CLASS tutorials

Collected works

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CLASS tutorial: I. Basics

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on behalf of the CLASS developers over time

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Need help?

GILDAS web page http://www.iram.fr/IRAMFR/GILDAS/

CLASS documentations and cookbooks Widget>Help>Class>...

Online help

```
LAS> HELP  ! Summary of all commands, gathered by language
...
LAS\
  ACCUMULATE   ASSOCIATE    AVERAGE      BASE         BOX          CATALOG
  CONSISTENCY  COPY         DROP         DUMP         EXTRACT      FILE
...
LAS> HELP LAS\ ! (with backslash) Language help with short command description
      LAS\ Command Language Summary
ACCUMULATE          Add R and T observation.
ASSOCIATE           Add an Associated Array to the R observation
AVERAGE             Average all the observations of the current index.
...
LAS> help average  ! Command help
    LAS\AVERAGE  [/RESAMPLE  [NX  Xref  Xval   Xinc   Unit]]   [/NOCHECK
[SOURCE|POSITION|LINE|SPECTROSCOPY|CALIBRATION]]

Average all the spectra of the current index using the current weighting
function (see SET WEIGHT).
...
LAS> help average /resample ! Command  subtopic help
...
```

Helpdesk (Questions? Comments? Bug reports?): gildas@iram.fr

Data exploration: I. What does the file contain?

```
LAS> file in demo
LAS> find
LAS> list
Current index contains:
 N;V   Source       Line          Telescope      Lambda     Beta Sys  Sca Sub
...
8600;4  B0355+508   12CO(1-0)     30M-V02-B100    +65.2    +60.0 Eq  9682.  2
8601;4  B0355+508   12CO(1-0)     30M-V02-B100    +68.2    +60.0 Eq  9682.  2
8602;4  B0355+508   12CO(1-0)     30M-V02-B100    +71.3    +60.0 Eq  9682.  2
8603;4  B0355+508   12CO(1-0)     30M-V02-B100    +74.4    +60.0 Eq  9682.  2
8604;4  B0355+508   12CO(1-0)     30M-V02-B100    +77.4    +60.0 Eq  9682.  2
8605;4  B0355+508   12CO(1-0)     30M-V02-B100    +80.5    +60.0 Eq  9682.  2
8606;4  B0355+508   12CO(1-0)     30M-V02-B100    +83.5    +60.0 Eq  9682.  2
8607;4  B0355+508   12CO(1-0)     30M-V02-B100    +86.6    +60.0 Eq  9682.  2
8608;4  B0355+508   12CO(1-0)     30M-V02-B100    +89.7    +60.0 Eq  9682.  2
8609;4  B0355+508   12CO(1-0)     30M-V02-B100    +92.7    +60.0 Eq  9682.  2
8610;4  B0355+508   12CO(1-0)     30M-V02-B100    +95.8    +60.0 Eq  9682.  2
8611;4  B0355+508   12CO(1-0)     30M-V02-B100    +98.8    +60.0 Eq  9682.  2
8612;4  B0355+508   12CO(1-0)     30M-V02-B100   +101.9    +60.0 Eq  9682.  2
8613;4  B0355+508   12CO(1-0)     30M-V02-B100   +104.9    +60.0 Eq  9682.  2
8614;4  B0355+508   12CO(1-0)     30M-V02-B100   +108.0    +60.0 Eq  9682.  2
LAS>
```

⇒ Too many information.

Data exploration: I. What does the file contain?

```
LAS> list /scan
...
 B0355+508    12CO(1-0)    30M-V02-B100    -108.5:   +108.8          +70.0       Eq  9626   73
 B0355+508    12CO(1-0)    30M-V01-A100    -108.5:   +108.8          +80.0       Eq  9627   73
 B0355+508    12CO(1-0)    30M-V02-B100    -108.5:   +108.8          +80.0       Eq  9627   73
 B0355+508    12CO(1-0)    30M-V01-A100    -109.4:   +107.9          +90.0       Eq  9628   73
 B0355+508    12CO(1-0)    30M-V02-B100    -109.4:   +107.9          +90.0       Eq  9628   73
 B0355+508    12CO(1-0)    30M-V01-A100    -109.6:   +107.7         +100.0       Eq  9629   73
 B0355+508    12CO(1-0)    30M-V02-B100    -109.6:   +107.7         +100.0       Eq  9629   73
 B0355+508    12CO(1-0)    30M-V01-A100        -100.0           -109.3:   +108.0 Eq  9634   73
 B0355+508    12CO(1-0)    30M-V02-B100        -100.0           -109.3:   +108.0 Eq  9634   73
 B0355+508    12CO(1-0)    30M-V01-A100         -90.0           -109.4:   +107.9 Eq  9635   73
 B0355+508    12CO(1-0)    30M-V02-B100         -90.0           -109.4:   +107.9 Eq  9635   73
 B0355+508    12CO(1-0)    30M-V01-A100         -80.0           -109.5:   +107.8 Eq  9636   73
 B0355+508    12CO(1-0)    30M-V02-B100         -80.0           -109.5:   +107.8 Eq  9636   73
 B0355+508    12CO(1-0)    30M-V01-A100         -70.0           -109.2:   +108.1 Eq  9637   73
...
LAS>
```

$\Rightarrow$ One line per scan and front-end/back-end combination

Data exploration: I. What does the file contain?

```
LAS> list /scan /brief
Current index contains:
 9608: 146   9609: 146   9610: 146   9611: 146   9612: 146   9613: 146
 9614: 146   9615: 146   9616: 146   9617: 146   9619: 146   9620: 146
 9621: 146   9622: 146   9623: 146   9624: 146   9625: 146   9626: 146
 9627: 146   9628: 146   9629: 146   9634: 146   9635: 146   9636: 146
 9637: 146   9638: 146   9639: 146   9640: 146   9641: 146   9642: 146
 9643: 146   9645: 146   9646: 146   9647: 146   9648: 146   9649: 146
 9650: 146   9651: 146   9652: 146   9653: 146   9654: 146   9655: 146
 9665: 146   9666: 146   9667: 146   9668: 146   9669: 146   9670: 146
 9671: 146   9672: 146   9673: 146   9674: 146   9676: 146   9677: 146
 9678: 146   9679: 146   9680: 146   9681: 146   9682: 146
LAS>
```

$\Rightarrow$ Just the list of scans and the number of dumps per scan.

Data exploration: I. What does the file contain?

```
LAS> list /toc

equivalent to

LAS> list /toc source line telescope
Current index contains:
Number of sources......   1
    B0355+508          8614 (100.0%)
Number of lines........   1
    12CO(1-0)          8614 (100.0%)
Number of backends.....   2
    30M-V01-A100       4307 ( 50.0%)
    30M-V02-B100       4307 ( 50.0%)
Number of setups.......   2
    B0355+508    12CO(1-0)    30M-V01-A100       4307 ( 50.0%)
    B0355+508    12CO(1-0)    30M-V02-B100       4307 ( 50.0%)
LAS>
```

$\Rightarrow$ Default table of contents.

Data exploration: I. What does the file contain?

```
LAS> list /toc observed scan
Number of observation dates   1
    12-SEP-2005        8614 (100.0%)
Number of scans.......  59
            9608        146 (  1.7%)
            9609        146 (  1.7%)
            9610        146 (  1.7%)
            9611        146 (  1.7%)
            9612        146 (  1.7%)
            9613        146 (  1.7%)
            9614        146 (  1.7%)
            ...
Number of setups.......  59
    12-SEP-2005          9608        146 (  1.7%)
    12-SEP-2005          9609        146 (  1.7%)
    12-SEP-2005          9610        146 (  1.7%)
    12-SEP-2005          9611        146 (  1.7%)
    12-SEP-2005          9612        146 (  1.7%)
    12-SEP-2005          9613        146 (  1.7%)
    12-SEP-2005          9614        146 (  1.7%)
    ...
LAS>
```

$\Rightarrow$ Customized table of content.

Data exploration: II. Is the data set in the current index consistent?

```
LAS> set nomatch ! OTF data => disable consistency on spectra positions
LAS> consistency
Consistency checks:
  Checking Data type and regular x-axis sampling
  Checking Source Name
  Checking Position information
  Leaving  Offset position
  Checking Line Name
  Checking Spectroscopic information
  Checking Calibration information
Reference spectrum:
  Source Name       : B0355+508
  Coordinate System : EQUATORIAL  2000.0
  Proj. Center (rad): lambda     1.044998, beta     0.889488, tolerance 4.8E-08
  Line Name         : 12CO(1-0)
  Frequency (MHz)   : rest  115.271E+03, resol     3.906E-02, offset     0.000E+00
  Velocity (km/s)   : resol   -1.016E-01, offset   -1.000E+01
  Alignment (chan)  : tolerance    10.0%
  Calibration       : beeff  0.950,gain  0.010
W-CONSISTENCY,  Obs #74 differs. Inconsistent:
W-CONSISTENCY,    F range (left) :   1.1522356E+05,   1.1521357E+05 (-2.56E+02 channels)
W-CONSISTENCY,    F range (right):   1.1532859E+05,   1.1531859E+05 (-2.56E+02 channels)
W-CONSISTENCY,    V range (left) :    1.139119E+02,    1.399194E+02 (-2.56E+02 channels)
W-CONSISTENCY,    V range (right):   -1.592693E+02,   -1.332617E+02 (-2.56E+02 channels)
E-CONSISTENCY,  Index is inconsistent
```

$\Rightarrow$ Inconsistent spectroscopic information in index.

Data exploration: II. Is the data set in the current index consistent?

```
LAS> consistency
W-CONSISTENCY,     Already checked Spectroscopic information:Inconsistent
```

$\Rightarrow$ Check not repeated (it avoids long waiting time)

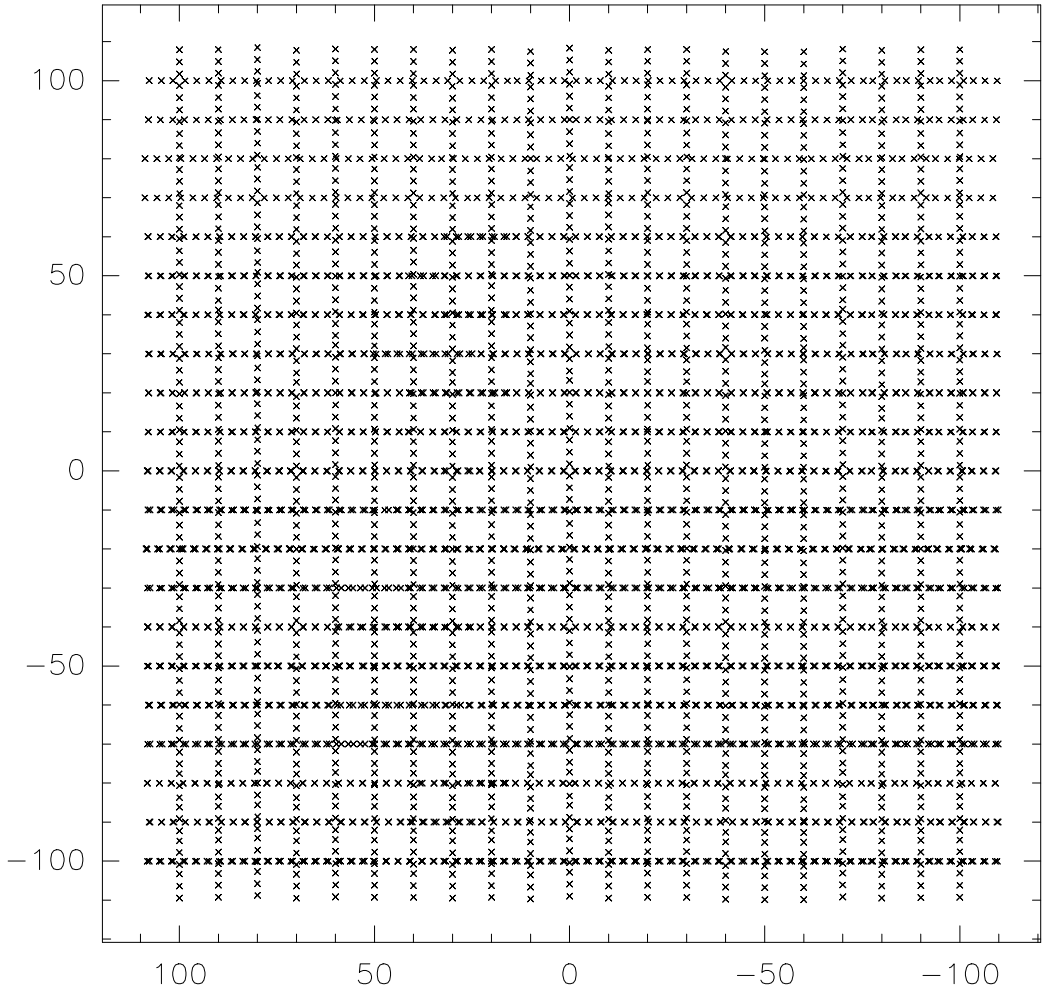
Data exploration: II. Is the data set in the current index consistent?

```
LAS> find /tel 30M-V01-A100
LAS> consistency
Consistency checks:
  Checking Data type and regular x-axis sampling
  Checking Source Name
  Checking Position information
  Leaving  Offset position
  Checking Line Name
  Checking Spectroscopic information
  Checking Calibration information
Reference spectrum:
  Source Name       : B0355+508
  Coordinate System : EQUATORIAL  2000.0
  Proj. Center (rad): lambda     1.044998, beta     0.889488, tolerance 4.8E-08
  Line Name         : 12CO(1-0)
  Frequency (MHz)   : rest  115.271E+03, resol     3.906E-02, offset     0.000E+00
  Velocity (km/s)   : resol   -1.016E-01, offset   -1.000E+01
  Alignment (chan)  : tolerance    10.0%
  Calibration       : beeff  0.950,gain  0.010
I-CONSISTENCY,  Index is consistent
```

- `find` enforces a new consistency check from scratch.
- Selection of a data subset $\Rightarrow$ Consistent index.

Data exploration: III. Where do we observe?

```
LAS> go where
```

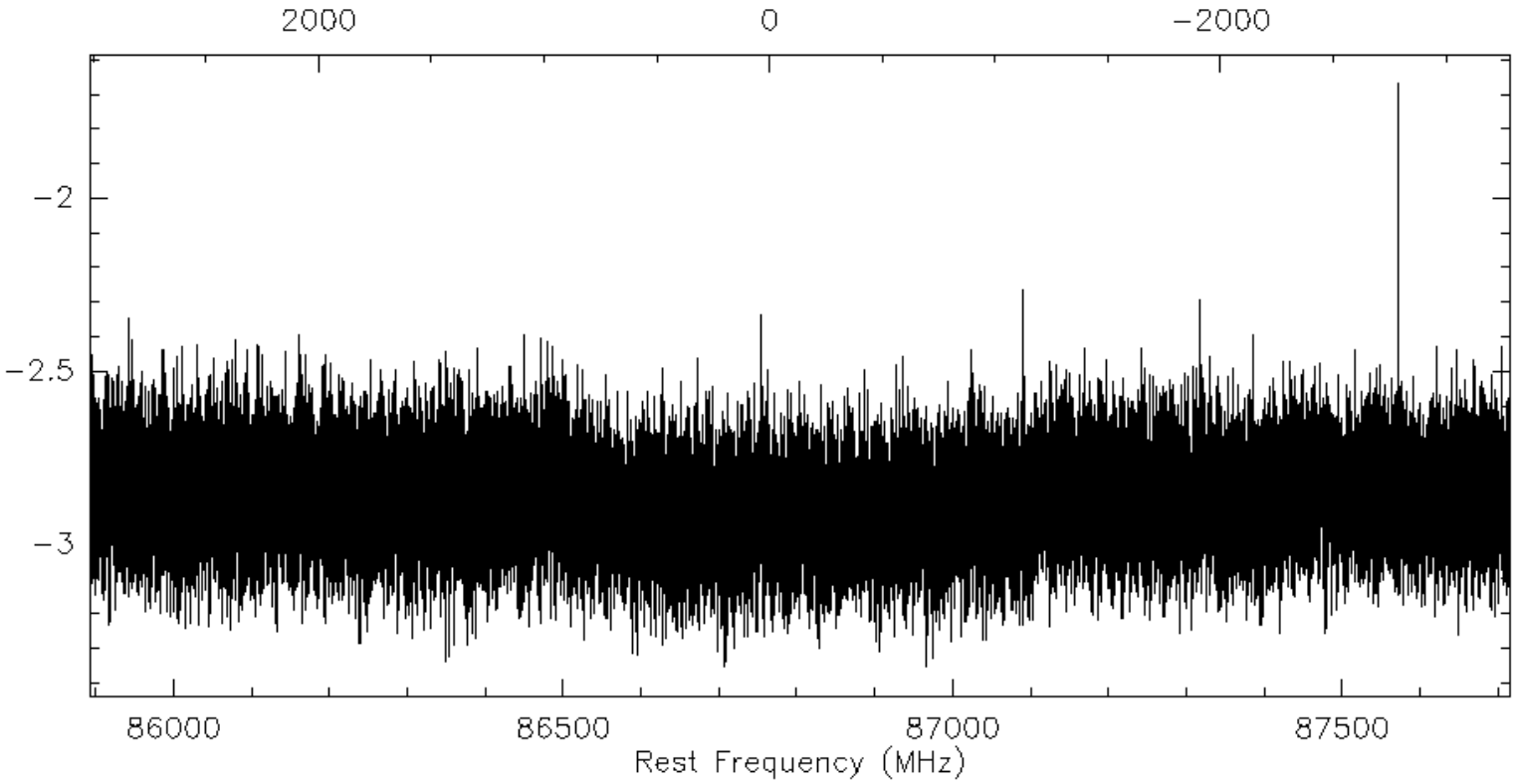


One point per spectrum
⇒ Lambda + Beta scanning
⇒ Mapping experiment

Data exploration: III. What does the data look like?

- Many different lines of different species in the same spectrum ⇒ Spectral axis default unit is FREQUENCY and the VELOCITY unit is meaningful only close to the rest frequency F0.
- How to display one spectrum with 37275 channels on a 5 000 pixel screen?

```
1;1 SDC13 CORE1  H13CO+       30MEOHLI-F01 O:26-SEP-2011 R:26-SEP-2011
     RA: 18:14:30.84 DEC: -17:33:18.8 Eq 2000.0 Rad. 0.0° Offs: +0.0 +0.0
       Unknown   tau:   0.092  Tsys:   177.  Time:   2.8    min  El: 23.0
   N: 37275  I0:  17614.0          V0:   37.00      Dv: -0.1687      LSR
         F0:   86754.3300      Df:  4.8828E-02  Fi:   99252.1276
```

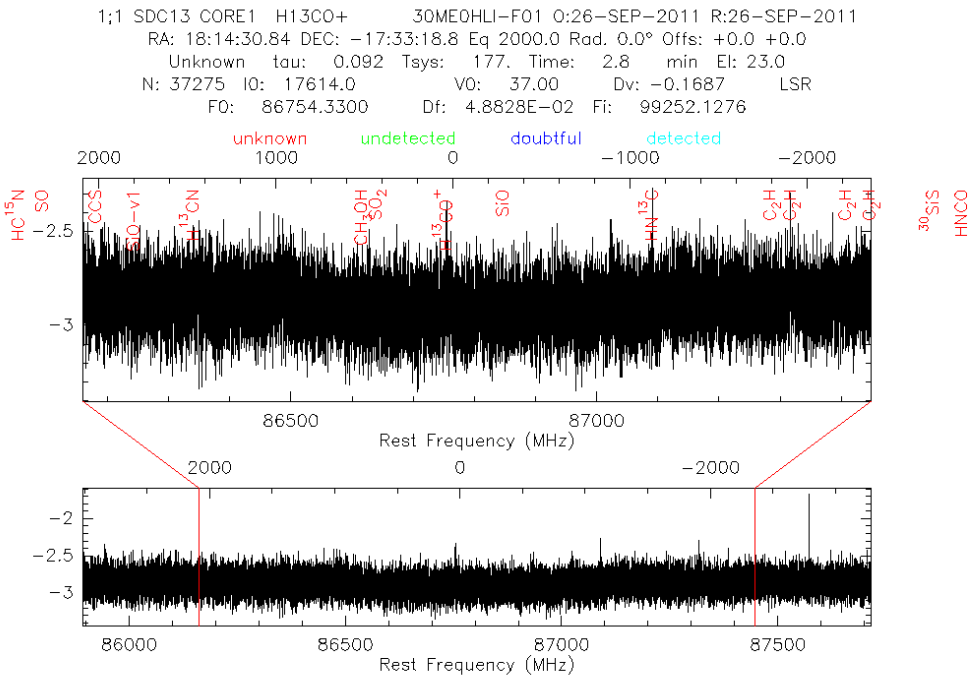


Data exploration: III. What does the data look like?

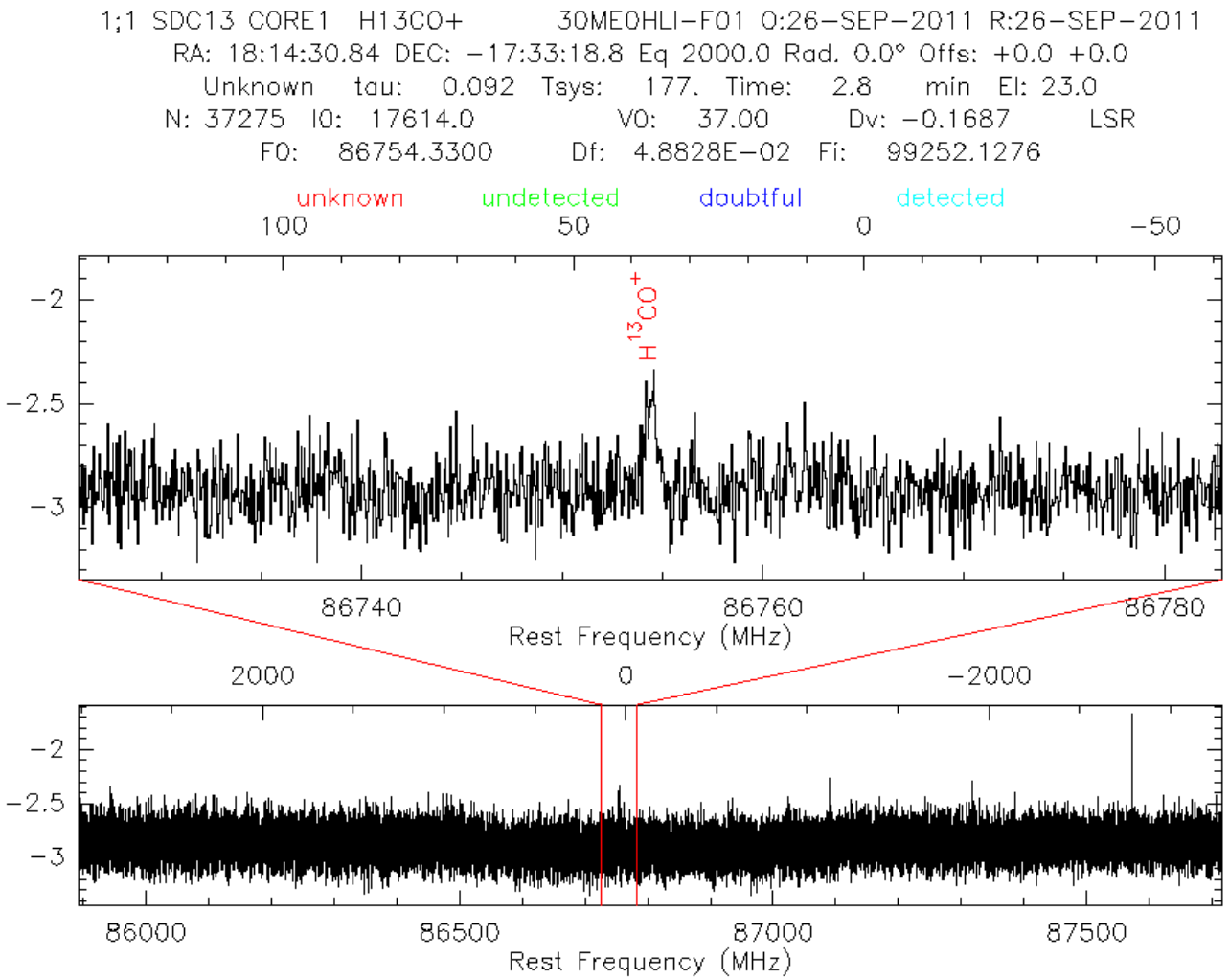
Interactive browsing of a spectrum and
automatic annotation of potential lines from a line catalog.

```
LAS> type mycatalog.cat
 72.0393124     DCOp-1-0          ! cdms
 72.1877041     CCD-1-0           ! cdms
 72.3237890     CCS               ! jpl
 72.4146936     DCN-1-0           ! cdms
 72.7835431     CCS               ! jpl
 72.9767794     OCS               ! jpl
...
LAS> let browse%cat mycatalog.cat
LAS> go browse
Authors: S.Bardeau & J.Pety (2010-2011)
Left  clic: Center zoom at cursor location
Right clic: Exit
Press SPACE key: Center zoom at cursor location
Press   Z   key: Zoom at cursor location
Press   U   key: Unzoom at cursor location
Press   B   key: Reset zoom factor to default
Press   D   key: Default zoom width and location
Press   V   key: Values at cursor location
Press   N   key: Shift forward  the zoom window b
Press   P   key: Shift backward the zoom window b
Press   Y   key: Zoom Y axis scale (Intensity)
Press   T   key: Back to full scale for Y axis
Press   E   key: Exit loop
Press   H   key: Help display

Y scales are ruled by the current SET MODE Y value
```



Data exploration: III. What does the data look like?



