Example of LMTSLR OTF processing

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There are four steps to processing an individual OTF map:

- process the OTF raw data and prepare a "SpecFile" with all reduced spectra
- view the "SpecFile" and identify good data for inclusion in the data cube.
- grid the spectra in the SpecFile into a data cube
- view and check the data cube

Processing programs are controlled with a set of command line arguments. This functionality is provided by `getopt` which is available in both python and c.

There is also a provision to prepare a text file ('configuration file') with the keyword/value pairs. It should be noted that keywords and values can have no white space. There are several kinds of possible values:

- strings
- boolean (entered as True or False)
- int
- float
- python lists (e.g. [0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15] to list all pixels for SEQUOIA
- lists of lists (e.g. [[-620,-320],[-220,80]] to provide a list of regions for baseline fits

The long form of the keywords are preceeded with a `--` , as in `--config` . For some common keywords, there is a single letter shortcut provided. Shortcuts only have a single `-` . The `config` keyword shortcut is `-c` .

Process the OTF Data --- process_oft_map

The first step in the reduction procedure is to process the OTF raw data from a single observation at the telescope. All observations are written with a unique `ObsNum` and so this is used as the index to find the relevant data.

OTF maps produce a dump of raw spectra tagged with information about the position of the telescope and whether the particular spectral dump is to be used to create a reference spectrum. The processing program opens netCDF files to read all data. Reference spectra are formed and subtracted from the spectra that will be used to make the map. Users can specify whether to remove baselines from the spectra and whether to limit the number of spectral channels by taking a "slice" from the full spectrum. This step is useful as a way to limit the size of the output file and improve the speed of this and future processing steps.

The final result of this step is a netCDF file with all the reduced spectra. We call this a "SpecFile" and it is used as input to the next processing step involving gridding the data into a final data cube.

Command Line Arguments

```
--config [-c]    : name of configuration file to set param
eters
--output [-o]    : name of output SpecFile

DATA SPECIFICATION

--path [-p]      : set data path
--obsnum [-O]    : set obsnum
--obs_list       : enter list of obsnums
--bank           : spectral bank for processing
--pix_list       : enter list of pixels for processing

CALIBRATION

--use_cal        : use calibration scan for cal
--tsys           : value for tsys if use_cal==False

SPECTRAL LINE REDUCTION

--x_axis         : select spectral x axis [VLSR,VSKY,VBARY
,VSRC,FLSR,FSKY,FBARY,FSRC]
--b_order        : set polynomial baseline order
--b_regions      : enter list of lists for baseline region
s
--l_regions      : enter list of lists for line fit region
s
--slice          : enter list to specify slice from spectr
um for processing
```

Example

This is the reduction of a single OTF map on a region in M31. Observation number is 85778 and the path to the raw data is `/Volumes/FPS/data_lmt/` .

Here is the configuration file `M31_J-K_config.txt` :

```
path              /Volumes/FPS/data_lmt/
output            ./M31_Region_J-K_CO_1.nc
obsnum            85778                  # test
obs_list          [85778]                # test
bank              0
pix_list          [0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15]
use_cal           False
tsys              220.0
x_axis            VLSR
b_order           0
b_regions         [[-620,-320],[-220,80]]
l_regions         [[-320,-220]]
slice             [-620,80]
```

I note that this step takes several minutes to run.

In [3]:

```
run process_otf_map -c M31_J-K_config.txt
```

```
program process_otf_map options
data path        =  /Volumes/FPS/data_lmt/
obsnum           =  85778
obsnum list      =  [85778]
bank             =  0
pixel list       =  [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 1
0, 11, 12, 13, 14, 15]
use cal          =  False
tsys             =  220.0
baseline order   =  0
baseline regions =  [[-620, -320], [-220, 80]]
line regions     =  [[-320, -220]]
slice            =  [-620, 80]
output file      =  ./M31_Region_J-K_CO_1.nc

found roach0_85778_0_1_Region_J-K_2019-10-31_073122.
nc
append roach0_85778_0_1_Region_J-K_2019-10-31_073122
.nc
found roach1_85778_0_1_Region_J-K_2019-10-31_073122.
nc
append roach1_85778_0_1_Region_J-K_2019-10-31_073122
```

```
.nc
found roach2_85778_0_1_Region_J-K_2019-10-31_073122.
nc
append roach2_85778_0_1_Region_J-K_2019-10-31_073122
.nc
found roach3_85778_0_1_Region_J-K_2019-10-31_073122.
nc
append roach3_85778_0_1_Region_J-K_2019-10-31_073122
.nc
found ifproc_2019-10-31_085778_00_0001.nc
before read npix
from pixels npix = 16
from xlen npix = 16
TRACKING Sequoia PIXEL  10
Map Parameters: Ra Continuous
HPBW= 12.0 XLength=   300.0 YLength=   300.0 XStep=
1.25 YStep=  0.40
/Volumes/FPS/data_lmt/ifproc/ifproc_2019-10-31_08577
8_00_0001.nc does not have bs parameters
85778 is a Map observation
read_roach /Volumes/FPS/data_lmt/spectrometer/roach0
/roach0_85778_0_1_Region_J-K_2019-10-31_073122.nc
r:0 inp:0 pix:0 to:-0.030000
r:0 inp:1 pix:1 to:-0.030000
r:0 inp:2 pix:2 to:-0.030000
r:0 inp:3 pix:3 to:-0.030000
read_roach /Volumes/FPS/data_lmt/spectrometer/roach1
/roach1_85778_0_1_Region_J-K_2019-10-31_073122.nc
r:1 inp:0 pix:4 to:-0.030000
r:1 inp:1 pix:5 to:-0.030000
r:1 inp:2 pix:6 to:-0.030000
r:1 inp:3 pix:7 to:-0.030000
read_roach /Volumes/FPS/data_lmt/spectrometer/roach2
/roach2_85778_0_1_Region_J-K_2019-10-31_073122.nc
r:2 inp:0 pix:8 to:-0.030000
r:2 inp:1 pix:9 to:-0.030000
r:2 inp:2 pix:10 to:-0.030000
r:2 inp:3 pix:11 to:-0.030000
read_roach /Volumes/FPS/data_lmt/spectrometer/roach3
/roach3_85778_0_1_Region_J-K_2019-10-31_073122.nc
r:3 inp:0 pix:12 to:-0.030000
r:3 inp:1 pix:13 to:-0.030000
r:3 inp:2 pix:14 to:-0.030000
r:3 inp:3 pix:15 to:-0.030000
0 14334 14334
```

```
1 14334 28668
2 14334 43002
3 14334 57336
4 14332 71668
5 14332 86000
6 14332 100332
7 14332 114664
8 14334 128998
9 14334 143332
10 14334 157666
11 14334 172000
12 14333 186333
13 14333 200666
14 14333 214999
15 14333 229332
Total Number of Spectra = 229332
netCDF ./M31_Region_J-K_CO_1.nc Done
```

Review the SpecFile --- view_spec_file

Command Line Arguments

```
--config [-c]    : name of configuration file to set param
eters
--input [-i]     : set input file name
--pix_list       : enter list of pixels to be displayed
--show_pixel [-p]: select specific pixel for display
--rms_cut        : set rms threshold for data
--plot_range     : list to set limits for data axis in plo
t
```

Example

This example views the SpecFile we just created `/M31_Region_J-K_CO_1.nc` . We will run first without specifying an rms cutoff to look at the data as is.

By default the viewer will present plots of results for all 16 pixels in the array. They are ordered: column 1: 0-3; column 2: 4-7; column 3: 8-11; column 4: 12-15.

5 plots are presented:

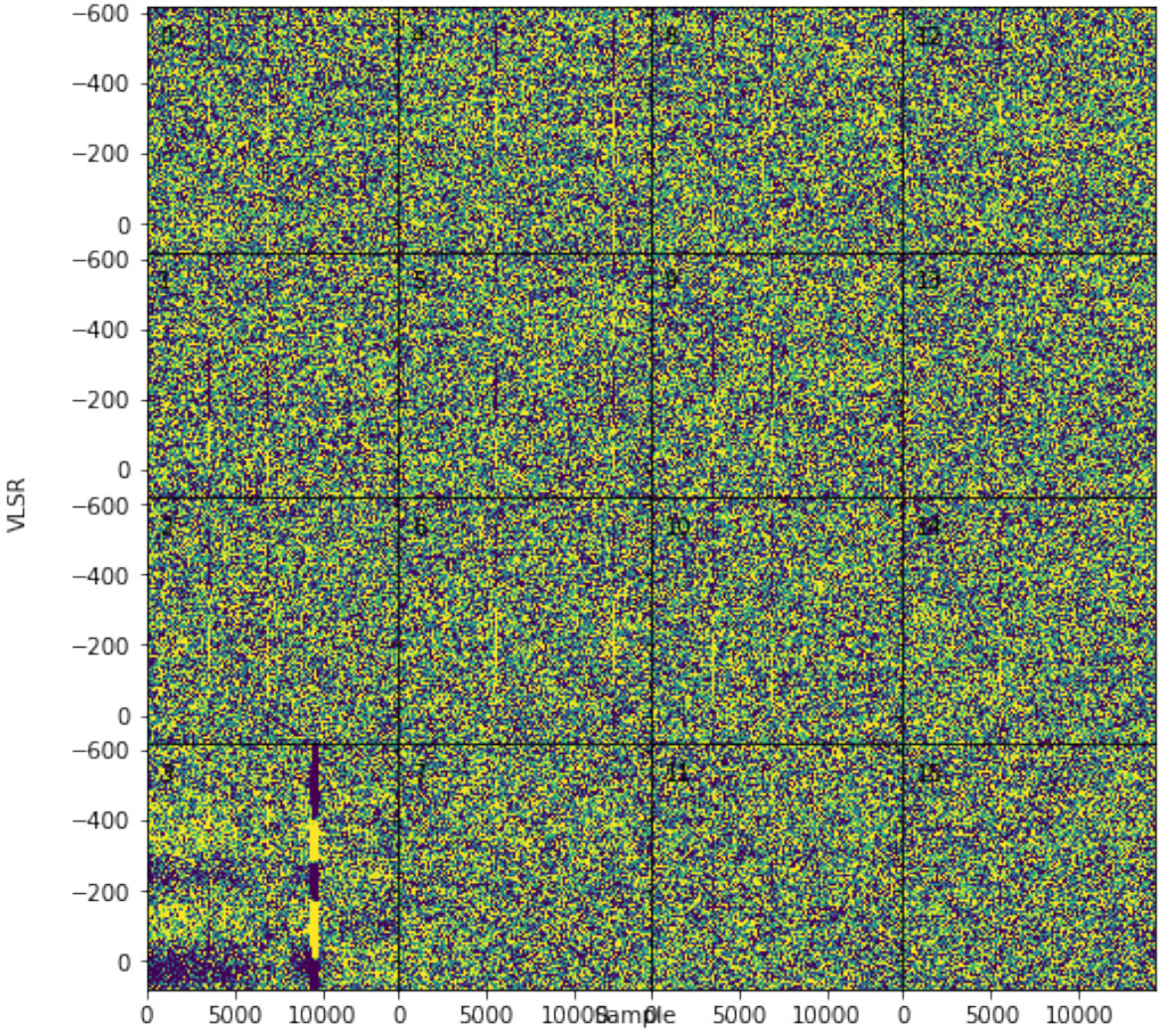
- waterfall plot of all spectra for each pixel
- plot of rms for each spectrum for each pixel
- histogram of rms values for each pixel
- mean of ALL spectra for each pixel
- x-y scatter plot to show region sampled

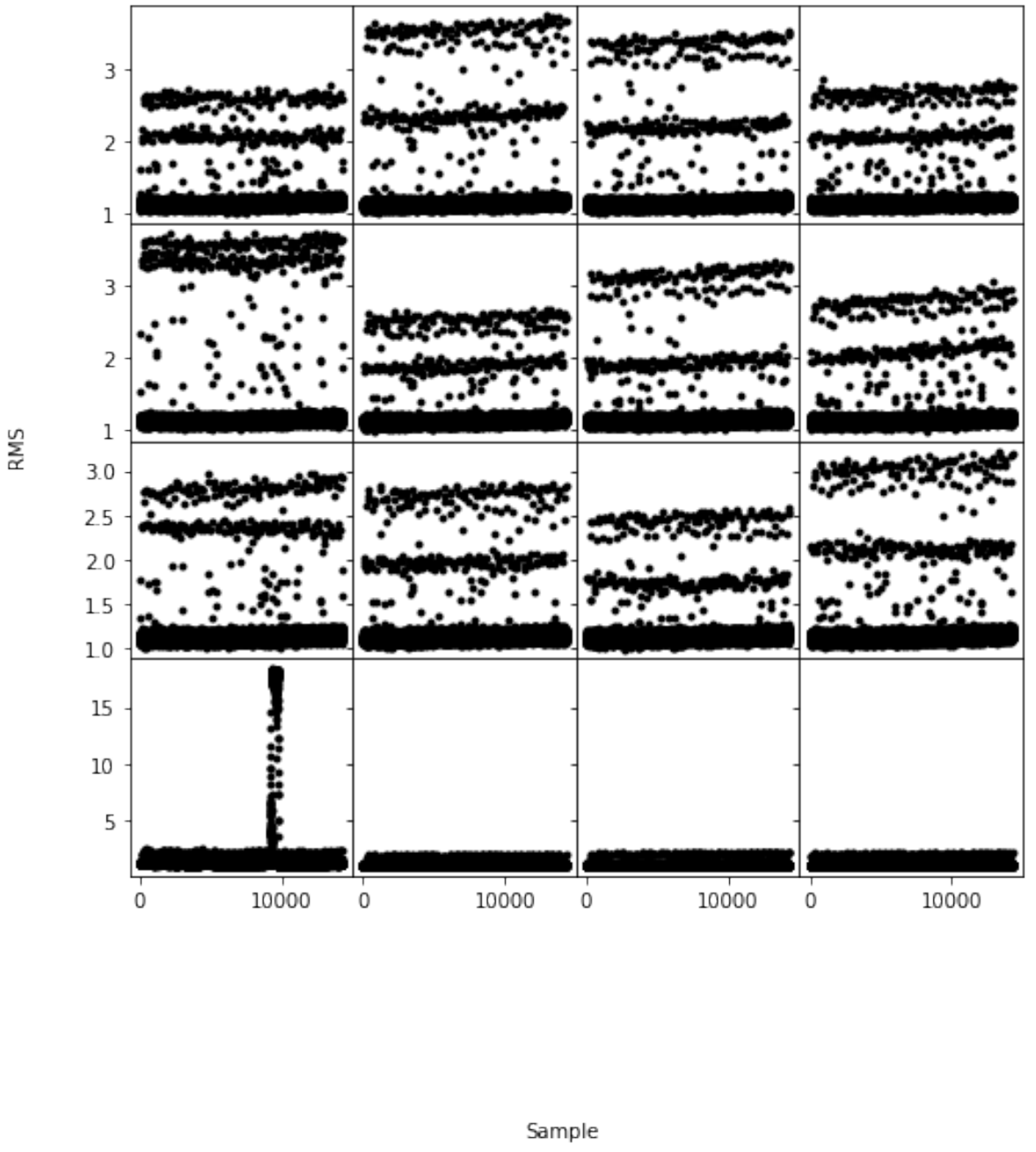
It is worth noting that there is some work to be done on the basic plots, particularly within the jupyter notebook. However, the basic features are clear. The waterfall plots and the plots of rms's of individual spectra show some bad spectra. Pixel 3 has a lot of bad spectra.

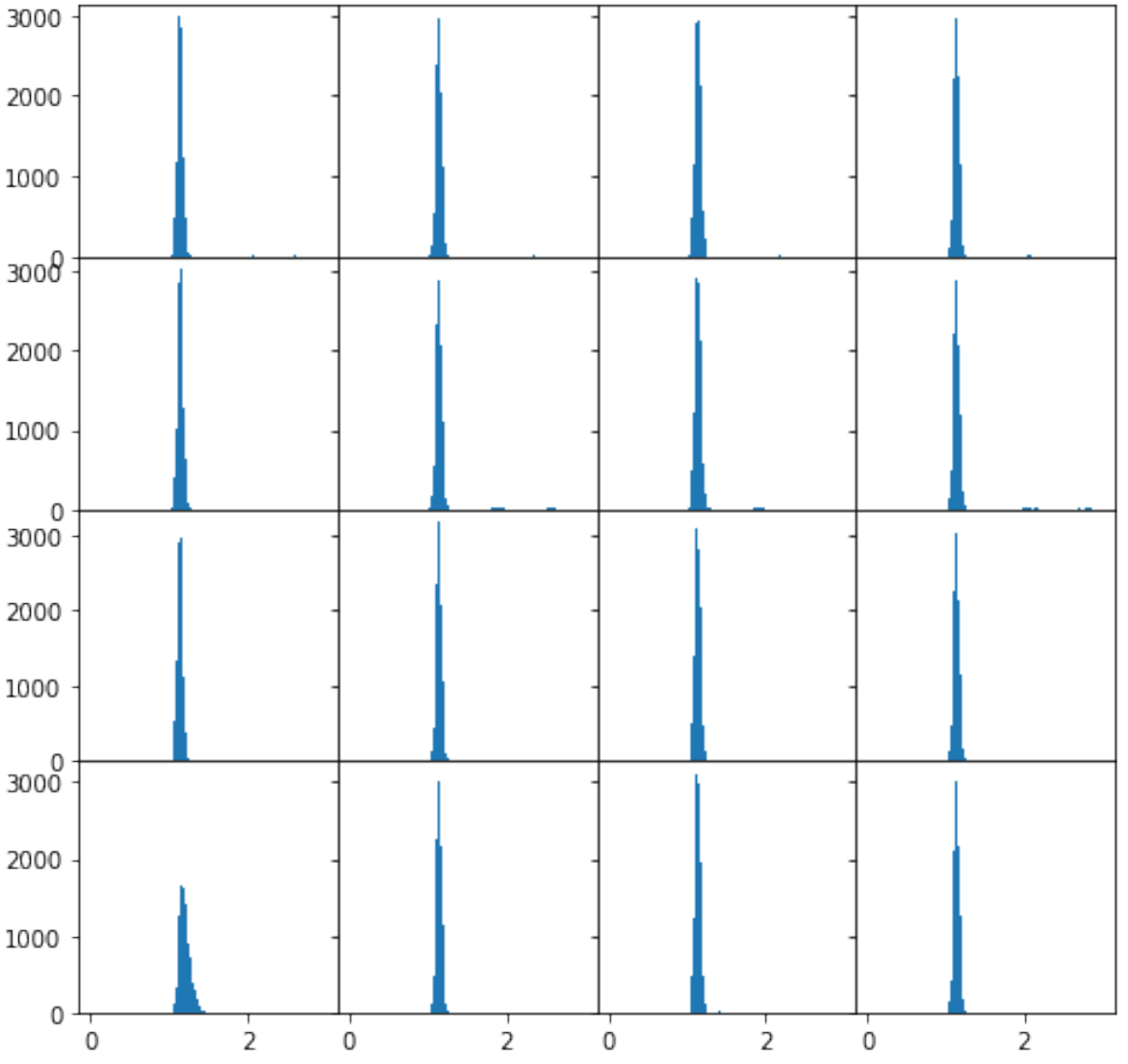
In [4]:

```
run view_spec_file -i M31_Region_J-K_CO_1.nc --plot_range [-1.,1
.]
```

