 km/s



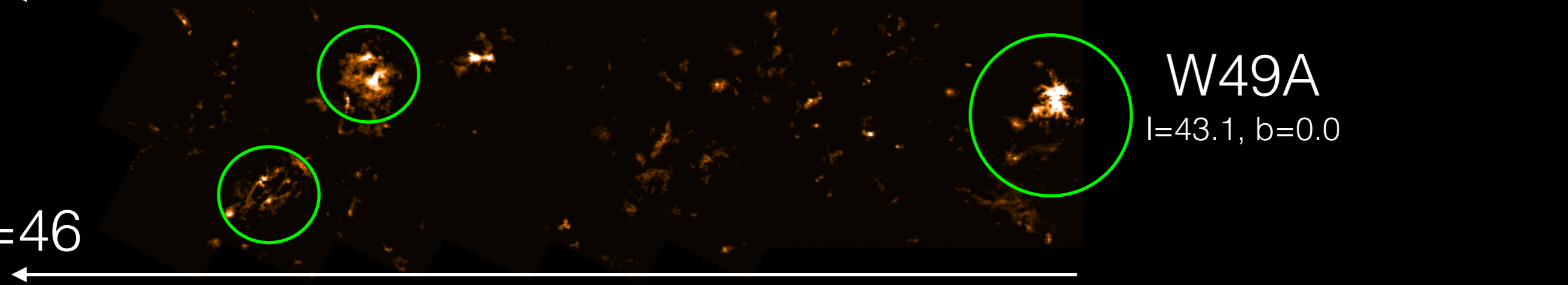
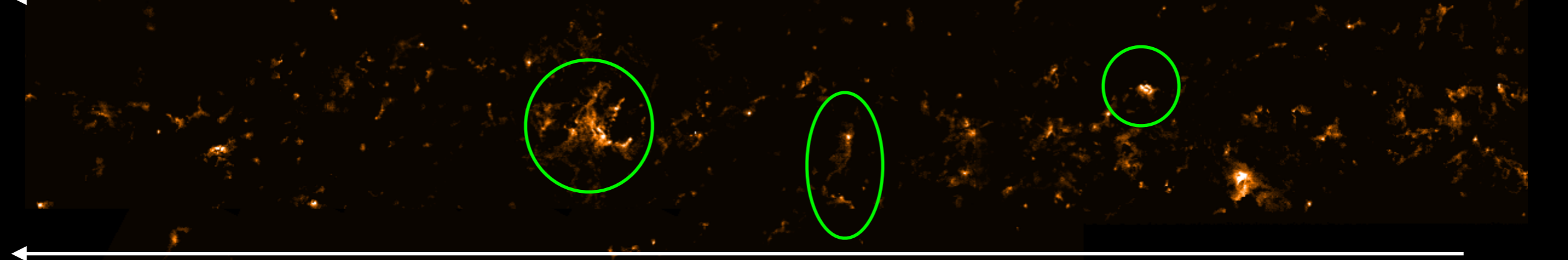
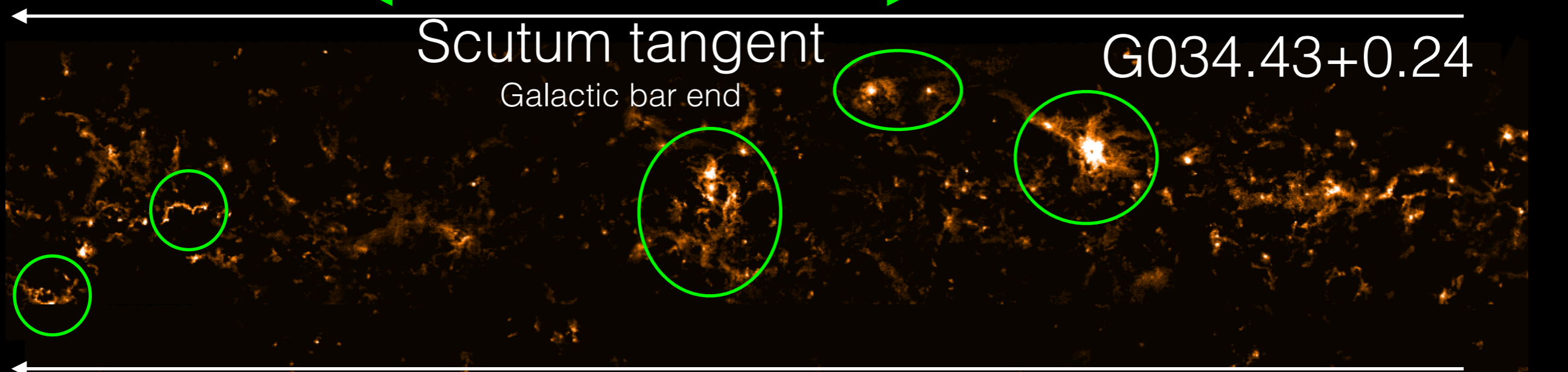
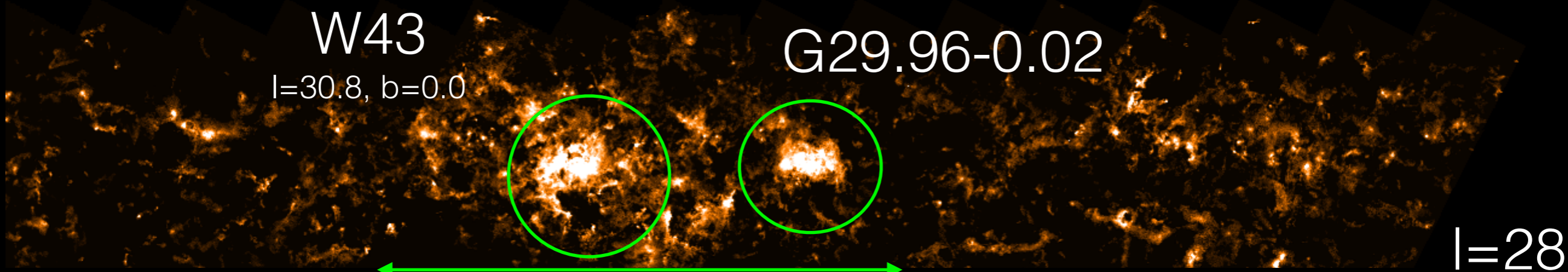
e.g 58 km/s channel

