CMZ in CO isotopologue lines and the HESS TeV view

Rebecca Blackwell[1], Michael Burton[2], Gavin Rowell[1]

[1]University of Adelaide

[2]University of New South Wales

NANTEN2 Adelaide 2014 Meeting

Table of Contents

Motivation: Gas. I

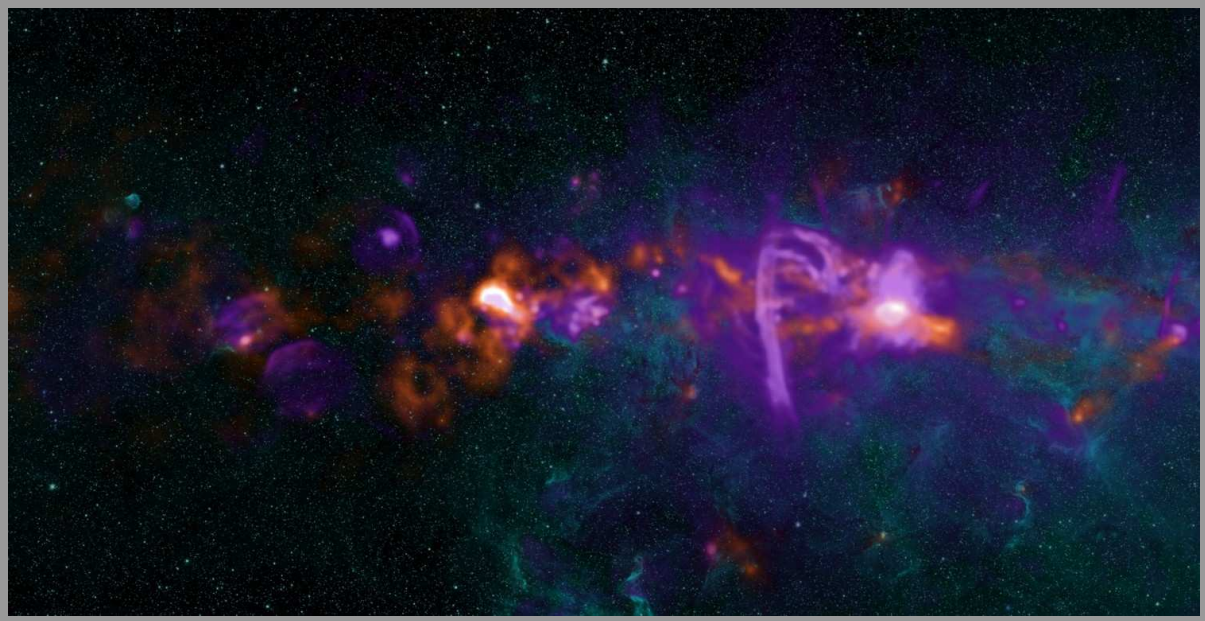


Figure: *The Galactic Centre.* Image courtesy of NRAO/AUI. Purple = 20cm (HII regions), orange = 1.1mm (cold dust), cyan = Spitzer IR (stars, point sources, PAHs). Source: http://images.nrao.edu/664

Motivation: Gas. II

Key Science Questions:
1. What allows the distribution of organic molecules to be so widespread in the CMZ, compared to their limited distribution within the hot molecular cores in GMCs elsewhere in the Galaxy, and
2. How have their complex dynamical motions been driven?

CMZ in radio astronomy:
Burton et al 7mm:109-115 GZ - Galactic CO survey
Jones et al 3mm:90 GHz - the CMZ broadly and Sgr B2 in particular
Jones et al 7mm: 45 GHz - the CMZ broadly and Sgr B2 in particular
Walsh et al 12mm:22 GHz - HOPS (H_2O Southern Galactic Plane) survey

Motivation: VHE Gamma-Rays and CR. I

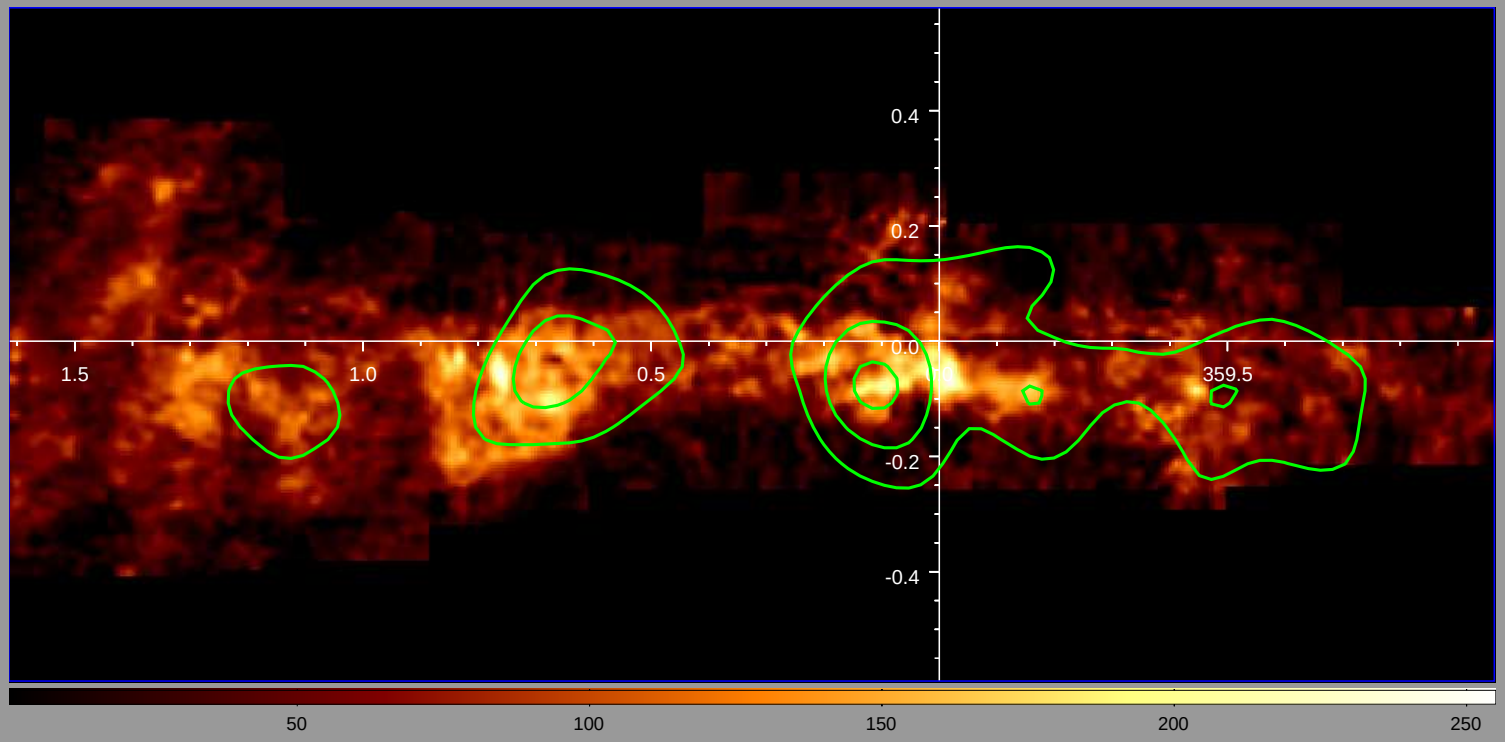


Figure: CS (J=1-0) integrated intensity map ($T_{rms} = 6.3$K.km/s), overlaid with H.E.S.S. diffuse galactic ridge TeV excess emission contours (at 300, 330, 360 events). Sources: Tsuboi et al (1999) ApJ 120. Aharonian et al (2006), Nature (Letters).

Project. I

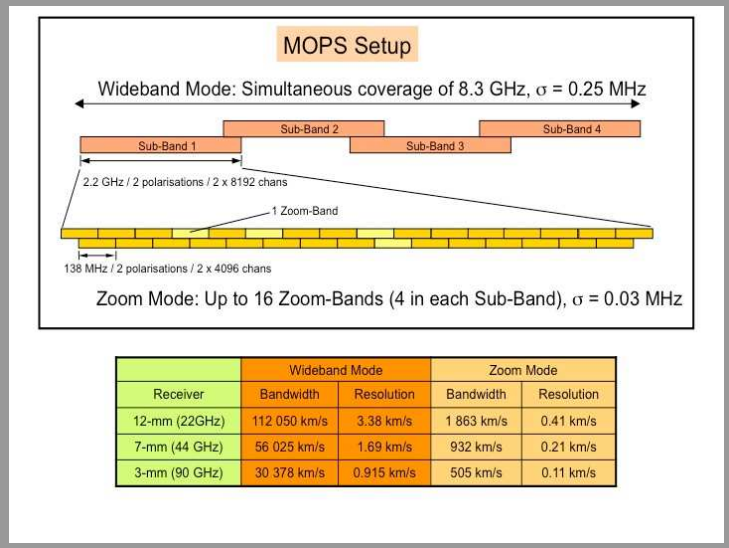
Data was taken across the CMZ, including the ranges:
$358.5^\circ \leq l \leq 2.5^\circ$ and $-0.5^\circ \leq b \leq 1.0^\circ$.

IF	Molecular Species	Frequency (GHz)
1	^{13}CO	110.201353
2	C^{18}O	109.782173
3	C^{17}O	112.358985
4	CN	113.490982
5	^{12}CO	115.271202
5	^{12}CO (red)	115.15
6	^{12}CO	115.271202
7	^{12}CO (blue)	115.43

Table: MOPS Spectrometer Intermediate Frequency settings for the data collection. In February IF1-5 were used, while in May the red/blue ^{12}CO lines were added, resulting in IF1-7 (1-4 unchanged). All spectra are the (J=1-0) line.