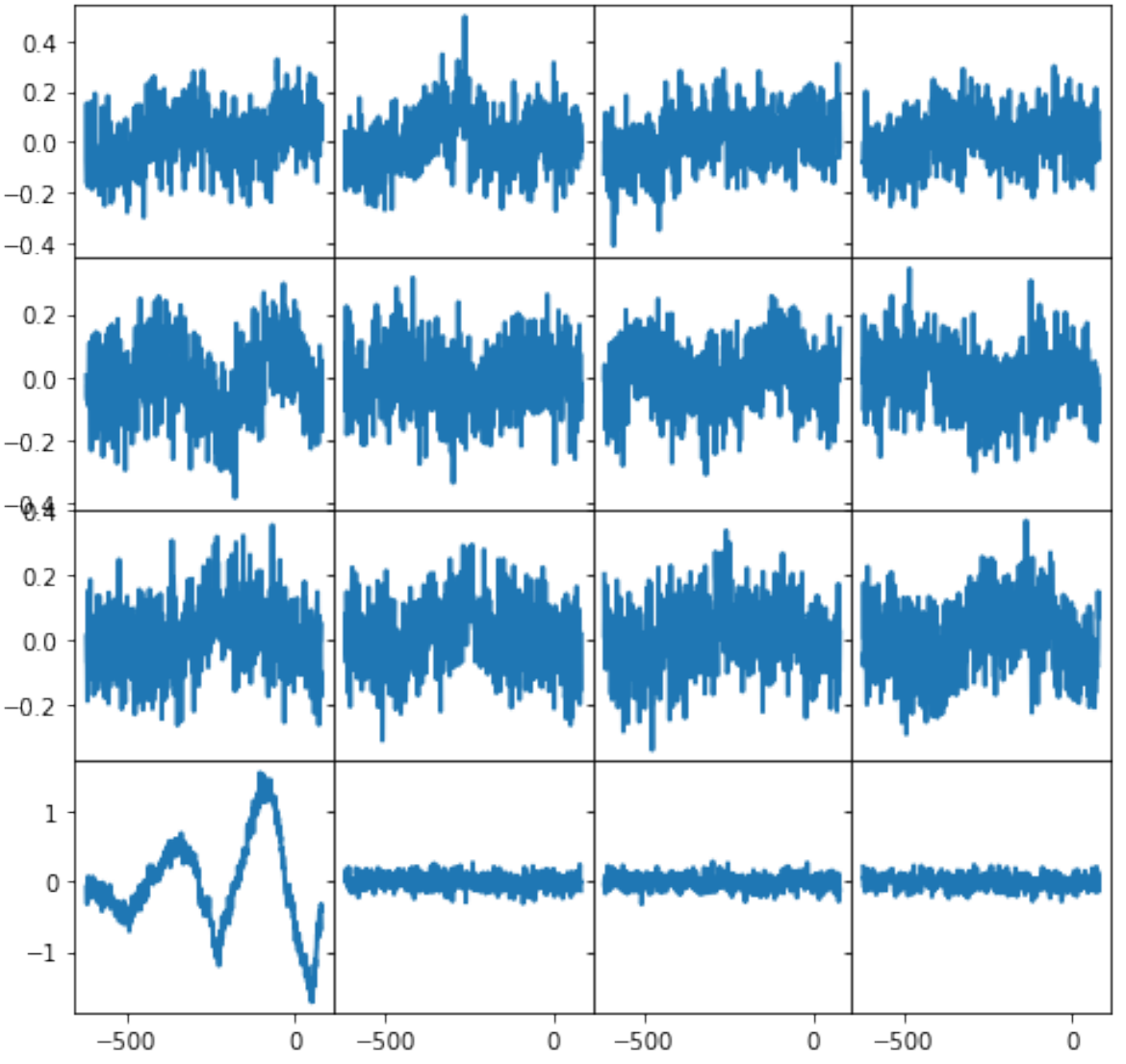
```
program view_spec_file options
input file        =  M31_Region_J-K_CO_1.nc
show all pixels   =  True
pixel list        =  [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 1
0, 11, 12, 13, 14, 15]
rms cutoff        =  10000.0
plot range        =  [-1.0, 1.0]
```



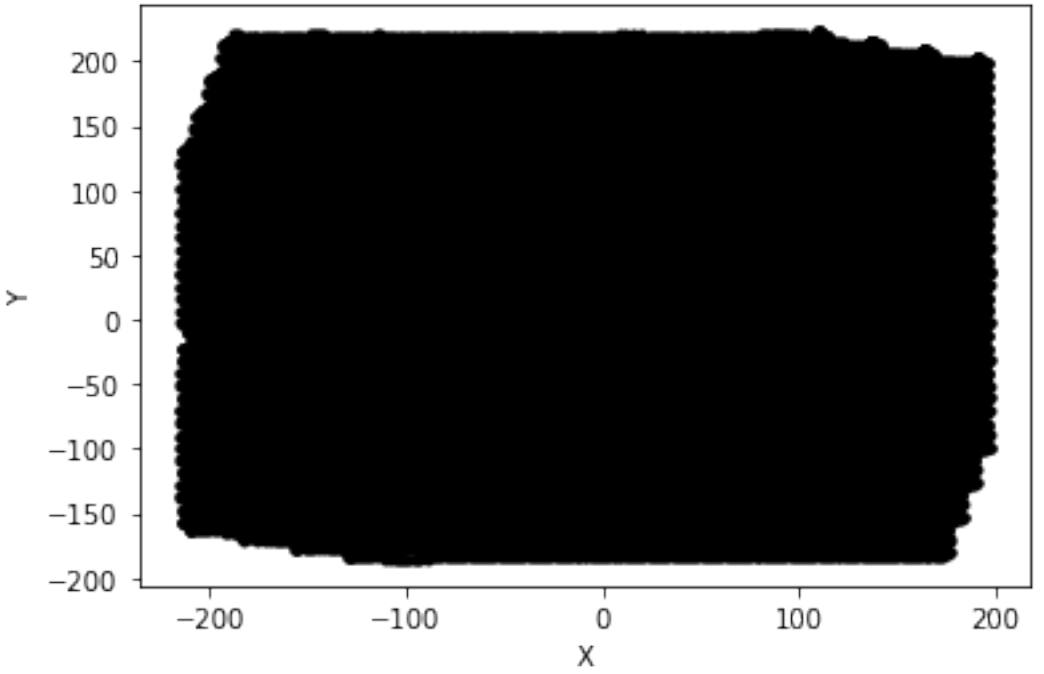

RMS
Sample
3
2
1
3
2
1
3.0
2.5
2.0
1.5
1.0
15
10
5
0
10000
0
10000
0
10000
0
10000



RMS



VLSR



Grid the Spectra in the SpecFile into a Data Cube --- grid_data

This step calls a "c" program to do the actual gridding step. The command line arguments are mostly command line arguments used by the "c" program.

Command Line Arguments

```
--config [-c]      : configuration file
--program_path [-p]: full path name to grid program
--input [-i]       : input SpecFile name
--output [-o]      : output file name
--resolution       : resolution (arcsec)
--cell             : cell size (arcsec)
--pix_list         : list of pixels to process
--rms_cut          : rms threshold (K)
--x_extent         : x extent of cube (arcsec) note: cube
will go to +/- x_extent
--y_extent         : y extent of cube (arcsec) note: cube
will go to +/- y_extent
--otf_select       : filter code (0=box,1=jinc,2=gaussian)
--rmax             : maximum radius of convolution (units
lambda/D)
--n_samples        : number of samples in convolution filt
er
--otf_a            : otf a parameter
--otf_b            : otf b parameter
--otf_c            : otf_c parameter
```

Example

The SpecFile `M31_Region_J-K_CO_1.nc` is read and individual spectra are gridded into a data cube using the executable `spec_driver_fits` . We adopt a resolution ($\frac{\lambda}{D}$) of 14 arcsec and create the grid on 7 arcsec bins which correspond to the Nyquist cell size (half the resolution). Spectra with an rms greater than 1.3K are removed, based on the views seen in the previous result.

The feature to select pixels for processing has not been implemented in `spec_driver_fits` . At the moment the program is hard coded to reject pixel 3.