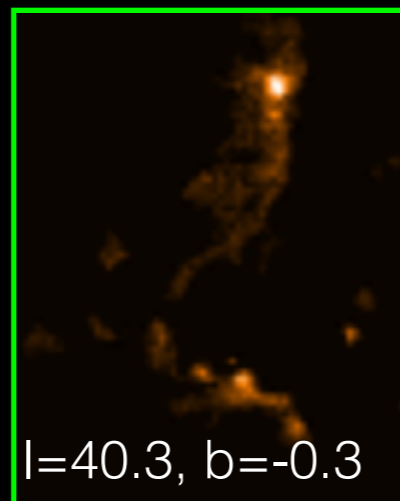
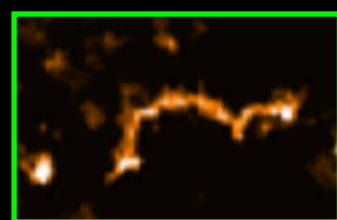
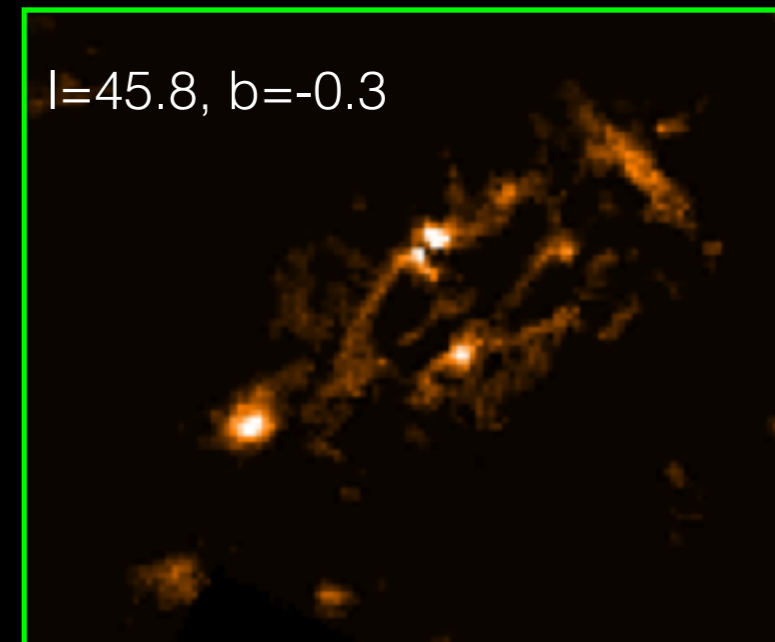
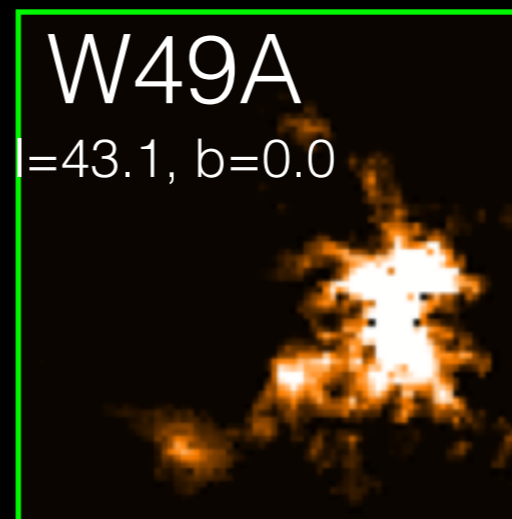
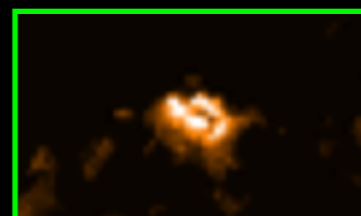
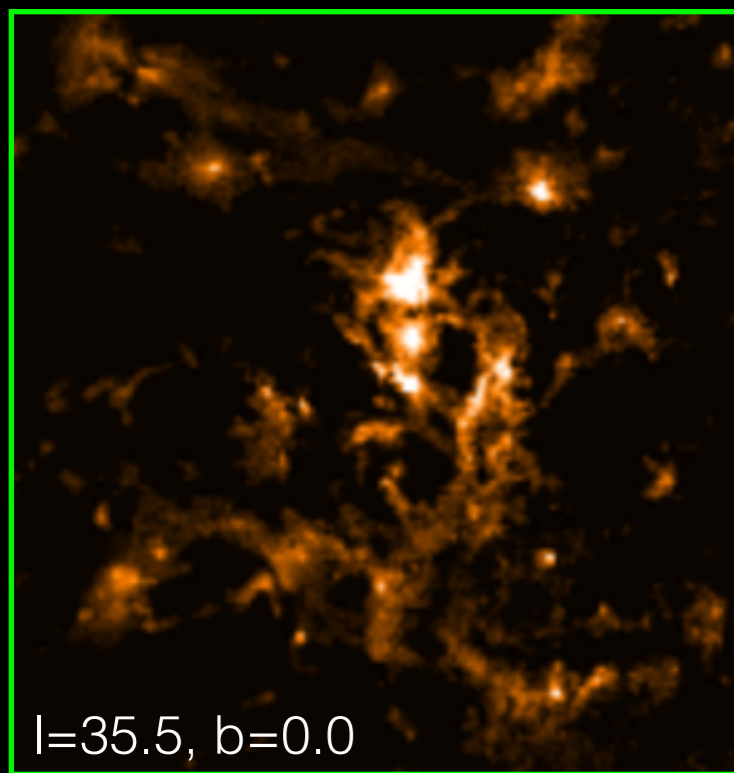
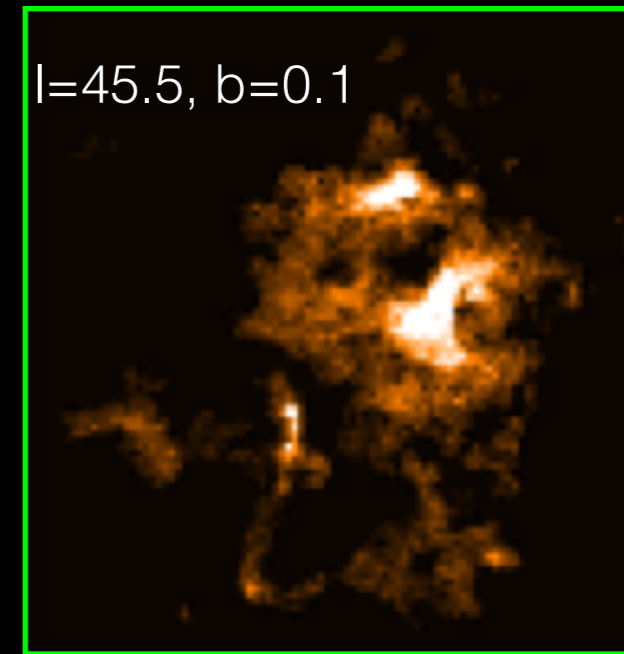
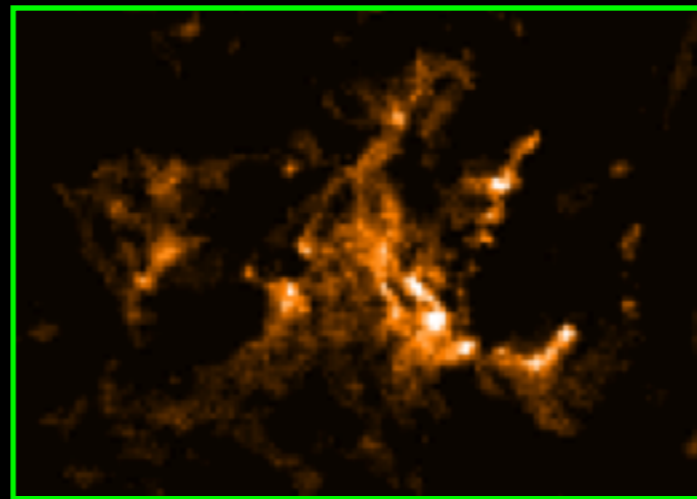
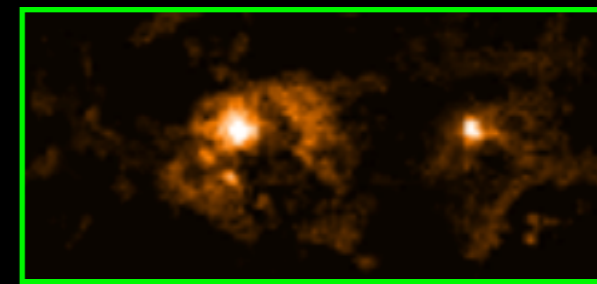
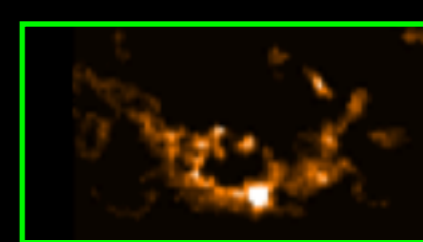
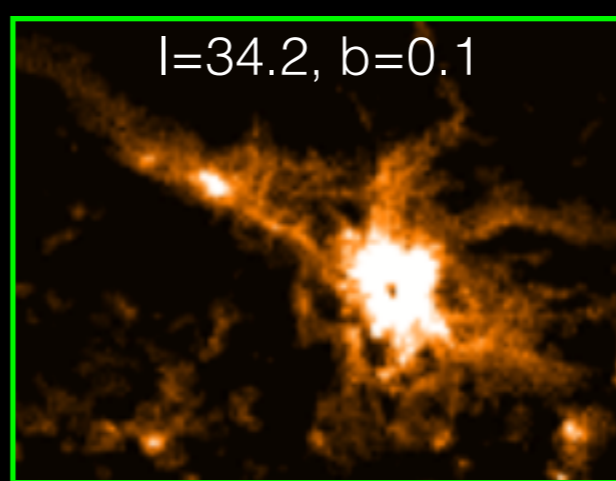
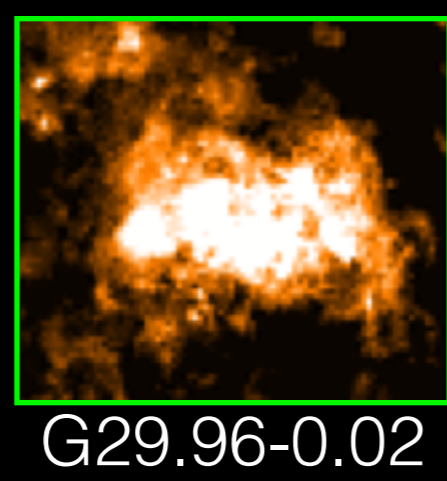
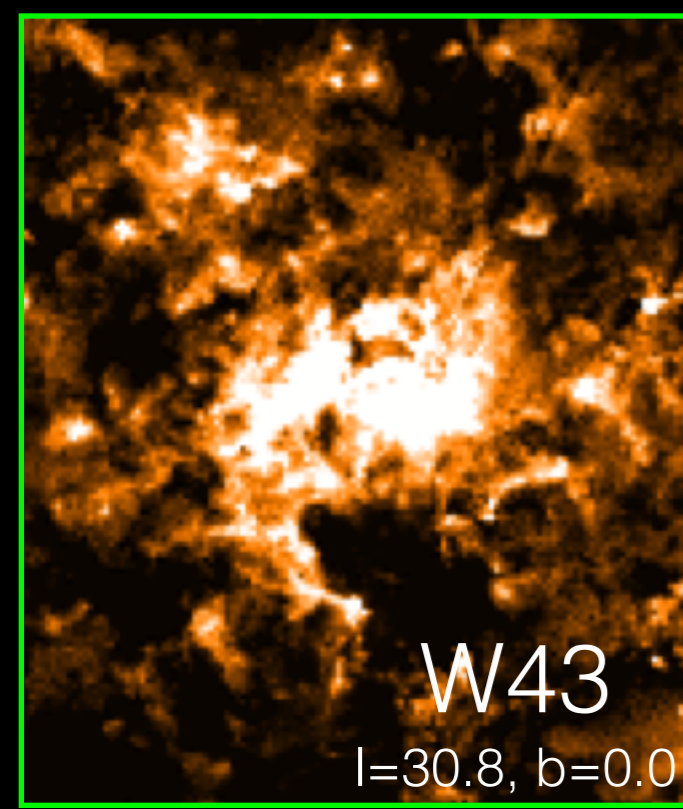