Project. II

(a) The Mopra Telescope

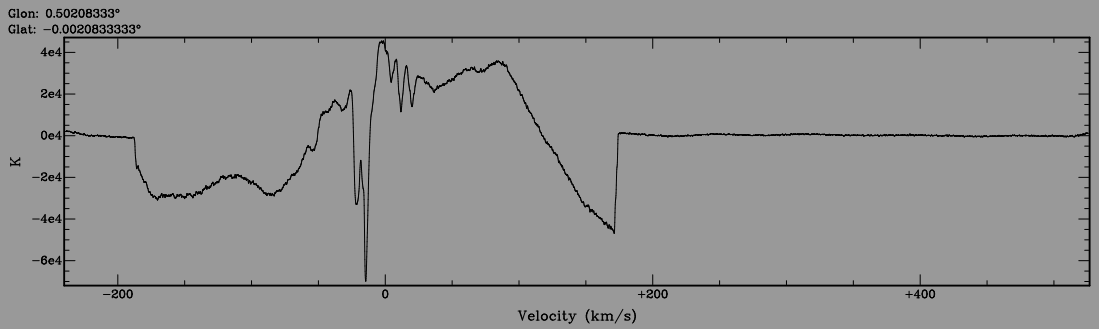


	Wideband Mode		Zoom Mode	
Receiver	Bandwidth	Resolution	Bandwidth	Resolution
12-mm (22GHz)	112 050 km/s	3.38 km/s	1 863 km/s	0.41 km/s
7-mm (44 GHz)	56 025 km/s	1.69 km/s	932 km/s	0.21 km/s
3-mm (90 GHz)	30 378 km/s	0.915 km/s	505 km/s	0.11 km/s

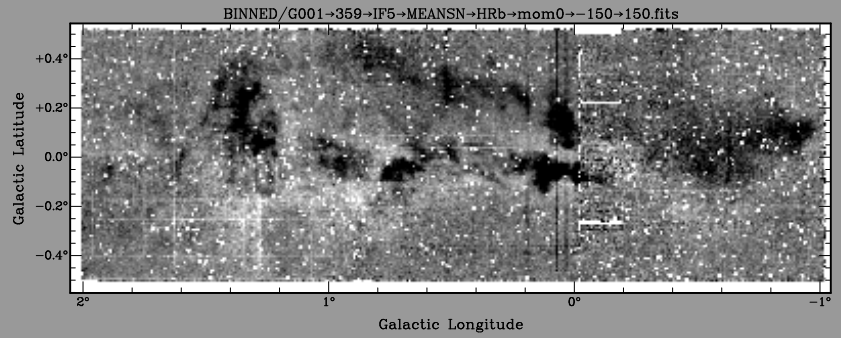
(b) The MOPS Spectrometer

Figure: Images Source: http://www.narrabri.atnf.csiro.au/mopra/obsinfo.html

Thick 12CO. I

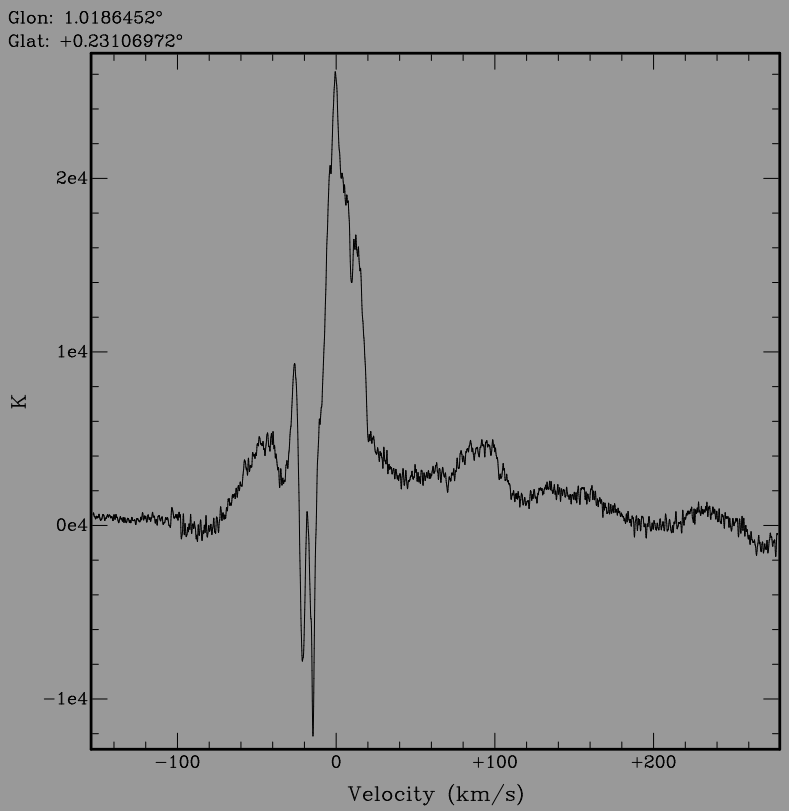


(a) Spectrum.

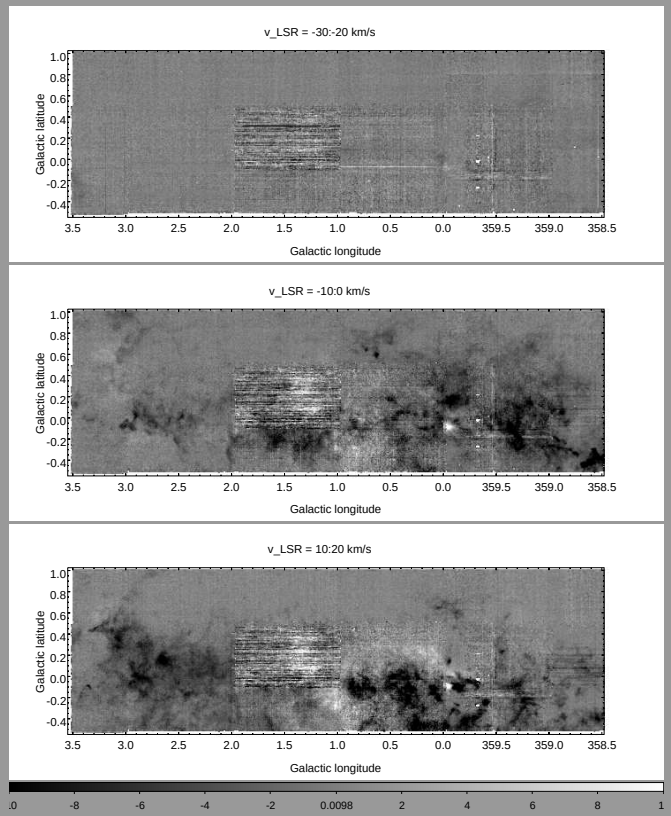


(b) Moment-0 map (integrated peak intensity), from v_{LSR}=-150:150 km/s.

^{13}CO. I

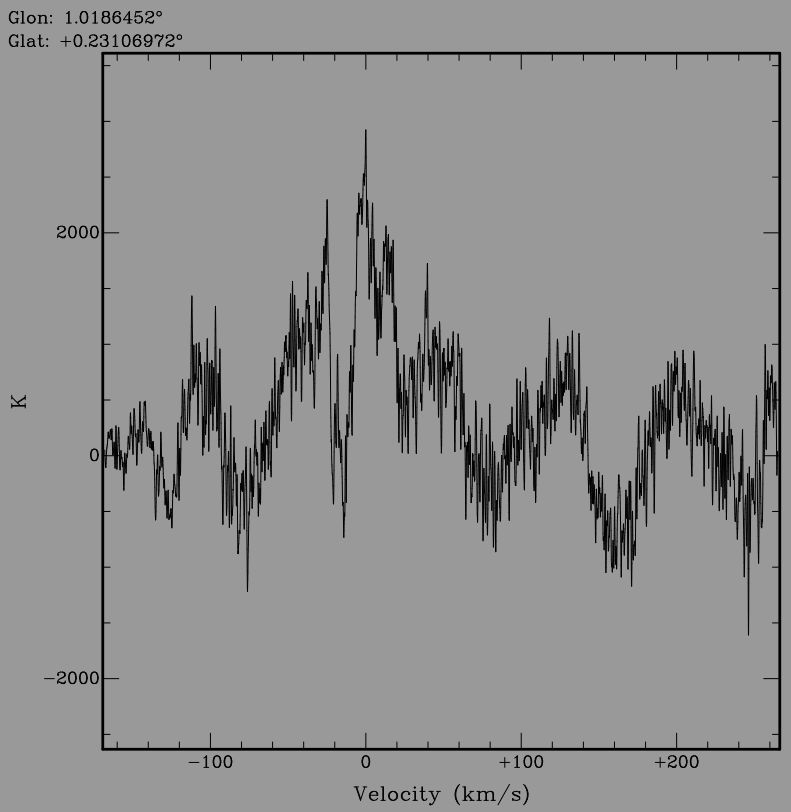


(c) Spectrum.

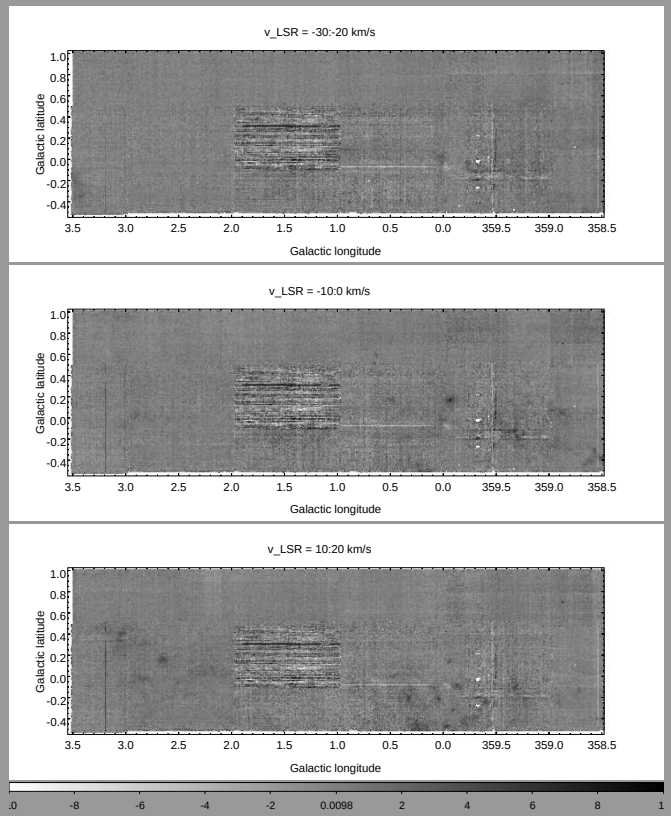


(d) Narrow 10 km/s integrated peak intensity maps.