The final cube is written as a FITS file: `M31_Region_J-K_CO_1.fits`

Here is the configuration file used: `M31_J-K_grid_config.txt`

```
program_path          ./spec_driver_fits
input                 M31_Region_J-K_CO_1.nc
output                M31_Region_J-K_CO_1.fits
resolution            14
cell                  7
pix_list              [0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,1
5]
rms_cut               1.3
x_extent              250
y_extent              250
otf_select            1
rmax                  3.0
n_samples             256
otf_a                 1.1
otf_b                 4.75
otf_c                 2.0
```

In [6]:

```
run grid_data -c M31_J-K_grid_config.txt
```

```
program grid_data options
program path      =  ./spec_driver_fits
input file name   =  M31_Region_J-K_CO_1.nc
output file name  =  M31_Region_J-K_CO_1.fits
resolution        =  14
cell size         =  7
pix list          =  [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 1
0, 11, 12, 13, 14, 15]
rms cutoff        =  1.3
x extent          =  250
y extent          =  250
otf filter select=  jinc
r max             =  3.0
n conv samples    =  256
otf a             =  1.1
otf b             =  4.75
otf c             =  2.0

STDOUT ****************************
about to open file M31_Region_J-K_CO_1.nc
```

```
file M31_Region_J-K_CO_1.nc opened
Dimensions complete 229332 689
Header.Obs complete
Header.SpectrumAxis.CRVAL
Header.SpectrumAxis.CRPIX
Header.SpectrumAxis.CDELT
Header.SpectrumAxis.CTYPE
Header.SpectrumAxis.XAxis
Data.Spectra
Data.Spectra completed
Data.XPos
Data.YPos
Data.Pixel
Data.Sequence
Data.RMS
file: M31_Region_J-K_CO_1.nc nspec= 229332 nchan= 68
9
allocated theData
n_cell= 7
r (as)   c
 0.00   1.0000
 0.16   0.9994
 0.33   0.9975
 0.49   0.9945
 0.66   0.9902
 0.82   0.9847
 0.99   0.9780
 1.15   0.9701
 1.32   0.9611
 1.48   0.9509
 1.65   0.9396
 1.81   0.9273
 1.98   0.9139
 2.14   0.8995
 2.31   0.8842
 2.47   0.8679
 2.64   0.8507
 2.80   0.8327
 2.96   0.8139
 3.13   0.7943
 3.29   0.7741
 3.46   0.7531
 3.62   0.7316
 3.79   0.7096
 3.95   0.6870
```

4.12	0.6640
4.28	0.6407
4.45	0.6170
4.61	0.5930
4.78	0.5689
4.94	0.5445
5.11	0.5201
5.27	0.4956
5.44	0.4712
5.60	0.4467
5.76	0.4224
5.93	0.3983
6.09	0.3744
6.26	0.3507
6.42	0.3274
6.59	0.3044
6.75	0.2818
6.92	0.2596
7.08	0.2379
7.25	0.2167
7.41	0.1961
7.58	0.1760
7.74	0.1565
7.91	0.1377
8.07	0.1196
8.24	0.1021
8.40	0.0853
8.56	0.0693
8.73	0.0540
8.89	0.0394
9.06	0.0256
9.22	0.0125
9.39	0.0002
9.55	-0.0113
9.72	-0.0220
9.88	-0.0320
10.05	-0.0412
10.21	-0.0497
10.38	-0.0574
10.54	-0.0643
10.71	-0.0706
10.87	-0.0761
11.04	-0.0810
11.20	-0.0852

11.36	-0.0887
11.53	-0.0916
11.69	-0.0939
11.86	-0.0956
12.02	-0.0967
12.19	-0.0973
12.35	-0.0974
12.52	-0.0970
12.68	-0.0962
12.85	-0.0949
13.01	-0.0933
13.18	-0.0912
13.34	-0.0889
13.51	-0.0862
13.67	-0.0833
13.84	-0.0800
14.00	-0.0766
14.16	-0.0730
14.33	-0.0692
14.49	-0.0652
14.66	-0.0612
14.82	-0.0570
14.99	-0.0528
15.15	-0.0486
15.32	-0.0443
15.48	-0.0400
15.65	-0.0358
15.81	-0.0316
15.98	-0.0274
16.14	-0.0233
16.31	-0.0193
16.47	-0.0155
16.64	-0.0117
16.80	-0.0081
16.96	-0.0046
17.13	-0.0013
17.29	0.0019
17.46	0.0049
17.62	0.0077
17.79	0.0103
17.95	0.0128
18.12	0.0150
18.28	0.0171
18.45	0.0190

18.61	0.0207
18.78	0.0222
18.94	0.0235
19.11	0.0246
19.27	0.0255
19.44	0.0263
19.60	0.0269
19.76	0.0273
19.93	0.0276
20.09	0.0277
20.26	0.0277
20.42	0.0275
20.59	0.0272
20.75	0.0268
20.92	0.0262
21.08	0.0256
21.25	0.0249
21.41	0.0240
21.58	0.0231
21.74	0.0221
21.91	0.0211
22.07	0.0200
22.24	0.0189
22.40	0.0177
22.56	0.0165
22.73	0.0153
22.89	0.0140
23.06	0.0128
23.22	0.0115
23.39	0.0103
23.55	0.0091
23.72	0.0079
23.88	0.0067
24.05	0.0055
24.21	0.0044
24.38	0.0033
24.54	0.0023
24.71	0.0013
24.87	0.0004
25.04	-0.0005
25.20	-0.0014
25.36	-0.0022
25.53	-0.0029
25.69	-0.0036

25.86	-0.0042
26.02	-0.0047
26.19	-0.0053
26.35	-0.0057
26.52	-0.0061
26.68	-0.0064
26.85	-0.0067
27.01	-0.0069
27.18	-0.0071
27.34	-0.0072
27.51	-0.0073
27.67	-0.0074
27.84	-0.0073
28.00	-0.0073
28.16	-0.0072
28.33	-0.0071
28.49	-0.0070
28.66	-0.0068
28.82	-0.0066
28.99	-0.0063
29.15	-0.0061
29.32	-0.0058
29.48	-0.0055
29.65	-0.0053
29.81	-0.0049
29.98	-0.0046
30.14	-0.0043
30.31	-0.0040
30.47	-0.0037
30.64	-0.0033
30.80	-0.0030
30.96	-0.0027
31.13	-0.0024
31.29	-0.0021
31.46	-0.0018
31.62	-0.0015
31.79	-0.0012
31.95	-0.0010
32.12	-0.0007
32.28	-0.0005
32.45	-0.0003
32.61	-0.0001
32.78	0.0001
32.94	0.0003

33.11	0.0005
33.27	0.0006
33.44	0.0008
33.60	0.0009
33.76	0.0010
33.93	0.0011
34.09	0.0011
34.26	0.0012
34.42	0.0012
34.59	0.0013
34.75	0.0013
34.92	0.0013
35.08	0.0013
35.25	0.0013
35.41	0.0013
35.58	0.0013
35.74	0.0012
35.91	0.0012
36.07	0.0012
36.24	0.0011
36.40	0.0011
36.56	0.0010
36.73	0.0010
36.89	0.0009
37.06	0.0008
37.22	0.0008
37.39	0.0007
37.55	0.0007
37.72	0.0006
37.88	0.0005
38.05	0.0005
38.21	0.0004
38.38	0.0004
38.54	0.0003
38.71	0.0003
38.87	0.0002
39.04	0.0002
39.20	0.0002
39.36	0.0001
39.53	0.0001
39.69	0.0001
39.86	0.0001
40.02	0.0000
40.19	0.0000

```
40.35   0.0000
40.52  -0.0000
40.68  -0.0000
40.85  -0.0000
41.01  -0.0000
41.18  -0.0000
41.34  -0.0000
41.51  -0.0000
41.67  -0.0000
41.84  -0.0000
42.00   0.0000
Weight of 0.000000 0.000000 is 157.127914
0   80.399   0.03
 1   79.383   0.05
 2   78.367   0.06
 3   77.351  -0.20
 4   76.335   0.11
 5   75.319   0.06
 6   74.303   0.09
 7   73.287  -0.19
 8   72.271   0.08
 9   71.255  -0.11
 10   70.239  -0.10
 11   69.224  -0.06
 12   68.208  -0.06
 13   67.192  -0.20
 14   66.176   0.08
 15   65.160  -0.00
 16   64.144  -0.06
 17   63.128  -0.07
 18   62.112  -0.01
 19   61.096  -0.12
 20   60.080  -0.09
 21   59.064   0.01
 22   58.048   0.02
 23   57.033   0.05
 24   56.017  -0.03
 25   55.001   0.10
 26   53.985  -0.11
 27   52.969  -0.00
 28   51.953  -0.13
 29   50.937  -0.07
 30   49.921  -0.00
 31   48.905   0.02
```

32	47.889	-0.11
33	46.873	-0.04
34	45.857	0.03
35	44.841	-0.07
36	43.826	0.02
37	42.810	-0.07
38	41.794	-0.19
39	40.778	-0.04
40	39.762	-0.09
41	38.746	0.08
42	37.730	-0.01
43	36.714	0.11
44	35.698	0.06
45	34.682	-0.02
46	33.666	-0.01
47	32.650	0.13
48	31.635	-0.18
49	30.619	-0.06
50	29.603	-0.07
51	28.587	-0.01
52	27.571	0.06
53	26.555	-0.06
54	25.539	-0.00
55	24.523	-0.06
56	23.507	-0.02
57	22.491	-0.05
58	21.475	-0.01
59	20.459	0.04
60	19.443	-0.10
61	18.428	0.14
62	17.412	0.00
63	16.396	-0.10
64	15.380	0.06
65	14.364	-0.05
66	13.348	0.00
67	12.332	-0.06
68	11.316	0.08
69	10.300	0.20
70	9.284	0.04
71	8.268	0.01
72	7.252	-0.01
73	6.236	0.02
74	5.221	0.02
75	4.205	0.03