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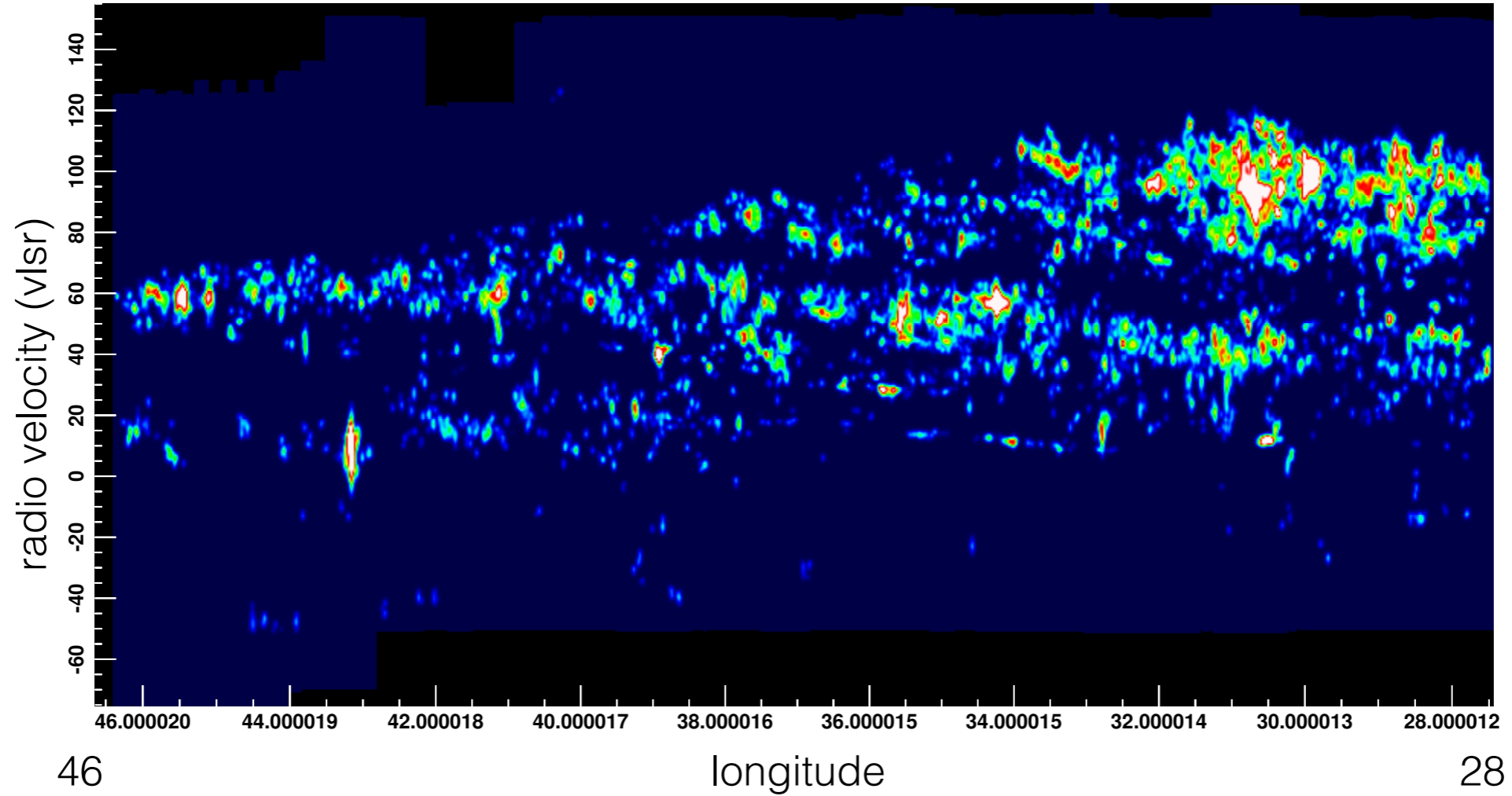