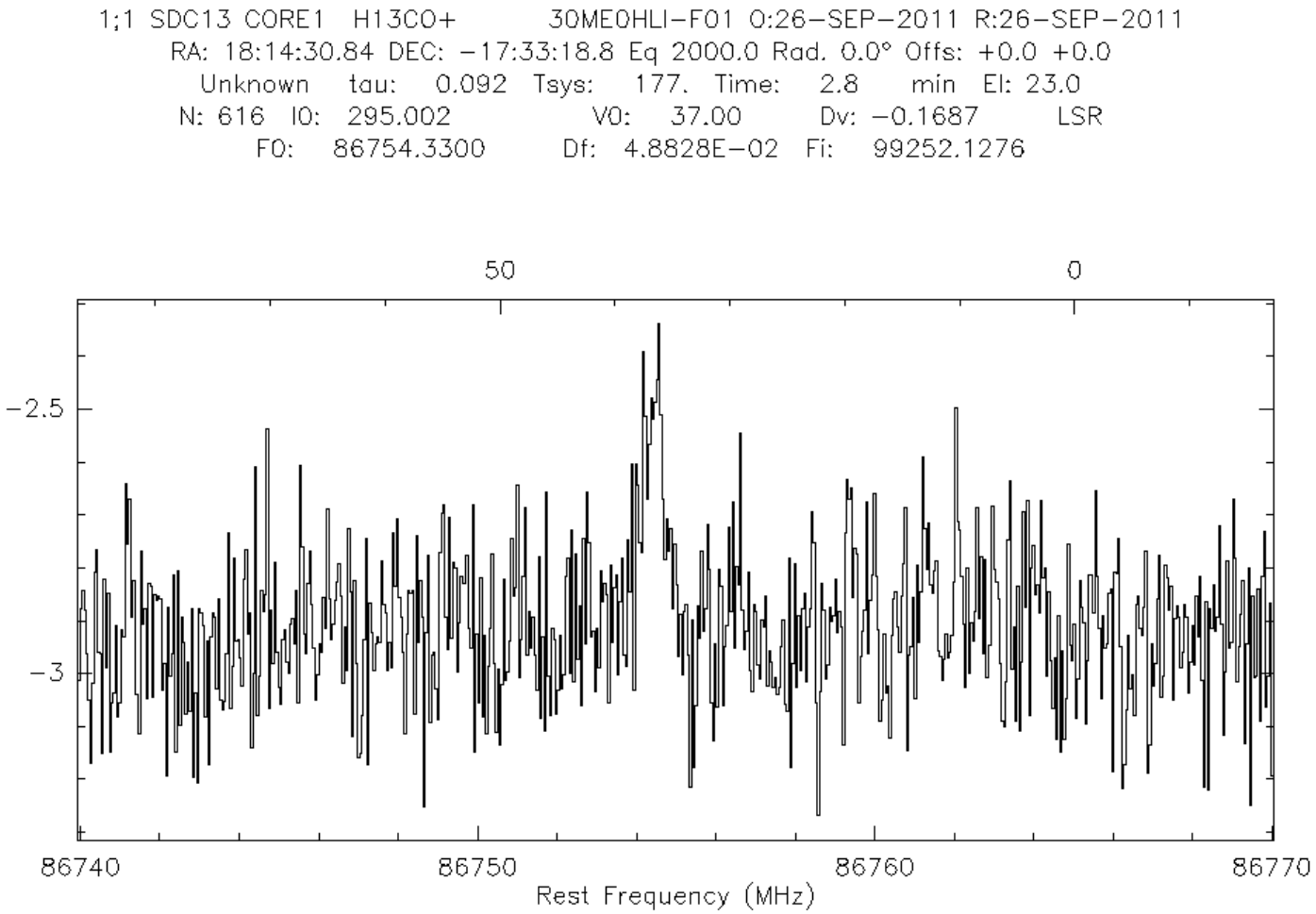
See also the tutorials

Line surveys by J. Pety.
Line identification with `LINEDB` and `WEEDS` by S. Bardeau and S. Maret.

Data exploration: III. What does the data look like?

Extracting a subset around the line rest frequency and
plotting it with a meaningful velocity axis

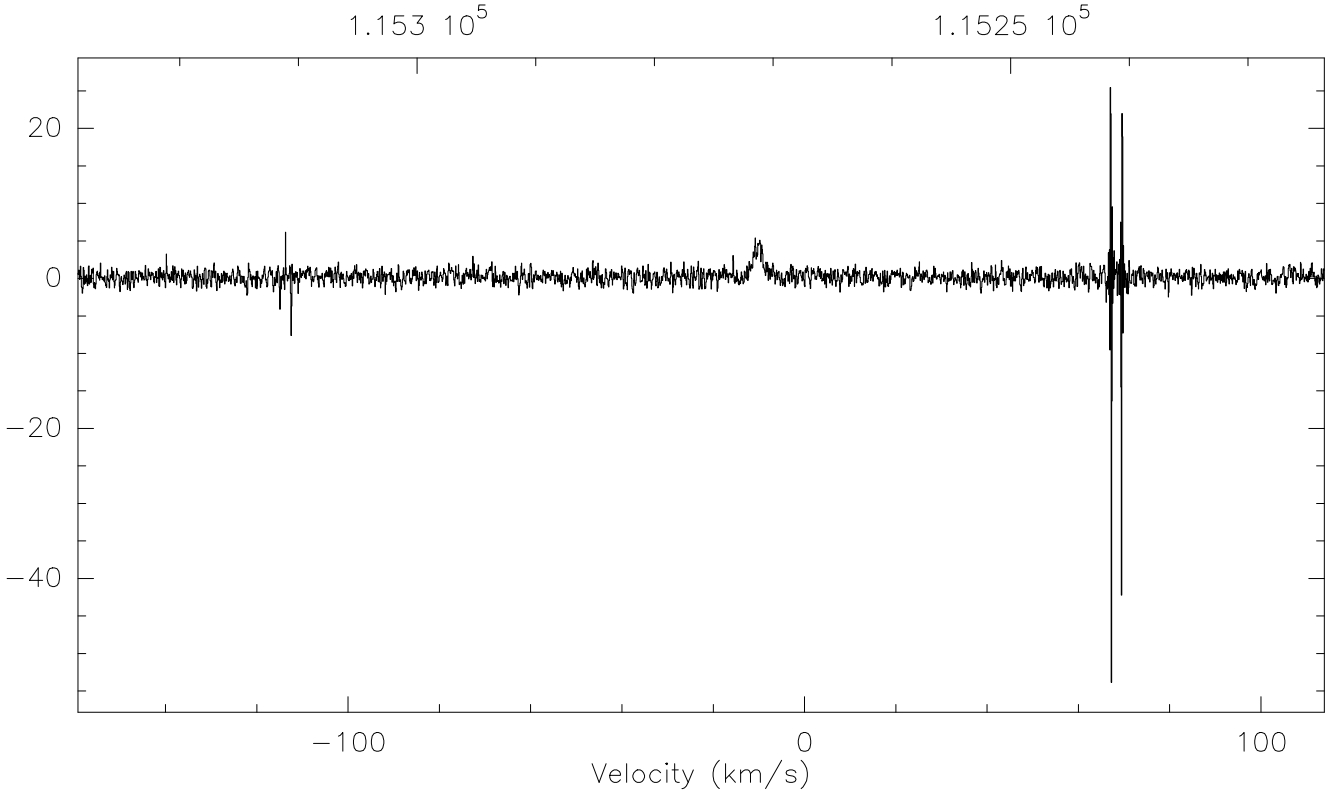
```
LAS> extract 86740 86770 F      ! => Extract 30 MHz from 86740 to 86770 MHz
LAS> modify frequency 86754.29 ! => Align the velocity axis on the new rest frequency
LAS> plot                       ! => Plot the extracted spectrum
```



Data exploration: III. What does the data look like?

```
LAS> set unit v f  ! => Bottom axis in velocity, top axis in frequency
LAS> get first     ! Get first spectrum of index
LAS> plot
```

```
16;  4 B0355+508    12CO(1-0)    30M-V01-A100 O:12-SEP-2005 R:23-AUG-2009
  RA:  03:59:29.74  DEC:   50:57:50.1  Eq 2000.0 Offs:    -65.6      -100.0
     Unknown   tau:   0.324  Tsys:   212.  Time:  1.67E-02min  El: 76.0
   N:   2689 I0:  1220.20          V0:  -10.00      Dv: -0.1016      LSR
        F0:   115271.204      Df:  3.9063E-02  Fi:   118267.104
```

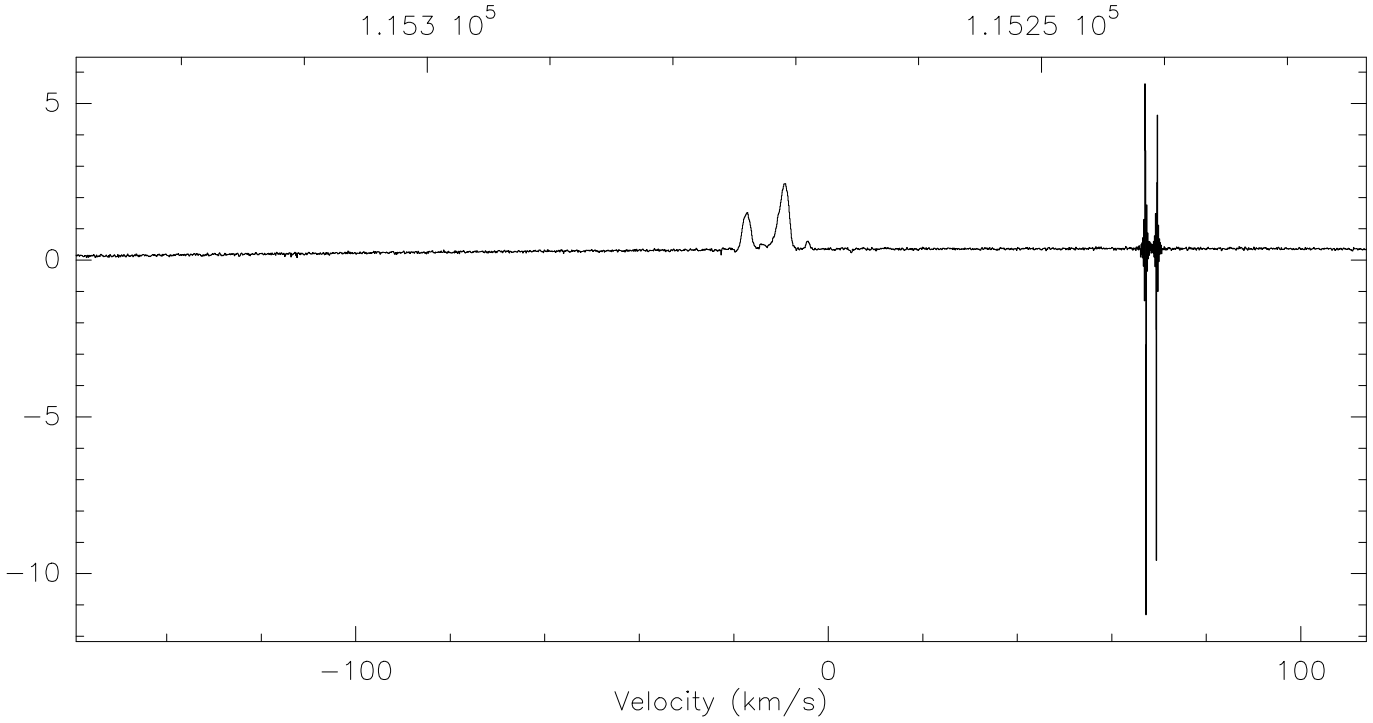


- Line + Spike visible.
- ```
  LAS> get next
  LAS> plot
  LAS> get next
  LAS> plot...
  ```
  8000 times ⇒ a bit long...
  ```

Data exploration: III. What does the data look like?

```
LAS> set nomatch      ! Disable check about position consistency
LAS> set align f c    ! Toggle frequency resampling
LAS> average          ! Average all spectra in index
LAS> plot
```

```
1;  4 B0355+508    12CO(1-0)    30M-V01-A100 O:12-SEP-2005 R:23-AUG-2009
 RA:  03:59:29.74  DEC:   50:57:50.1  Eq 2000.0 Offs:   +108.0       +60.0
     Unknown   tau:   0.334  Tsys:   236.  Time:   72.    min  El: 51.8
  N:   2689 I0:   1220.20          V0:  -10.00      Dv: -0.1016      LSR
       F0:   115271.204      Df:  3.9063E-02  Fi:   118267.104
```

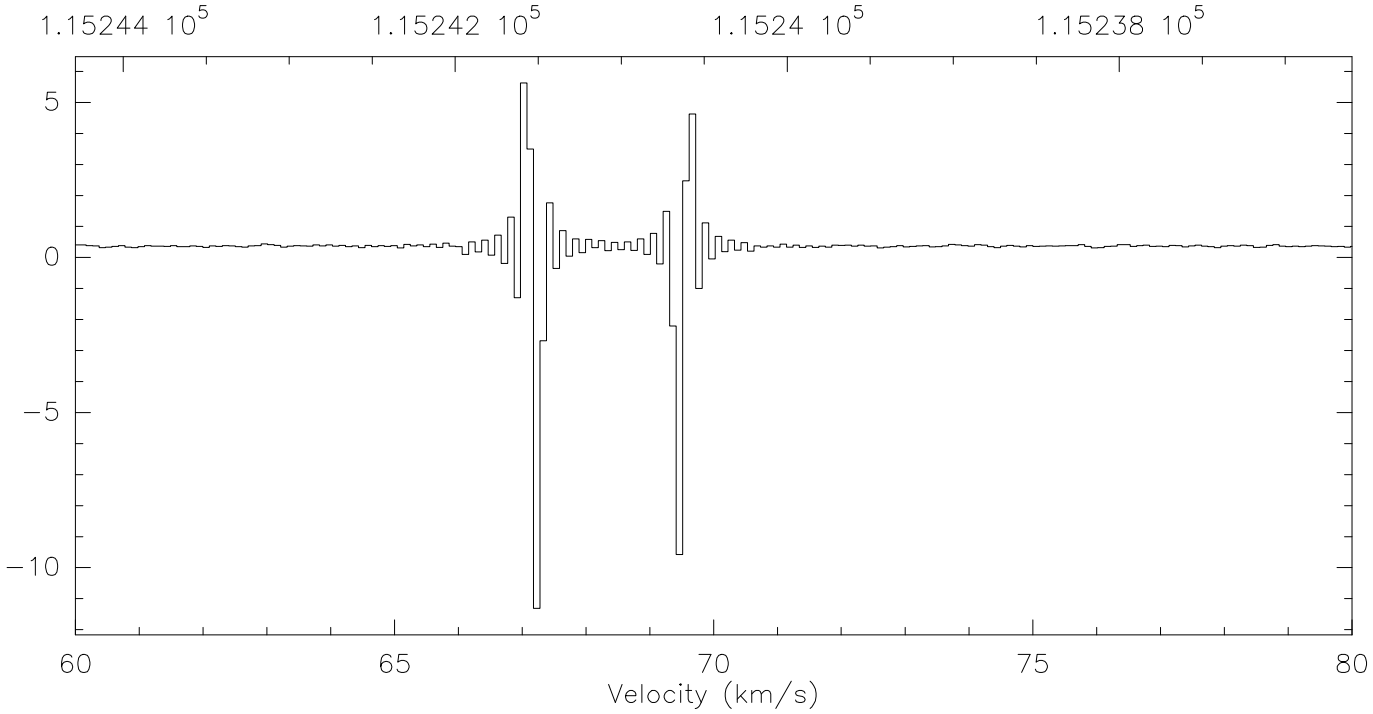


Line + Spike + platforming visible.

Data exploration: III. What does the data look like?

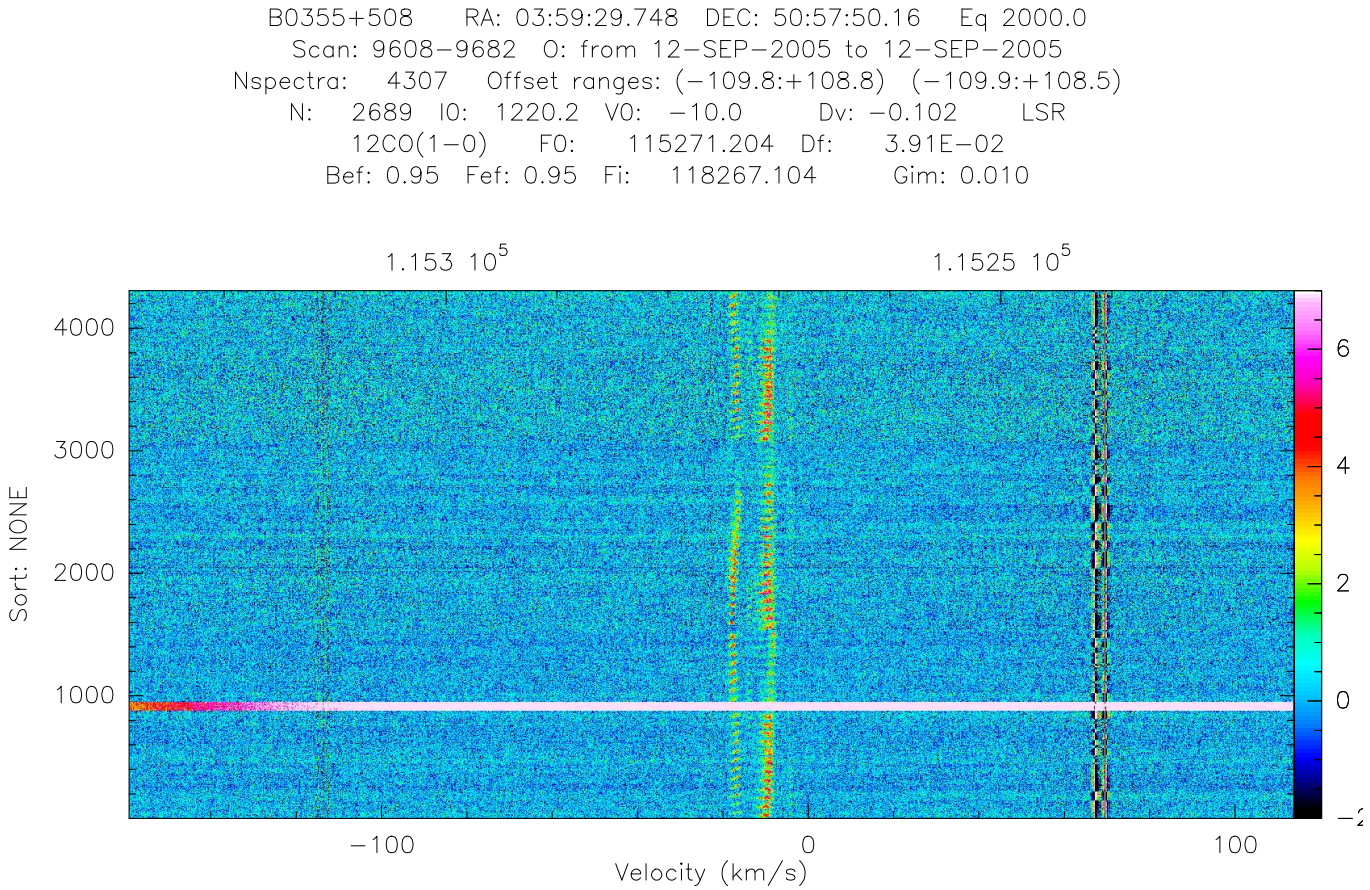
```
LAS> set mode x 60 80 ! => Zoom on spike
LAS> plot
LAS> set mode x total ! => Zoom back
LAS> plot
```

```
1;  4 B0355+508    12CO(1-0)    30M-V01-A100 0:12-SEP-2005 R:23-AUG-2009
  RA:  03:59:29.74  DEC:   50:57:50.1  Eq 2000.0 Offs:   +108.0      +60.0
       Unknown   tau:   0.334  Tsys:   236.  Time:   72.    min  El: 51.8
   N:   2689 I0:  1220.20          V0:  -10.00      Dv: -0.1016      LSR
        F0:   115271.204      Df:  3.9063E-02  Fi:   118267.104
```



Data exploration: III. What does the data look like?

```
LAS> find /tel 30M-V01-A100
LAS> load         ! Load the spectra in the current index as an image
LAS> plot /index ! Plot the image
```

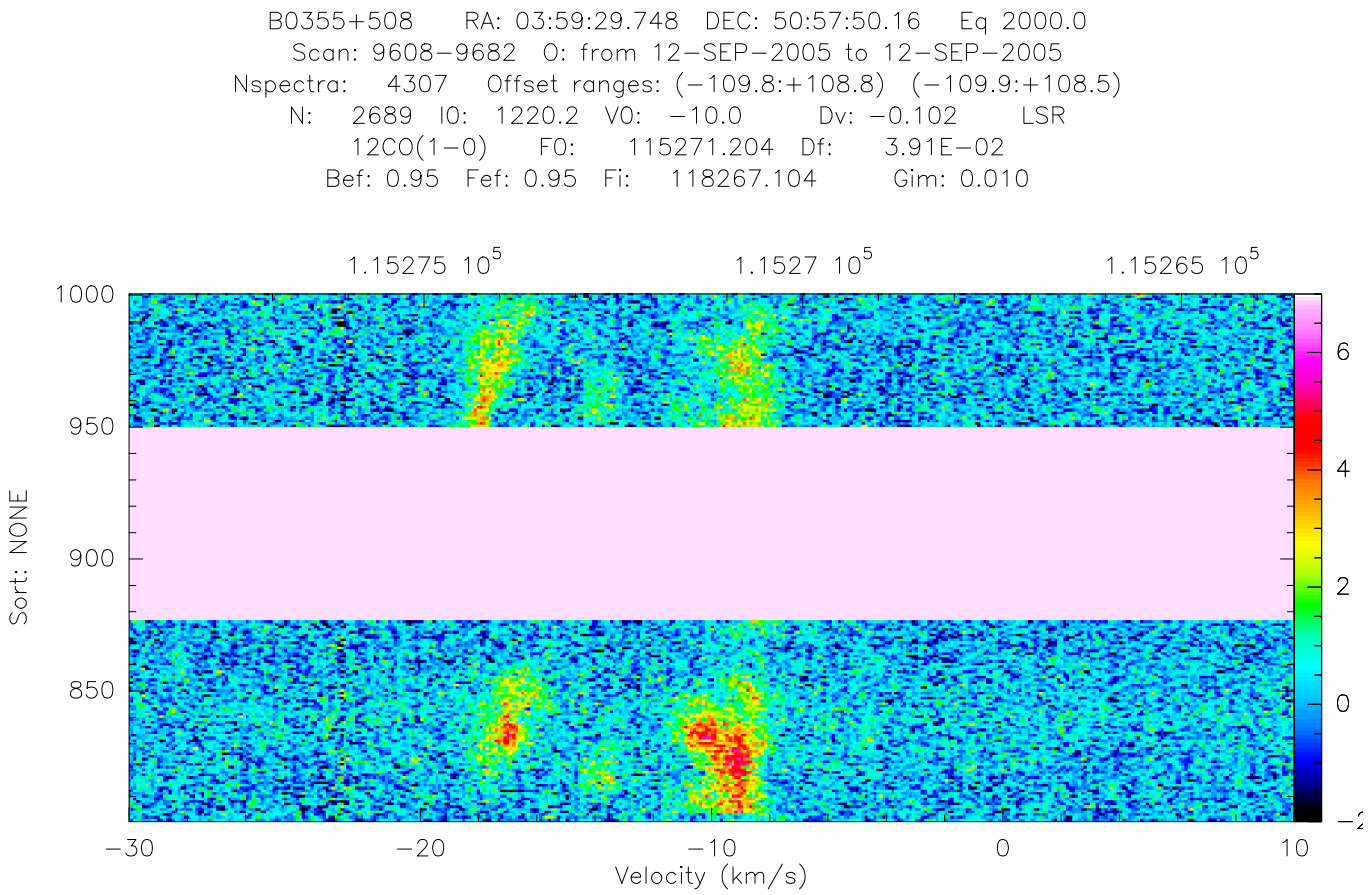


- Line + Spike visible.
- Variation of continuum level before baselining.
- 4000 spectra displayed at the same time.
- Possibility to quickly swap between average and image:

  ```
  LAS> plot
  LAS> plot /index
  LAS> plot
  ```

Data exploration: III. What does the data look like?

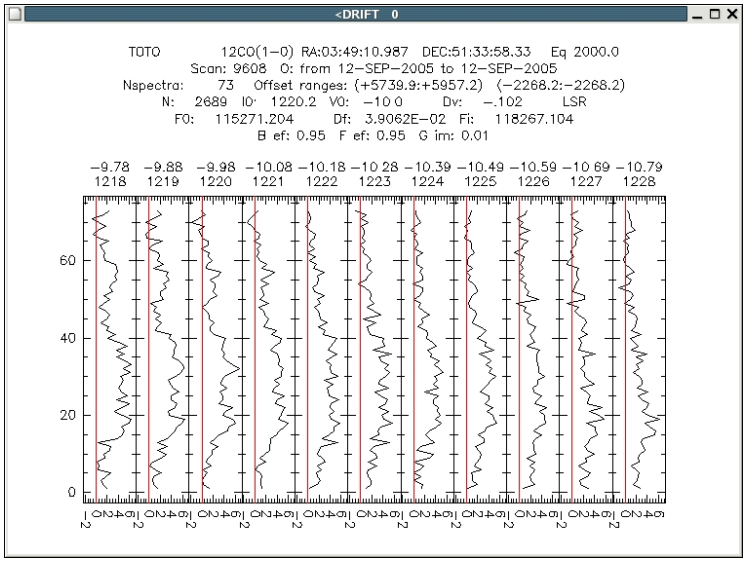
```
LAS> set mode x -30 10     ! Velocity zoom
LAS> set mode y -1 5       ! Intensity zoom
LAS> set mode z 800 1000   ! Index part zoom
LAS> plot /index
```

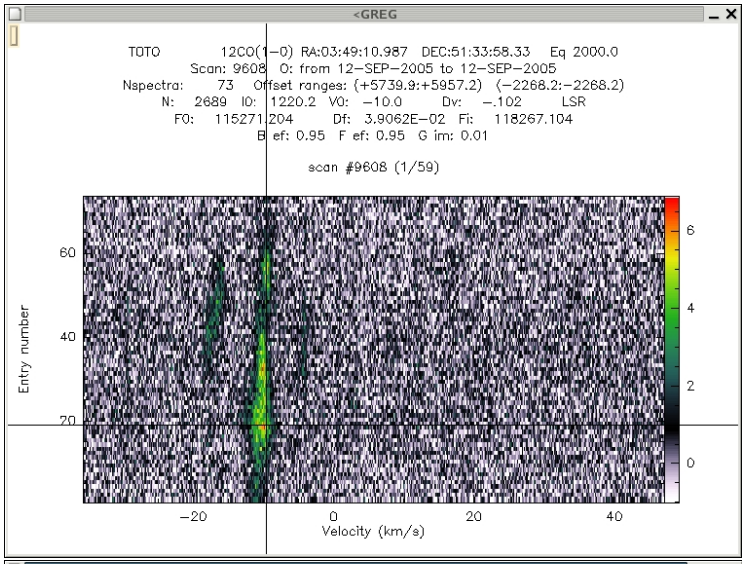


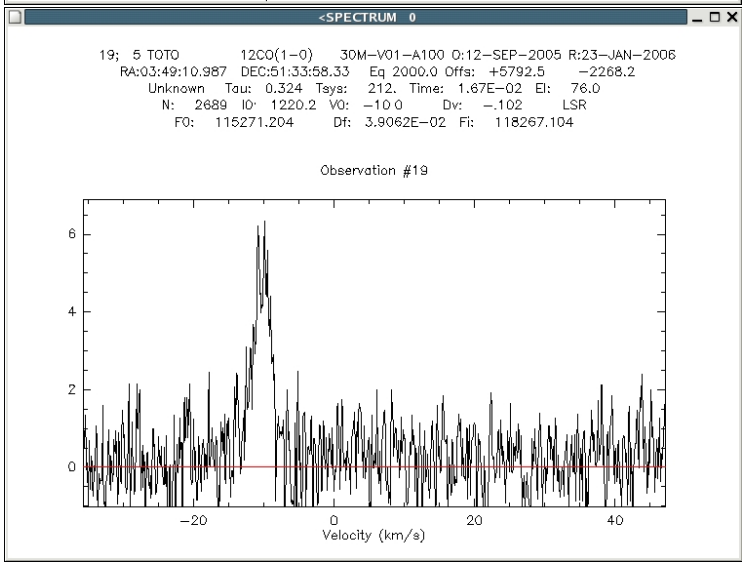
- Line + Spike visible.
- Image saturation due to variation of the continuum level.

Data exploration: III. What does the data look like?

All previous possibilities integrated in an exploration tool:
Look at the `Explore Data File` in the `CLASS` main menu.



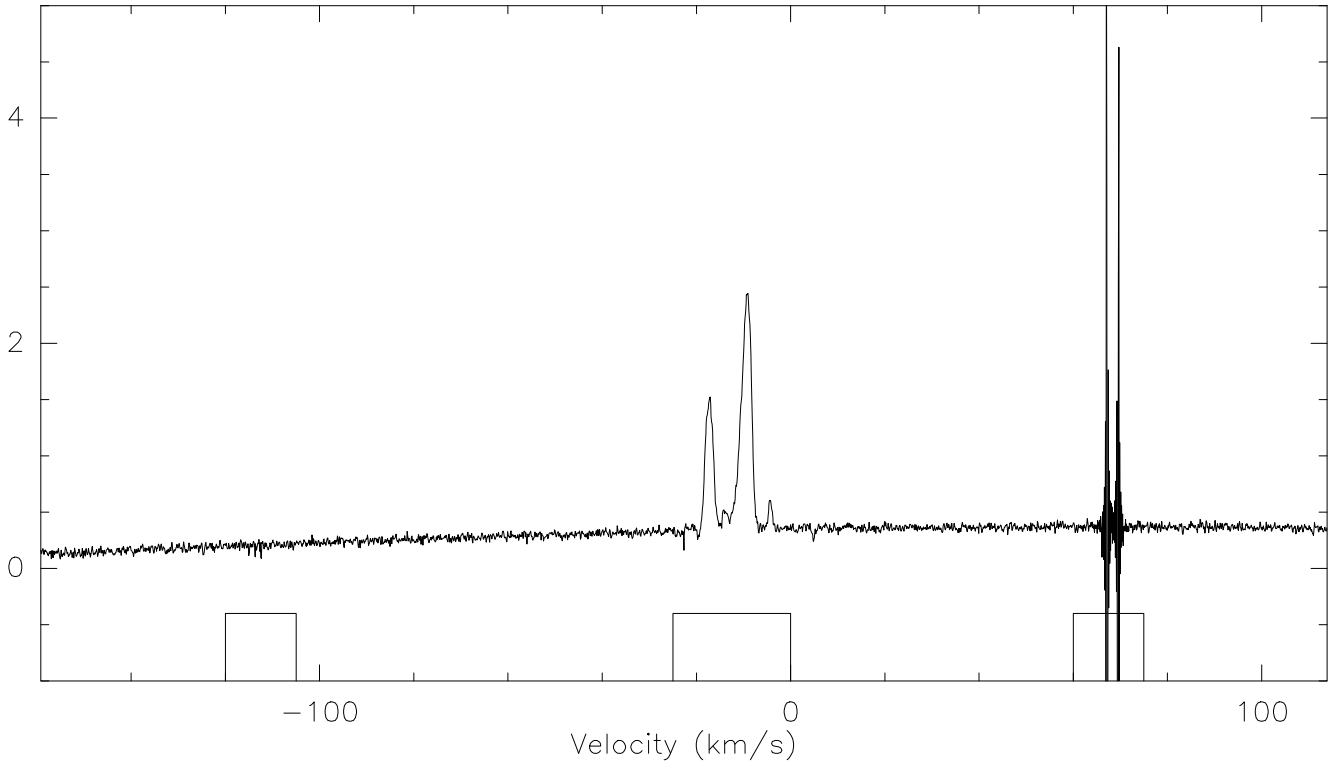




Data reduction: I. Windowing