76	3.189	0.09
77	2.173	0.06
78	1.157	-0.12
79	0.141	0.06
80	-0.875	0.16
81	-1.891	0.12
82	-2.907	0.04
83	-3.923	-0.05
84	-4.939	-0.01
85	-5.955	0.18
86	-6.970	-0.04
87	-7.986	-0.02
88	-9.002	0.14
89	-10.018	-0.08
90	-11.034	-0.00
91	-12.050	0.07
92	-13.066	0.12
93	-14.082	0.15
94	-15.098	-0.03
95	-16.114	0.00
96	-17.130	-0.23
97	-18.146	0.10
98	-19.162	-0.06
99	-20.177	-0.13
100	-21.193	0.08
101	-22.209	-0.05
102	-23.225	0.02
103	-24.241	0.04
104	-25.257	-0.07
105	-26.273	0.02
106	-27.289	0.07
107	-28.305	-0.05
108	-29.321	-0.09
109	-30.337	0.01
110	-31.353	-0.05
111	-32.369	0.12
112	-33.384	0.21
113	-34.400	0.01
114	-35.416	-0.09
115	-36.432	0.01
116	-37.448	-0.01
117	-38.464	0.08
118	-39.480	-0.07
119	-40.496	0.01

120	-41.512	-0.03
121	-42.528	-0.03
122	-43.544	0.09
123	-44.560	-0.05
124	-45.575	0.05
125	-46.591	0.13
126	-47.607	0.01
127	-48.623	0.02
128	-49.639	0.04
129	-50.655	0.06
130	-51.671	-0.06
131	-52.687	-0.05
132	-53.703	0.17
133	-54.719	0.12
134	-55.735	-0.05
135	-56.751	-0.06
136	-57.767	-0.07
137	-58.782	-0.16
138	-59.798	0.15
139	-60.814	-0.05
140	-61.830	-0.15
141	-62.846	-0.01
142	-63.862	-0.02
143	-64.878	-0.06
144	-65.894	0.04
145	-66.910	0.09
146	-67.926	-0.05
147	-68.942	0.04
148	-69.958	0.03
149	-70.974	-0.04
150	-71.989	0.08
151	-73.005	0.22
152	-74.021	0.09
153	-75.037	-0.07
154	-76.053	0.09
155	-77.069	-0.11
156	-78.085	-0.09
157	-79.101	0.01
158	-80.117	-0.00
159	-81.133	0.02
160	-82.149	0.04
161	-83.165	0.02
162	-84.180	-0.09
163	-85.196	-0.11

164	-86.212	0.00
165	-87.228	0.15
166	-88.244	-0.00
167	-89.260	-0.10
168	-90.276	0.01
169	-91.292	0.02
170	-92.308	-0.03
171	-93.324	0.08
172	-94.340	-0.12
173	-95.356	-0.03
174	-96.372	0.08
175	-97.387	-0.13
176	-98.403	-0.06
177	-99.419	0.03
178	-100.435	0.13
179	-101.451	0.02
180	-102.467	-0.02
181	-103.483	0.17
182	-104.499	0.02
183	-105.515	0.01
184	-106.531	0.02
185	-107.547	-0.02
186	-108.563	0.03
187	-109.578	-0.07
188	-110.594	-0.08
189	-111.610	0.13
190	-112.626	-0.23
191	-113.642	0.02
192	-114.658	-0.03
193	-115.674	-0.06
194	-116.690	0.02
195	-117.706	0.07
196	-118.722	0.01
197	-119.738	0.00
198	-120.754	0.11
199	-121.770	0.16
200	-122.785	-0.07
201	-123.801	-0.04
202	-124.817	0.08
203	-125.833	-0.13
204	-126.849	0.12
205	-127.865	-0.08
206	-128.881	0.11
207	-129.897	-0.04

208	-130.913	-0.01
209	-131.929	-0.03
210	-132.945	-0.01
211	-133.961	0.08
212	-134.977	-0.02
213	-135.992	-0.16
214	-137.008	-0.05
215	-138.024	-0.07
216	-139.040	-0.04
217	-140.056	-0.03
218	-141.072	-0.09
219	-142.088	0.05
220	-143.104	0.08
221	-144.120	0.05
222	-145.136	0.05
223	-146.152	-0.03
224	-147.168	-0.08
225	-148.184	-0.11
226	-149.199	0.02
227	-150.215	0.10
228	-151.231	-0.04
229	-152.247	0.03
230	-153.263	-0.04
231	-154.279	-0.15
232	-155.295	-0.02
233	-156.311	-0.19
234	-157.327	-0.05
235	-158.343	0.03
236	-159.359	-0.08
237	-160.375	0.09
238	-161.390	-0.01
239	-162.406	0.09
240	-163.422	0.05
241	-164.438	0.16
242	-165.454	0.08
243	-166.470	-0.01
244	-167.486	-0.11
245	-168.502	-0.08
246	-169.518	-0.06
247	-170.534	0.06
248	-171.550	-0.06
249	-172.566	-0.01
250	-173.582	0.10
251	-174.597	-0.02

252	-175.613	-0.07
253	-176.629	-0.01
254	-177.645	-0.08
255	-178.661	0.06
256	-179.677	-0.08
257	-180.693	0.03
258	-181.709	0.04
259	-182.725	0.09
260	-183.741	0.01
261	-184.757	-0.12
262	-185.773	-0.17
263	-186.788	-0.18
264	-187.804	0.05
265	-188.820	0.00
266	-189.836	-0.13
267	-190.852	-0.08
268	-191.868	-0.06
269	-192.884	0.09
270	-193.900	0.02
271	-194.916	0.07
272	-195.932	-0.08
273	-196.948	0.12
274	-197.964	0.12
275	-198.980	0.02
276	-199.995	-0.20
277	-201.011	-0.00
278	-202.027	-0.00
279	-203.043	0.01
280	-204.059	-0.13
281	-205.075	0.06
282	-206.091	0.03
283	-207.107	0.05
284	-208.123	-0.13
285	-209.139	0.10
286	-210.155	-0.03
287	-211.171	-0.07
288	-212.186	-0.12
289	-213.202	-0.01
290	-214.218	-0.06
291	-215.234	0.01
292	-216.250	0.07
293	-217.266	0.09
294	-218.282	0.04
295	-219.298	-0.06

296	-220.314	-0.10
297	-221.330	-0.03
298	-222.346	0.15
299	-223.362	0.02
300	-224.378	0.02
301	-225.393	-0.03
302	-226.409	0.04
303	-227.425	-0.01
304	-228.441	-0.04
305	-229.457	0.02
306	-230.473	-0.18
307	-231.489	0.04
308	-232.505	-0.07
309	-233.521	-0.04
310	-234.537	0.08
311	-235.553	-0.04
312	-236.569	0.00
313	-237.585	0.15
314	-238.600	0.15
315	-239.616	0.06
316	-240.632	0.13
317	-241.648	0.10
318	-242.664	-0.10
319	-243.680	-0.00
320	-244.696	-0.12
321	-245.712	-0.02
322	-246.728	-0.07
323	-247.744	0.00
324	-248.760	-0.19
325	-249.776	0.02
326	-250.792	0.17
327	-251.807	-0.13
328	-252.823	0.03
329	-253.839	-0.08
330	-254.855	0.11
331	-255.871	-0.01
332	-256.887	0.01
333	-257.903	-0.02
334	-258.919	0.04
335	-259.935	0.05
336	-260.951	0.02
337	-261.967	-0.05
338	-262.983	0.21
339	-263.998	0.12

340	-265.014	0.08
341	-266.030	0.04
342	-267.046	-0.06
343	-268.062	0.04
344	-269.078	0.02
345	-270.094	-0.06
346	-271.110	0.08
347	-272.126	0.01
348	-273.142	0.02
349	-274.158	0.11
350	-275.174	-0.04
351	-276.190	-0.02
352	-277.205	0.18
353	-278.221	0.14
354	-279.237	0.16
355	-280.253	0.09
356	-281.269	0.08
357	-282.285	0.05
358	-283.301	-0.10
359	-284.317	-0.29
360	-285.333	0.00
361	-286.349	0.09
362	-287.365	0.18
363	-288.381	0.10
364	-289.396	-0.00
365	-290.412	-0.04
366	-291.428	-0.02
367	-292.444	-0.04
368	-293.460	-0.09
369	-294.476	-0.11
370	-295.492	-0.05
371	-296.508	-0.03
372	-297.524	0.03
373	-298.540	0.09
374	-299.556	0.06
375	-300.572	-0.01
376	-301.588	0.05
377	-302.603	0.03
378	-303.619	0.14
379	-304.635	-0.03
380	-305.651	0.20
381	-306.667	-0.06
382	-307.683	0.13
383	-308.699	-0.16

384	-309.715	0.08
385	-310.731	-0.08
386	-311.747	-0.05
387	-312.763	-0.03
388	-313.779	0.16
389	-314.794	-0.06
390	-315.810	0.06
391	-316.826	0.05
392	-317.842	-0.08
393	-318.858	-0.04
394	-319.874	0.02
395	-320.890	-0.04
396	-321.906	0.03
397	-322.922	-0.00
398	-323.938	-0.00
399	-324.954	-0.04
400	-325.970	0.03
401	-326.986	0.05
402	-328.001	-0.03
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404	-330.033	-0.12
405	-331.049	0.08
406	-332.065	0.08
407	-333.081	-0.10
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409	-335.113	-0.00
410	-336.129	-0.08
411	-337.145	-0.10
412	-338.161	0.12
413	-339.177	-0.10
414	-340.193	-0.11
415	-341.208	0.06
416	-342.224	-0.01
417	-343.240	0.01
418	-344.256	-0.04
419	-345.272	0.10
420	-346.288	0.09
421	-347.304	0.09
422	-348.320	-0.03
423	-349.336	-0.10
424	-350.352	-0.08
425	-351.368	0.12
426	-352.384	-0.01
427	-353.400	-0.09