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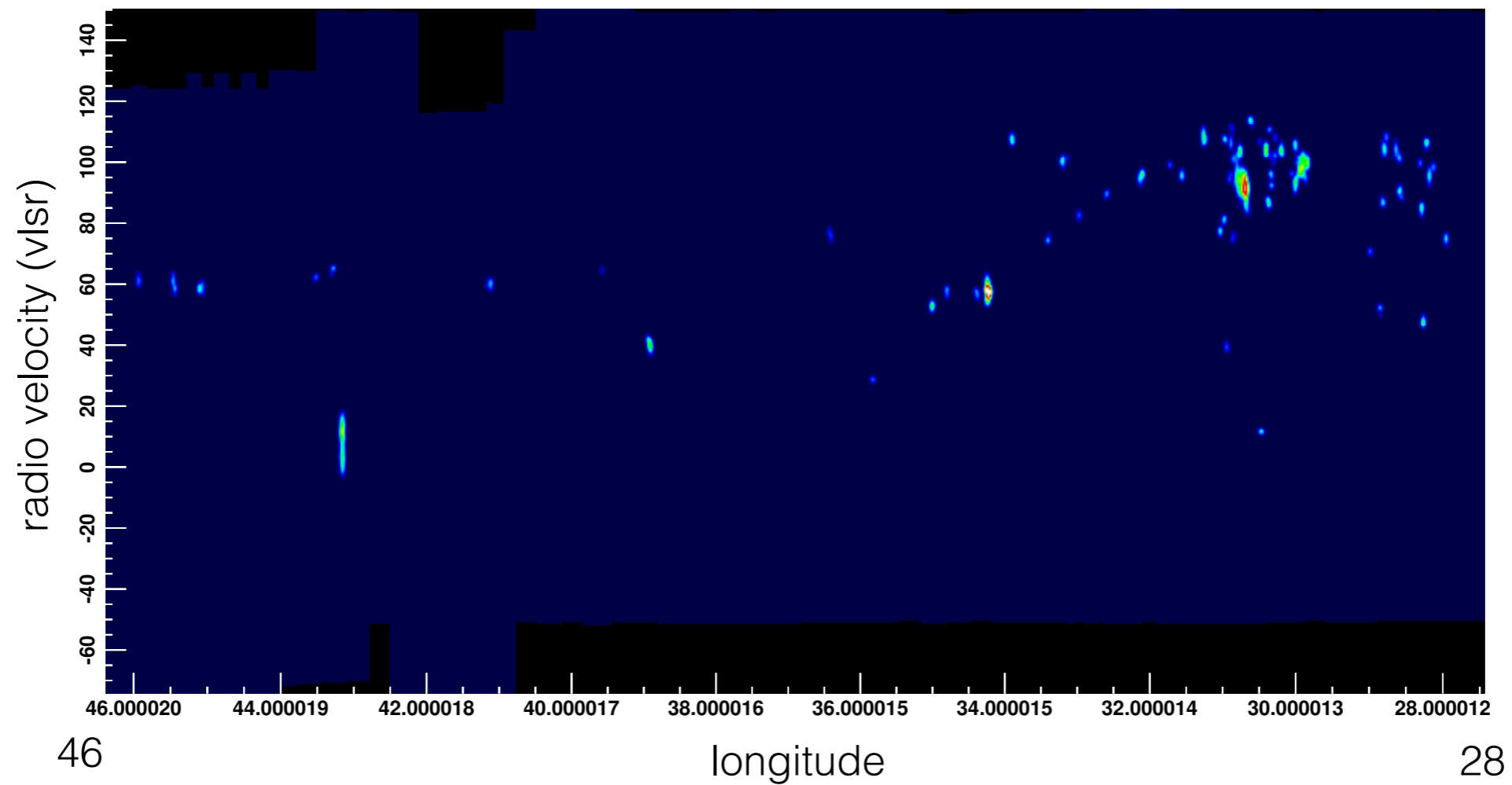