```
LAS> average
LAS> plot
LAS> set window -120 -105 -25 0 60 75   ! Define the windows
LAS> draw window                        ! Overplot the windows
```

```
1;  4 B0355+508    12CO(1-0)    30M-V01-A100 O:12-SEP-2005 R:23-AUG-2009
  RA:  03:59:29.74  DEC:   50:57:50.1  Eq 2000.0 Offs:   +108.0      +60.0
       Unknown   tau:   0.334  Tsys:   236.  Time:   72.    min  El: 51.8
   N:   2689 I0:  1220.20          V0:  -10.00      Dv: -0.1016      LSR
        F0:   115271.204      Df:  3.9063E-02  Fi:   118267.104
```

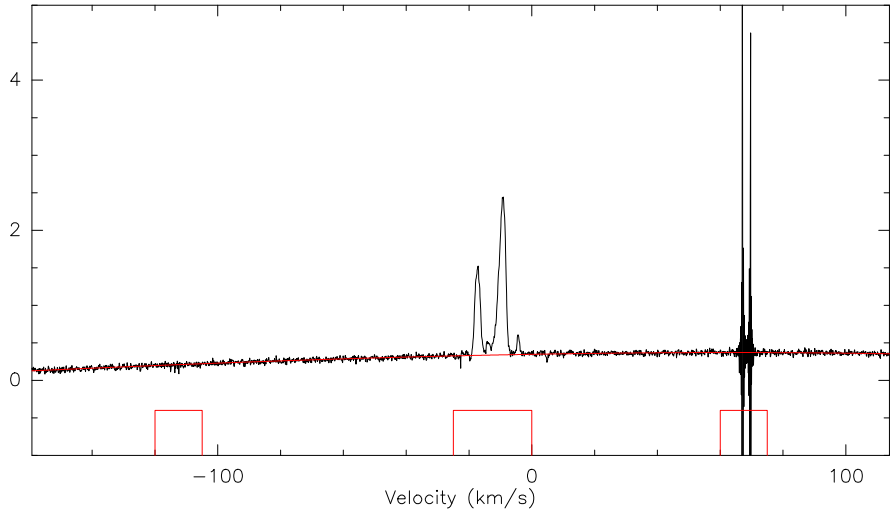


- One window to avoid the signal
- two windows to avoid the spikes

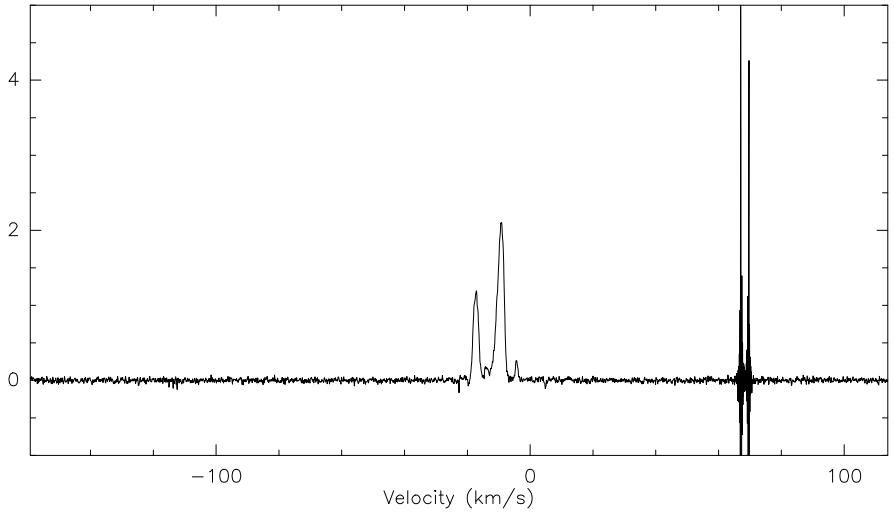
Data reduction: II. Selecting baseline order

```
LAS> base 0 /plot      ! Fit 0-order baseline and overplot baseline polynomial
I-POLYNO,  degree:   0 rms: 7.942E-02 area:  7.87     v0:-21.98     width: 0.000
LAS> swap              ! Get back averaged spectrum before baselining
LAS> clear segment     ! Clear overplotted baseline
LAS> base 1 /plot      ! Increase baseline polynomial order and check residual rms
I-POLYNO,  degree:   1 rms: 3.559E-02 area:  7.58     v0:-26.01     width: 0.000
LAS> swap; clear segment
LAS> base 2 /plot      ! Increase baseline polynomial order and check residual rms
I-POLYNO,  degree:   2 rms: 2.292E-02 area:  7.02     v0:-25.84     width: 0.000
LAS> plot              ! Plot baselined spectra
```

1; 4 B0355+508 12CO(1−0) 30M−V01−A100 0:12−SEP−2005 R:23−AUG−2009
RA: 03:59:29.74 DEC: 50:57:50.1 Eq 2000.0 Offs: +108.0 +60.0
Unknown tau: 0.334 Tsys: 236. Time: 72. min El: 51.8
N: 2689 I0: 1220.20 V0: −10.00 Dv: −0.1016 LSR
F0: 115271.204 Df: 3.9063E−02 Fi: 118267.104

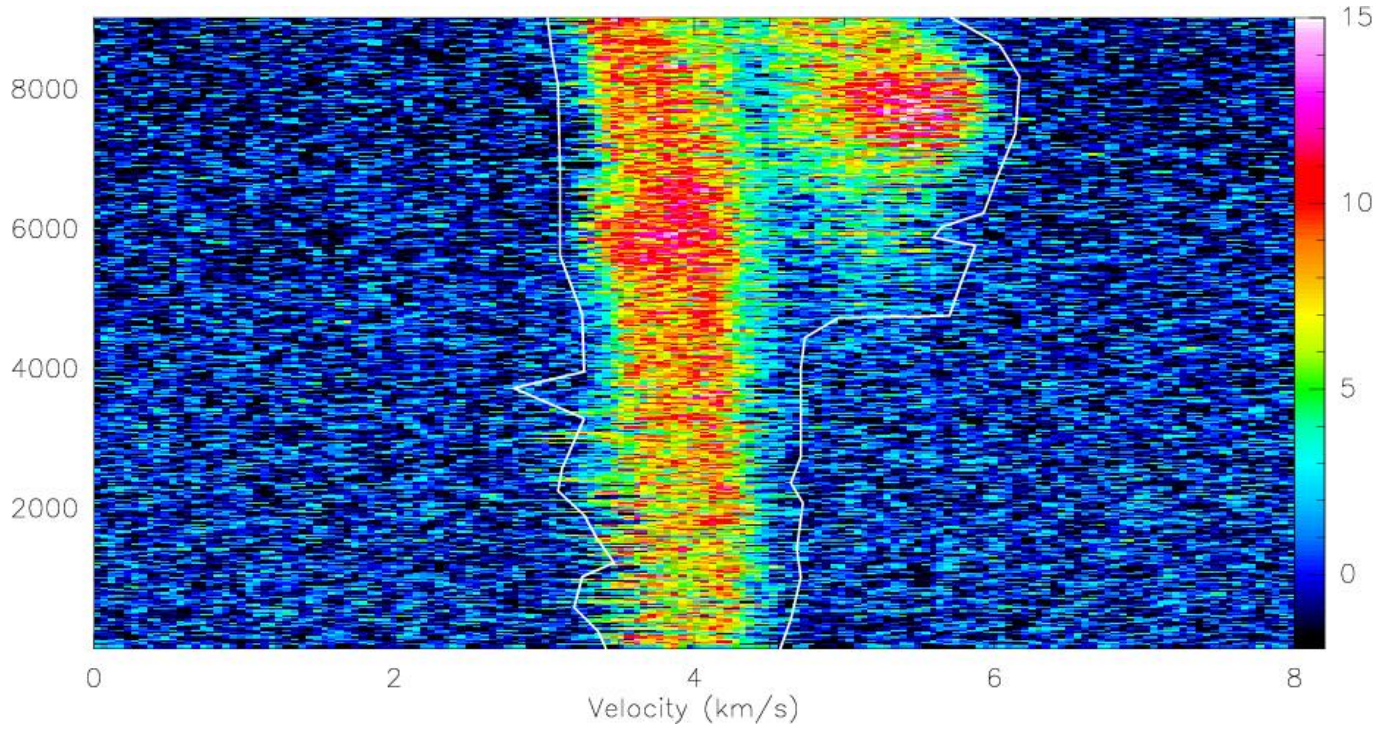


1; 4 B0355+508 12CO(1−0) 30M−V01−A100 0:12−SEP−2005 R:23−AUG−2009
RA: 03:59:29.74 DEC: 50:57:50.1 Eq 2000.0 Offs: +108.0 +60.0
Unknown tau: 0.334 Tsys: 236. Time: 72. min El: 51.8
N: 2689 I0: 1220.20 V0: −10.00 Dv: −0.1016 LSR
F0: 115271.204 Df: 3.9063E−02 Fi: 118267.104



Data reduction: III. Signal dependent window

```
LAS> plot /index          ! Plot the whole set of spectrum
LAS> set window /poly 1   ! Define 1 polygon
```



Data reduction: III. Looping on the index

Implicit loops provided by some commands (/INDEX option):

```
LAS> extract ...         ! Process current spectrum only (updated in memory)
LAS> extract ... /index  ! Process all spectra in index (FILE IN to FILE OUT)
```

Explicit loops for custom processing:

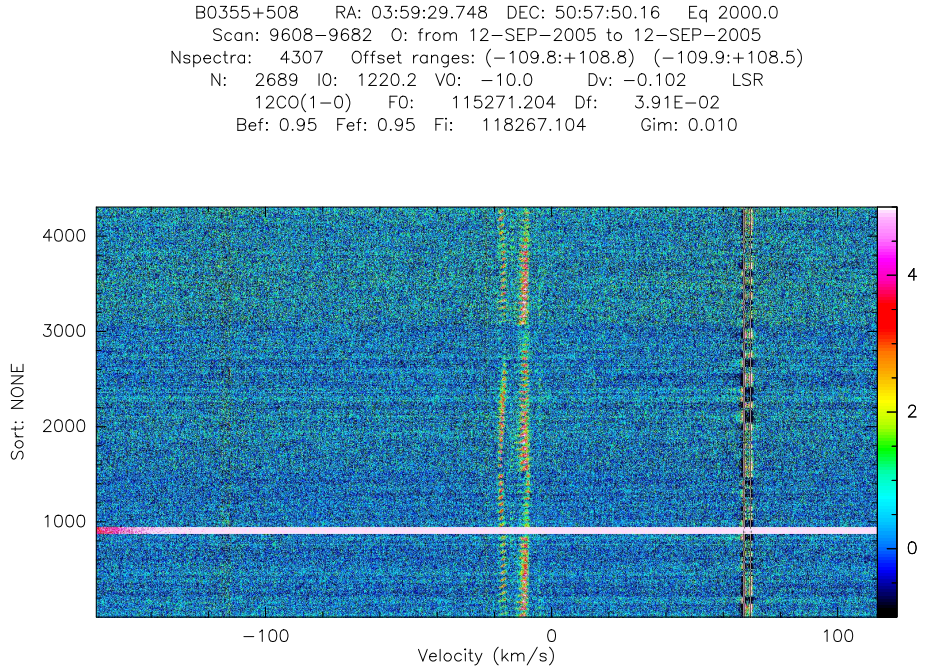
```
LAS> file in ...
LAS> find ...                ! Load the current index of spectra
LAS> file out ...
LAS> quiet                   ! Turn off informational messages
LAS> for ient 1 to found     ! Loop over the current index entries
LAS>    get next             ! Get next spectrum in index into R
LAS>    ...                  ! Your job here
LAS>    write                ! Write updated R version
LAS> next ient
LAS> verbose                 ! Turn on informational messages
```

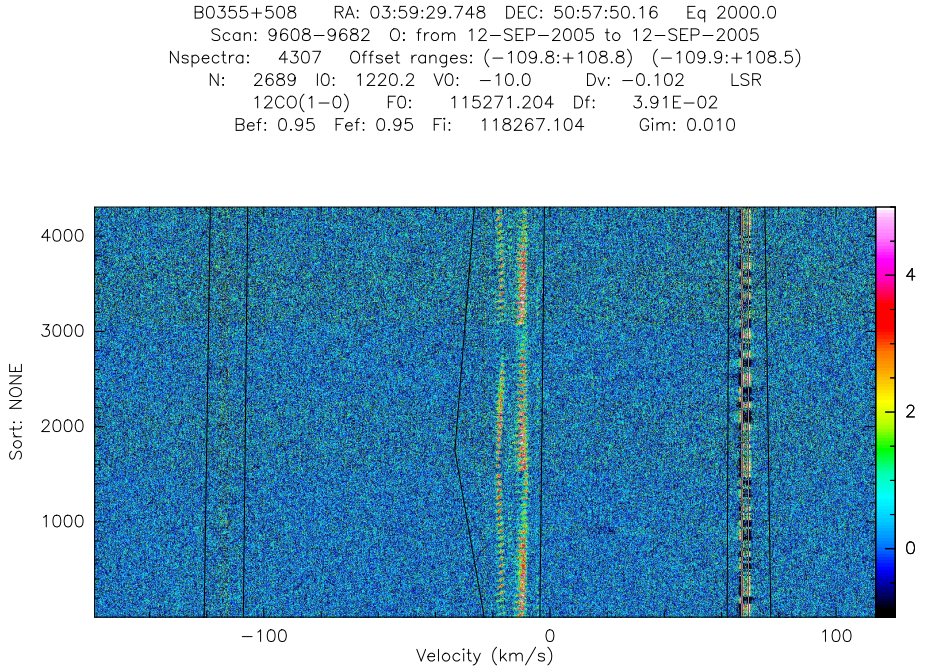
Messages in terminal (there can be millions) slow down the processing. Turn them on/off through symbols (command aliases):

```
LAS> symbol verbose "sic message class s+i" ! Add (+) infos (i) to screen (s)
LAS> symbol quiet   "sic message class s-i" ! Remove (-) infos (i) from screen (s)
```

Data reduction: IV. Baselining

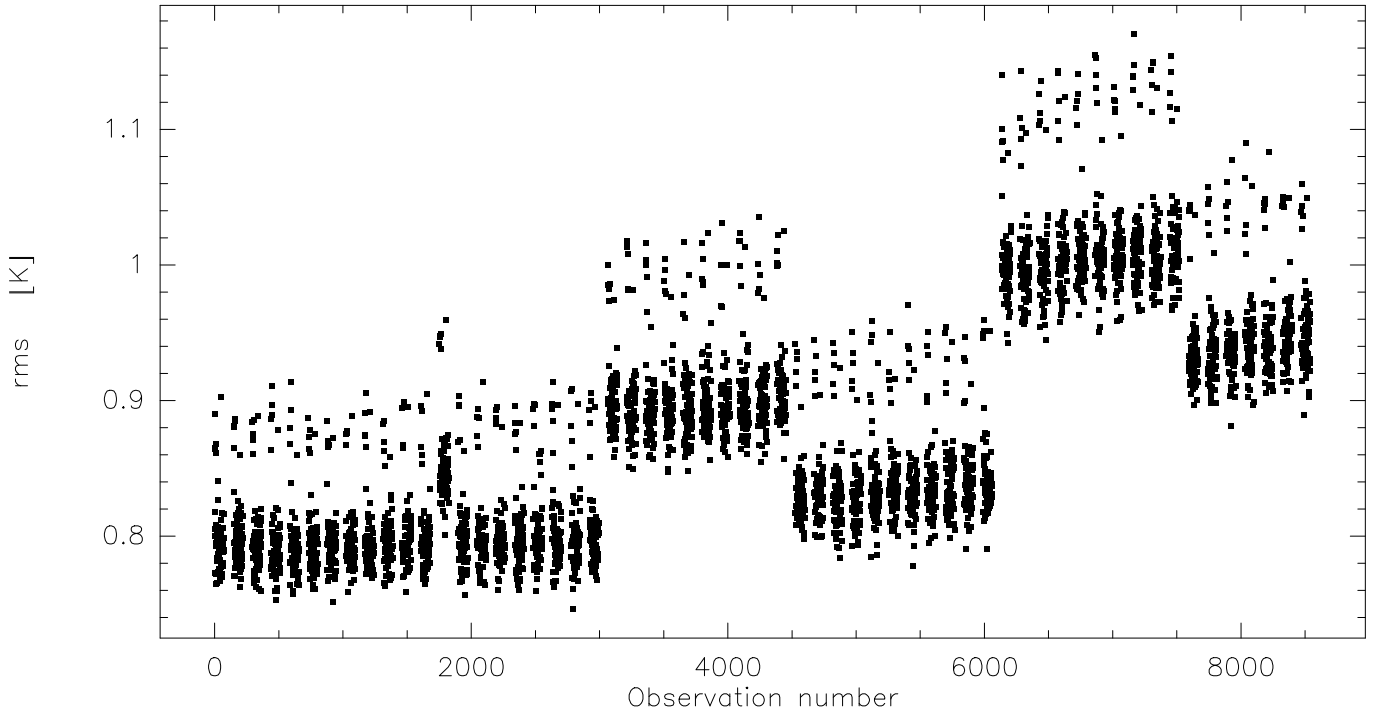
```
LAS> file out a100-base single /over  ! Open output file in single and overwrite modes
LAS> get zero                         ! Reset index counter to zero
LAS> quiet                            ! Turn off informational messages
LAS> for ient 1 to found              ! Loop over the index entries
LAS>    get next                      ! Get next spectra in index
LAS>    base 3                        ! Fit baseline and compute residual spectrum
LAS>    write                         ! Write residual spectrum in output file
LAS> next ient
LAS> verbose                          ! Turn on informational messages
```





Data reduction: V. Baseline RMS

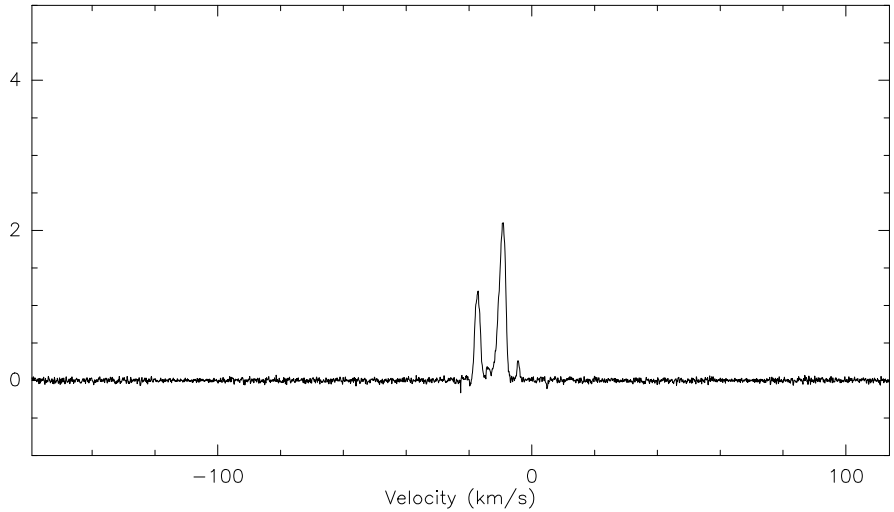
```
LAS> clear plot
LAS> file in a100-base     ! Open file of residual spectra as input
LAS> find
LAS> variable base /index  ! Fill variable IDX%HEAD%BAS% with values from all spectra
LAS> g\limit /var idx%num idx%head%bas%sigfi
LAS> g\box
LAS> g\set marker 4 3 0.15
LAS> g\point idx%num idx%head%bas%sigfi
LAS> g\label "Observation number" /X
LAS> g\label "rms   [K]" /Y
```



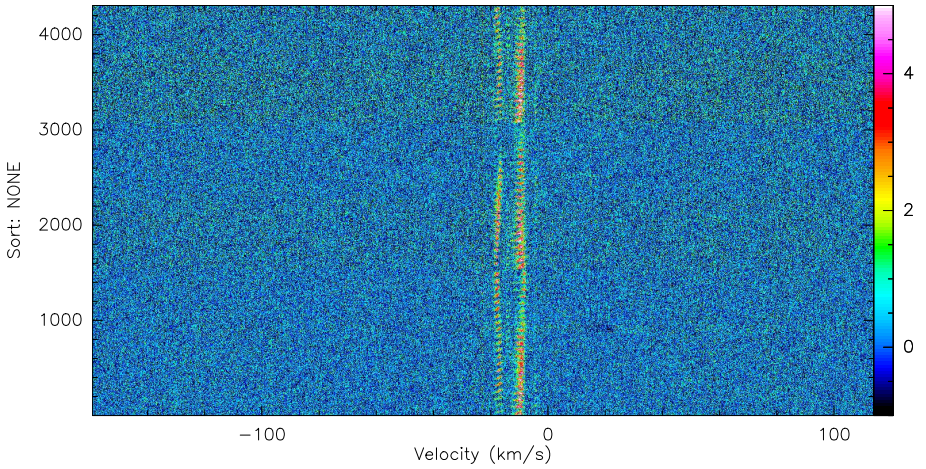
Data reduction: VI. "Despiking"

```
LAS> file out a100-fill single /over
LAS> find
LAS> for ient 1 to found
LAS>    get next
LAS>    fill -120 -100 60 75 /noise    ! Fill contaminated channels with Gaussian noise
LAS>    write
LAS> next ient
```

```
1;  6 B0355+508     12CO(1-0)     30M-V01-A100 O:12-SEP-2005 R:04-SEP-2009
  RA:  03:59:29.74  DEC:   50:57:50.1  Eq 2000.0 Offs:   +108.0        +60.0
       Unknown   tau:   0.334  Tsys:   236.  Time:   72.     min  El: 51.8
   N:   2689  I0:  1220.20          V0:  -10.00      Dv: -0.1016      LSR
        F0:   115271.204      Df:  3.9063E-02  Fi:   118267.104
```




```
B0355+508     RA: 03:59:29.748  DEC: 50:57:50.16   Eq 2000.0
Scan: 9608-9682  O: from 12-SEP-2005 to 12-SEP-2005
Nspectra:   4307   Offset ranges: (-109.8:+108.8)  (-109.9:+108.5)
N:   2689  I0:  1220.2  V0:  -10.0      Dv: -0.102      LSR
        12CO(1-0)     F0:    115271.204  Df:    3.91E-02
Bef: 0.95  Fef: 0.95  Fi:   118267.104      Gim: 0.010
```



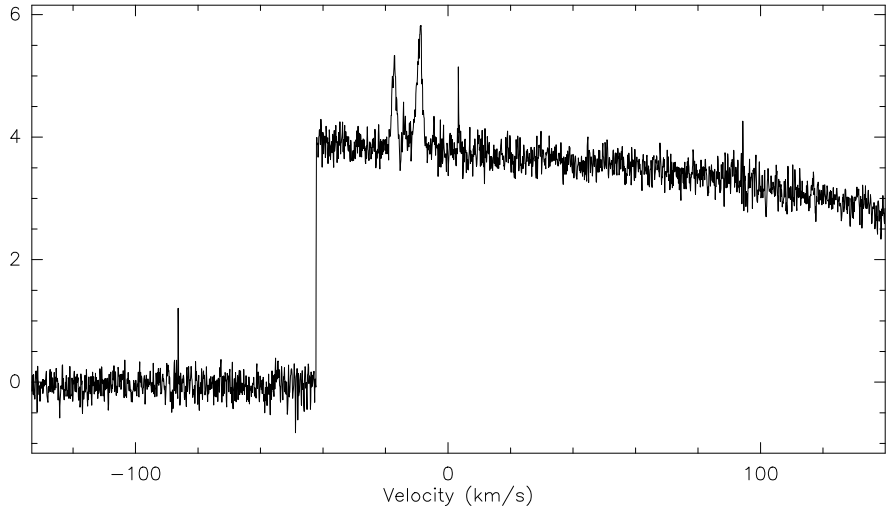
Data reduction: VII.1 Platforming diagnostic

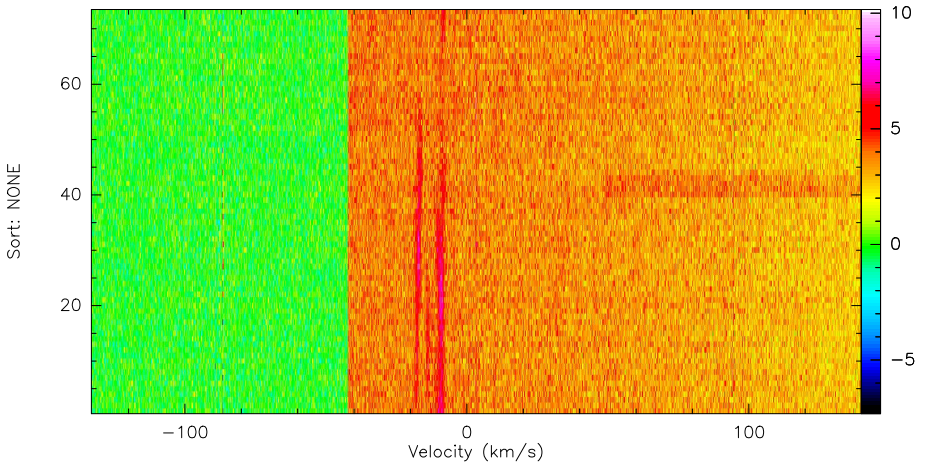
Platforming affects a single scan (#9621)
⇒ Copy all the 2nd receiver data in a file where correction will happen in-place.