428	-354.415	-0.10
429	-355.431	0.10
430	-356.447	0.11
431	-357.463	-0.00
432	-358.479	0.15
433	-359.495	0.21
434	-360.511	0.22
435	-361.527	0.02
436	-362.543	0.01
437	-363.559	-0.10
438	-364.575	0.06
439	-365.591	0.15
440	-366.606	0.03
441	-367.622	0.01
442	-368.638	-0.06
443	-369.654	0.02
444	-370.670	-0.15
445	-371.686	-0.10
446	-372.702	0.14
447	-373.718	-0.03
448	-374.734	-0.16
449	-375.750	-0.08
450	-376.766	-0.01
451	-377.782	0.05
452	-378.798	0.09
453	-379.813	-0.02
454	-380.829	-0.07
455	-381.845	-0.02
456	-382.861	0.09
457	-383.877	-0.19
458	-384.893	0.03
459	-385.909	-0.01
460	-386.925	0.10
461	-387.941	0.07
462	-388.957	-0.05
463	-389.973	-0.06
464	-390.989	0.15
465	-392.004	0.02
466	-393.020	0.06
467	-394.036	-0.16
468	-395.052	-0.10
469	-396.068	0.10
470	-397.084	-0.01
471	-398.100	0.03
472	-399.116	0.05

473	-400.132	-0.10
474	-401.148	0.01
475	-402.164	0.06
476	-403.180	0.06
477	-404.196	0.06
478	-405.211	0.15
479	-406.227	0.15
480	-407.243	0.04
481	-408.259	0.06
482	-409.275	-0.09
483	-410.291	-0.02
484	-411.307	-0.09
485	-412.323	-0.08
486	-413.339	-0.14
487	-414.355	-0.24
488	-415.371	0.00
489	-416.387	0.02
490	-417.403	-0.05
491	-418.418	0.02
492	-419.434	-0.16
493	-420.450	-0.02
494	-421.466	-0.07
495	-422.482	0.00
496	-423.498	0.03
497	-424.514	0.03
498	-425.530	-0.01
499	-426.546	0.07
500	-427.562	-0.09
501	-428.578	0.03
502	-429.594	0.03
503	-430.609	0.14
504	-431.625	-0.08
505	-432.641	-0.04
506	-433.657	-0.06
507	-434.673	-0.17
508	-435.689	0.12
509	-436.705	0.17
510	-437.721	0.07
511	-438.737	-0.00
512	-439.753	-0.02
513	-440.769	-0.19
514	-441.785	0.13
515	-442.801	0.07
516	-443.816	-0.03

517	-444.832	0.10
518	-445.848	-0.06
519	-446.864	-0.03
520	-447.880	0.03
521	-448.896	0.00
522	-449.912	-0.00
523	-450.928	0.03
524	-451.944	0.11
525	-452.960	-0.13
526	-453.976	-0.10
527	-454.992	0.07
528	-456.008	-0.07
529	-457.023	0.07
530	-458.039	-0.00
531	-459.055	0.18
532	-460.071	0.08
533	-461.087	0.06
534	-462.103	0.09
535	-463.119	-0.01
536	-464.135	-0.03
537	-465.151	0.01
538	-466.167	0.10
539	-467.183	-0.14
540	-468.199	0.01
541	-469.215	-0.02
542	-470.230	0.07
543	-471.246	0.19
544	-472.262	0.12
545	-473.278	-0.01
546	-474.294	0.08
547	-475.310	0.04
548	-476.326	-0.05
549	-477.342	-0.05
550	-478.358	-0.03
551	-479.374	0.03
552	-480.390	-0.03
553	-481.406	0.04
554	-482.421	-0.05
555	-483.437	0.07
556	-484.453	-0.09
557	-485.469	0.05
558	-486.485	0.02
559	-487.501	0.04
560	-488.517	-0.02

561	-489.533	-0.05
562	-490.549	0.14
563	-491.565	0.05
564	-492.581	-0.02
565	-493.597	-0.05
566	-494.613	0.02
567	-495.628	0.01
568	-496.644	0.11
569	-497.660	0.09
570	-498.676	-0.12
571	-499.692	-0.18
572	-500.708	-0.01
573	-501.724	0.14
574	-502.740	0.10
575	-503.756	-0.02
576	-504.772	-0.10
577	-505.788	-0.15
578	-506.804	-0.07
579	-507.819	-0.08
580	-508.835	-0.08
581	-509.851	-0.01
582	-510.867	0.04
583	-511.883	0.06
584	-512.899	0.02
585	-513.915	-0.04
586	-514.931	-0.00
587	-515.947	0.13
588	-516.963	0.00
589	-517.979	0.00
590	-518.995	-0.04
591	-520.011	0.03
592	-521.026	-0.01
593	-522.042	0.20
594	-523.058	0.01
595	-524.074	0.05
596	-525.090	-0.06
597	-526.106	-0.07
598	-527.122	0.21
599	-528.138	-0.00
600	-529.154	-0.13
601	-530.170	-0.06
602	-531.186	0.10
603	-532.202	-0.01
604	-533.218	-0.14

605	-534.233	0.15
606	-535.249	0.07
607	-536.265	0.09
608	-537.281	-0.09
609	-538.297	0.10
610	-539.313	-0.01
611	-540.329	0.10
612	-541.345	0.07
613	-542.361	-0.09
614	-543.377	-0.00
615	-544.393	-0.18
616	-545.409	0.00
617	-546.424	-0.09
618	-547.440	-0.01
619	-548.456	-0.04
620	-549.472	0.02
621	-550.488	0.08
622	-551.504	0.02
623	-552.520	-0.10
624	-553.536	-0.02
625	-554.552	0.04
626	-555.568	0.01
627	-556.584	0.05
628	-557.600	0.03
629	-558.616	0.05
630	-559.631	0.07
631	-560.647	-0.10
632	-561.663	-0.01
633	-562.679	0.00
634	-563.695	0.03
635	-564.711	0.19
636	-565.727	-0.01
637	-566.743	0.02
638	-567.759	-0.06
639	-568.775	-0.07
640	-569.791	0.00
641	-570.807	-0.03
642	-571.823	-0.03
643	-572.838	-0.06
644	-573.854	-0.03
645	-574.870	-0.18
646	-575.886	0.08
647	-576.902	0.09
648	-577.918	0.11

```
 649 -578.934  -0.07
 650 -579.950  -0.08
 651 -580.966   0.09
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 661 -591.125  -0.02
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 683 -613.475   0.03
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 685 -615.507  -0.09
 686 -616.523  -0.09
 687 -617.539  -0.09
 688 -618.555   0.04

STDERR ****************************

Exit Code: 0
```

View the Data Cube --- view_cube

The preparation of the data cube is the final step. The `view-cube` process allows a quick look at the result to check for problems.

FITS files are written using FITS standards, which means velocities in m/s and angles in degrees. The default units for entry of velocities in the command line arguments below are km/s and arcsec. But, by changing the scale parameters `v_scale` and `scale` these can be adapted to other units.

Command Line Arguments

```
--config [-c]    : name of configuration file to set param
eters
--input [-i]     : input FITS file
--v_range        : [vlo,vhi] is velocity range for integra
ted intensity (km/s)
--v_scale        : scale factor for velocity [default=1/10
00 to convert m/s to km/s]
--location       : [dx,dy] is location for spectrum plot (
offset in arcsec)
--scale          : scale factor for position offset [defau
lt=1/3600 to convert arcsec to degrees]
--limits         : [xlo,xhi,ylo,yhi] limits for final map
--tmax_range     : [data_lo,data_hi] data range for tmax i
mage
--tint_range     : [data_lo,data_hi] data range for tint i
mage
--plot_type      : data to plot - valid options: TINT, TMA
X
--interpolation  : valid options: none, nearest, bilinear,
bicubic. default=bilinear
```

Example

This example makes a set of plots for the data cube created above. There are 5 figures created:

- SV slice through cube at constant declination. The exact position is given by the `location` keyword which identifies a point in the map by offsets from the center position.
- SV slice through cube at constant right ascension. The exact position is given by the `location` keyword which identifies a point in the map by offsets from the center position.
- Image of the parameter indicated by `plot_type` . In this example it is the integrated intensity `TINT` . The `location` point is shown as a white +.
- Spectrum from the cube at the position given in `location` .
- Image of `TINT` presented using full WCS coordinates.