^{13}CO
(3-2)

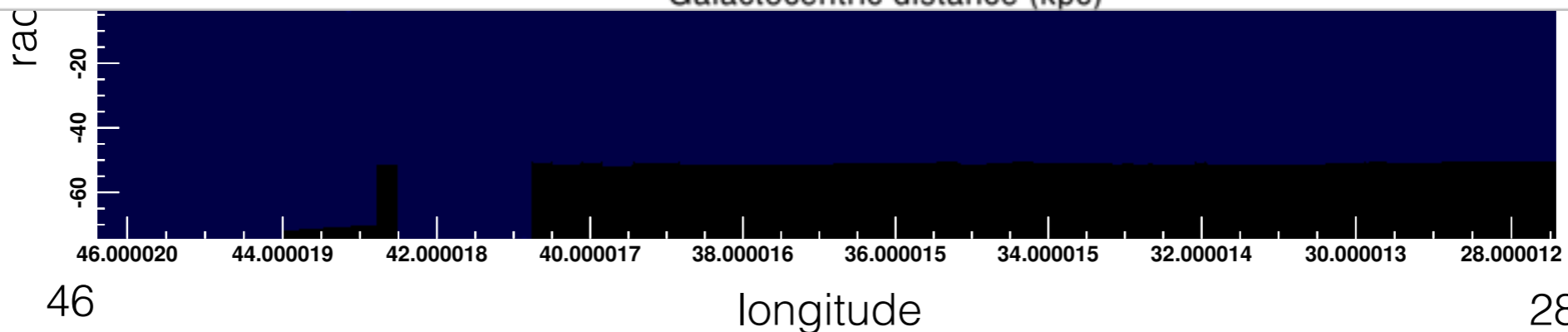
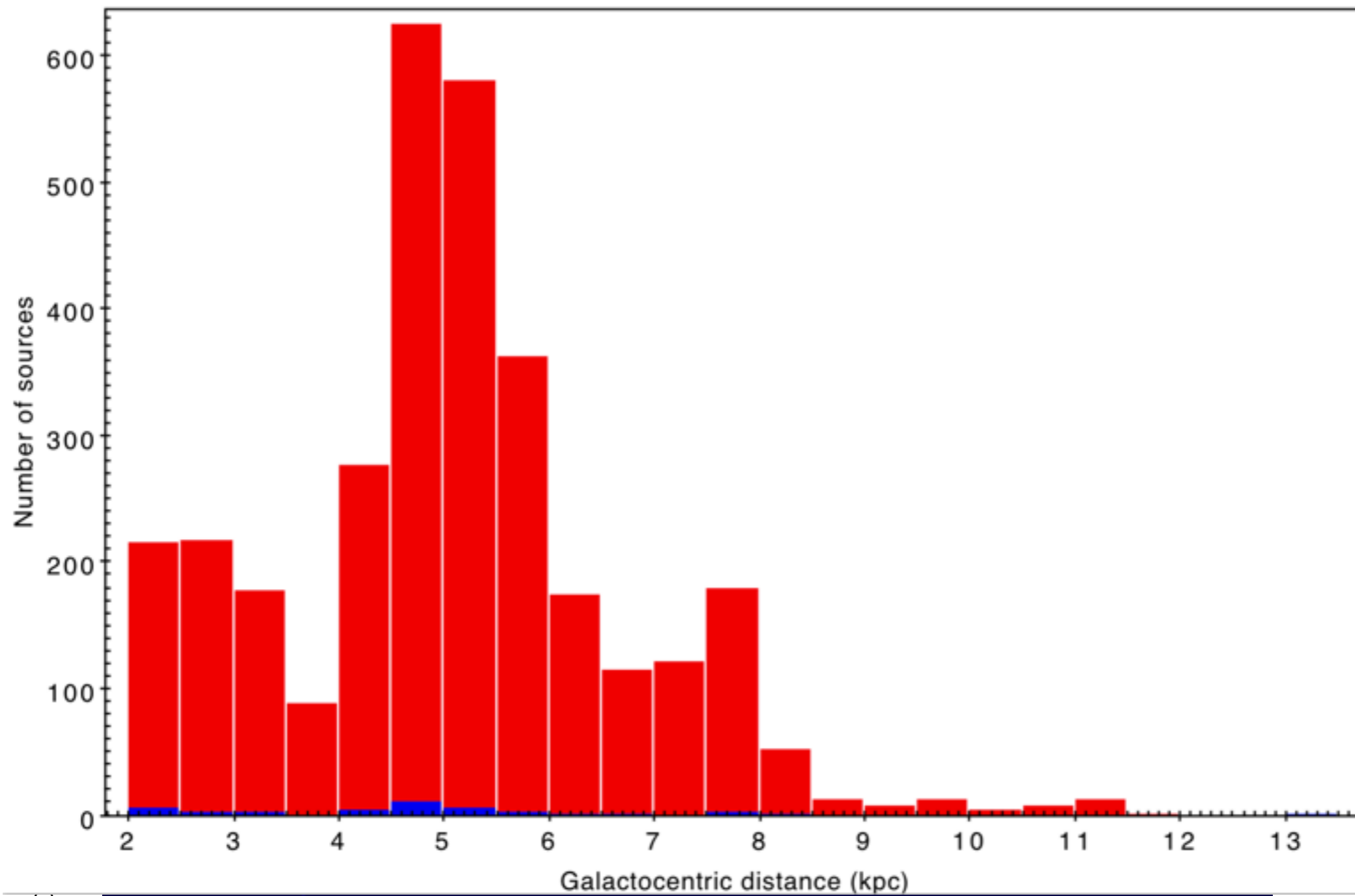
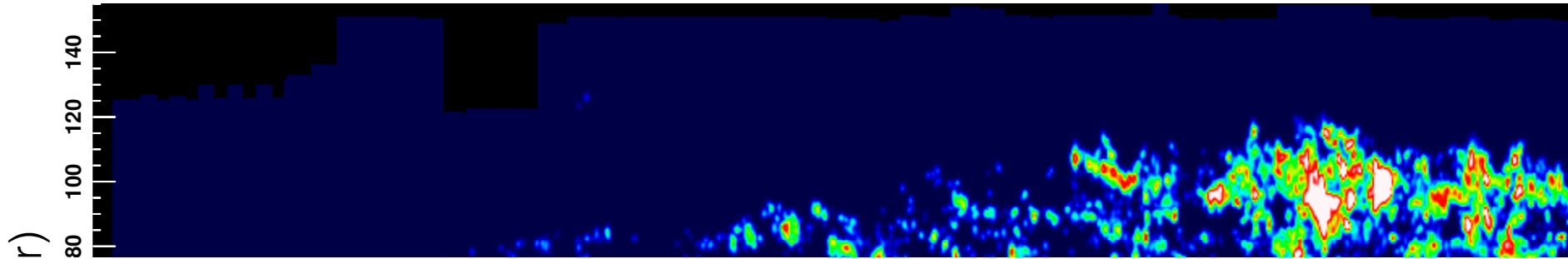