$C^{18}O$. I

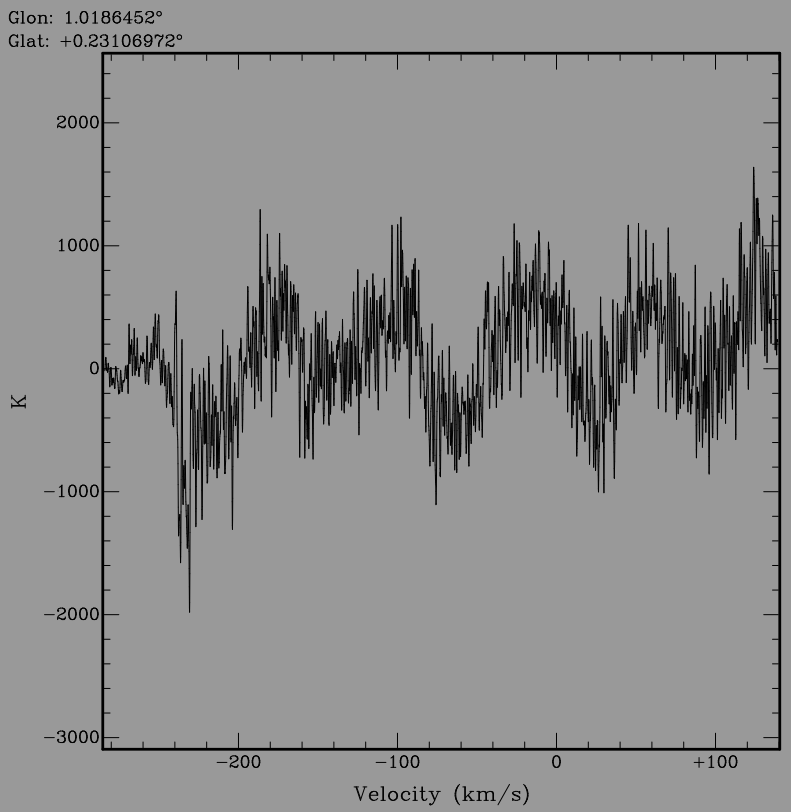


(e) Spectrum.

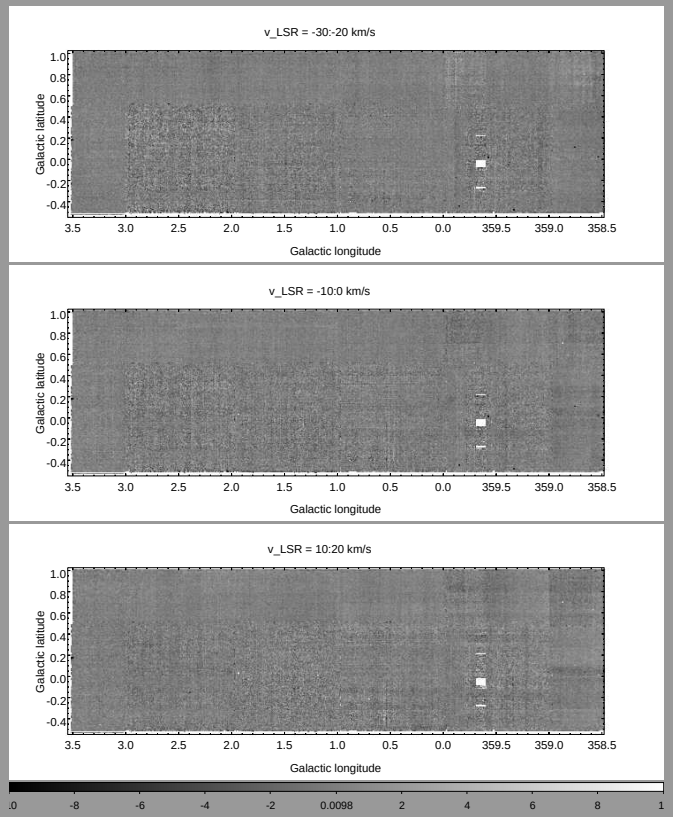


(f) Narrow 10 km/s integrated peak intensity maps.

$C^{17}O$. I

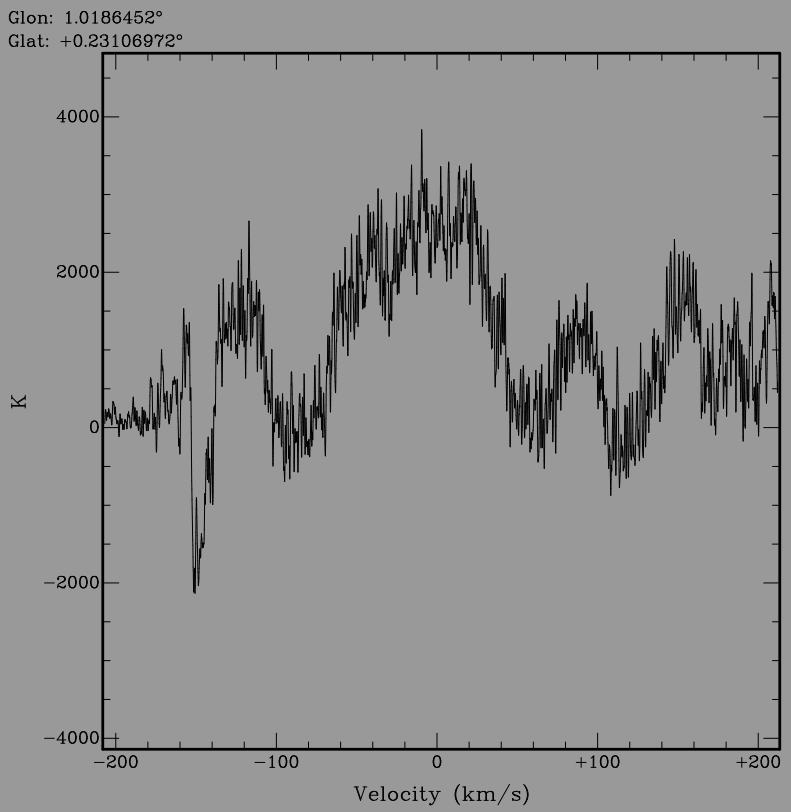


(g) Spectrum.

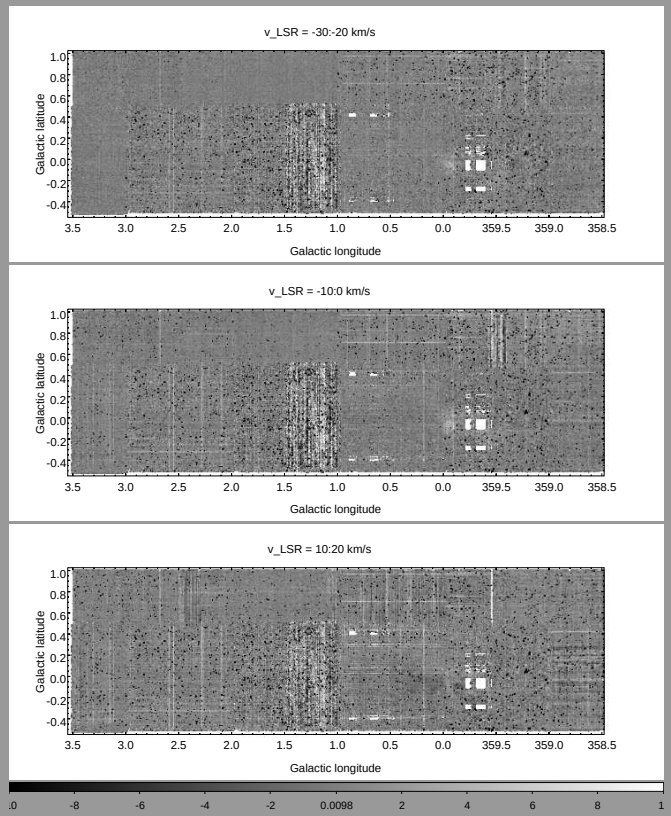


(h) Narrow 10 km/s integrated peak intensity maps.

CN. I



(i) Spectrum.



(j) Narrow 10 km/s integrated peak intensity maps.