Here is the configuration file: `M31_view_cube_peak_1.txt`

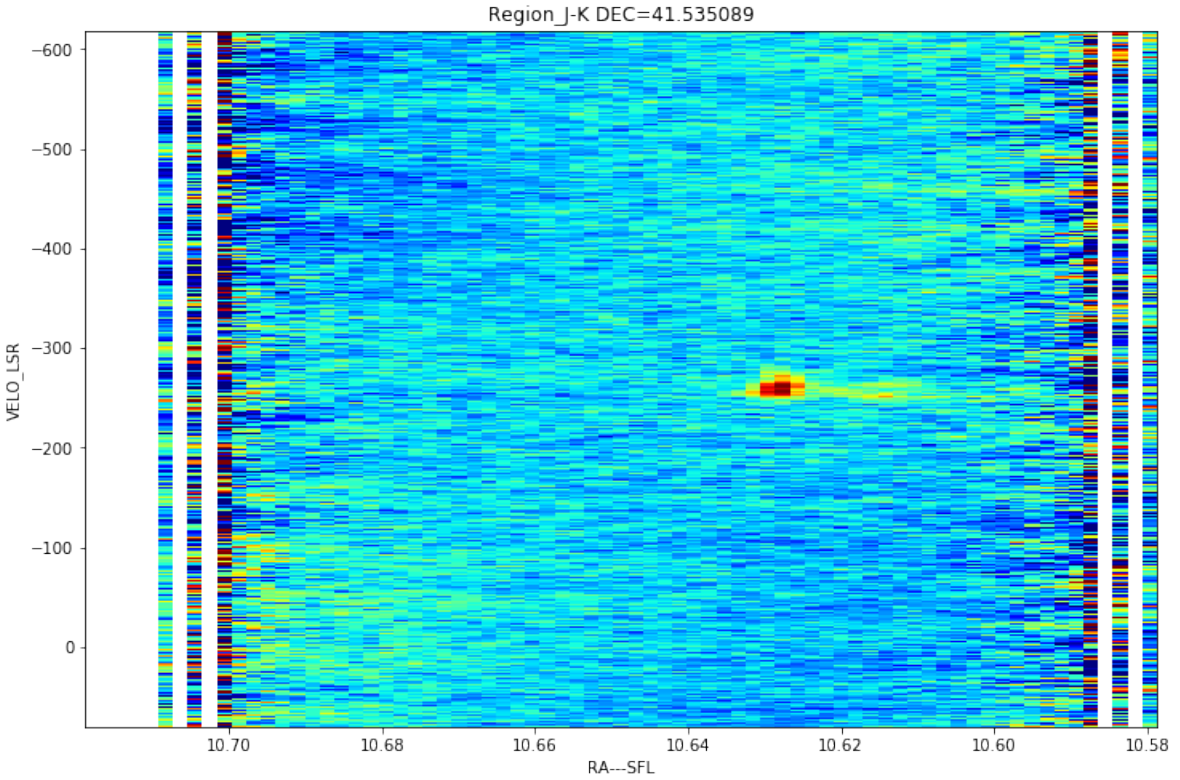
```
input         M31_Region_J-K_CO_1.fits
v_range       [-300,-200]
location      [42,77] # this is a bright peak in NE quadran
t
limits        [-240,240,-240,240]
tmax_range    [-.5,1.]
tint_range    [-1.,20.]
plot_type     TINT
```

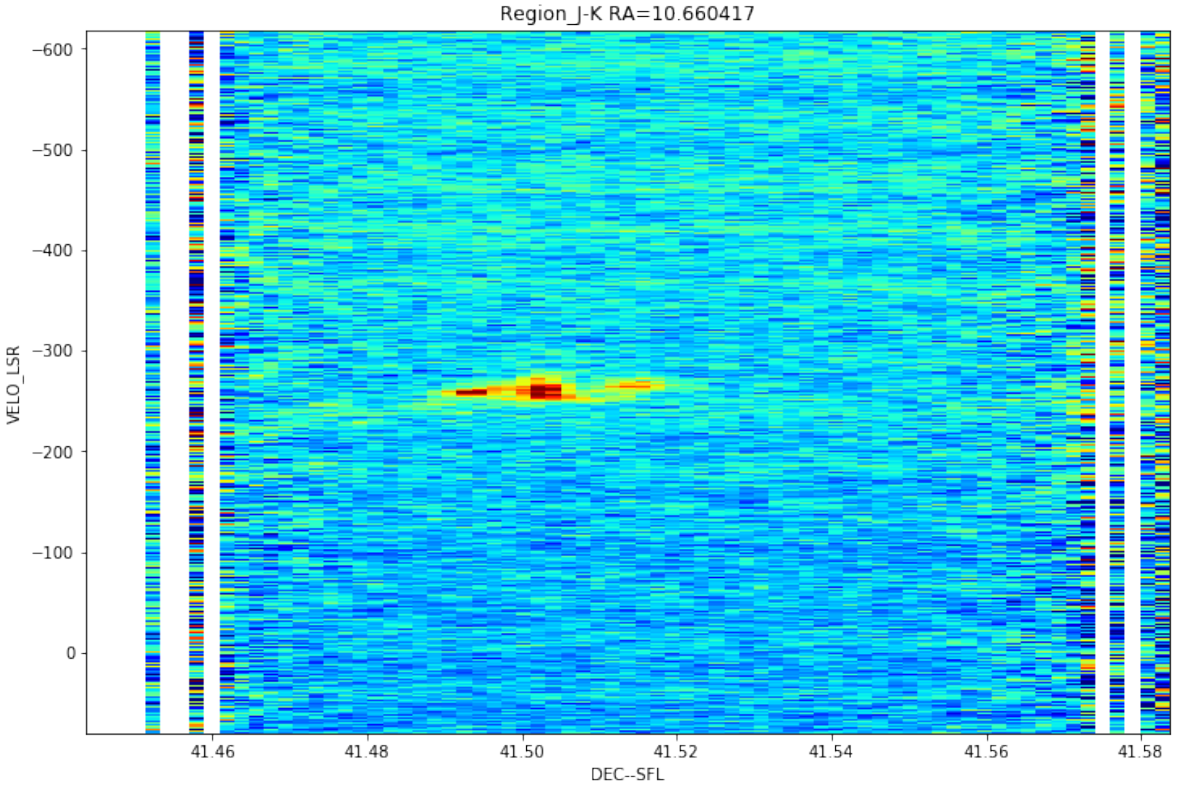
In [12]:

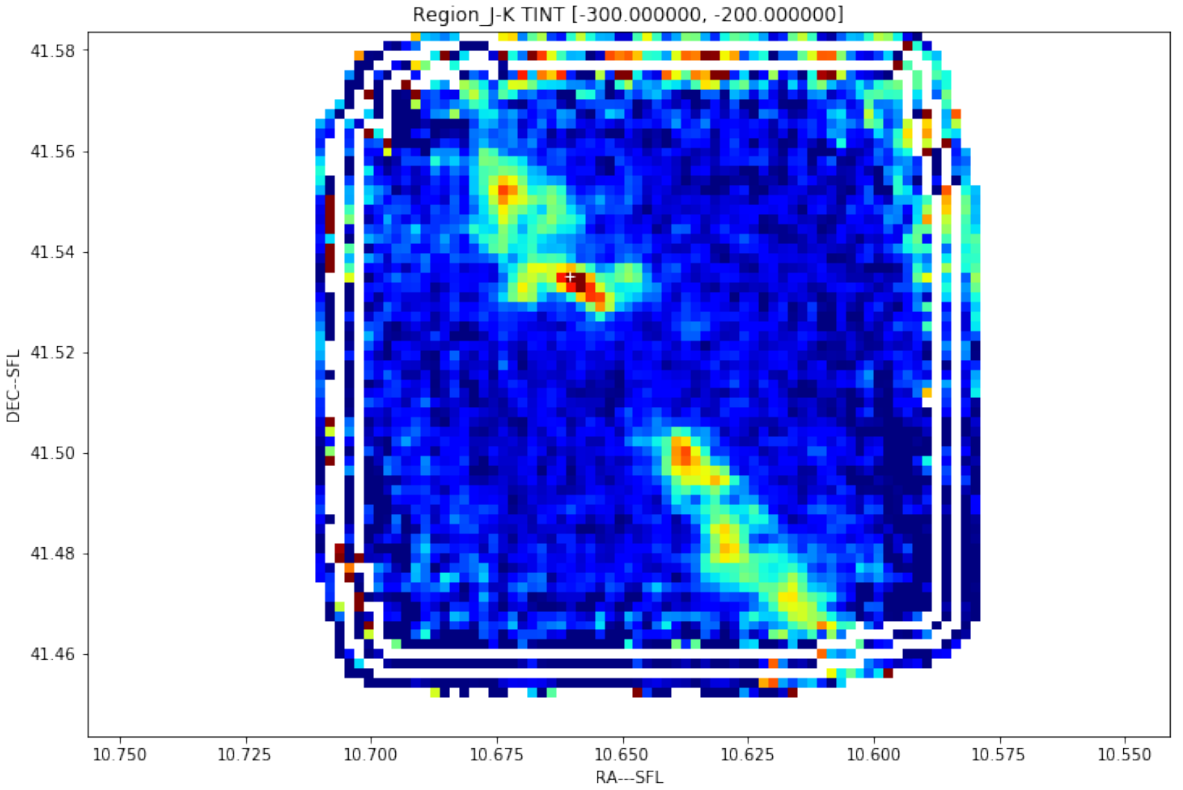
```
run view_cube -c M31_view_cube_peak_1.txt
```