C^{18}O
(3-2)

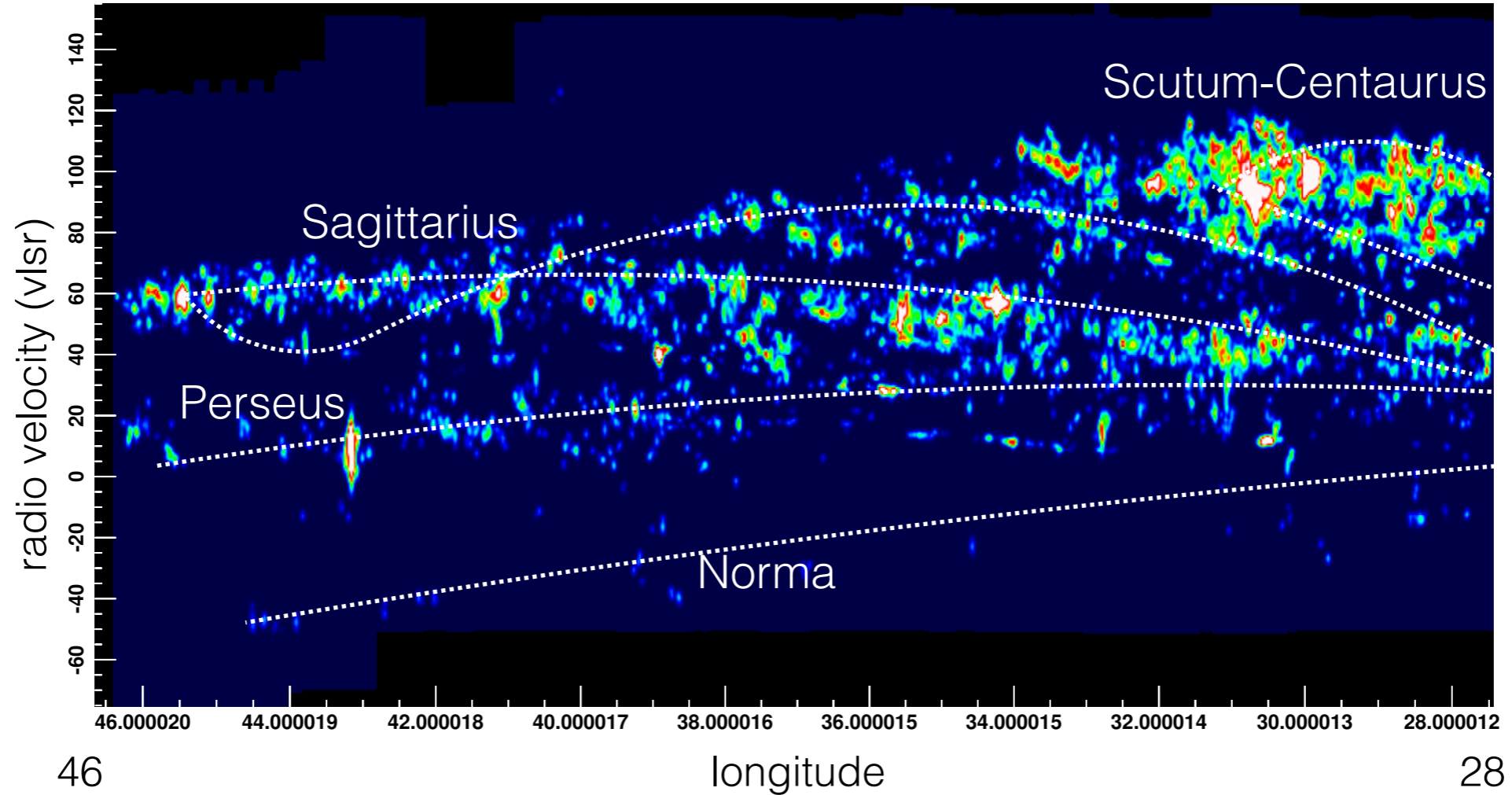


^{13}CO
(3-2)