Preliminary Multiwavelength. I

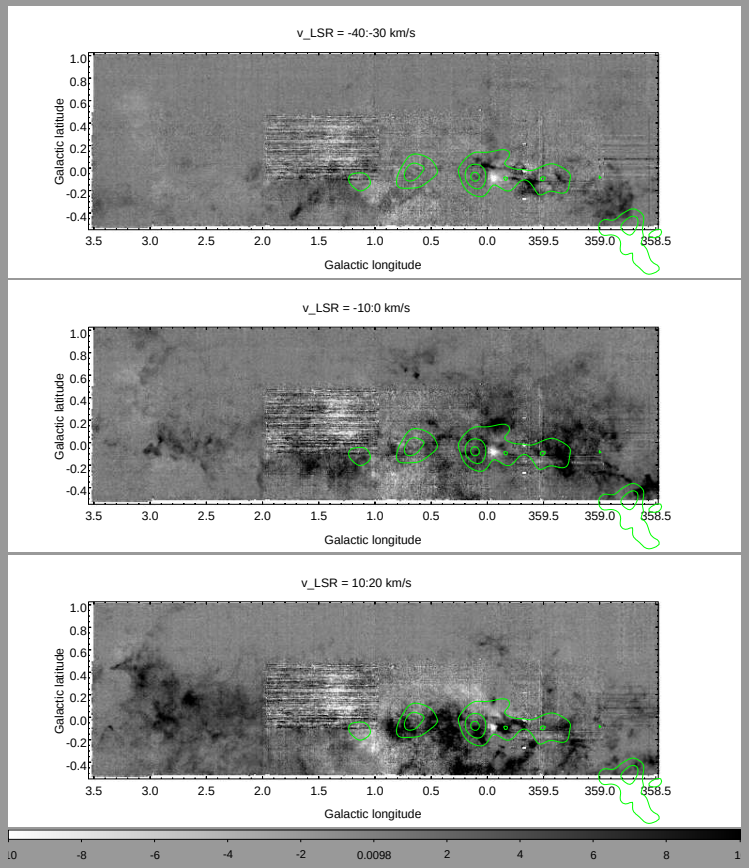
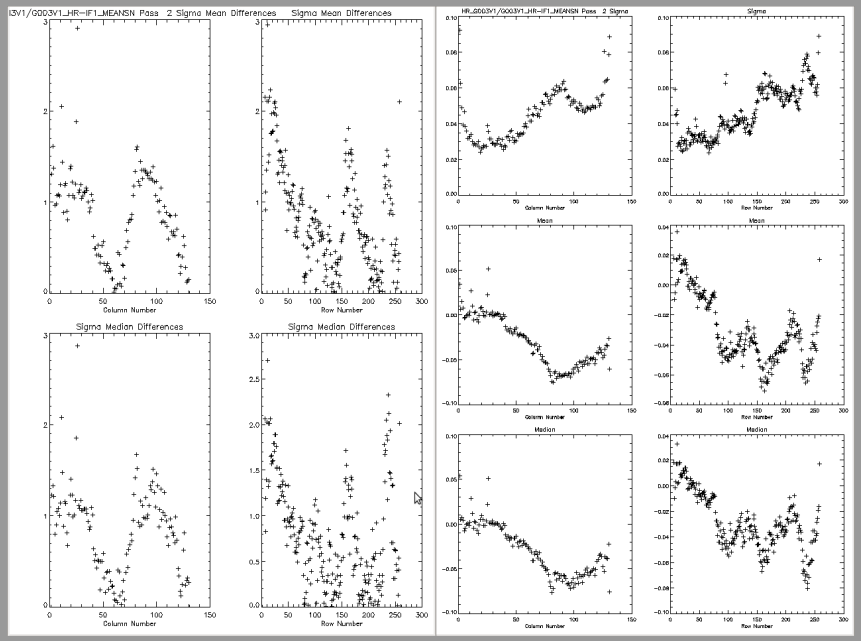


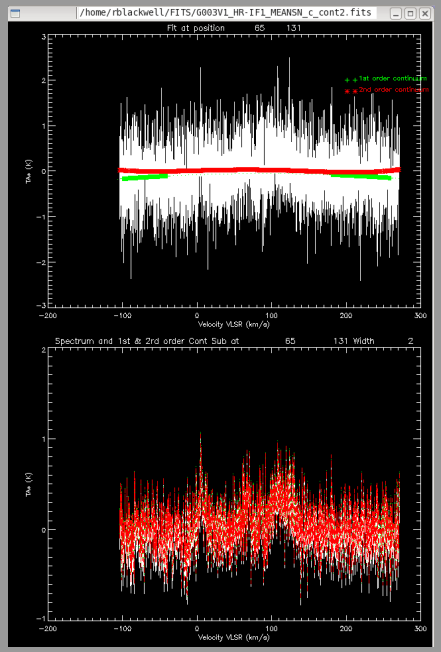
Figure: H.E.S.S. diffuse Galactic Ridge TeV γ-ray contours overlaid on the narrow integrated velocity maps of ^{13}CO.

Future Work: Processing. I

Future work: additional cleaning/continuum subtraction
Future work: cleaning/continuum subtraction of ^{12}CO



(a) Pixel and row/column cleaning.



(b) Continuum subtraction.

Figure: Examples of cleaning the G003V1 block; this is accomplished via IDL scripts.

Future Work: Analysis. I

Future work: line ratio calculations.
Future work: optical depths, column densities.

Future work: feature analysis.

Future work: further TeV γ-ray multiwavelength analysis.
Future work: additional multiwavelength studies, possibly including NH_3, CS, HIGAL dust, HE γ-rays, and X-rays.

Thank you! I

Are there any questions?

References

http://www.narrabri.atnf.csiro.au/mopra/
http://www.phys.unsw.edu.au/mopracmz/index.html
http://www.phys.unsw.edu.au/mopraco/
Aharonian, F; et al. (2006). Nature, Letters 04467, Vol 439.
Burton, M.G., et al. (2013) PASA, 30, e044.
Jones, D., et al. (2010) Proceedings of Science, Vol 180.
Jones, P., et al. (2008) MNRAS, 386, 117.
Jones, P., et al. (2011). MNRAS, 411, 2293.
Jones, P., et al. (2012) MNRAS, 419, 2961.
Jones, P., et al. (2013) MNRAS, submitted.
Molinari, S., et al. (2011) ApJ 735 L33.
Tsuboi, M., et al. (1999) ApJS, Vol 120, p1.
Walsh, A., et al. (2011) MNRAS, 416, 1764.
Walsh, A., et al. (2008) PASA, 25, 105.

Additional. I

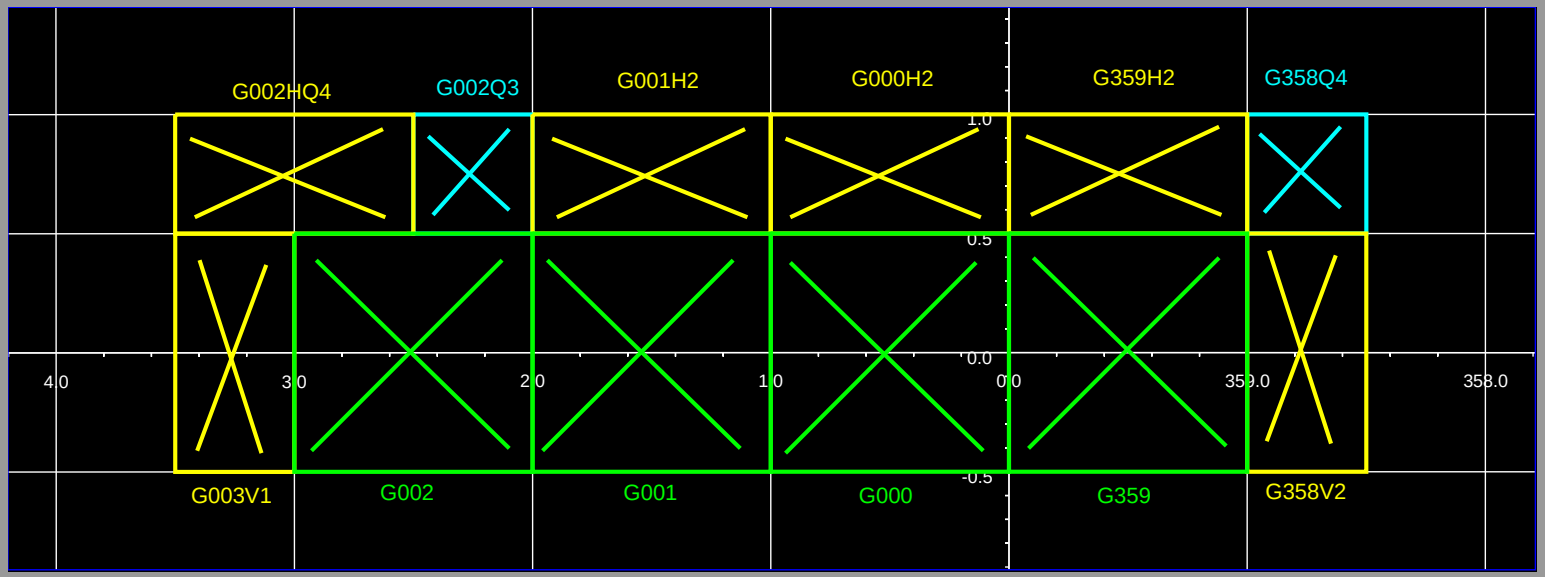
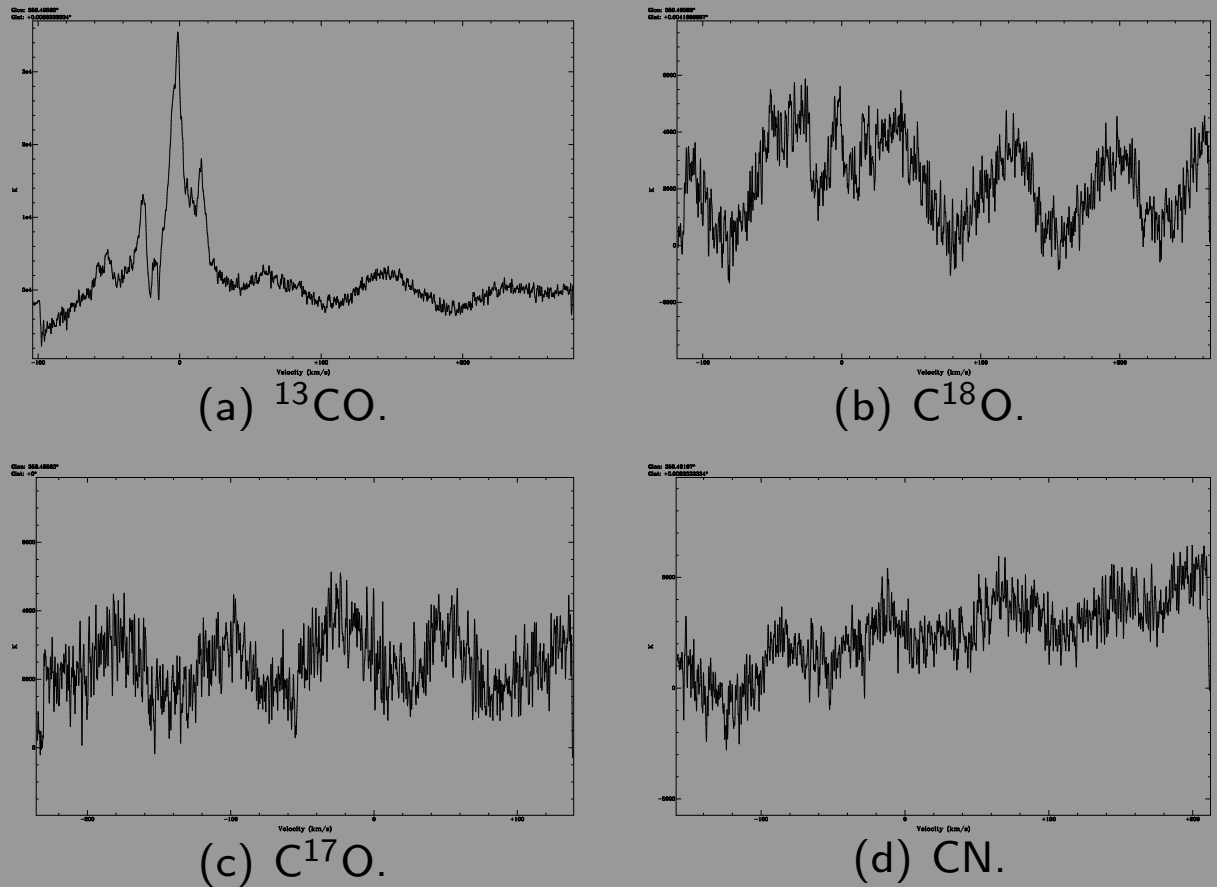


Figure: Blocks across the CMZ. (Note that there were two long scans which have been broken into half- and quarter- blocks for cleaning and processing: G001H2 and G002Q3; G358Q4 and G359H2).