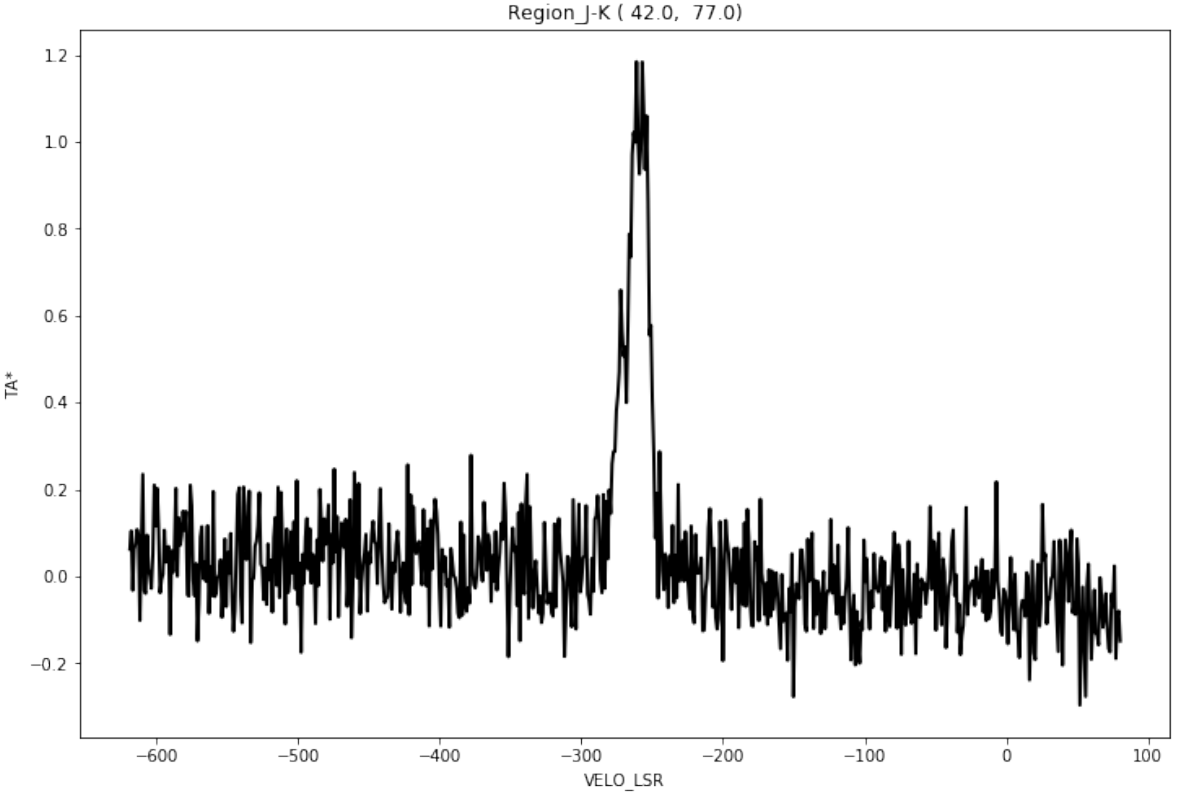
```
program view_cube options
input file name  =  M31_Region_J-K_CO_1.fits
velocity range   =  [-300, -200]
velocity scale   =  1000.0
location         =  [42, 77]
scale            =  0.00027777777777777778
limits           =  [-240, 240, -240, 240]
tmax plot range  =  [-0.5, 1.0]
tint plot range  =  [-1.0, 20.0]
plot type        =  TINT
interpolation    =  bilinear

-300 276 -200 374
42 30 77 47
[-240, 240, -240, 240]
```

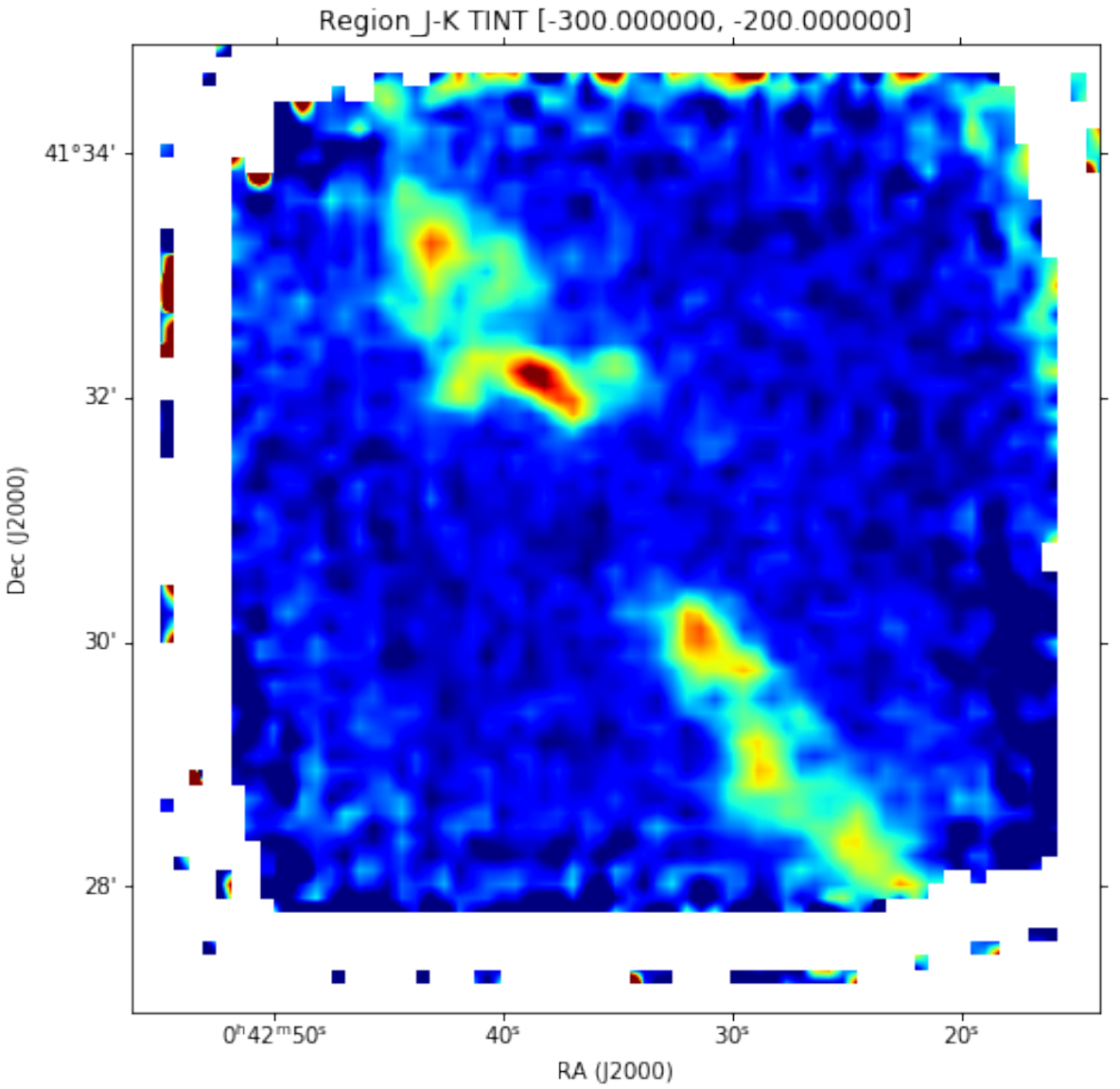
```
[2, 70, 2, 70]
SIMPLE  =                    T / file does conform t
o FITS standard
BITPIX  =                  -32 / number of bits per
data pixel
NAXIS   =                    3 / number of data axes
NAXIS1  =                   73 / length of data axis
1
NAXIS2  =                   73 / length of data axis
2
NAXIS3  =                  689 / length of data axis
3
EXTEND  =                    T / FITS dataset may co
ntain extensions
COMMENT   FITS (Flexible Image Transport System) for
mat is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; b
ibcode: 2001A&A...376..359H
TELESCOP= 'LMT     '           /
OBJECT  = 'Region_J-K'         /
OBSNUM  =                85778 /
BUNIT   = 'K       '           /
CTYPE1  = 'RA---SFL'           /
CRVAL1  =             10.64875 / deg
CDELT1  =         -0.001944444 / deg
CRPIX1  =                  36. /
CUNIT1  = 'deg     '           /
CTYPE2  = 'DEC--SFL'           /
CRVAL2  =              41.5137 / deg
CDELT2  =          0.001944444 / deg
CRPIX2  =                  36. /
CUNIT2  = 'deg     '           /
CTYPE3  = 'VELO_LSR'           /
CRVAL3  =              80398.7 / m/s
CDELT3  =            -1015.921 / m/s
CRPIX3  =                   0. /
CUNIT3  = 'm/s     '           /
EQUINOX =                2000. /
RADESYS = 'FK5     '           /
10.660416664 41.535088884 23.087479
```


Region_J-K DEC=41.535089
VELO_LSR
−600
−500
−400
−300
−200
−100
0
10.70
10.68
10.66
10.64
10.62
10.60
10.58
RA---SFL


Region_J-K RA=10.660417
VELO_LSR
−600
−500
−400
−300
−200
−100
0
41.46
41.48
41.50
41.52
41.54
41.56
41.58
DEC--SFL


Region_J-K TINT [-300.000000, -200.000000]
41.58
41.56
41.54
41.52
41.50
41.48
41.46
DEC--SFL
10.750
10.725
10.700
10.675
10.650
10.625
10.600
10.575
10.550
RA---SFL


Region_J-K (42.0, 77.0)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
TA*
−600
−500
−400
−300
−200
−100
0
100
VELO_LSR


Region_J-K TINT [-300.000000, -200.000000]
41°34'
32'
30'
28'
Dec (J2000)
0h42m50s
40s
30s
20s
RA (J2000)