```
LAS> set sort none
LAS> file out b100-plat multiple /over ! Multiple occurences of one spectrum enabled
LAS> copy
```

```
1826;  4 B0355+508     12CO(1−0)     30M−V02−B100 O:12−SEP−2005 R:23−AUG−2009
     RA:  03:59:29.74  DEC:   50:57:50.1  Eq 2000.0 Offs:   +107.8        +20.0
          Unknown    tau:   0.310  Tsys:   209.  Time:   1.2     min  El: 75.5
      N:   2689 I0:  1476.20          V0:  −10.00      Dv: −0.1016      LSR
           F0:   115271.204      Df:  3.9063E−02  Fi:   118267.104
```

```
B0355+508     RA: 03:59:29.748  DEC: 50:57:50.16    Eq 2000.0
     Scan: 9621   O: from 12−SEP−2005 to 12−SEP−2005
Nspectra:     73   Offset ranges: (−109.5:+107.8)  (+20.0:+20.0)
     N:   2689  I0:  1476.2  V0:  −10.0       Dv: −0.102      LSR
          12CO(1−0)     F0:     115271.204  Df:     3.91E−02
     Bef: 0.95  Fef: 0.95  Fi:    118267.104       Gim: 0.010
```

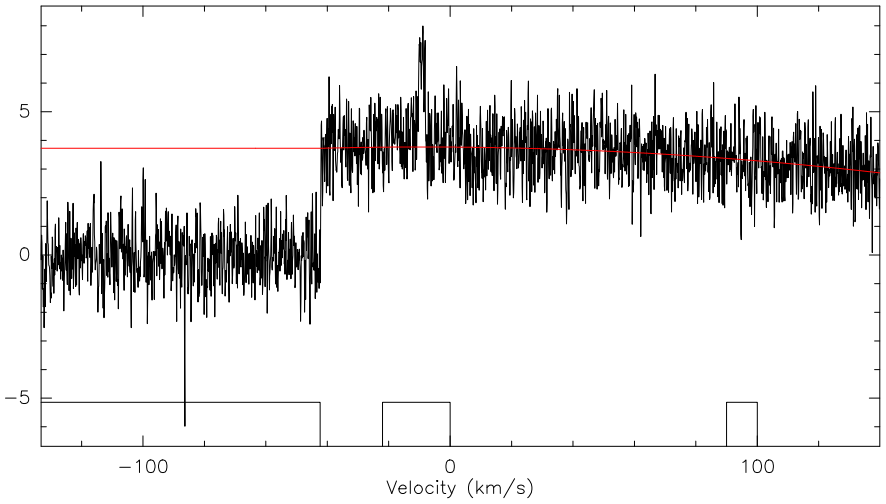




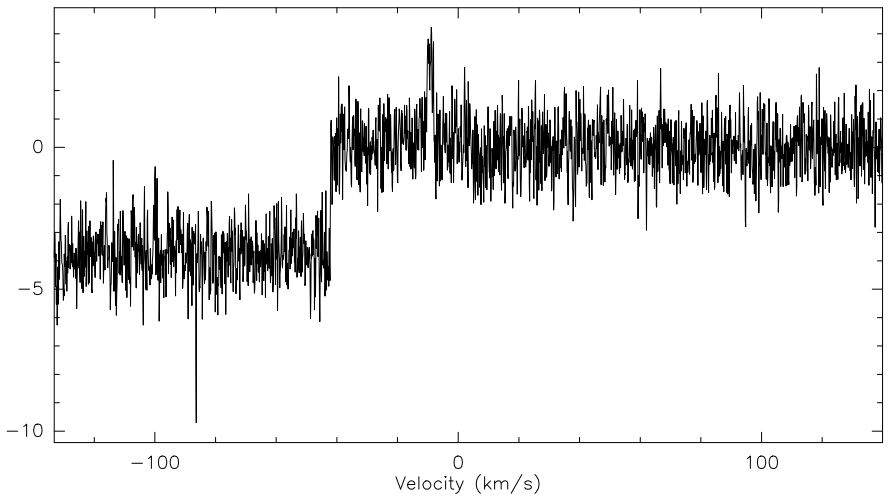
Data reduction: VII.2 Platforming correction #1

```
LAS> find /scan 9621
LAS> get first
LAS> define real ty /like ry   ! Define an intermediate array of intensities
LAS> get zero                  ! Reset index counter to zero
LAS> get next
LAS> plot
LAS> set window -200 -42.3 -22 0 90 100
LAS> base 2 /pl
LAS> let ty ry /where rx.gt.-42.3
```

1826; 4 B0355+508 12CO(1−0) 30M−V02−B100 0:12−SEP−2005 R:23−AUG−2009
RA: 03:59:29.74 DEC: 50:57:50.1 Eq 2000.0 Offs: −109.5 +20.0
Unknown tau: 0.310 Tsys: 209. Time: 1.67E−02min El: 75.6
N: 2689 I0: 1476.20 V0: −10.00 Dv: −0.1016 LSR
F0: 115271.204 Df: 3.9063E−02 Fi: 118267.104



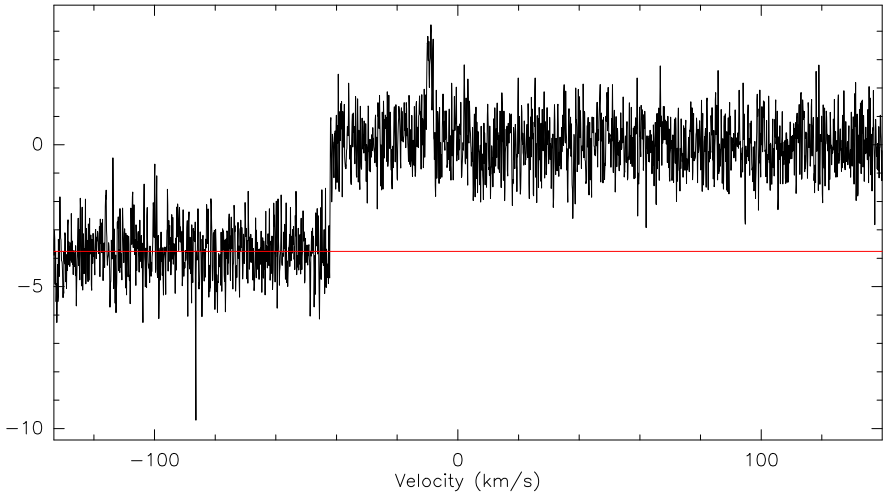
1826; 4 B0355+508 12CO(1−0) 30M−V02−B100 0:12−SEP−2005 R:23−AUG−2009
RA: 03:59:29.74 DEC: 50:57:50.1 Eq 2000.0 Offs: −109.5 +20.0
Unknown tau: 0.310 Tsys: 209. Time: 1.67E−02min El: 75.6
N: 2689 I0: 1476.20 V0: −10.00 Dv: −0.1016 LSR
F0: 115271.204 Df: 3.9063E−02 Fi: 118267.104



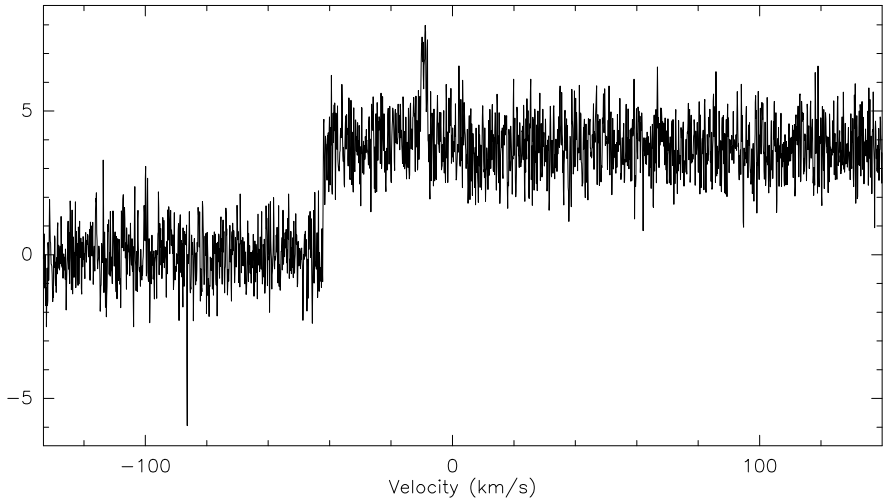
Data reduction: VII.3 Platforming correction #2

```
LAS> set window -95 -75 -42.3 +200
LAS> base 0 /pl
LAS> let ry ty /where rx.gt.-42.3
```

1826; 4 B0355+508 12CO(1−0) 30M−V02−B100 0:12−SEP−2005 R:23−AUG−2009
RA: 03:59:29.74 DEC: 50:57:50.1 Eq 2000.0 Offs: −109.5 +20.0
Unknown tau: 0.310 Tsys: 209. Time: 1.67E−02min El: 75.6
N: 2689 I0: 1476.20 V0: −10.00 Dv: −0.1016 LSR
F0: 115271.204 Df: 3.9063E−02 Fi: 118267.104



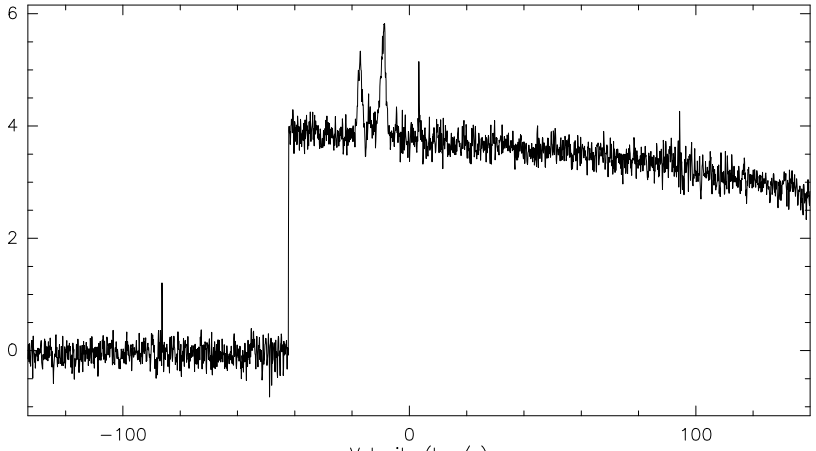
1826; 4 B0355+508 12CO(1−0) 30M−V02−B100 0:12−SEP−2005 R:23−AUG−2009
RA: 03:59:29.74 DEC: 50:57:50.1 Eq 2000.0 Offs: −109.5 +20.0
Unknown tau: 0.310 Tsys: 209. Time: 1.67E−02min El: 75.6
N: 2689 I0: 1476.20 V0: −10.00 Dv: −0.1016 LSR
F0: 115271.204 Df: 3.9063E−02 Fi: 118267.104

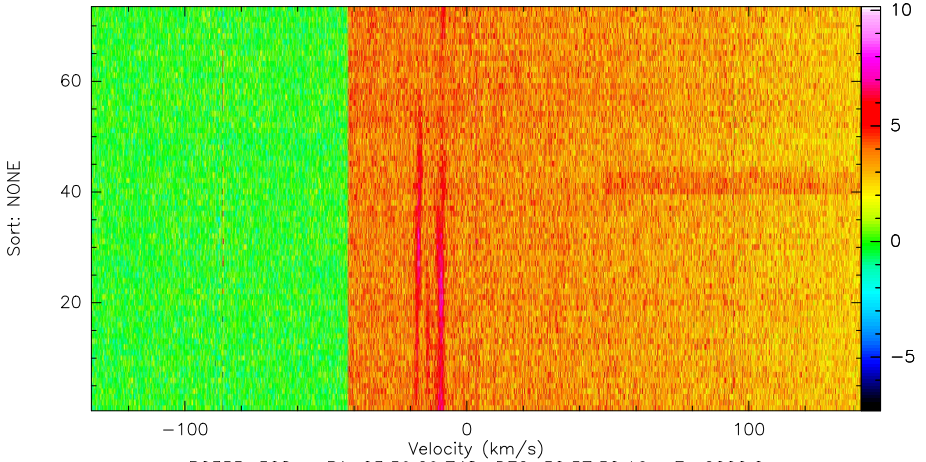


Data reduction: VII.4 After platforming correction

1826; 4 B0355+508 12CO(1−0) 30M−V02−B100 O:12−SEP−2005 R:23−AUG−2009
RA: 03:59:29.74 DEC: 50:57:50.1 Eq 2000.0 Offs: +107.8 +20.0
Unknown tau: 0.310 Tsys: 209. Time: 1.2 min El: 75.5
N: 2689 I0: 1476.20 V0: −10.00 Dv: −0.1016 LSR
F0: 115271.204 Df: 3.9063E−02 Fi: 118267.104

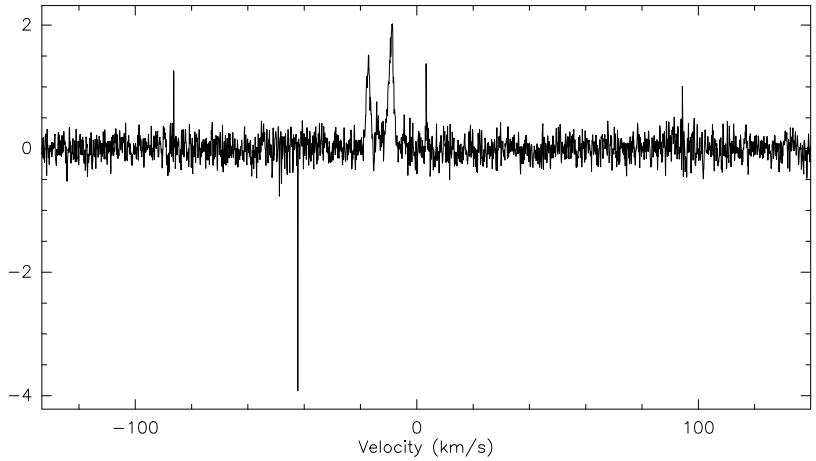
B0355+508 RA: 03:59:29.748 DEC: 50:57:50.16 Eq 2000.0
Scan: 9621 O: from 12−SEP−2005 to 12−SEP−2005
Nspectra: 73 Offset ranges: (−109.5:+107.8) (+20.0:+20.0)
N: 2689 I0: 1476.2 V0: −10.0 Dv: −0.102 LSR
12CO(1−0) F0: 115271.204 Df: 3.91E−02
Bef: 0.95 Fef: 0.95 Fi: 118267.104 Gim: 0.010

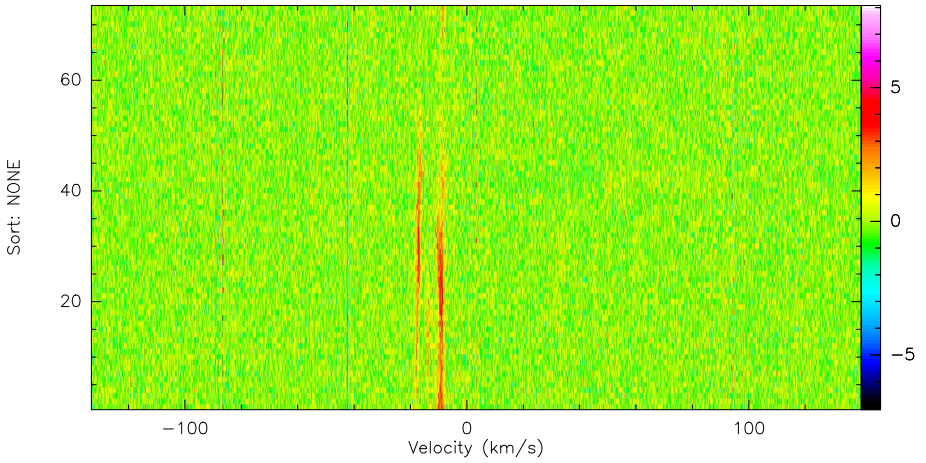




1826; 6 B0355+508 12CO(1−0) 30M−V02−B100 O:12−SEP−2005 R:04−SEP−2009
RA: 03:59:29.74 DEC: 50:57:50.1 Eq 2000.0 Offs: +107.8 +20.0
Unknown tau: 0.310 Tsys: 209. Time: 1.2 min El: 75.5
N: 2689 I0: 1476.20 V0: −10.00 Dv: −0.1016 LSR
F0: 115271.204 Df: 3.9063E−02 Fi: 118267.104

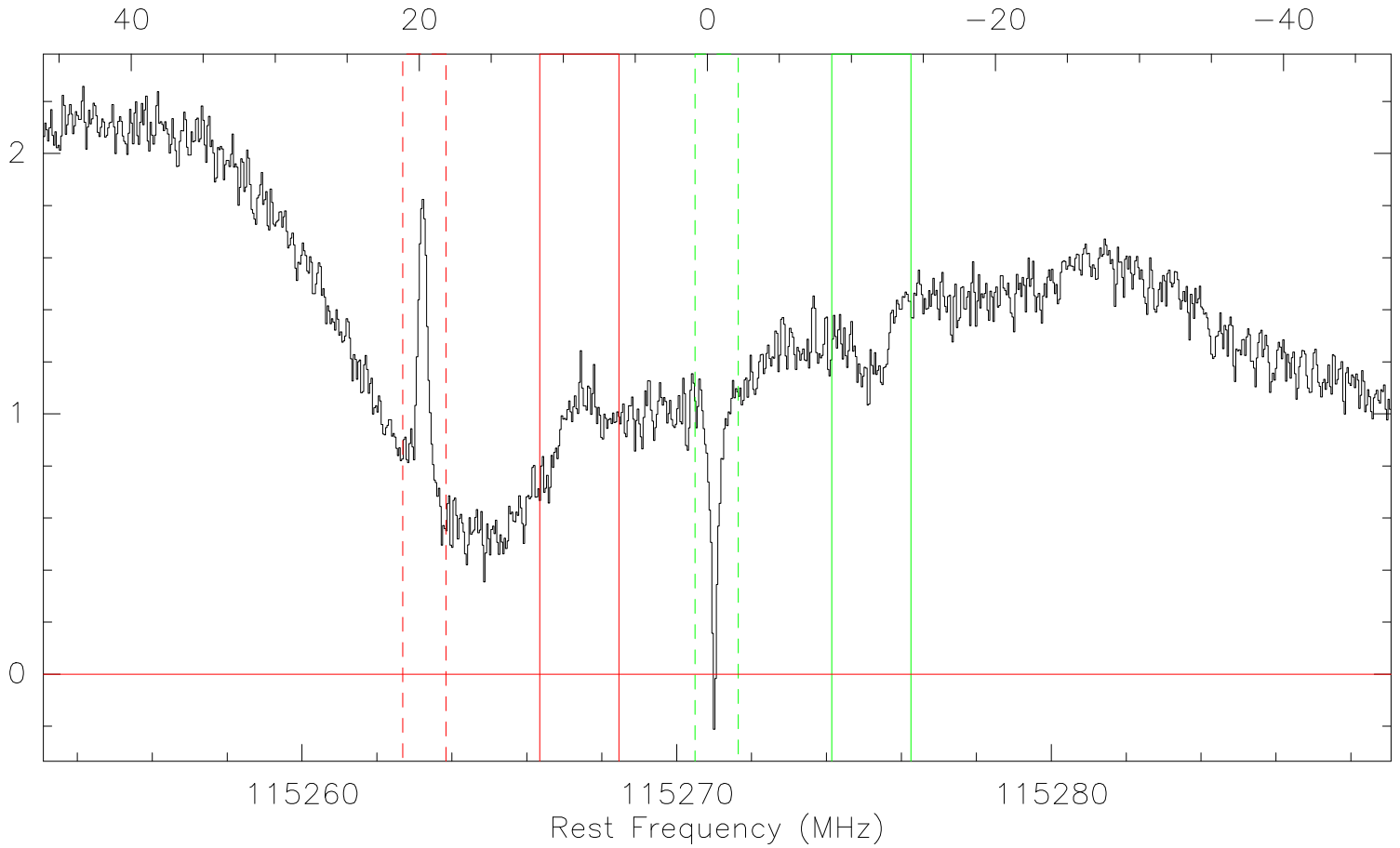
B0355+508 RA: 03:59:29.748 DEC: 50:57:50.16 Eq 2000.0
Scan: 9621 O: from 12−SEP−2005 to 12−SEP−2005
Nspectra: 73 Offset ranges: (−109.5:+107.8) (+20.0:+20.0)
N: 2689 I0: 1476.2 V0: −10.0 Dv: −0.102 LSR
12CO(1−0) F0: 115271.204 Df: 3.91E−02
Bef: 0.95 Fef: 0.95 Fi: 118267.104 Gim: 0.010





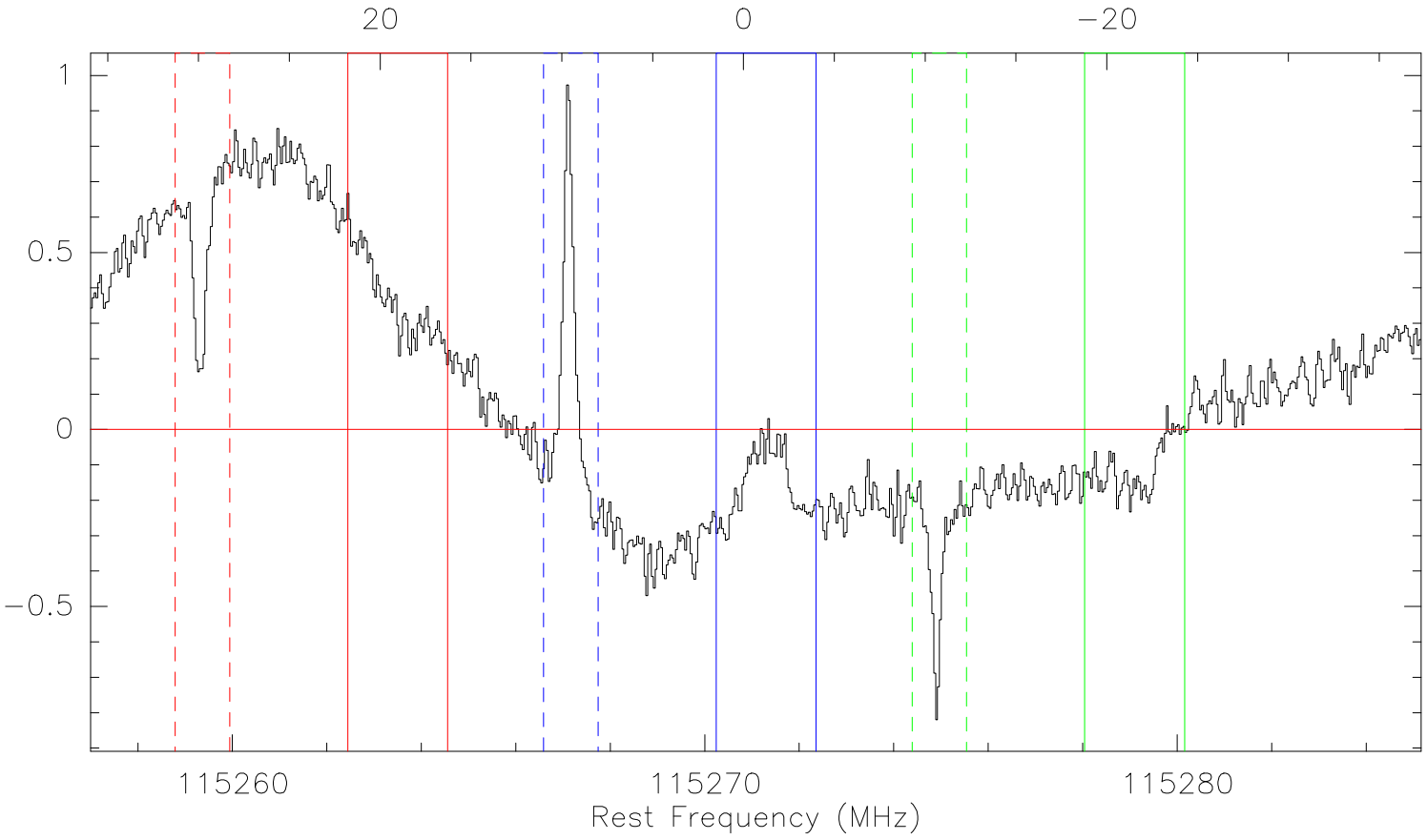
Data analysis: VIII.1 Line fitting