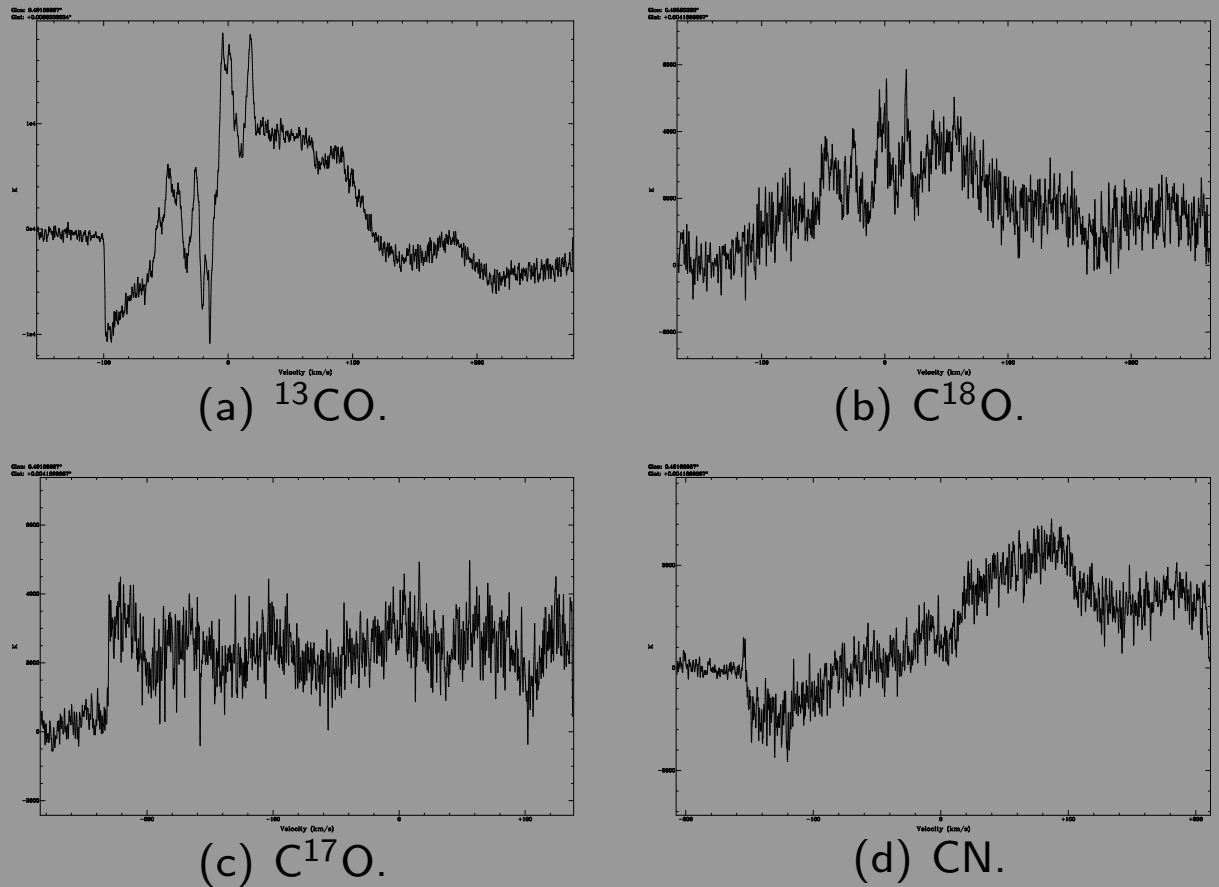
Additional. II



(a) ^{13}CO. (b) $C^{18}O$. (c) $C^{17}O$. (d) CN.

Figure: Spectral lines for the G359 block, smoothed to Hanning-9.

Additional. III

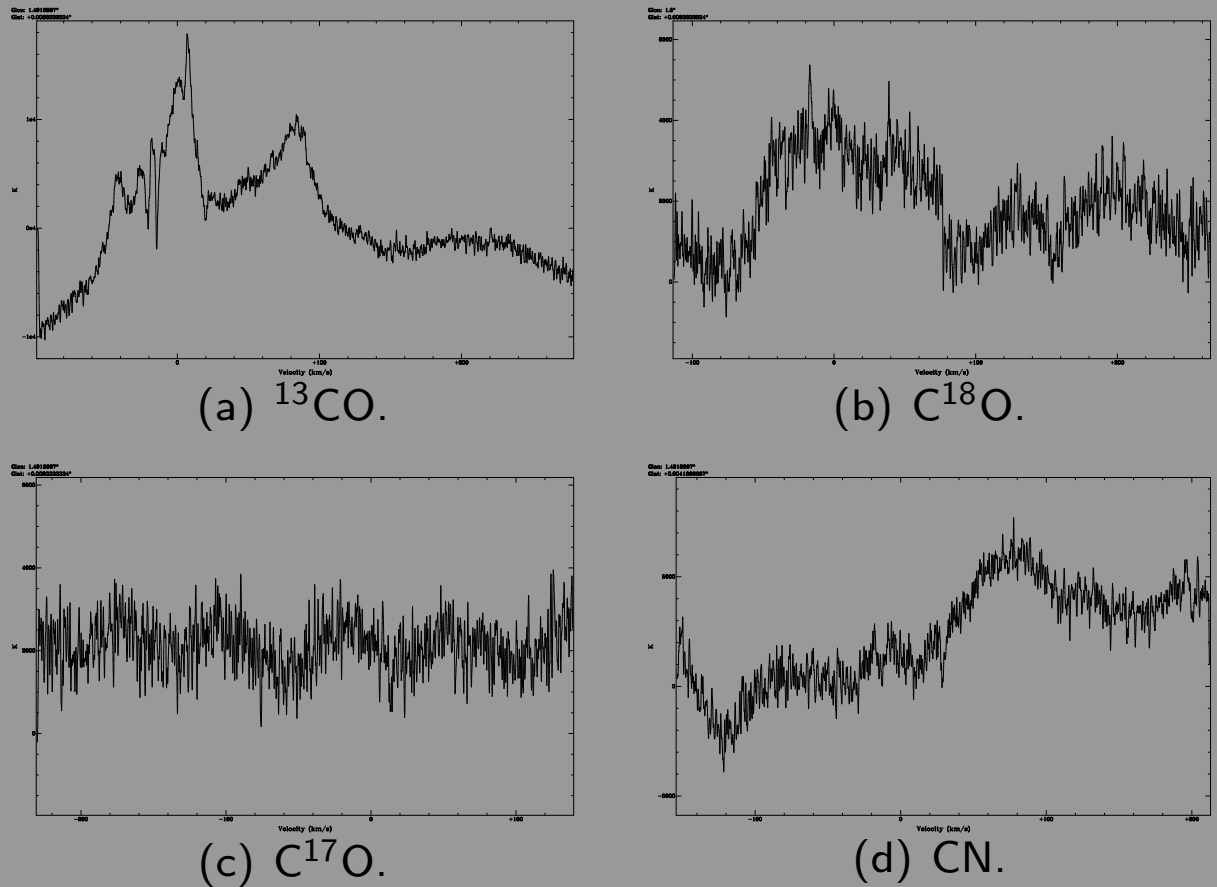


(a) ^{13}CO. (b) $C^{18}O$.

(c) $C^{17}O$. (d) CN.

Figure: Spectral lines for the G000 block, smoothed to Hanning-9.