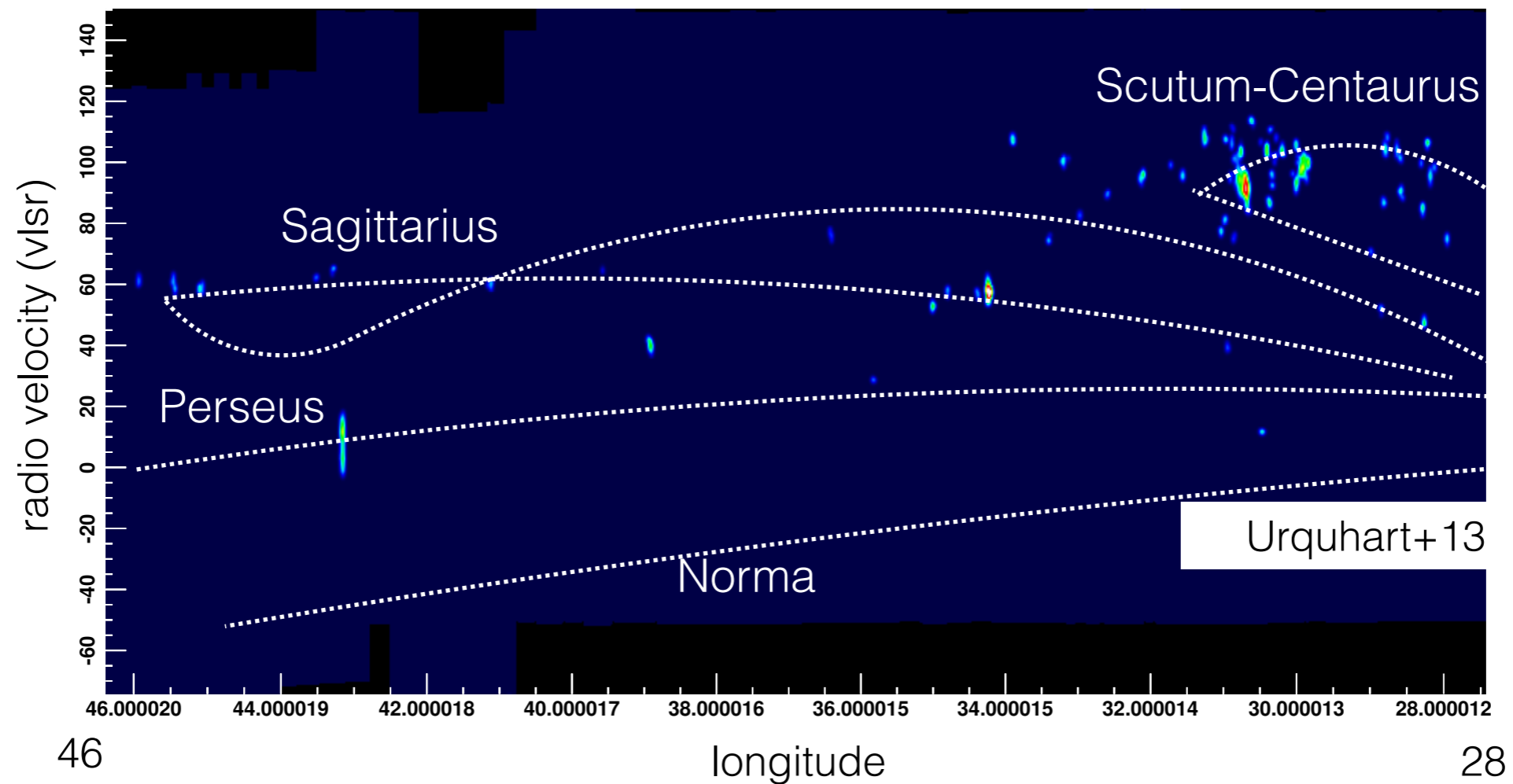
C^{18}O
(3-2)



^{13}CO
(3-2)



C^{18}O
(3-2)



Catalogue and release

- Public release coming soon! **Rigby et al.** (in prep.)
- 4999 clouds in the ^{13}CO catalogue
- 116 clouds in C^{18}O
- Positions, sizes, velocities, R_{GC} , masses, distances.
- Currently working on mass calculations & completeness tests.
 - $28^\circ < l < 46^\circ$ and $|b| < 0.5^\circ$

Thanks for listening.

CHIMPS



Rigby et al.

Coming soon!

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- $28^\circ < l < 46^\circ$ and $|b| < 0.5^\circ$

CHIMPS: rms ~ 1K /channel
Hi-GAL: 5 - 36" (Herschel)
JPS: 10 mJy/beam
ATLASGAL: 50-70 mJy/beam
BGPS: 11-53 mJy/beam

CHIMPS in conjunction with other molecular gas surveys

- COHRS (JCMT) - ^{12}CO J=3-2 at matching resolution. First release: $|b| < 0.5^\circ$ for $10.25^\circ < l < 17.5^\circ$ and $50.25^\circ < l < 55.25^\circ$, $|b| < 0.25^\circ$ for $17.5^\circ < l < 50.25^\circ$
- GRS (FCRAO): $18^\circ < l < 55.7$, $|b| < 1^\circ$, $^{13}\text{CO}(J=1-0)$, resolution $46'' + 0.2 \text{ km/s}$.
- Nobeyama 45m: $^{12}\text{CO}(1-0)$ at $15''$ resolution began 2014.

CHIMPS in conjunction with other submm continuum surveys

- JPS (JCMT): 450 & 850 μm in $4.5^\circ \times 2^\circ$ patches centred on $l = 10^\circ, 20^\circ, 30^\circ, 40^\circ, 50^\circ, 60^\circ$
- Hi-GAL: 70, 160, 250, 350, 500 μm for $-60^\circ < l < 60^\circ$, $|b| < 1^\circ$, resolution $\sim 5 - 36''$
- BGPS: 1.1mm for $-10^\circ < l < 90^\circ$, $|b| < 0.5^\circ @ 33''$
- ATLASGAL: 870 μm , $19''$