```
LAS> set unit f v
LAS> set mode a tot
LAS> file in off-positions
LAS> find /off -250 -30
LAS> consistency
LAS> aver
LAS> plot
```



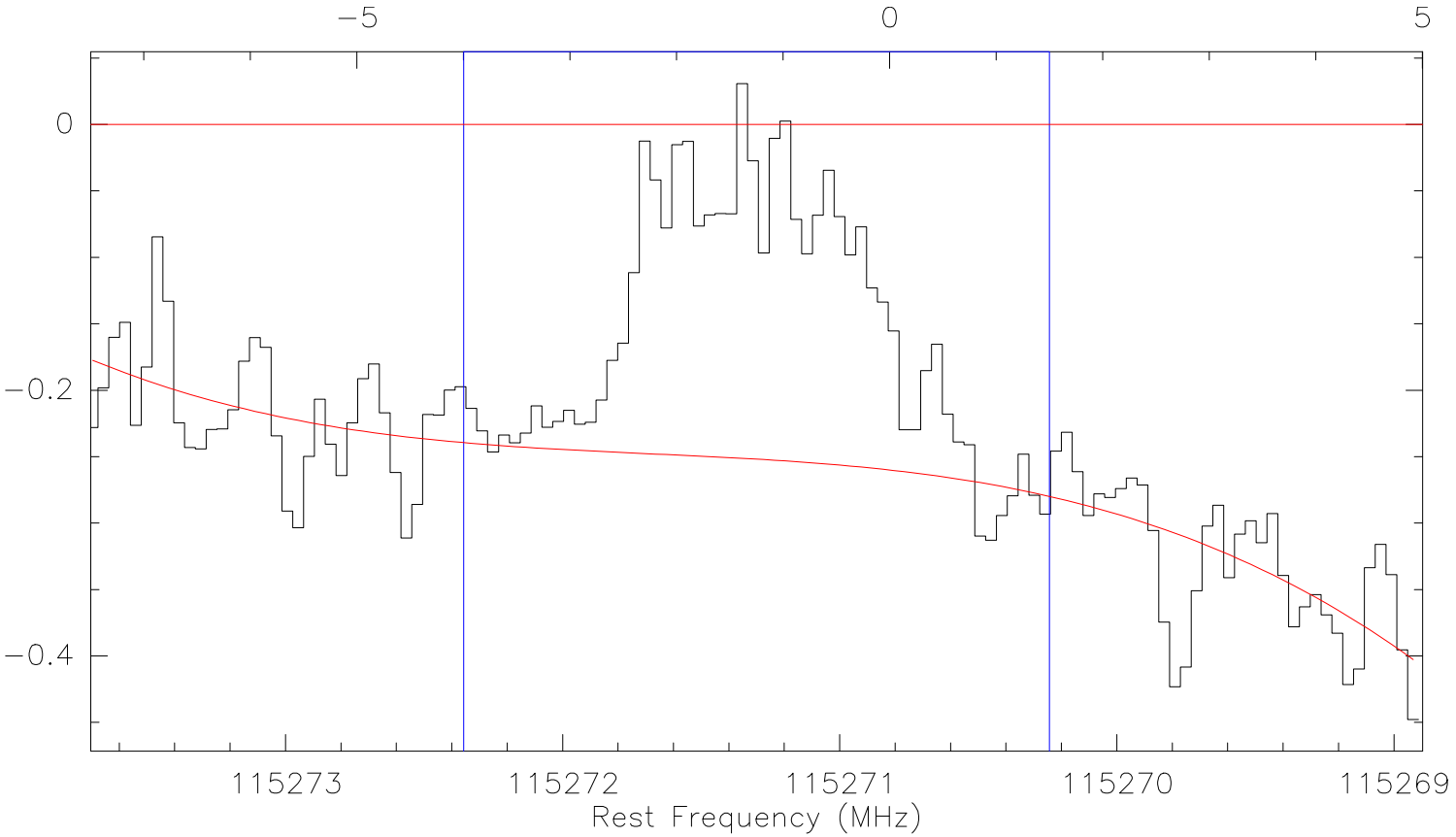
Data analysis: VIII.2 Line fitting

```
LAS> fold
LAS> plot
```



Data analysis: VIII.3 Line fitting

```
LAS> set mode x -7.5 5
LAS> set window -1.0 1.2
LAS> base 3 /plot
```



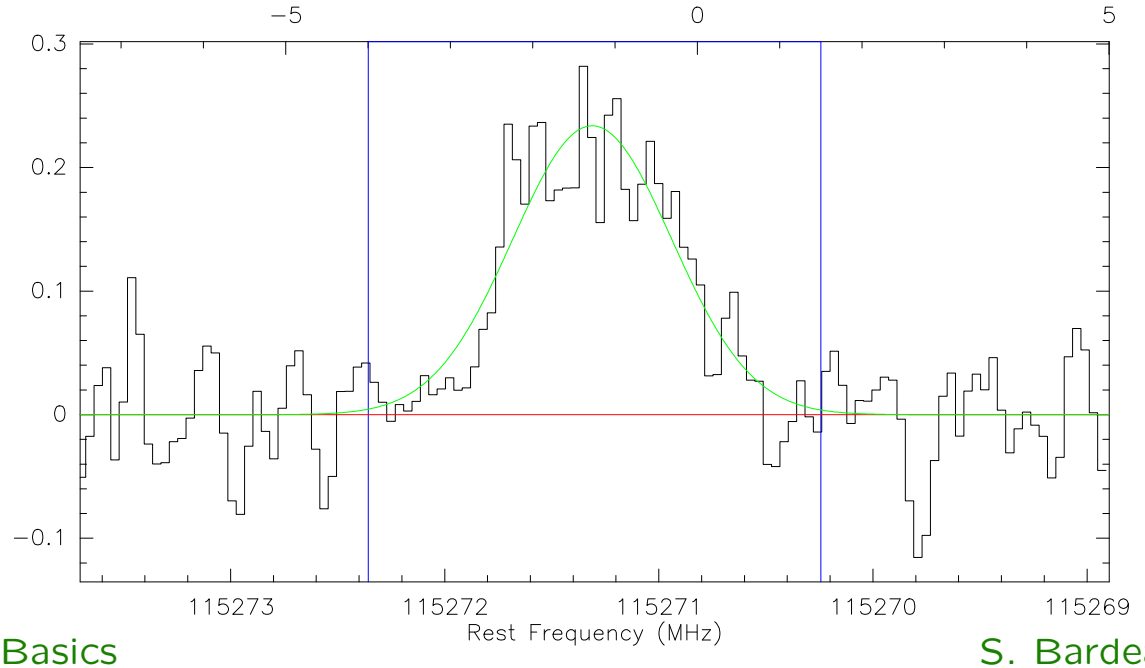
Data analysis: VIII.4 Line fitting

```
LAS> method gauss
LAS> lines 1 "0 0.2  0  0  0 0.9"
LAS> minimize
I-MIDGAUSS,  Input Parameters:  Area Position Fwhm
I-MIDGAUSS,   0.192      0.00      0.900
I-FITGAUSS,   RMS of Residuals :  Base =  4.17E-02  Line =  3.59E-02
I-FITGAUSS,   RMS of Residuals :  Base =  4.03E-02  Line =  3.76E-02
I-FITGAUSS,   Number of calls:           56

 Observation 0 RMS of Residuals :  Base =  4.03E-02  Line =  3.76E-02

          Fit results

 Line      Area                    Position            Width              Tpeak
 1    0.21791     (  0.011)     0.107 (  0.022)     0.875 (  0.048)  0.23384
    ! Beware results are in units of the lower axis (MHz here) !
LAS> visu /pen 2
```



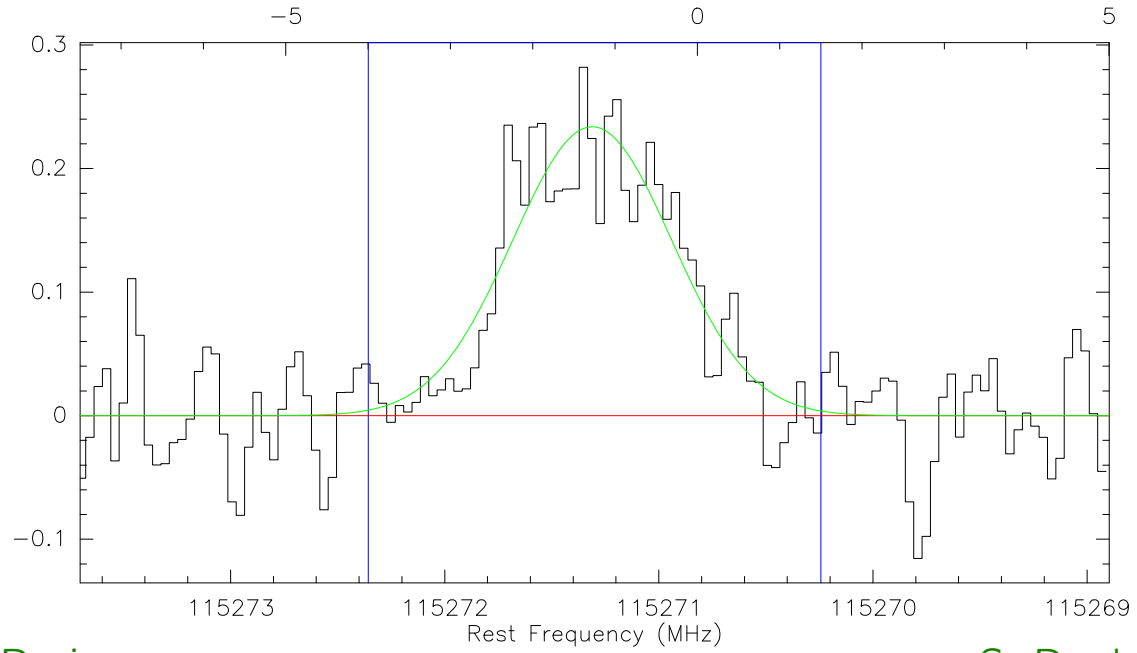
Data analysis: VIII.5 Line fitting

```
LAS> iterate
I-ITERATE,  Starting iteration #  1
I-MIDGAUSS,  Input Parameters:  Area Position Fwhm
I-MIDGAUSS,   0.218     0.107     0.875
I-FITGAUSS,   RMS of Residuals :  Base =  4.17E-02  Line =  3.59E-02
I-FITGAUSS,   RMS of Residuals :  Base =  4.03E-02  Line =  3.76E-02
I-FITGAUSS,   Number of calls:          25

 Observation 0 RMS of Residuals :  Base =  4.03E-02  Line =  3.76E-02

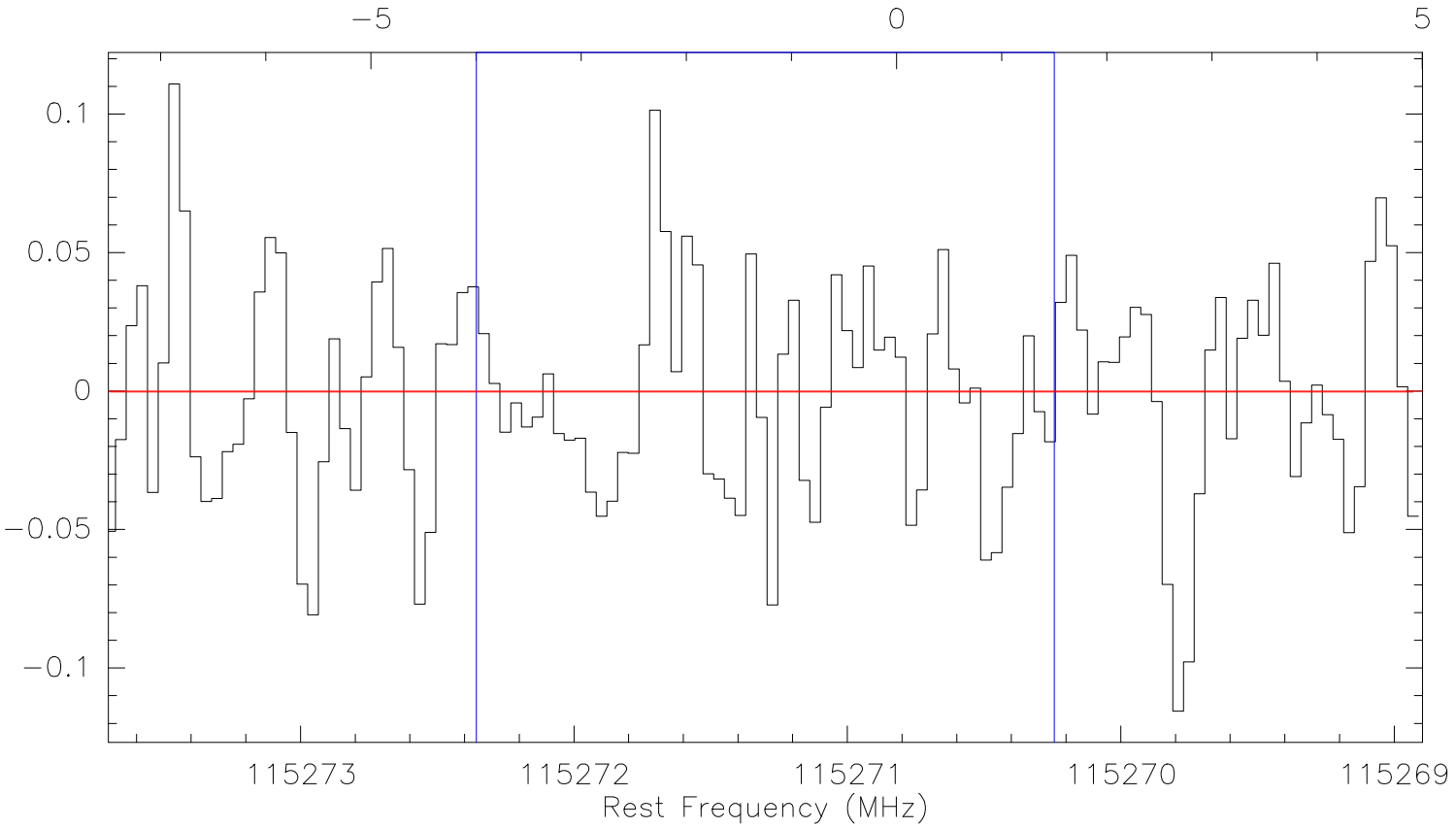
          Fit results

 Line      Area                    Position            Width              Tpeak
 1    0.21791     (  0.011)     0.107 (  0.022)     0.875 (  0.048)  0.23384
LAS> plot
LAS> visu /pen 2
```



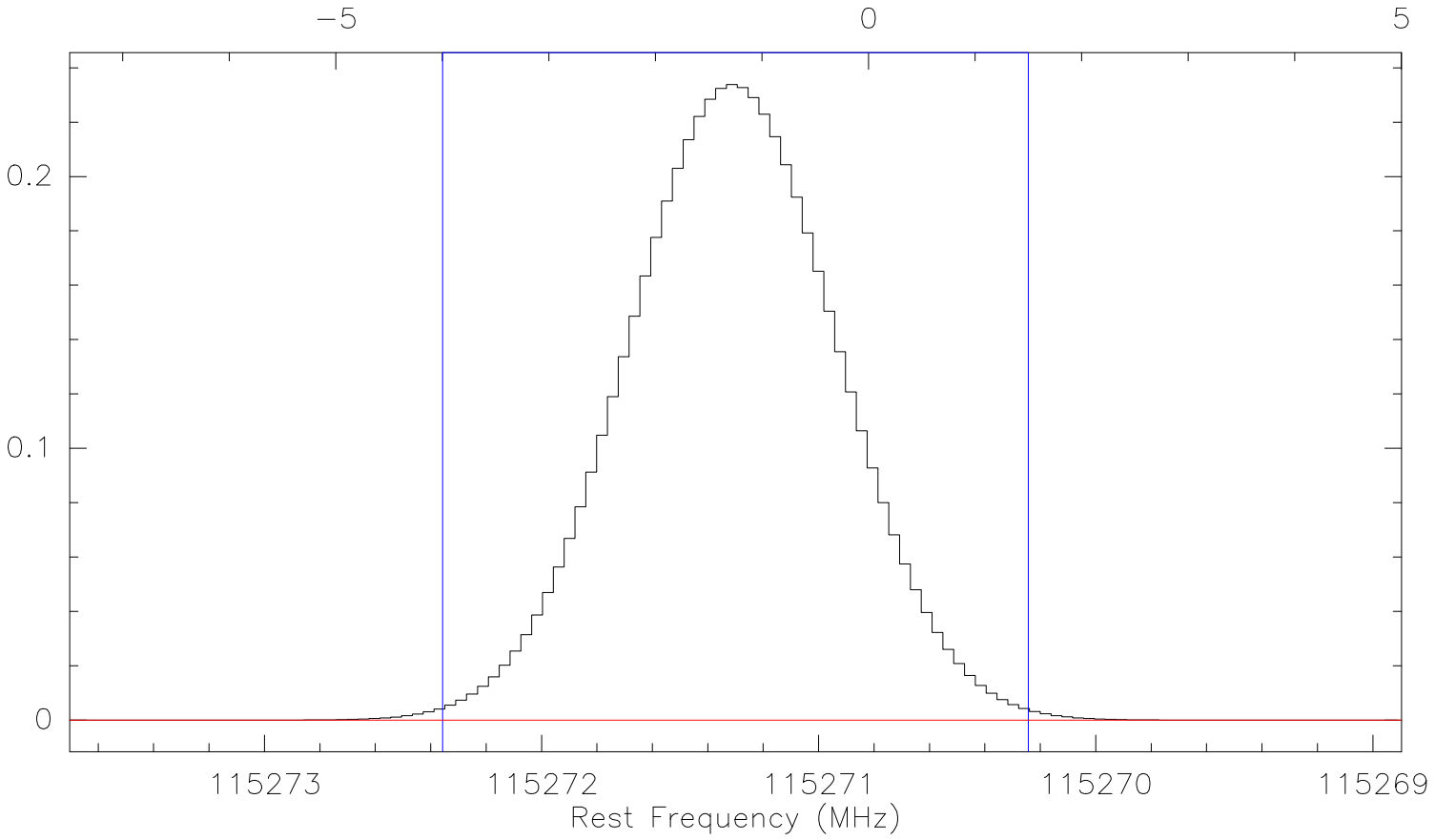
Data analysis: VIII.6 Line fitting

```
LAS> residual
LAS> plot
```



Data analysis: VIII.7 Line fitting

```
LAS> result
LAS> plot
```



CLASS tutorial: II. Imaging Single-Dish Data

Presentation by Sébastien BARDEAU & Jérôme PETY
(IRAM/Grenoble)
Current CLASS developers: Sébastien BARDEAU, Jérôme PETY,
& Stéphane GUILLOTEAU
on behalf of the CLASS developers over time

IRAM Science Software User Meeting
Apr. 6 - 8 2016, St Martin d'Hères

Typical data reduction:
I. Divide to conquer

```
LAS> file in spectra0dp     ! Complex setup => Huge data file
LAS> list in /toc           ! Check file content
LAS> file out 12co21 single ! New file for a single line => Smaller data file
LAS> find /line 12co21      ! Find everything concerning 12co21
LAS> copy
LAS> file in 12co21         ! From now on, work on the smaller data file
LAS> find
LAS> consistency            ! Start real work by checking the data consistency
...
```

Merging data sets

```
LAS> set tel *
LAS> file out merged single /over
LAS> file in spectra0dp1
LAS> list in /toc
LAS> find /line 12co21
LAS> copy
LAS> file in spectra0dp2
LAS> list in /toc
LAS> find /line 12co21
LAS> copy
LAS> file in merged
LAS> list in /toc
```

Typical data reduction:
I. Extract to conquer

```
LAS> file in spectra0dp     ! Complex setup => Huge data file
LAS> list in /toc           ! Check file content
LAS> file out 12co21 single ! New file for a single line => Smaller data file
LAS> find /line 12co21      ! Find everything concerning 12co21
LAS> extract '115271.202-100' '115271.202+100' f /index
LAS> file in 12co21         ! From now on, work on the smaller data file
LAS> find
LAS> consistency            ! Start real work by checking the data consistency
...
```

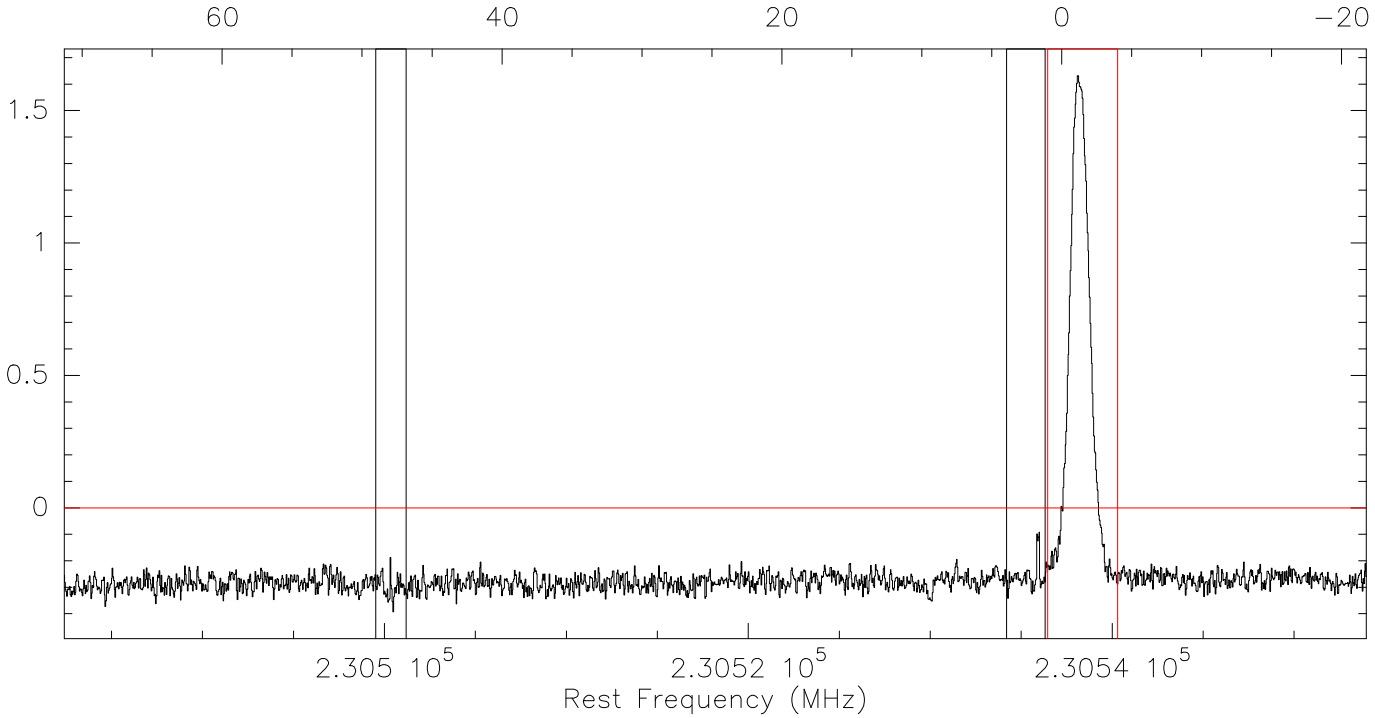
Merging data sets

```
LAS> set tel *
LAS> file out merged single /over
LAS> file in spectra0dp1
LAS> list in /toc
LAS> find /line 12co21
LAS> copy
LAS> file in spectra0dp2
LAS> list in /toc
LAS> find /line 12co21
LAS> copy
LAS> file in merged
LAS> list in /toc
```

Typical data reduction:
II. Choose global baseline windows on averaged spectrum

```
LAS> set nomatch      ! Disable check about position consistency
LAS> set align f c    ! Toggle frequency resampling
LAS> average          ! Average all spectra in index
LAS> plot
LAS> set window ...
```

```
1;  4 B2200+420    12CO21       30M-V04-B230 O:27-SEP-2007 R:07-DEC-2009
 RA:  22:02:43.29  DEC:   42:16:39.9  Eq 2000.0 Offs:   +396.4      -213.6
     Unknown   tau:   0.122  Tsys:   263.  Time:  2.26E+02min  El: 27.1
  N:   1833 I0:  1424.20          V0:  -1.000      Dv: -5.0797E-02  LSR
        F0:   230537.990      Df:  3.9063E-02  Fi:   239054.288
```



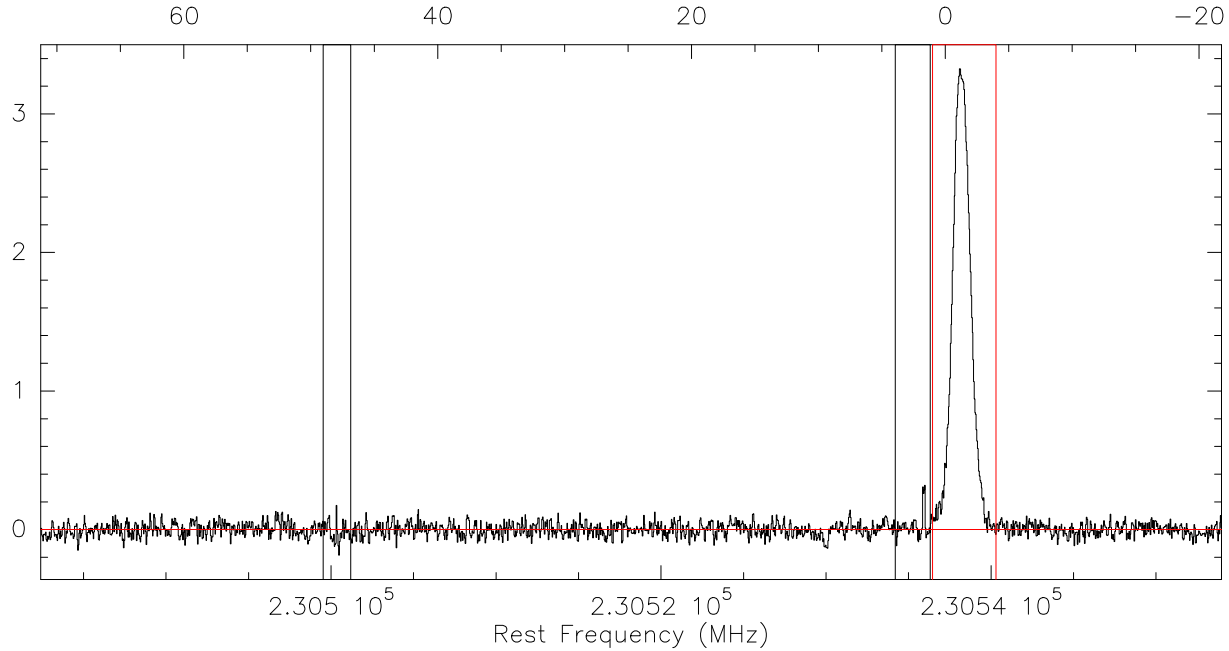
- Line + Spikes.
- Baseline at negative level.

Typical data reduction:

III. Fit a low order baseline (0 or 1) on every dumped spectra

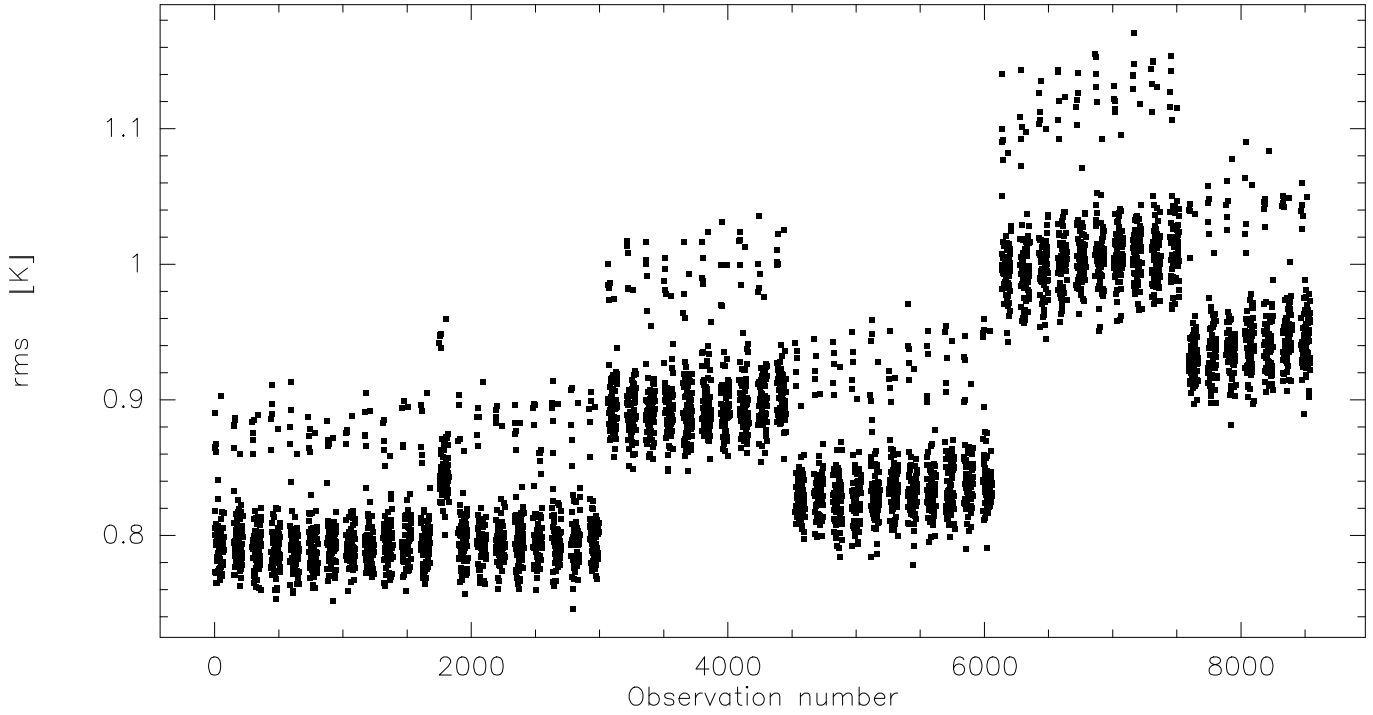
```
LAS> find
LAS> for ient 1 to found
LAS>    get next
LAS>    base 0
LAS>    write
LAS> next ient
```