Additional. IV

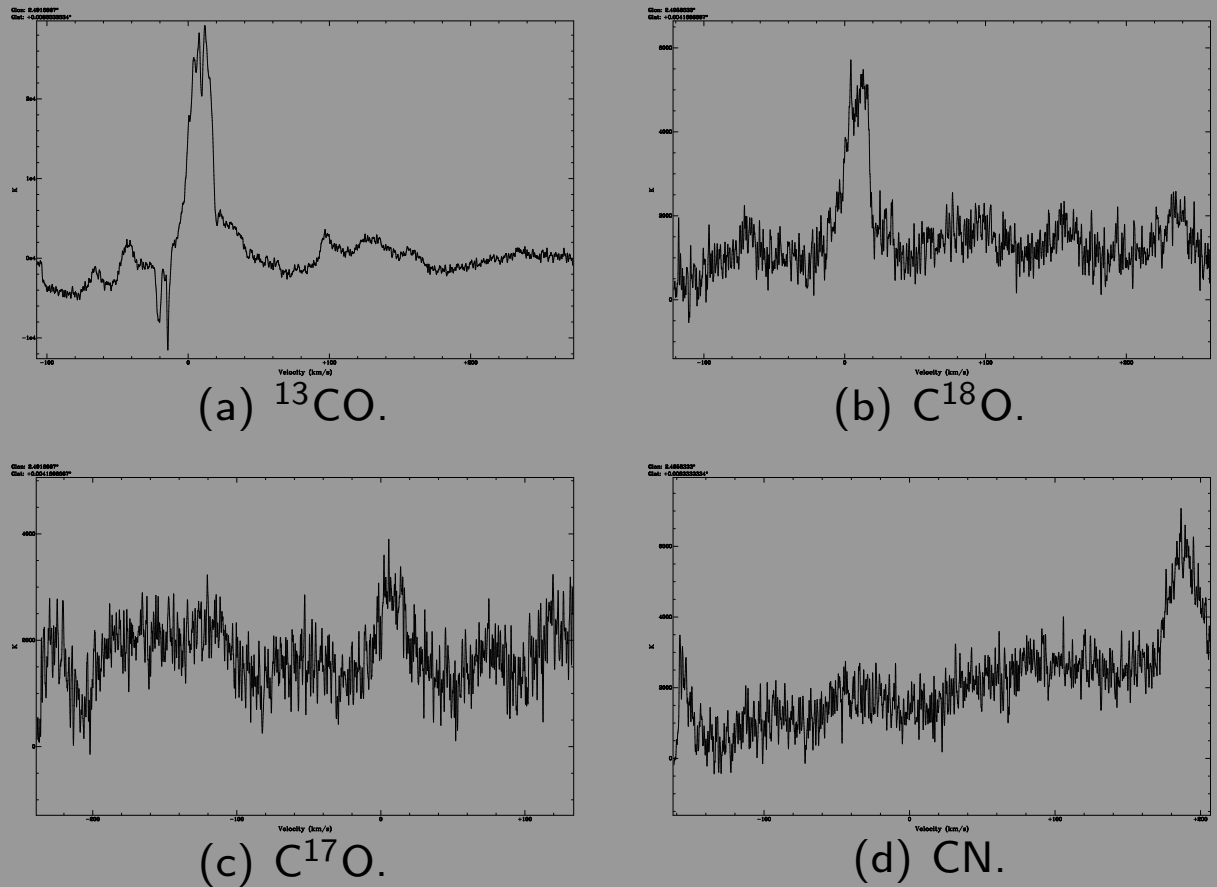


(a) ^{13}CO. (b) $C^{18}O$.

(c) $C^{17}O$. (d) CN.

Figure: Spectral lines for the G001 block, smoothed to Hanning-9.

Additional. V

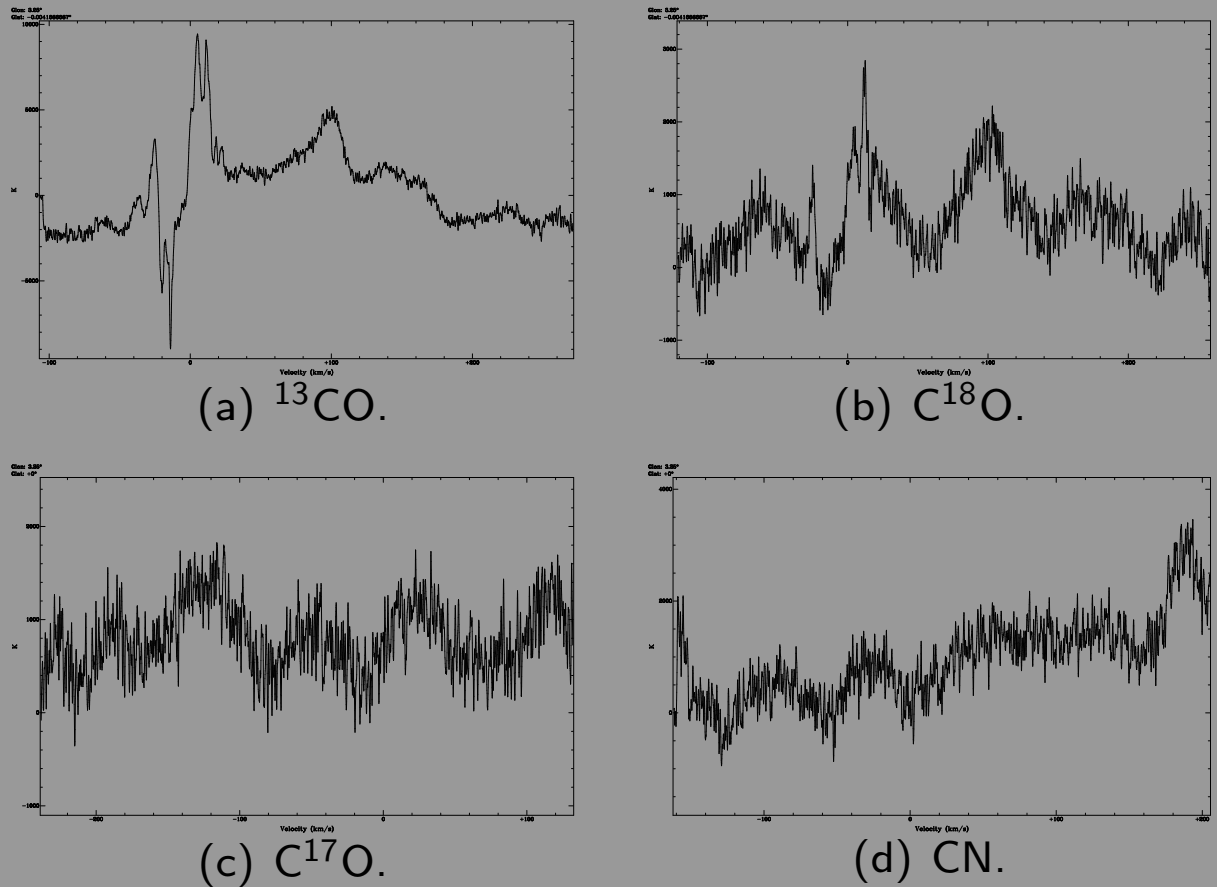


(a) ^{13}CO. (b) $C^{18}O$.

(c) $C^{17}O$. (d) CN.

Figure: Spectral lines for the G002 block, smoothed to Hanning-9.

Additional. VI



(a) ^{13}CO.

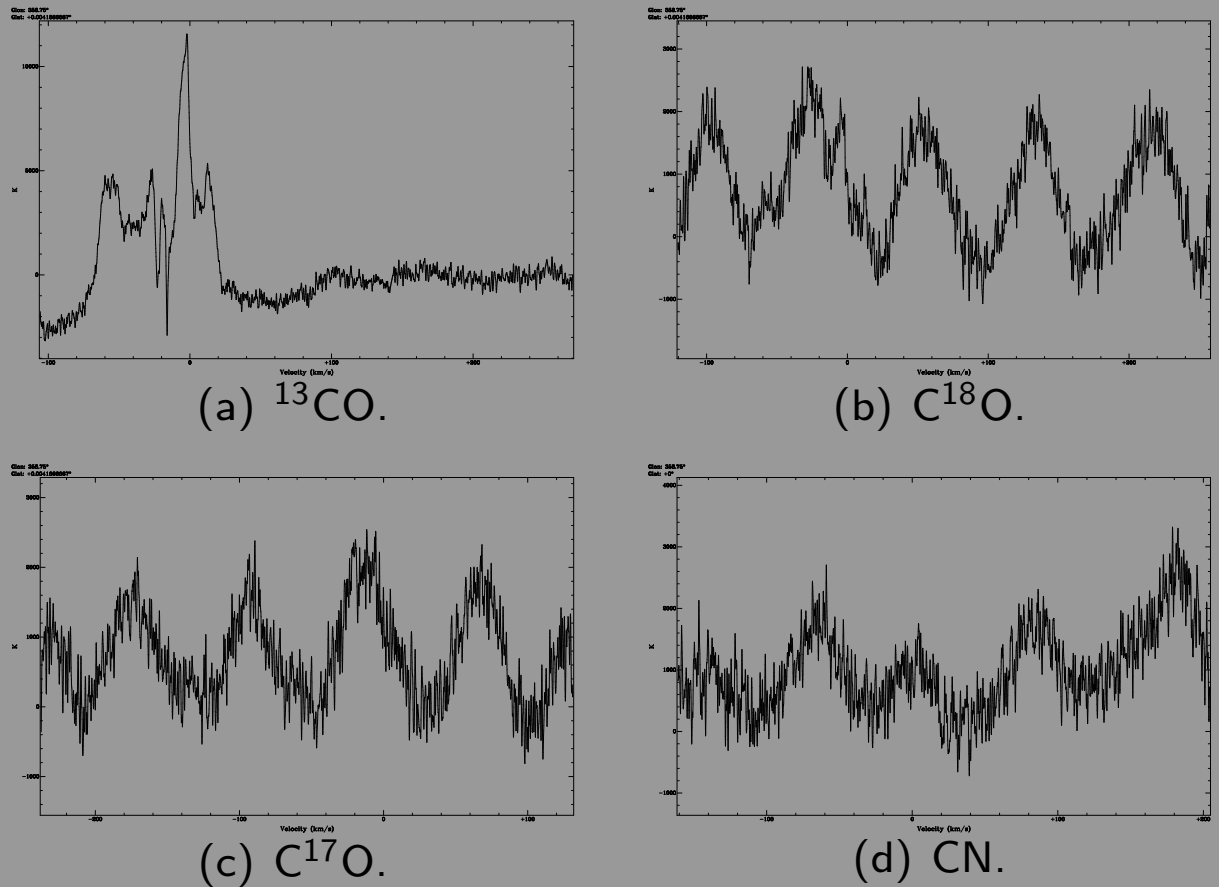
(b) $C^{18}O$.

(c) $C^{17}O$.

(d) CN.

Figure: Spectral lines for the G003V1 block, smoothed to Hanning-9.