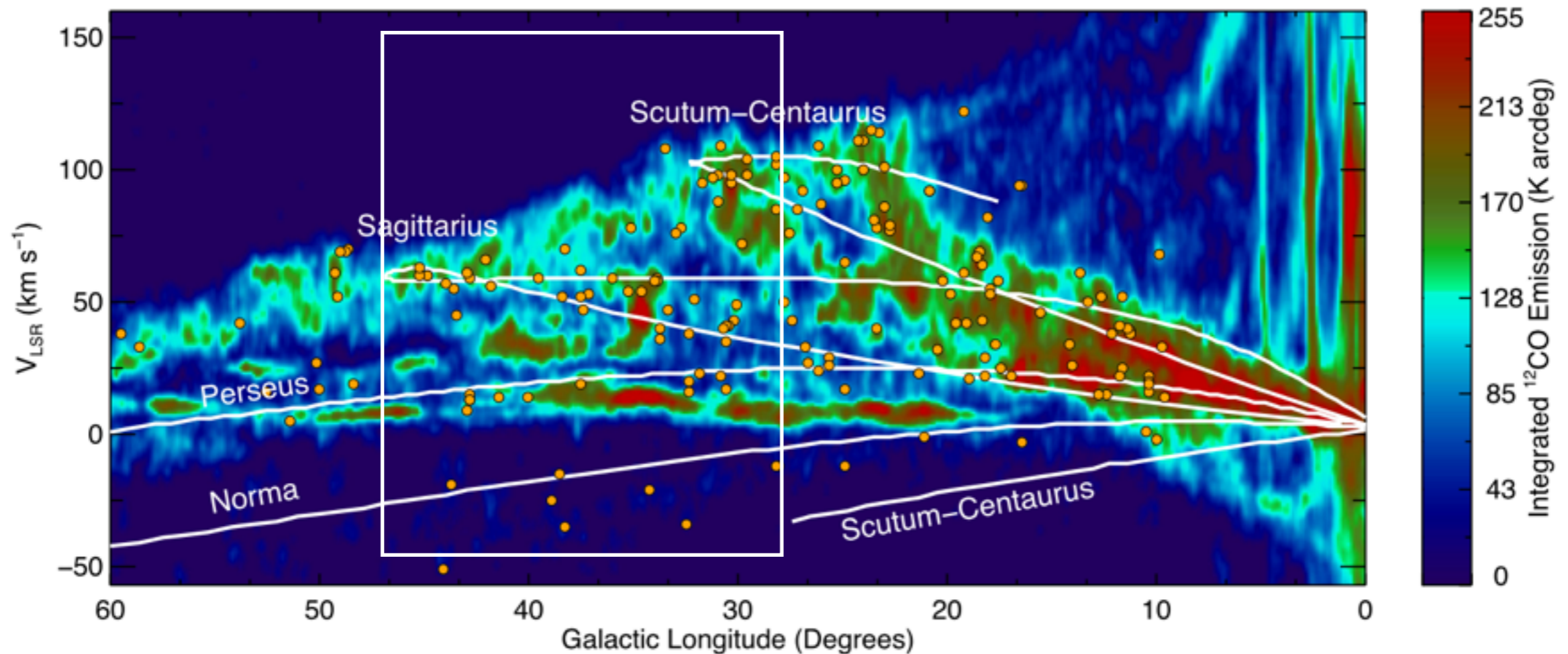


Figure 9. Galactic longitude–velocity distribution of H II-region associated clumps. The background image shows the distribution of molecular gas as traced by the integrated ¹²CO $J=1-0$ emission (Dame et al. 2001); the colour bar on the right shows the relative intensity of the emission. The orange circles mark the positions of the UC H II regions and the white lines indicate the location of the spiral arms taken from the model by Taylor & Cordes (1993) and updated by Cordes (2004).

CUPID: FellWalker

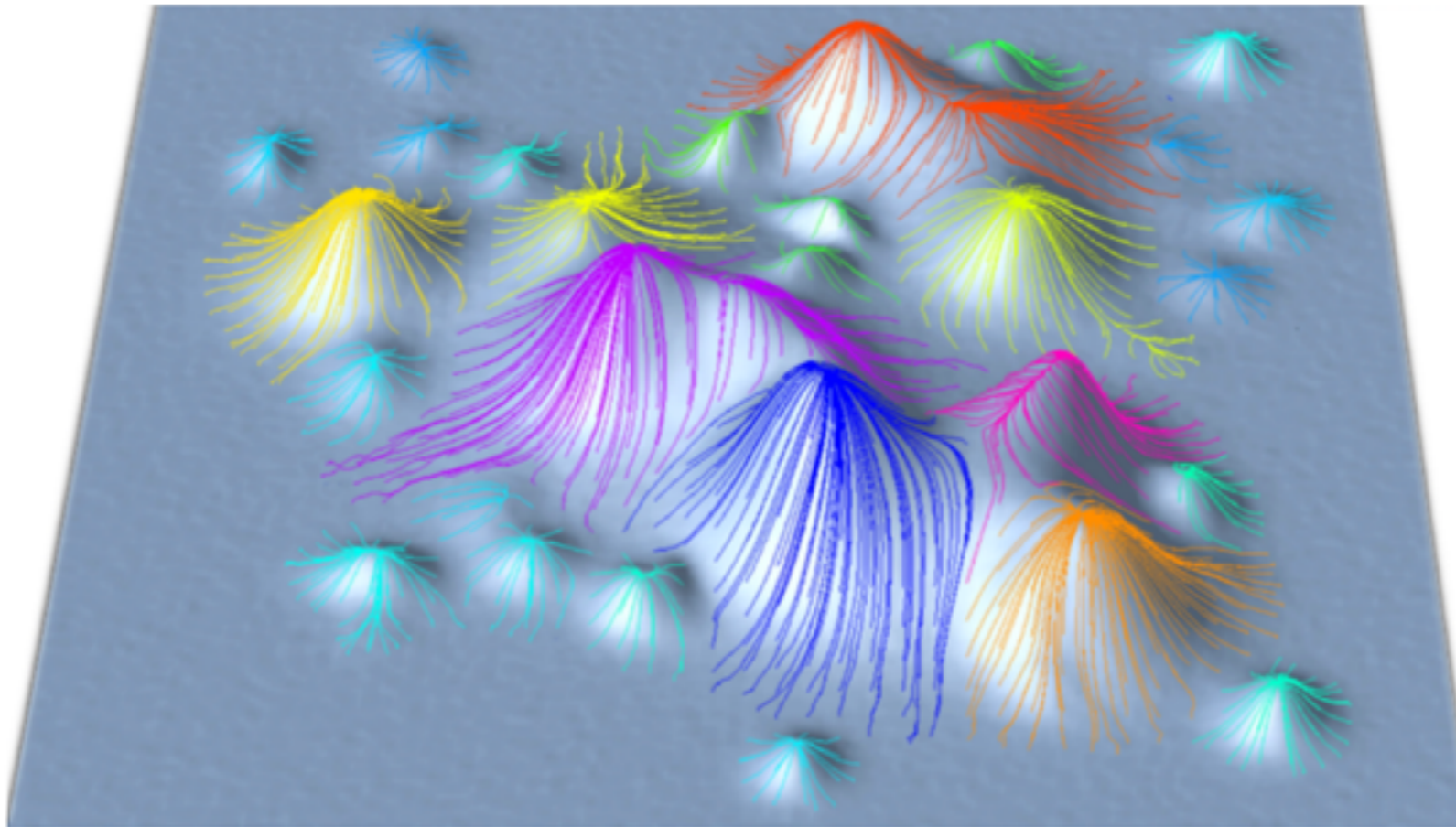


Figure 2: In 2-dimensions, peaks in data value are often reminiscent of the fells of northern England such as those in Fig. 1. The FellWalker algorithm performs many walks starting at various low-land pixels, and for each one follows a line of steepest ascent until a significant summit is reached. All walks that terminate at the same peak are assigned to the same clump, indicated by different colours in the above figure.

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