```
1;  7 B2200+420    12CO21       30M-V04-B230 0:27-SEP-2007 R:07-DEC-2009
 RA:  22:02:43.29  DEC:   42:16:39.9  Eq 2000.0 Offs:   +396.4      -213.6
     Unknown   tau:   0.122  Tsys:   263.  Time:  2.26E+02min  El: 27.1
  N:   1833 I0:  1424.20          V0:  -1.000      Dv: -5.0797E-02  LSR
        F0:   230537.990      Df:  3.9063E-02  Fi:   239054.288
```



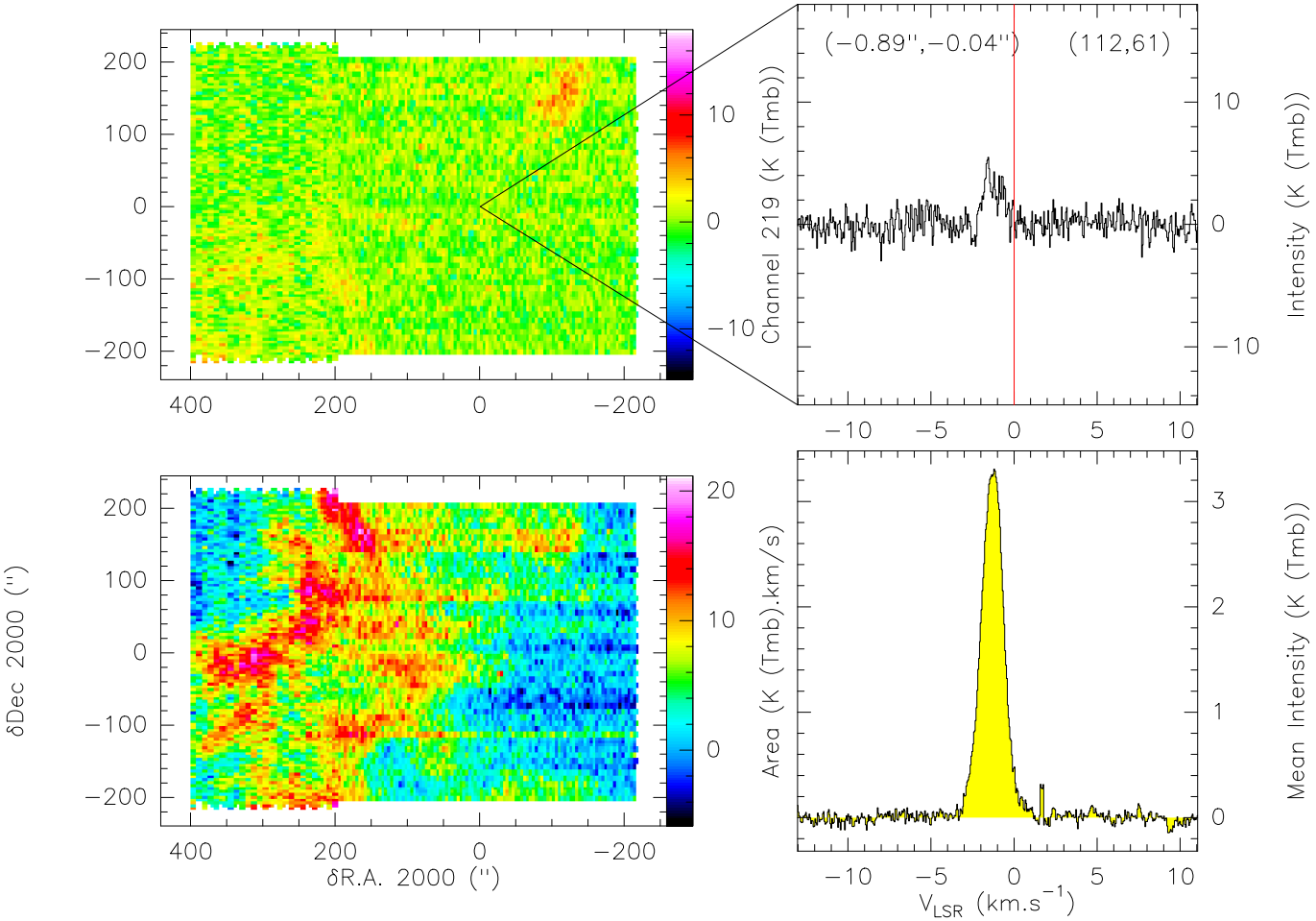
Typical data reduction:
IV. Filter using clever statistical tools

```
LAS> clear plot
LAS> variable base /index
LAS> g\limit /var idx%num idx%head%bas%sigfi
LAS> g\box
LAS> g\set marker 4 3 0.15
LAS> g\point idx%num idx%head%bas%sigfi
LAS> g\label "Observation number" /X
LAS> g\label "rms   [K]" /Y
```



Typical data reduction:
V. Grid the data

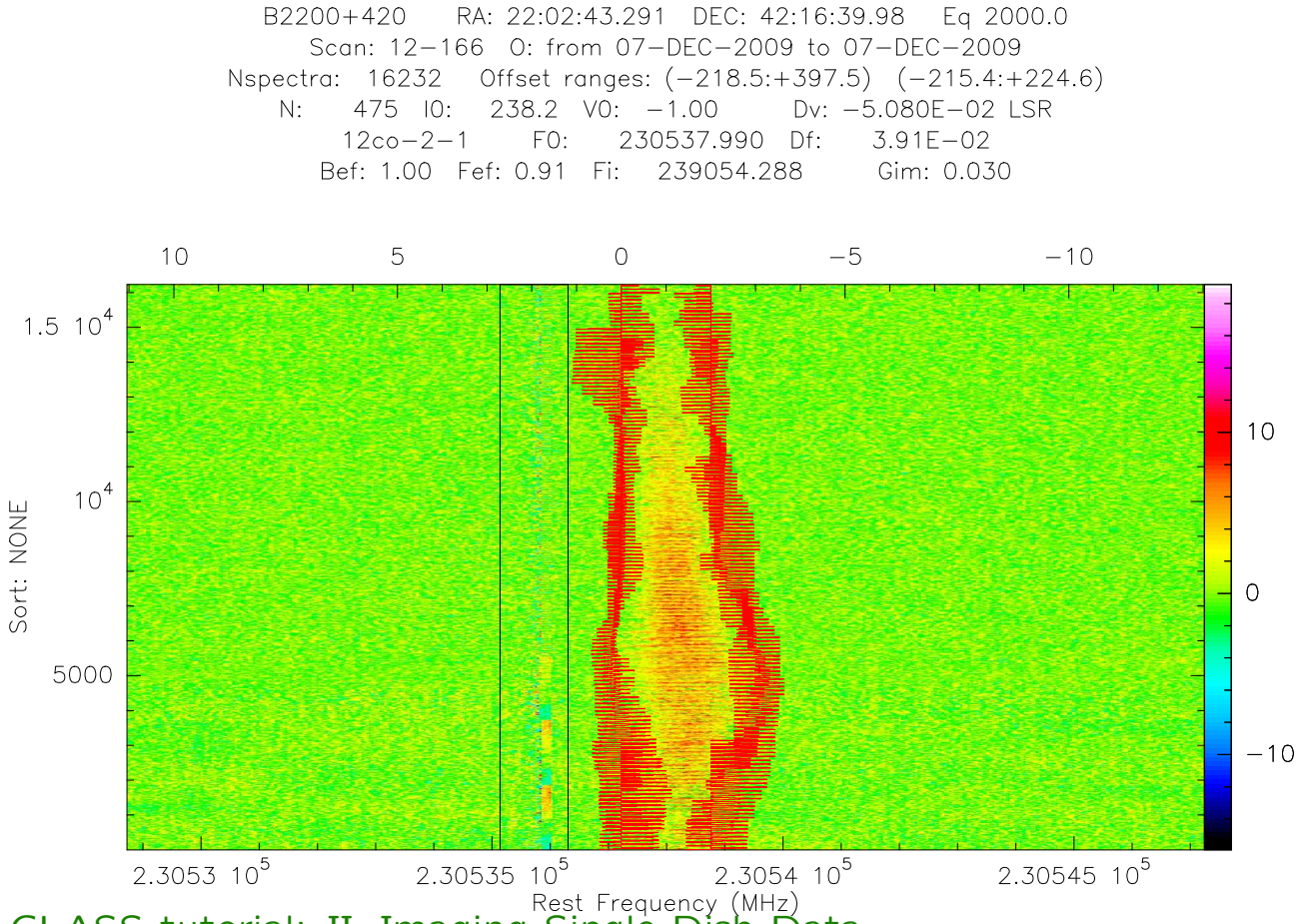
```
LAS> table 12co21 new /range -13 11 v
LAS> xy_map 12co21
LAS> let name 12co21
LAS> let type lmv
LAS> go view
```



- If lucky: Stop here!
- Else:
  - Griding is a linear operation.
  - Griding increases signal-to-noise ratio.
  - Goal: Higher order baseline on grided data.

Typical data reduction:
VI. Import LMV file and import (or define) local baseline windows

```
LAS> file out 12co21 single
LAS> lmv 12co21.lmv
LAS> file in 12co21
LAS> find
LAS> load
LAS> plot /index
```

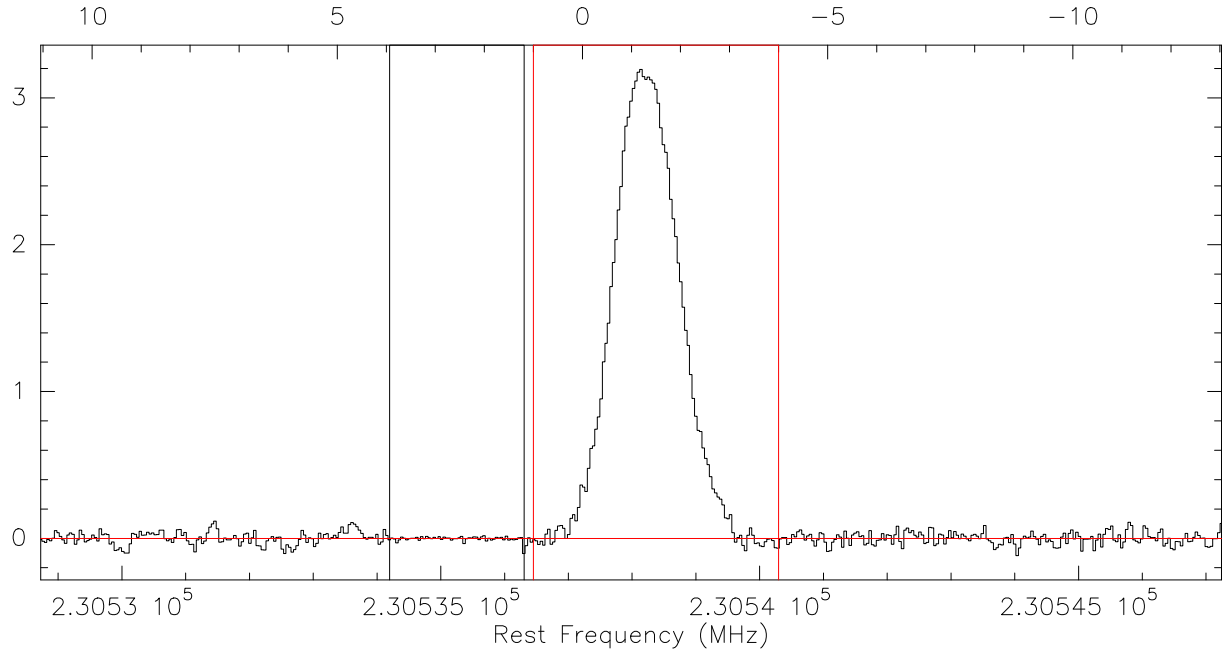


- One fixed window for spikes.
- Varying windows from another tracer (good quality 12co10 data): The 12co10 window widths are enlarged by 40% to avoid possible biases.

Typical data reduction:
VII. High-order baselining

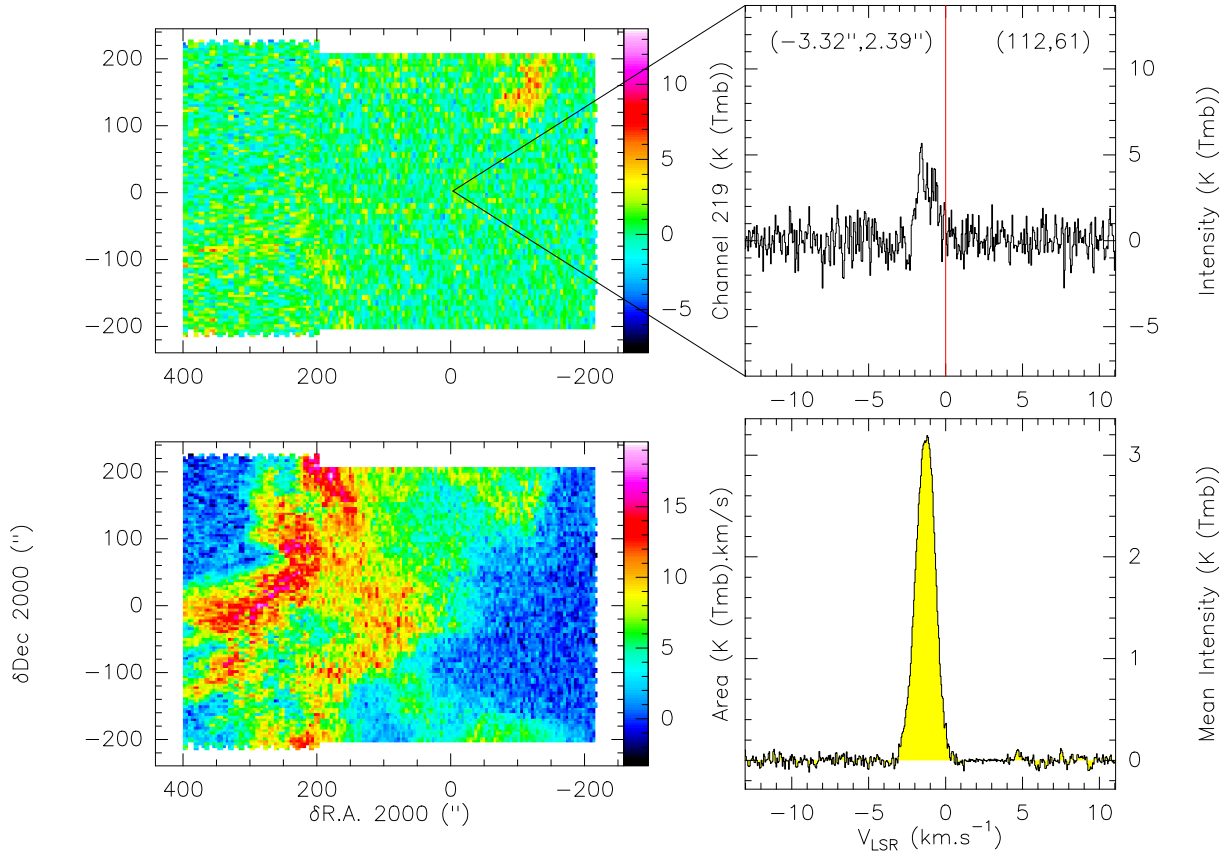
```
LAS> find
LAS> for ient 1 to found
LAS>    get next
LAS>    set window /var windows[,ient] ! Load baseline windows from a SIC array
LAS>    base 5
LAS>    write
LAS> next ient
```

```
1;  9 B2200+420    12co-2-1     30M          O:07-DEC-2009 R:07-DEC-2009
RA:  22:02:43.29  DEC:   42:16:39.9  Eq 2000.0 Offs:   -218.5      +128.6
     Unknown   tau:   0.122  Tsys:     1.  Time:  1.62E+04min  El: 27.1
 N:    475 I0:  238.200          V0:  -1.000      Dv: -5.0797E-02  LSR
       F0:   230537.990      Df:  3.9063E-02  Fi:   239054.288
```



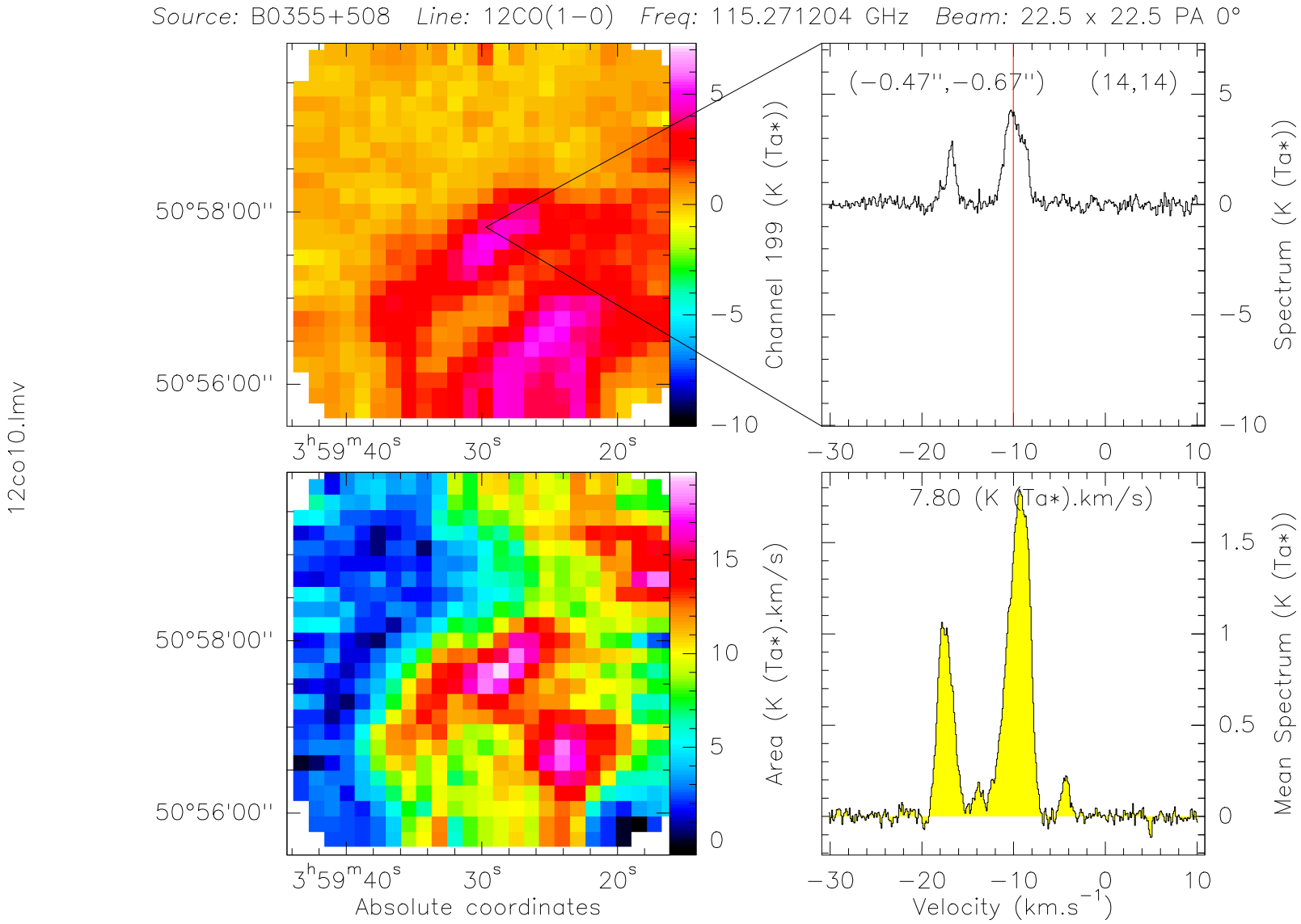
Typical data reduction:
VIII. Place the baselined spectra in the original LMV grid

```
LAS> find
LAS> table 12co21-base /sigma
LAS> let map%tele 30m ! Because the telescope field was lost during the previous LMV command
LAS> let map%like 12co21.lmv
LAS> xy_map 12co21-base /nogrid
LAS> let name 12co21-base
LAS> let type lmv
LAS> go view
```



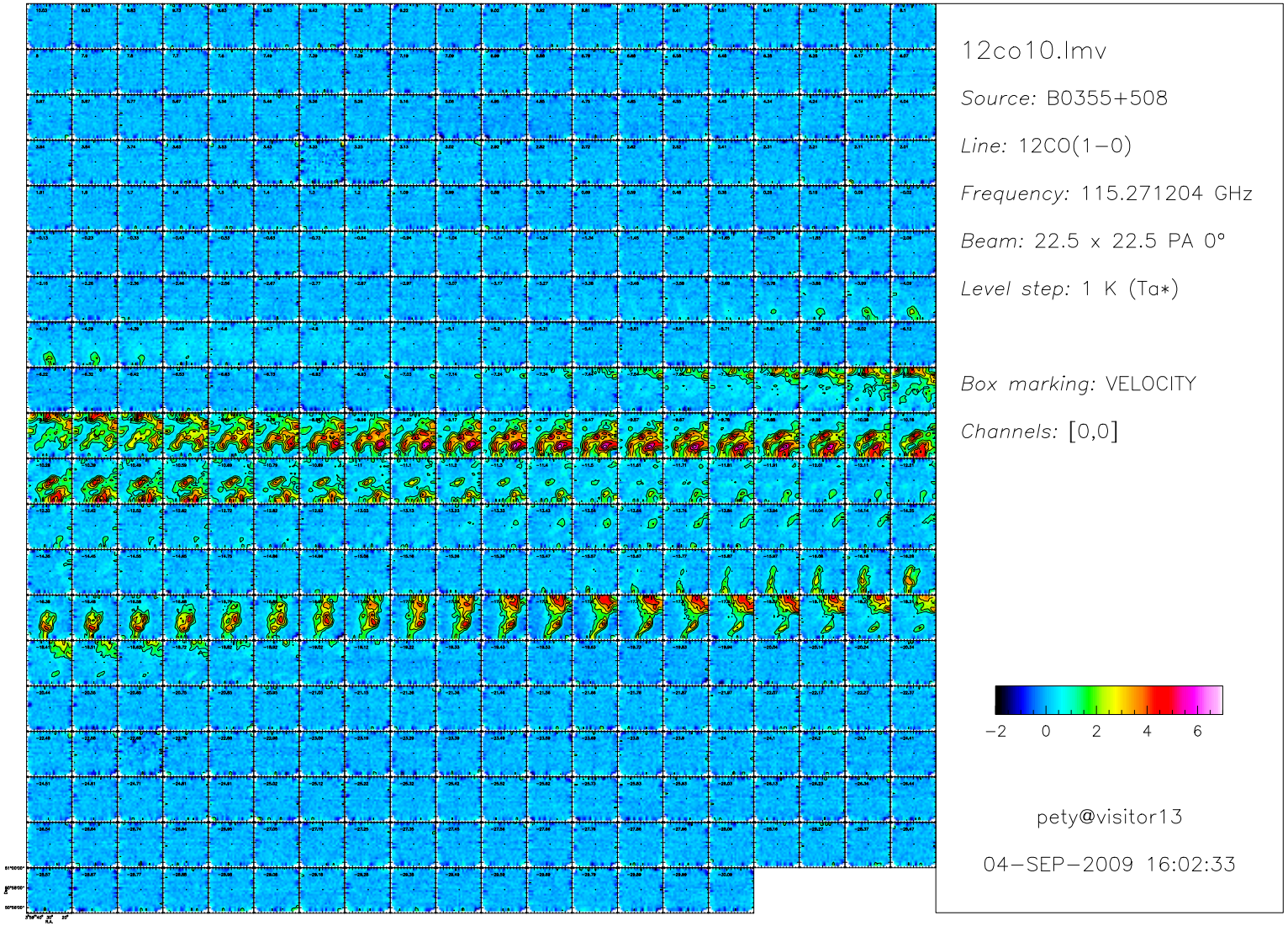
Visualization: I. GO VIEW