Additional. VII

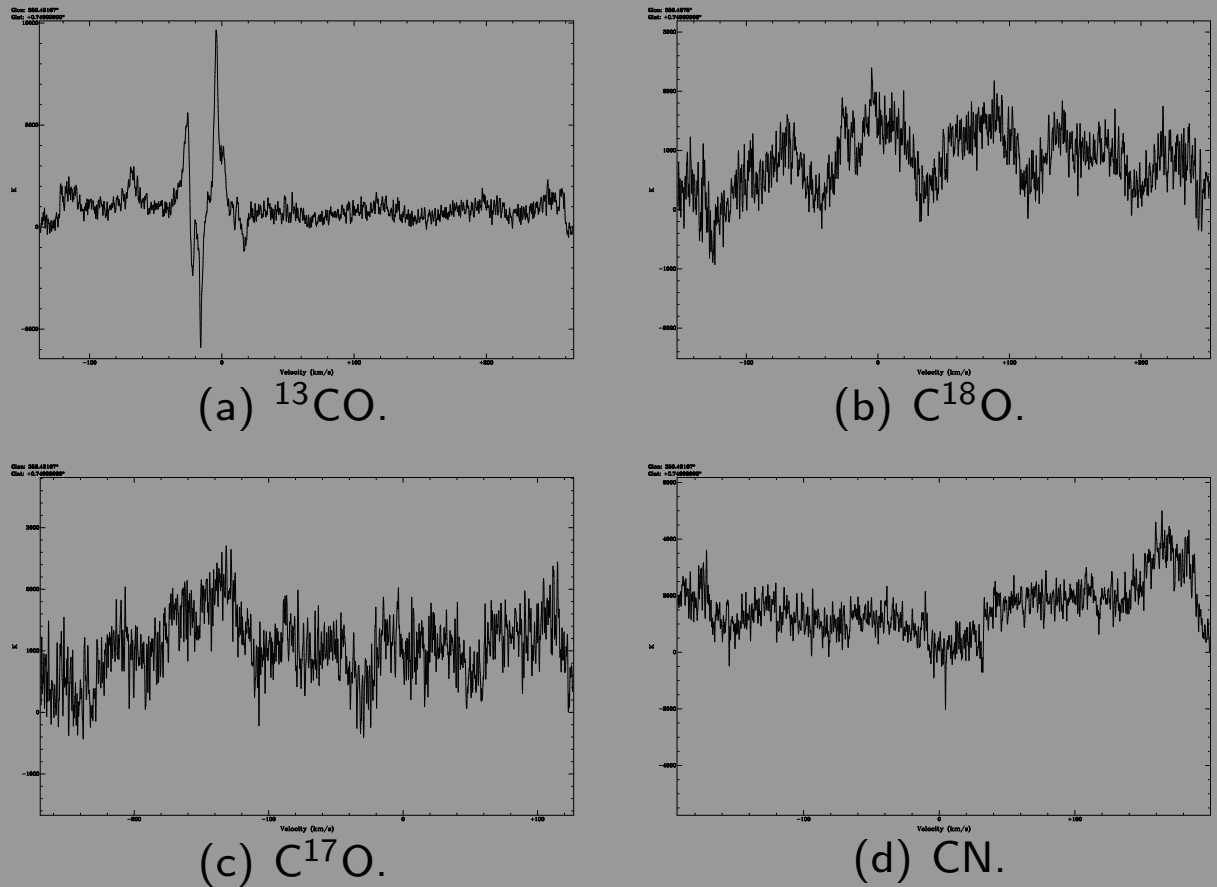


(a) ^{13}CO. (b) $C^{18}O$.

(c) $C^{17}O$. (d) CN.

Figure: Spectral lines for the G358V2 block, smoothed to Hanning-9.

Additional. VIII

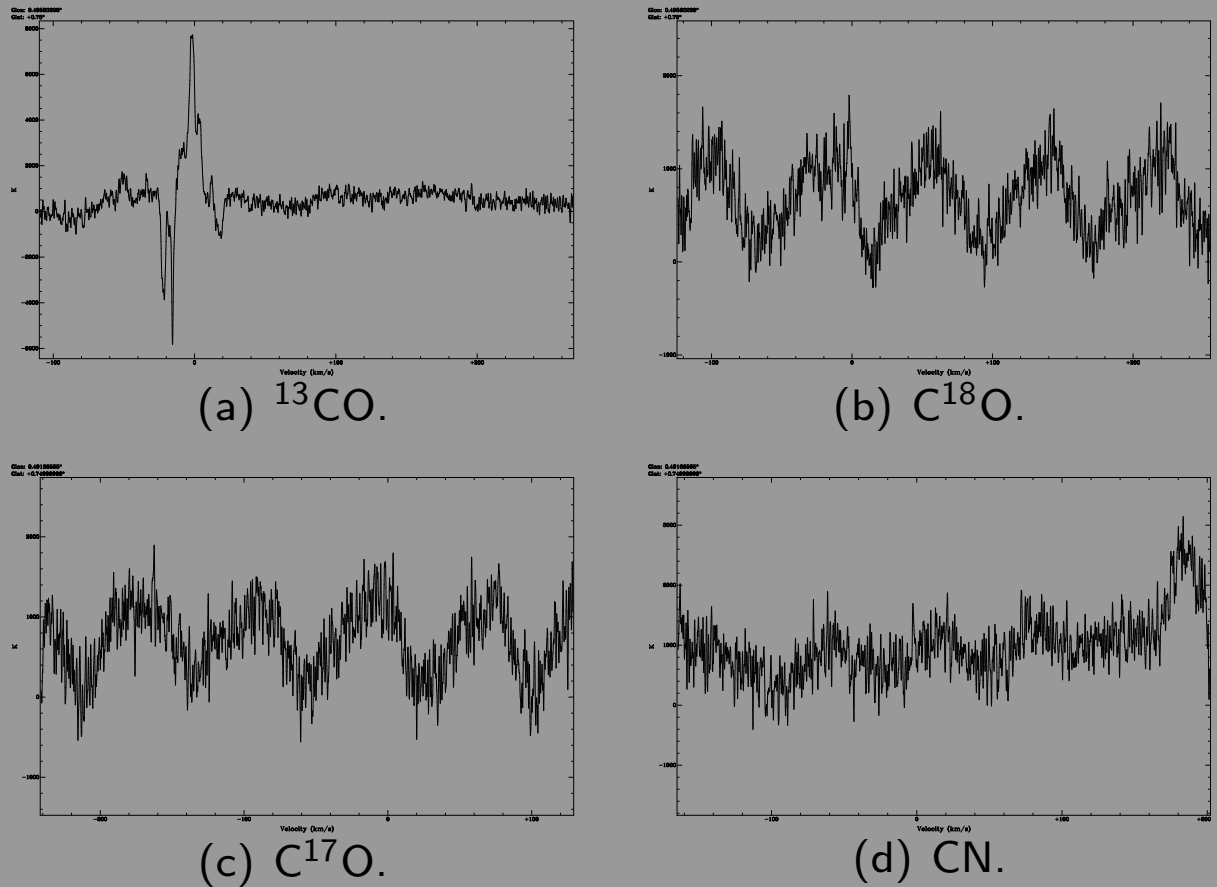


(a) ^{13}CO. (b) $C^{18}O$.

(c) $C^{17}O$. (d) CN.

Figure: Spectral lines for the G359H2 block, smoothed to Hanning-9.

Additional. IX



(a) ^{13}CO.

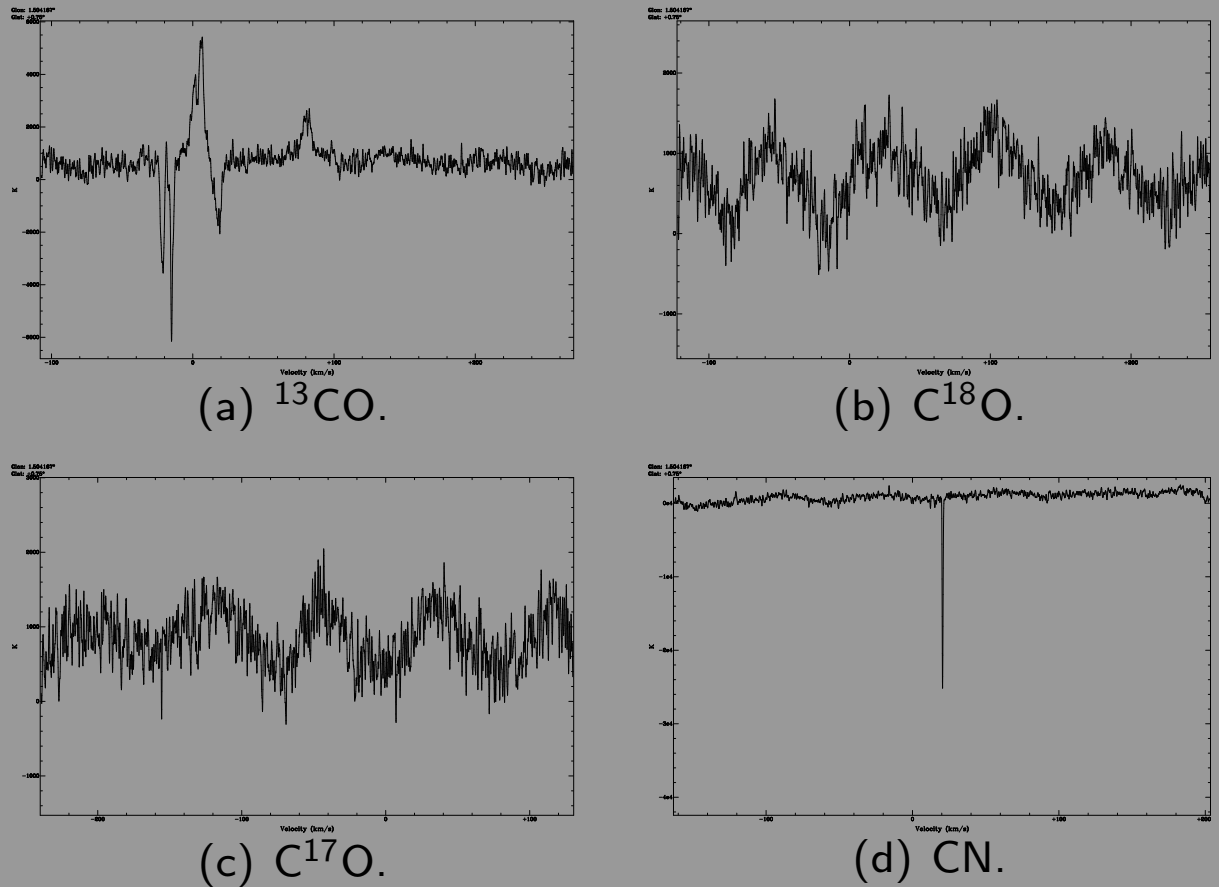
(b) $C^{18}O$.

(c) $C^{17}O$.

(d) CN.

Figure: Spectral lines for the G000H2 block, smoothed to Hanning-9.