```
LAS> let name 12co10
LAS> let type lmv
LAS> go view
```



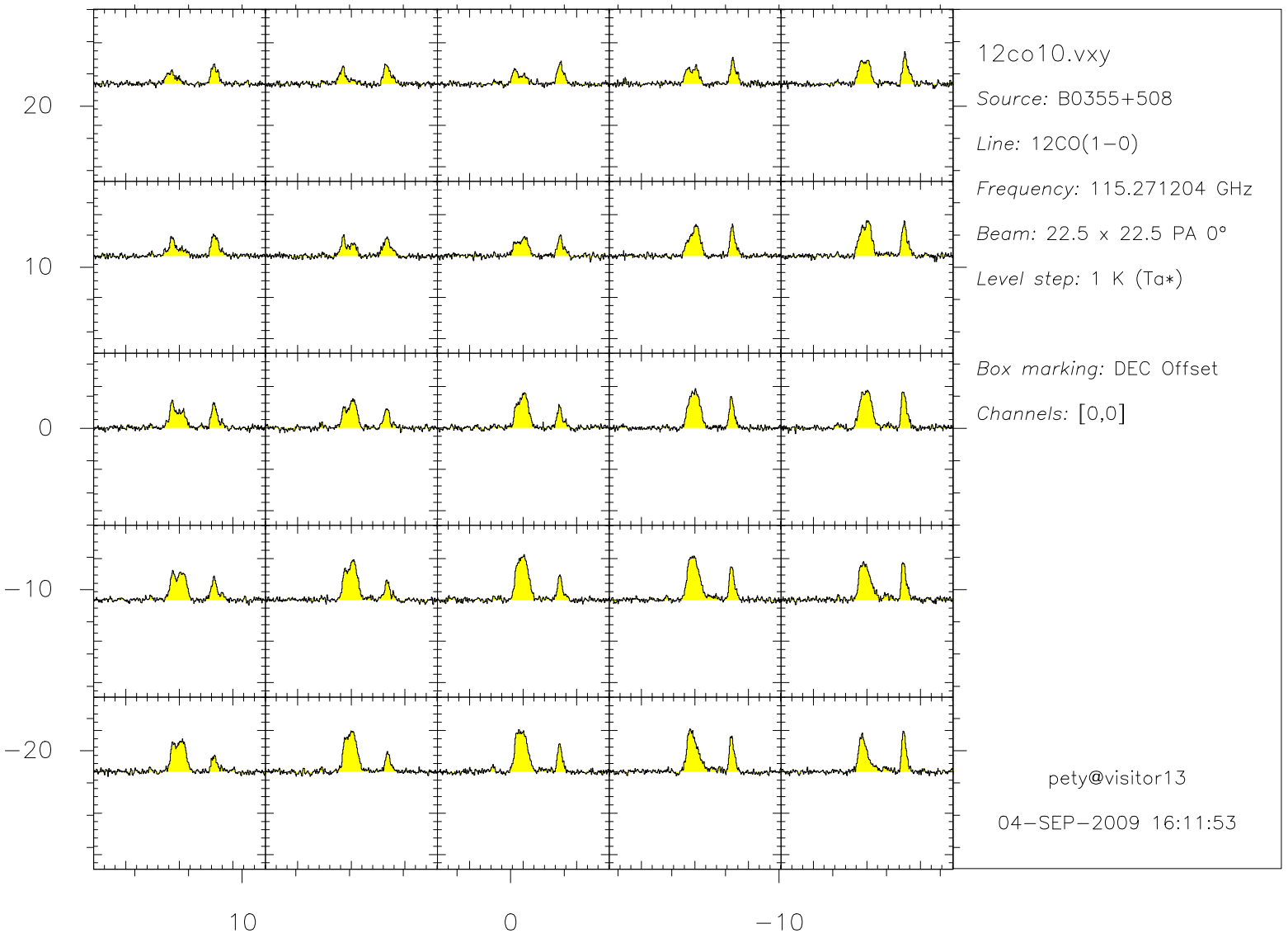
Visualization: II. GO BIT

```
LAS> let name 12co10
LAS> let type lmv
LAS> go bit
LAS> input bit
```



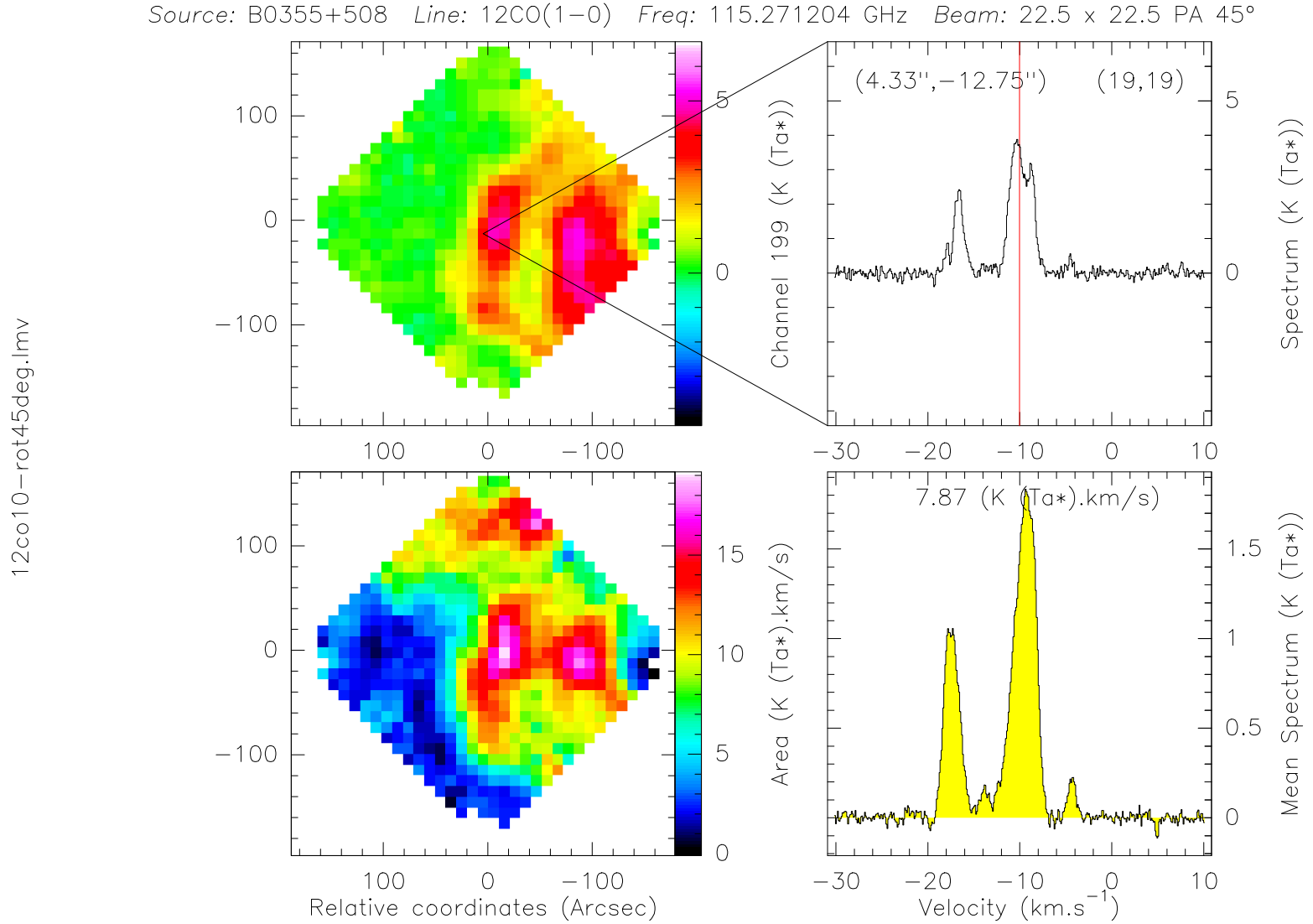
Visualization: III. GO SPECTRUM

```
LAS> let name 12co10
LAS> let type lmv
LAS> go spectrum
```



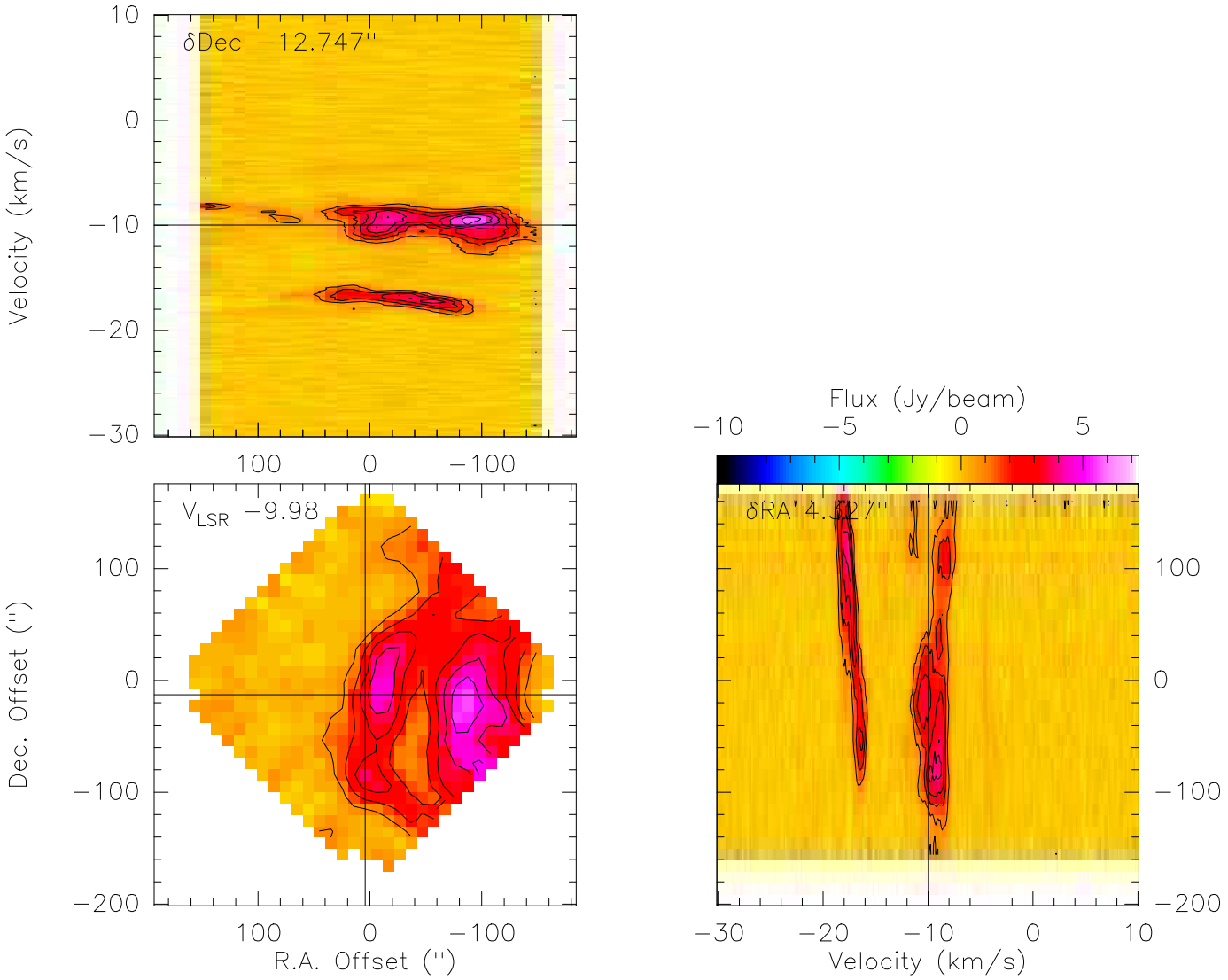
Visualization: IV. GO ROT

```
LAS> let name 12co10
LAS> let type lmv
LAS> let angle 45
LAS> go rot
LAS> go view
```



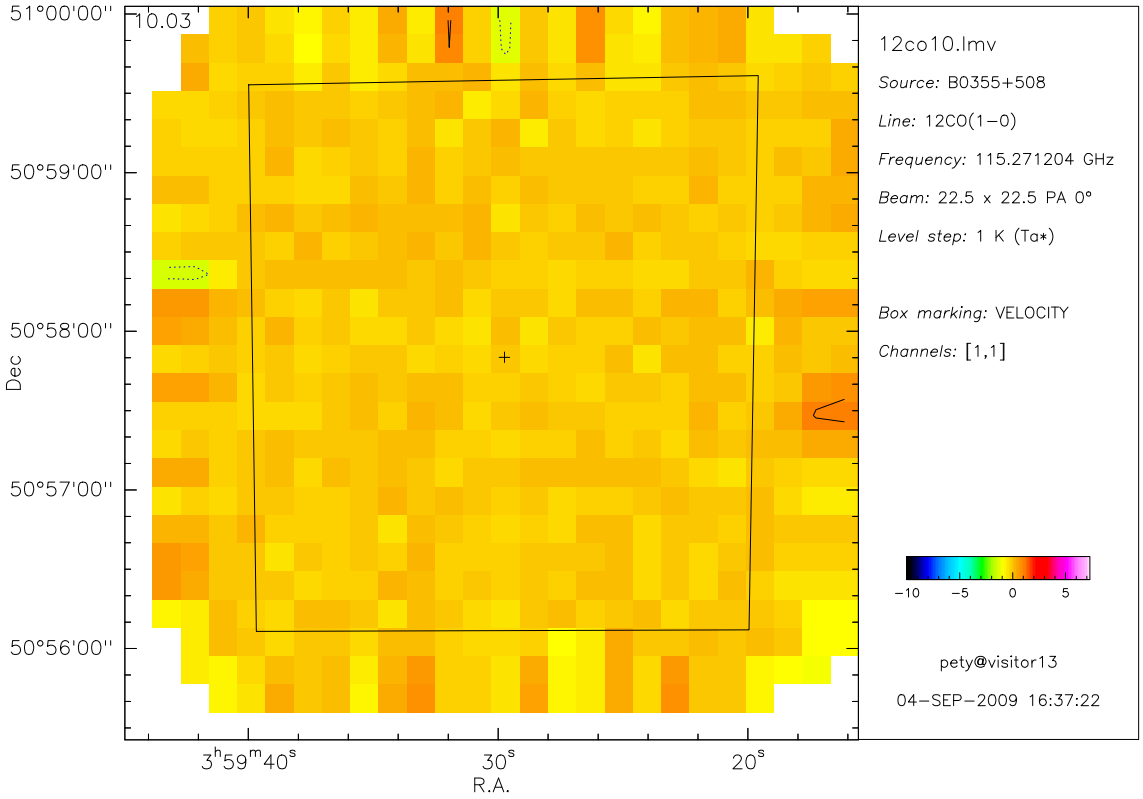
Visualization: V. GO 3VIEW

```
LAS> let name 12co10-rot45deg
LAS> let type lmv
LAS> go 3view
```



Analysis: Noise Estimation with MEAN

```
LAS> let name 12co10
LAS> let type lmv
LAS> let first 1
LAS> let last 1
LAS> go bit
LAS> poly
LAS> mean
I-MEAN,  Found    288 non-blanked pixels, of area: 7.7075E-07 Radians squared
I-MEAN,  Integrated intensity:-1.678452E-08 (Map Units * Radians squared)
I-MEAN,  Mean value: -2.17770E-02, r.m.s.:  0.16625
```

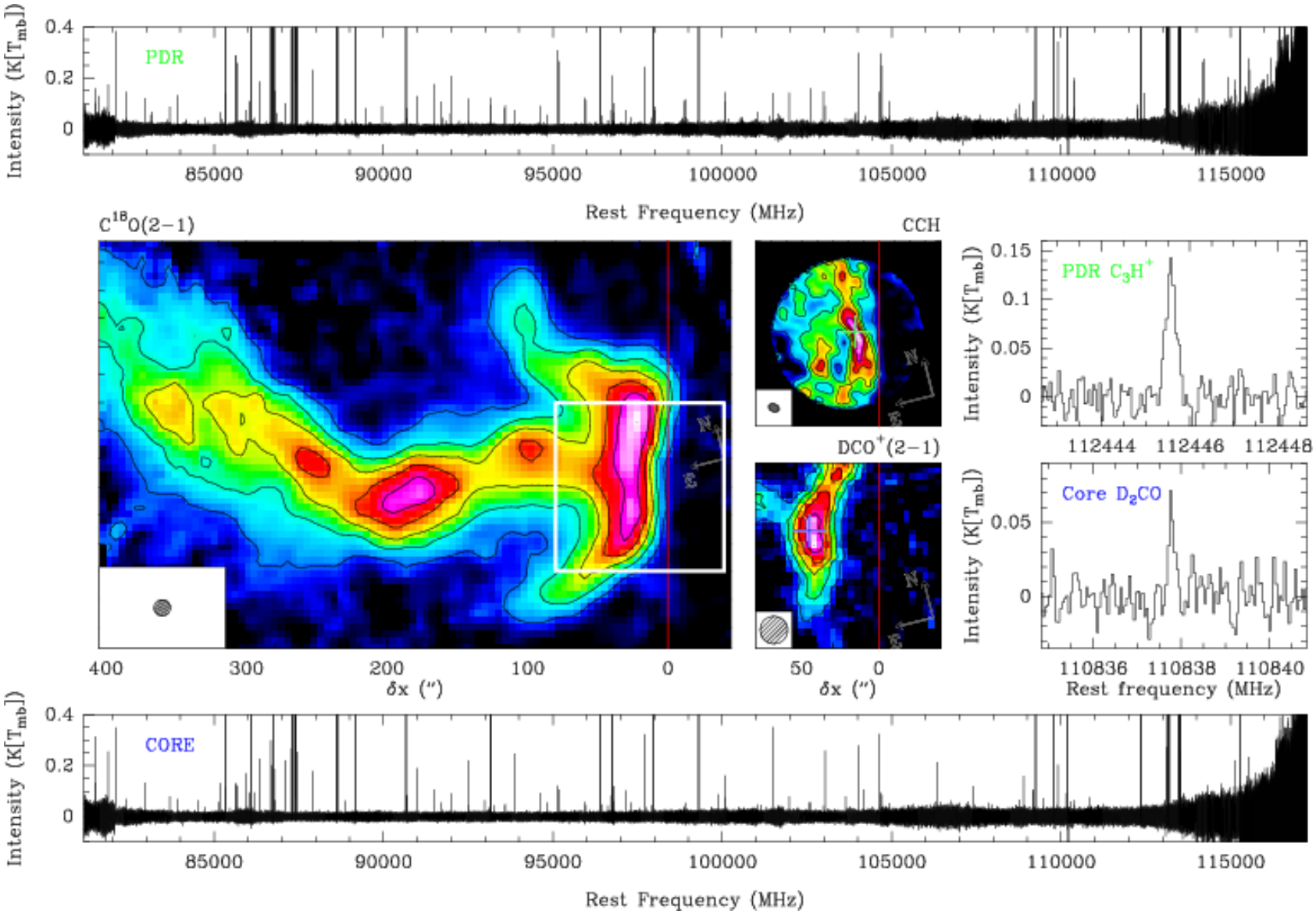


CLASS tutorial: III. Line surveys

Presentation by Jérôme PETY, Sébastien BARDEAU, &
Pierre GRATIER
(IRAM/Grenoble)
Current CLASS developers: Sébastien BARDEAU, Jérôme PETY,
& Stéphane GUILLOTEAU
on behalf of the CLASS developers over time

IRAM Science Software User Meeting
Apr. 6 - 8 2016, St Martin d'Hères

Line survey example (Horsehead WHISPER, PI: J. Pety): 740 000 channels, i.e., as many information as in a 860×860 pixel image!

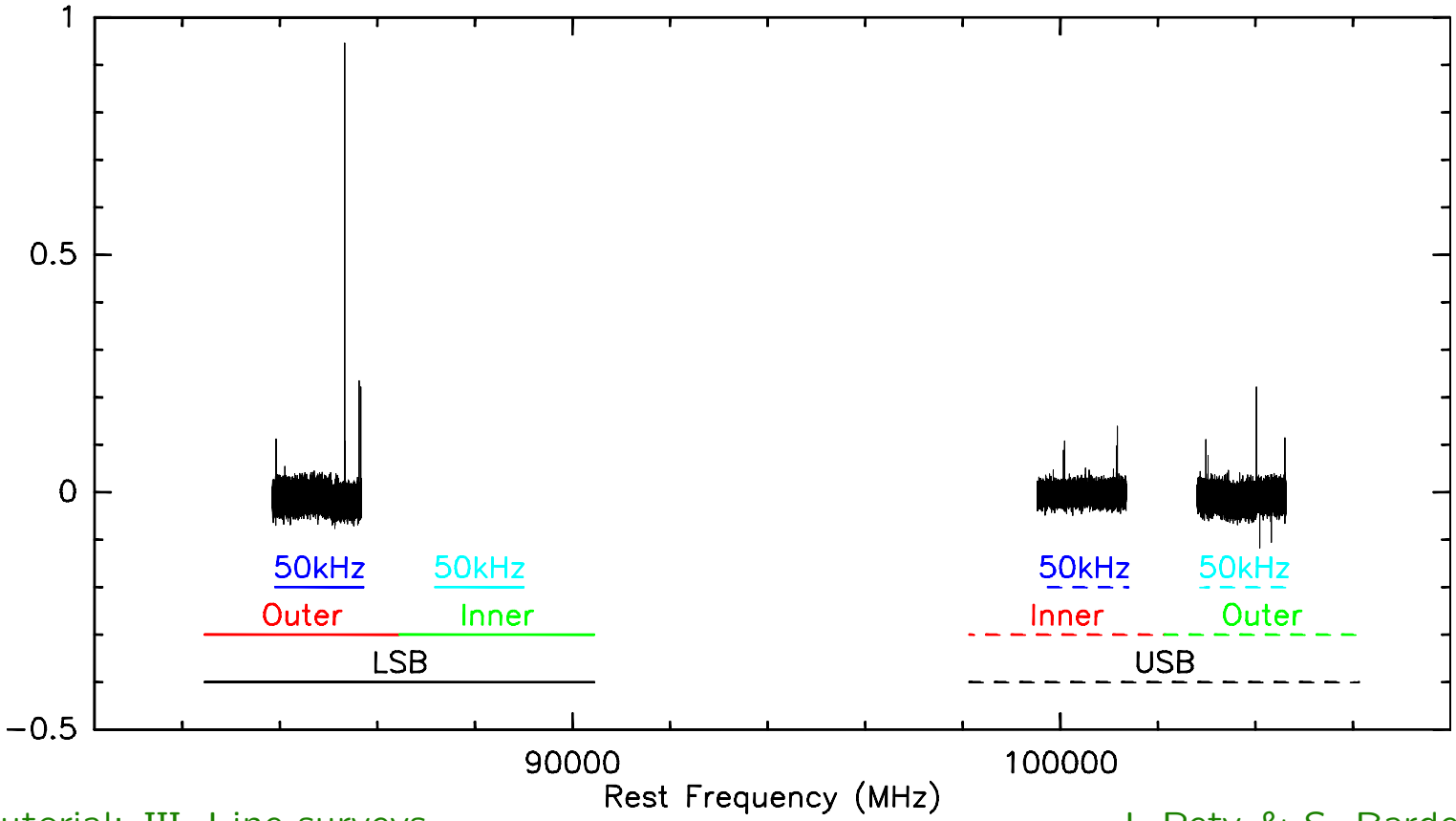


Line names: I. From observations

```
LAS> set sort line
LAS> file in red/survey-1
LAS> find
LAS> list /toc line
LAS> set sort none
Number of lines........  42
    100.5                48 (  3.3%)          139.8                16 (  1.1%)
    105                  48 (  3.3%)          140.7                12 (  0.8%)
    105.9                36 (  2.5%)          141.6                32 (  1.1%)
    106.8                48 (  3.3%)          142.5                32 (  1.1%)
    107.7                48 (  3.3%)          143.4                24 (  0.8%)
    108.6                36 (  2.5%)          144.3                24 (  0.8%)
    109.5                36 (  2.5%)          145.2                32 (  1.1%)
    110.4                48 (  3.3%)          146.1                40 (  1.4%)
    111.3                60 (  4.1%)          147                  32 (  1.1%)
    112.2                48 (  3.3%)          147.9                32 (  1.1%)
    113.1                48 (  3.3%)          87                   90 (  3.0%)
    130.8                10 (  0.7%)          87.9                226 (  7.7%)
    131.7                12 (  0.8%)          88.8                 66 (  2.2%)
    132.6                24 (  1.6%)          89.7                 72 (  2.4%)
    133.5                28 (  1.9%)          94.2                150 (  5.1%)
    134.4                20 (  1.4%)          95.1                102 (  3.5%)
    135.3                12 (  0.8%)          96                  114 (  3.9%)
    136.2                12 (  0.8%)          96.9                 72 (  2.4%)
    137.1                28 (  1.9%)          97.8                 72 (  2.4%)
    138                  20 (  1.4%)          98.7                162 (  5.5%)
    138.9                16 (  1.1%)          99.6                120 (  4.1%)
```

Line names: II. 2SB Receivers

```
LAS> file in red/survey-1
LAS> find /line 100.5
LAS> list /toc
Number of setups.......   6
    HORSEHEAD    100.5        30MEOHUI-F01          8 ( 16.7%)
    HORSEHEAD    100.5        30MEOVUI-F02          8 ( 16.7%)
    HORSEHEAD    100.5        30MEOHUO-F05          8 ( 16.7%)
    HORSEHEAD    100.5        30MEOHLO-F06          8 ( 16.7%)
    HORSEHEAD    100.5        30MEOVUO-F07          8 ( 16.7%)
    HORSEHEAD    100.5        30MEOVLO-F08          8 ( 16.7%)
```



Line names: III. How to modify them

```
LAS> set var spectro write
LAS> file out red/survey-2 single /overwrite
LAS> file in red/survey-1
LAS> find
LAS> quiet
LAS> for ient 1 to found
LAS>    get next
LAS>    let r%head%spe%line min('frequency+rx[1]','frequency+rx[channels]') /format f12.1
LAS>    write
LAS> next ient
LAS> verbose
LAS> set var spectro
```

Line names: IV. Result