Additional. X



(a) ^{13}CO.

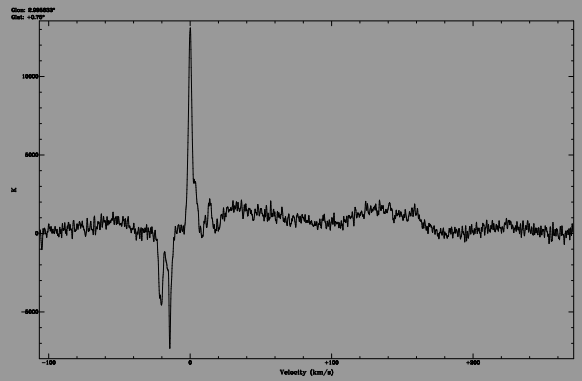
(b) $C^{18}O$.

(c) $C^{17}O$.

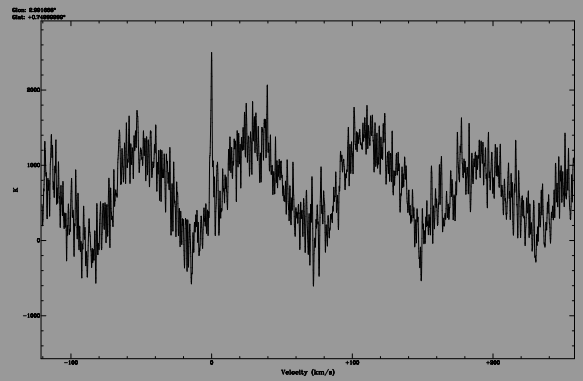
(d) CN.

Figure: Spectral lines for the G001H2 block, smoothed to Hanning-9.

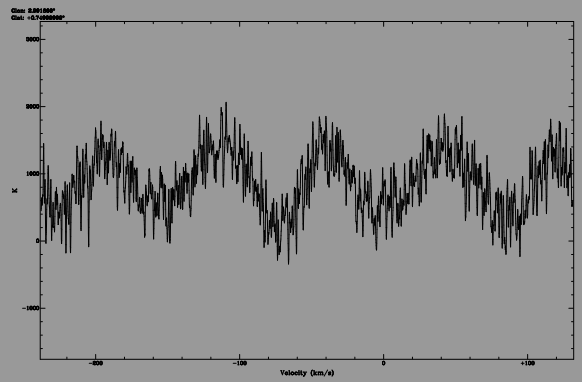
Additional. XI



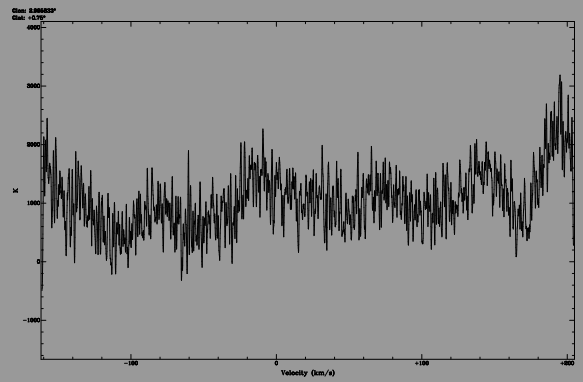
(a) ^{13}CO.



(b) $C^{18}O$.



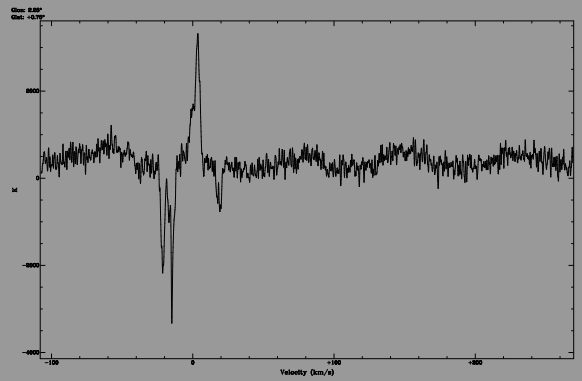
(c) $C^{17}O$.



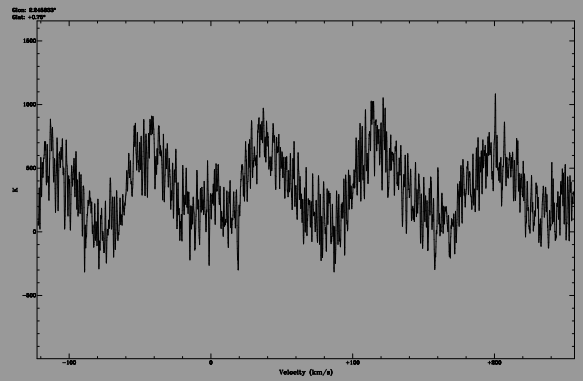
(d) CN.

Figure: Spectral lines for the G002HQ4 block, smoothed to Hanning-9.

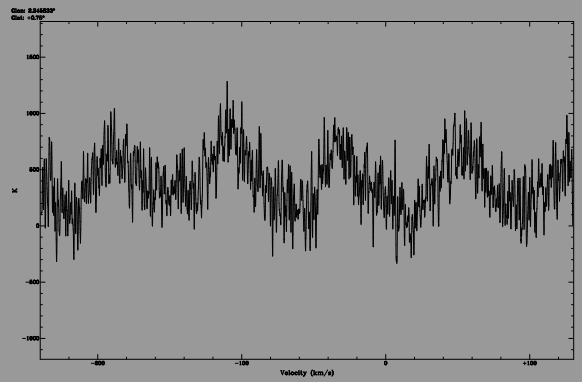
Additional. XII



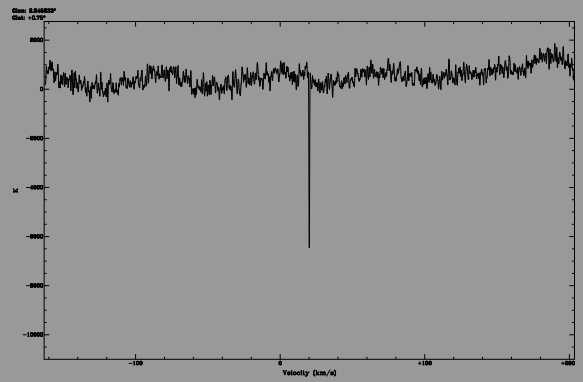
(a) ^{13}CO.



(b) $C^{18}O$.



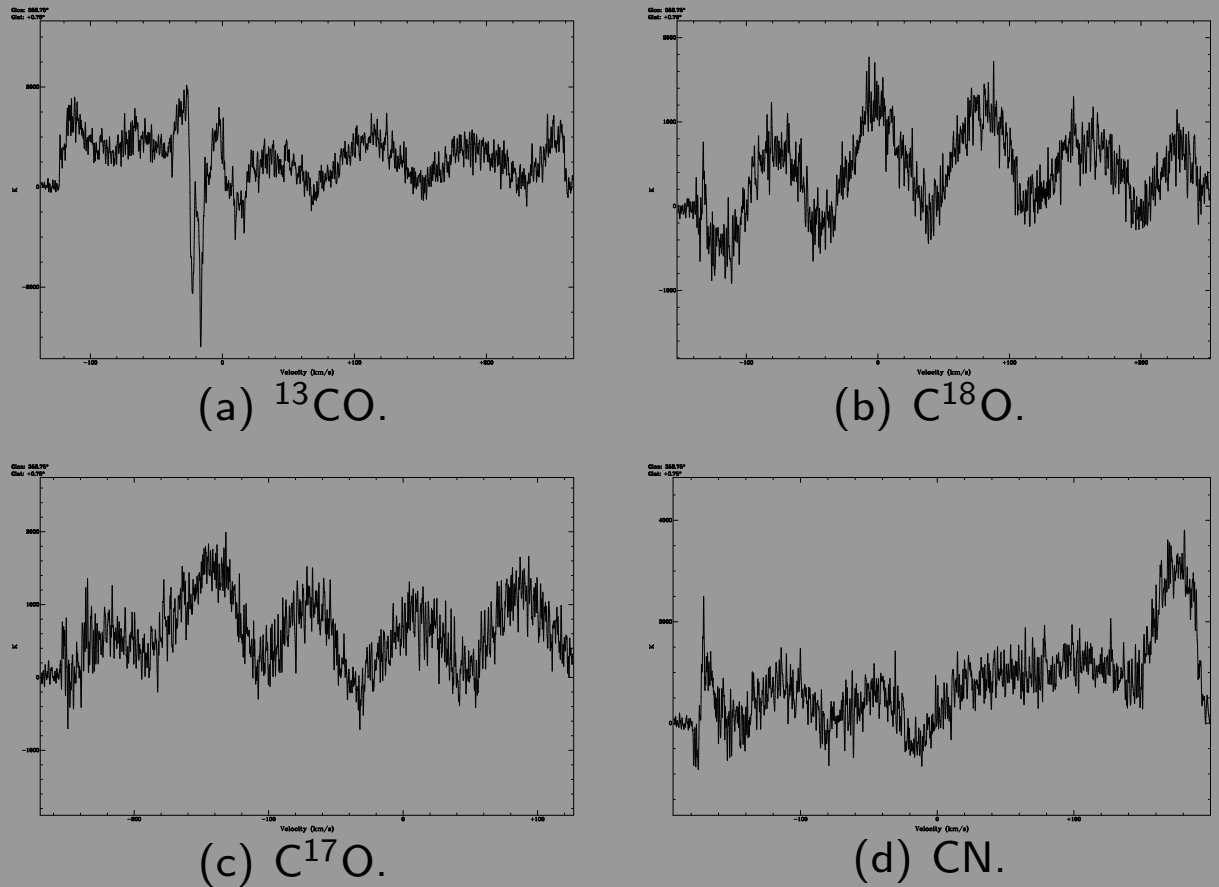
(c) $C^{17}O$.



(d) CN.

Figure: Spectral lines for the G002Q3 block, smoothed to Hanning-9.

Additional. XIII



(a) ^{13}CO.

(b) $C^{18}O$.

(c) $C^{17}O$.

(d) CN.

Figure: Spectral lines for the G358Q4 block, smoothed to Hanning-9.