```
LAS> set sort line
LAS> file in red/survey-2
LAS> find
LAS> list /toc line
LAS> set sort none
Number of lines.......  94
```

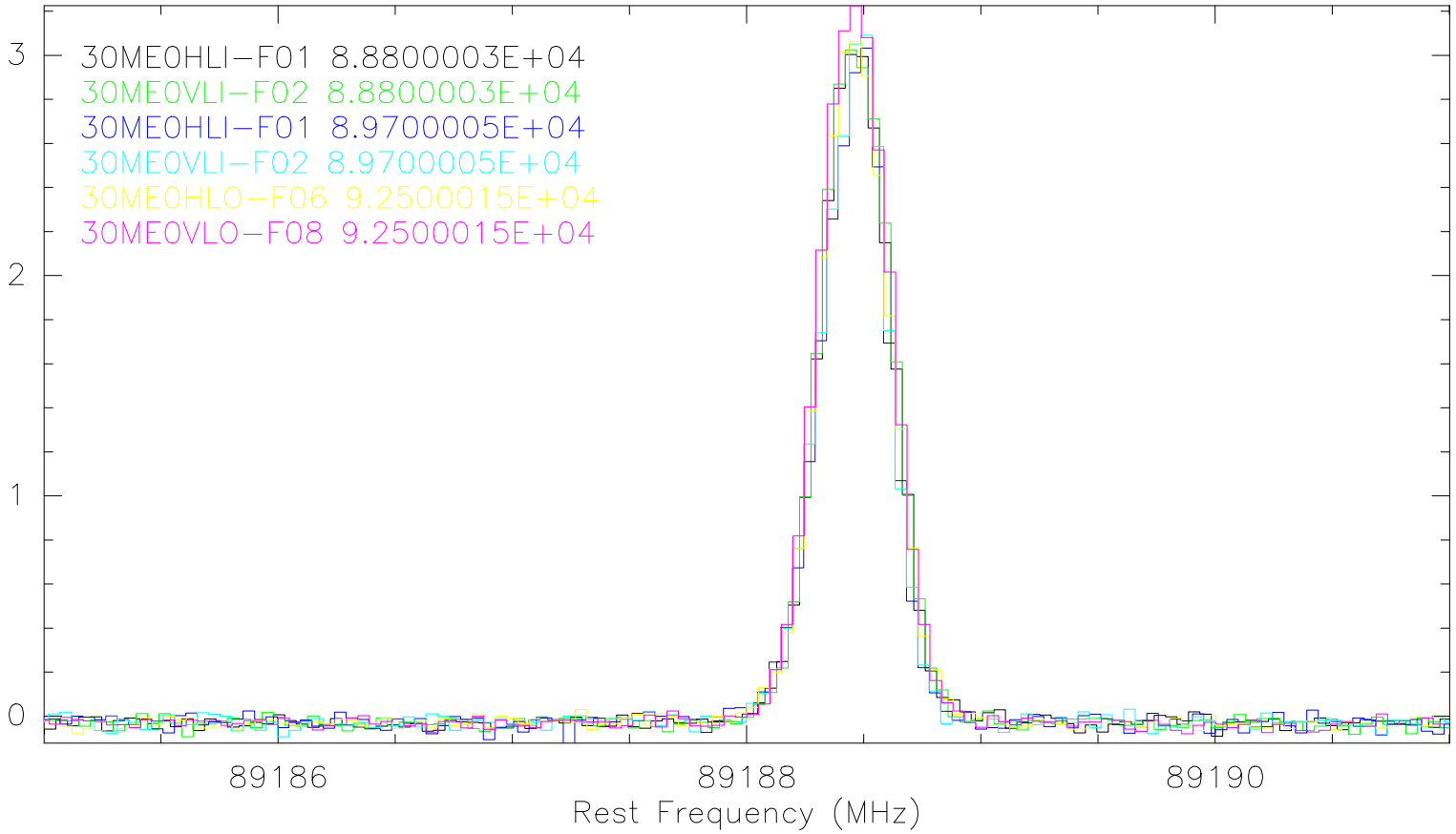
81159.7	12	(0.8%)	96459.6	16	(1.1%)	110820.4	20	(1.4%)
82059.6	16	(1.1%)	96840.0	12	(0.8%)	110920.1	12	(0.8%)
82059.7	12	(0.8%)	97740.0	28	(1.9%)	111240.0	16	(1.1%)
82859.9	12	(0.8%)	98640.0	20	(1.4%)	111720.3	12	(0.8%)
82959.7	20	(1.4%)	99440.4	20	(1.4%)	111820.1	12	(0.8%)
83759.8	20	(1.4%)	99540.0	16	(1.1%)	112140.0	16	(1.1%)
83759.9	10	(0.7%)	100120.0	12	(0.8%)	112720.1	16	(1.1%)
83859.7	16	(1.1%)	101020.0	12	(0.8%)	113620.1	20	(1.4%)
84659.8	10	(0.7%)	101020.1	16	(1.1%)	114520.1	16	(1.1%)
85559.8	12	(0.8%)	101820.3	12	(0.8%)	115420.1	16	(1.1%)
86140.0	12	(0.8%)	101920.1	20	(1.4%)	129939.9	10	(0.7%)
87040.0	30	(2.0%)	102720.3	10	(0.7%)	130839.9	12	(0.8%)
87940.0	10	(0.7%)	102720.6	20	(1.4%)	131739.9	24	(1.6%)
88359.7	16	(1.1%)	102820.1	16	(1.1%)	132639.9	28	(1.9%)
88840.0	12	(0.8%)	103620.5	10	(0.7%)	133539.9	20	(1.4%)
89259.7	12	(0.8%)	104040.0	16	(1.1%)	134439.9	12	(0.8%)
90059.8	12	(0.8%)	104520.5	8	(0.5%)	135339.9	12	(0.8%)
90059.9	12	(0.8%)	104520.6	4	(0.3%)	136239.9	28	(1.9%)
90159.6	16	(1.1%)	104940.0	12	(0.8%)	137139.9	20	(1.4%)
90959.9	18	(1.2%)	105840.0	16	(1.1%)	138039.9	16	(1.1%)
91059.7	16	(1.1%)	106740.0	16	(1.1%)	138939.9	16	(1.1%)
91859.9	20	(1.4%)	107320.0	16	(1.1%)	139839.9	12	(0.8%)
91959.7	12	(0.8%)	107640.0	12	(0.8%)	140739.9	16	(1.1%)
92759.9	12	(0.8%)	108220.1	12	(0.8%)	141639.9	16	(1.1%)
92859.7	12	(0.8%)	108540.0	12	(0.8%)	142539.9	12	(0.8%)

Line names: V. Using the modified line names

```
LAS> set sort line
LAS> file in  red/survey-2
LAS> find
LAS> quiet
LAS> sic output freq-range
LAS>    for ient 1 to found
LAS>       get next
LAS>       say 'line' 'telescope' 'frequency+rx[1]' 'frequency+rx[channels]' -
LAS-?           /format  a15 a15 f15.3 f15.3
LAS>    next ient
LAS> sic output
LAS> verbose
LAS> set sort none
LAS> type freq-range.dat
        81159.7   30MEOVLO-F08      81159.698      82979.751
        81159.7   30MEOHLO-F06      81159.698      82979.751
        82059.6   30MEOVLO-F08      82059.620      83879.682
        82059.6   30MEOHLO-F06      82059.620      83879.682
        82059.7   30MEOVLO-F08      82059.683      83879.738
        82059.7   30MEOHLO-F06      82059.683      83879.738
        82859.9   30MEOHLO-F06      82859.915      84679.968
        82859.9   30MEOVLO-F08      82859.915      84679.968
        82959.7   30MEOVLO-F08      82959.661      84779.718
        82959.7   30MEOHLO-F06      82959.661      84779.718
        83759.8   30MEOHLO-F06      83759.833      85579.923
        83759.8   30MEOVLO-F08      83759.833      85579.923
        83759.9   30MEOVLO-F08      83759.919      85579.971
        83759.9   30MEOHLO-F06      83759.919      85579.971
        83859.7   30MEOVLO-F08      83859.673      85679.729
        83859.7   30MEOHLO-F06      83859.673      85679.729
        ...
```

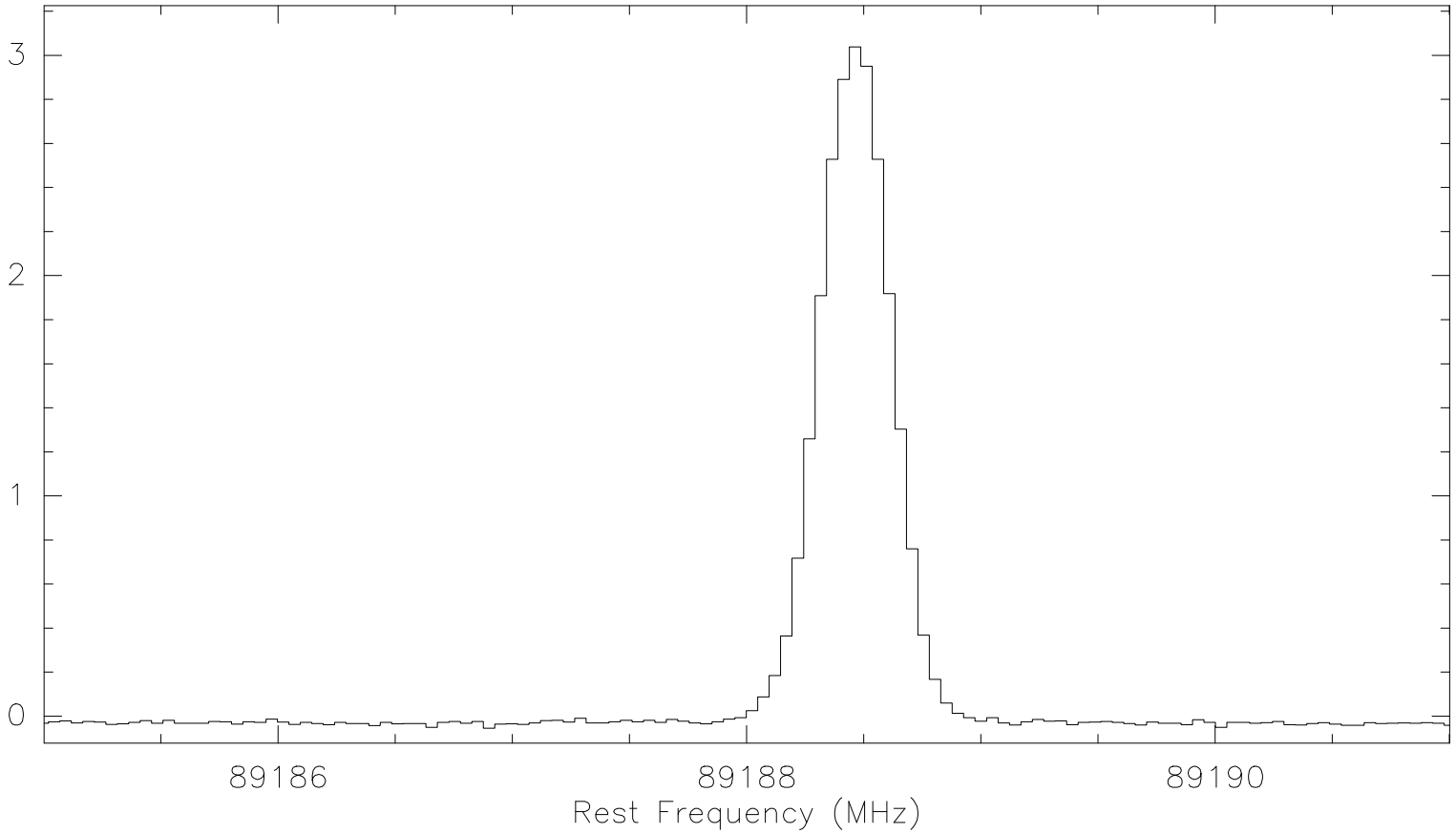
Averaging: I. From

21; 2 HORSEHEAD 87939.96 30ME0HLI−F01 0:24−AUG−2011 R:24−AUG−2011
RA: 05:40:54.27 DEC: −02:28:00.0 Eq 2000.0 Offs: −5.0 +0.0
Unknown tau: 0.046 Tsys: 103. Time: 28. min El: 50.2
N: 37275 I0: 17614.0 V0: 10.50 Dv: −1.6485E−04 LSR
F0: 88800.0030 Df: 4.8828E−02 Fi: 101300.461



Averaging: II. To

1; 0 HORSEHEAD Unknown Unknown O:23−SEP−2011 R:23−SEP−2011
RA: 05:40:54.27 DEC: −02:28:00.0 Eq 2000.0 Offs: −5.0 +0.0
Unknown tau: 0.046 Tsys: 118. Time: 2.13E+02min El: 50.2
N: 18844 I0: −817.350 V0: 10.50 Dv: −0.1649 LSR
F0: 88800.0030 Df: 4.8830E−02 Fi: 101300.461



Averaging: III. Per observing setup

```
LAS> set bad and
LAS> file out red/survey-3 single /over
LAS> file in  red/survey-2
LAS> find
LAS> list /toc line tele off1 off2
LAS> quiet
LAS> for isetup 1 to toc%nsetup
LAS>    find /line 'toc%setup[isetup,1]' /tele 'toc%setup[isetup,2]' -
LAS-?         /offset 'toc%setup[isetup,3]' 'toc%setup[isetup,4]'
LAS>    if (found.ne.0) then
LAS>       average /resample
LAS>       write
LAS>    endif
LAS>  next isetup
LAS>  verbose
```

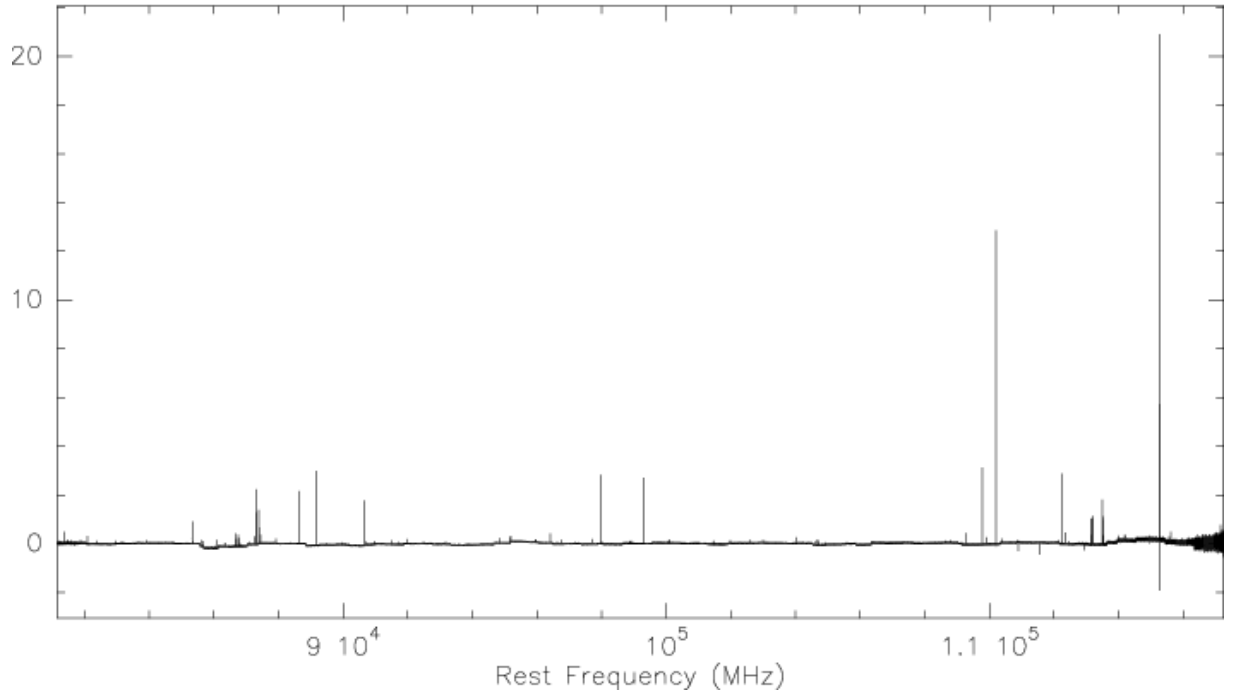
Stitching: I. Commands

```
LAS> set bad and
LAS> file out red/survey-4 single /over
LAS> file in red/survey-3
LAS> find
LAS> list /toc off1 off2
LAS> quiet
LAS> define double frange[2,3]
LAS> let frange[1]  80000 120000
LAS> let frange[2] 120000 170000
LAS> let frange[3] 200000 280000
LAS> define character lines*12[3] teles*12[3]
LAS> let lines "signal" "signal" "signal"
LAS> let teles "3mm" "2mm" "1mm"
LAS> for ifrange 1 to 3
LAS>    for isetup 1 to toc%nsetup
LAS>       find /freq 'frange[1,ifrange]' 'frange[2,ifrange]' -
LAS-?           /offset 'toc%setup[isetup,1]' 'toc%setup[isetup,2]'
LAS>       if (found.ne.0) then
LAS>          stitch /line 'lines[ifrange]' /tele 'teles[ifrange]'
LAS>          write
LAS>       endif
LAS>    next isetup
LAS> next ifrange
```

Stitching: II. Visualization

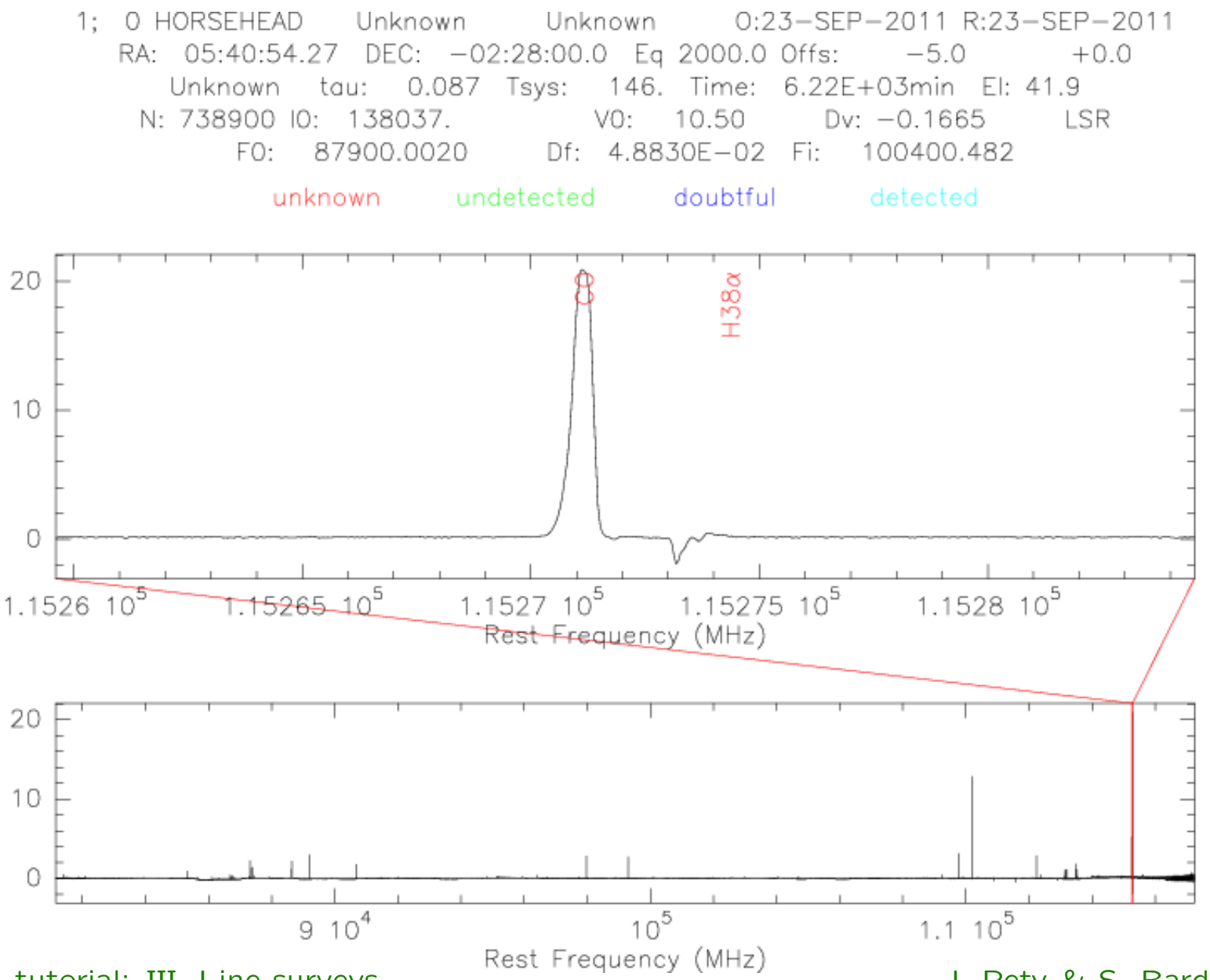
```
LAS> file in red/survey-4
LAS> find
LAS> get f
LAS> set unit f
LAS> set format long
LAS> plot
```

```
1;  0 HORSEHEAD     Unknown       Unknown       O:23-SEP-2011 R:23-SEP-2011
   RA:  05:40:54.27  DEC:  -02:28:00.0  Eq 2000.0 Offs:     -5.0        +0.0
      Unknown   tau:   0.087  Tsys:   146.  Time:  6.22E+03min  El: 41.9
   N: 738900 I0:  138037.          V0:   10.50      Dv: -0.1665      LSR
         F0:   87900.0020      Df:  4.8830E-02  Fi:   100400.482
```



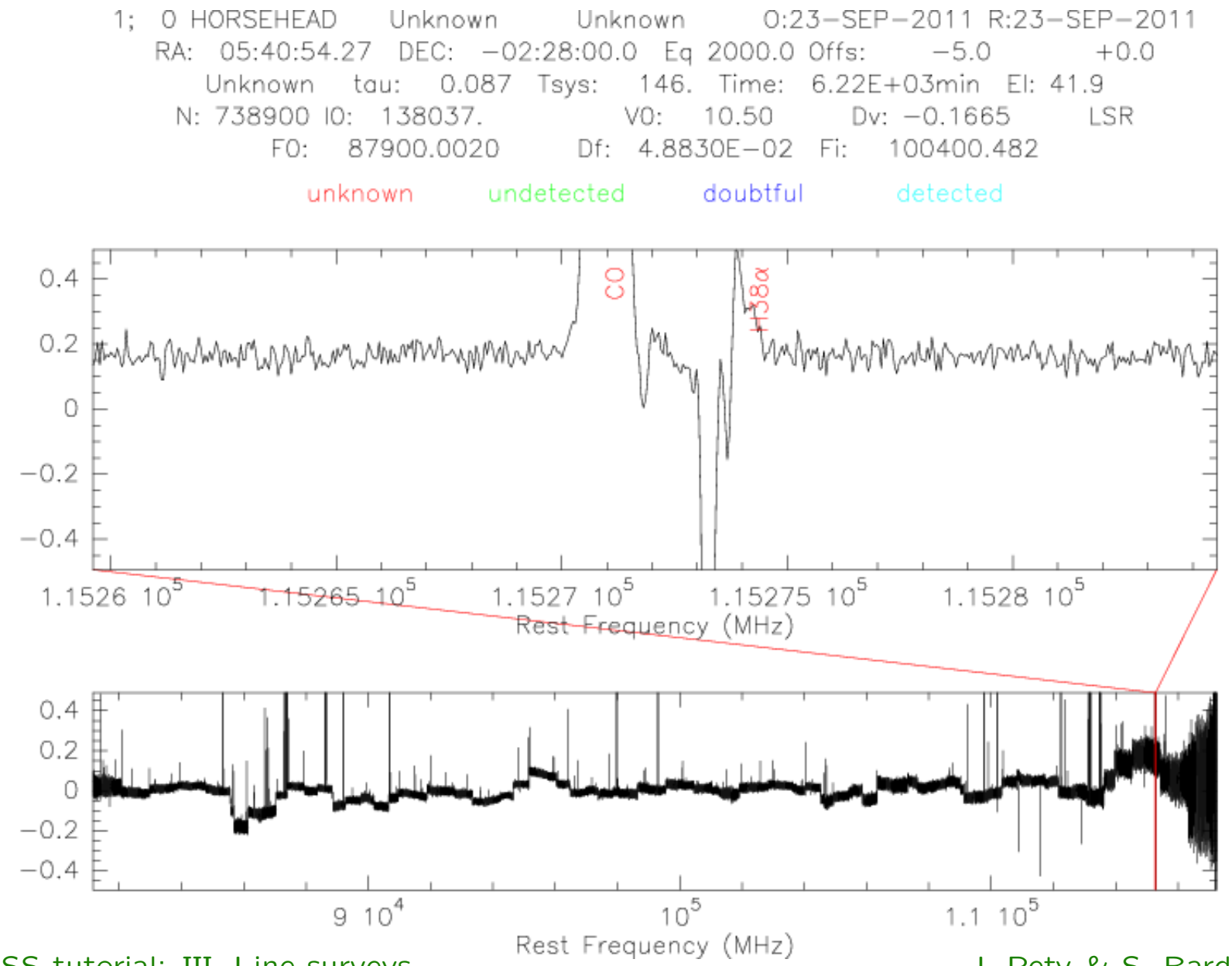
Browsing through wide spectra: I. Zooming in frequency

```
LAS> go browse
```

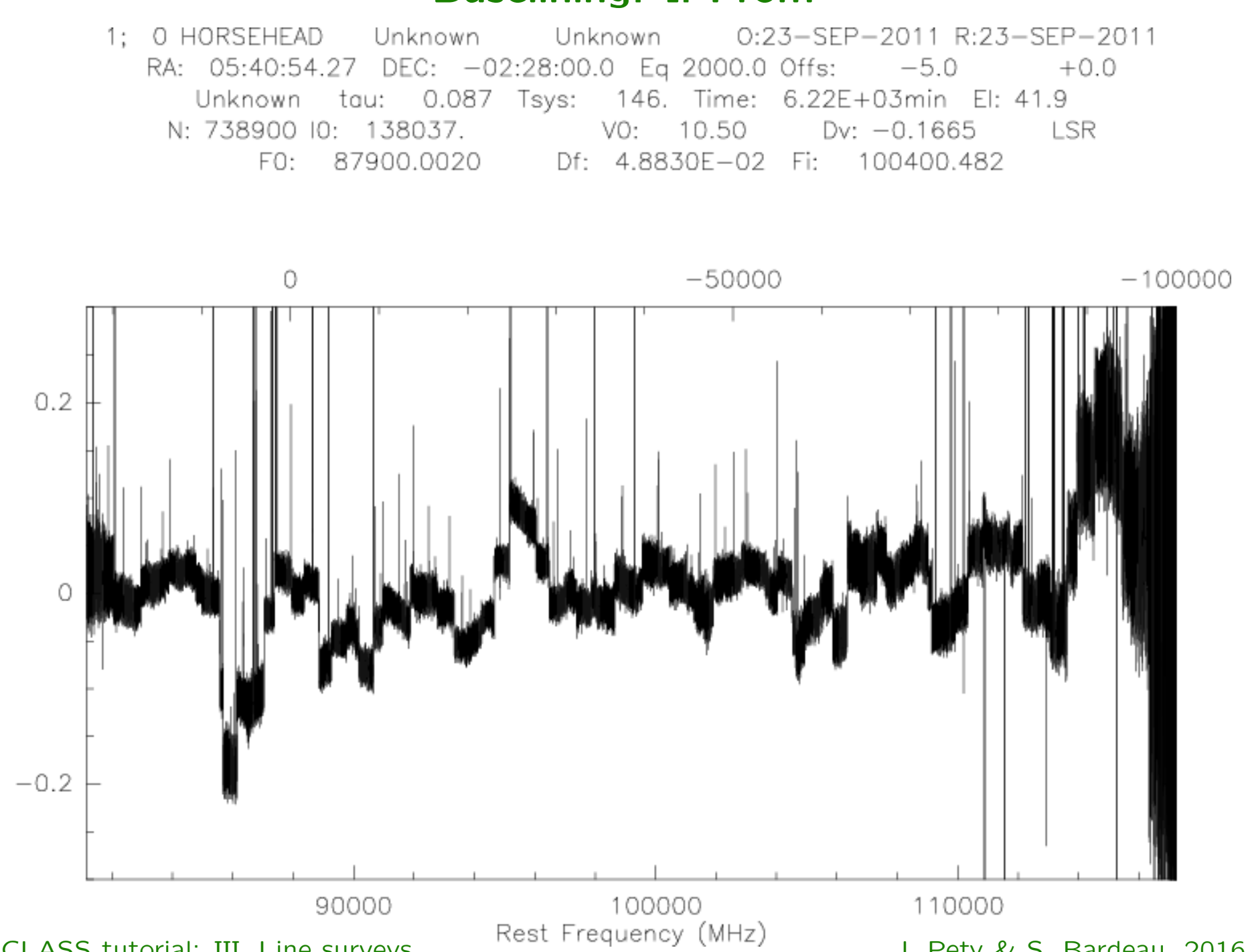


Browsing through wide spectra: II. Zooming in intensity

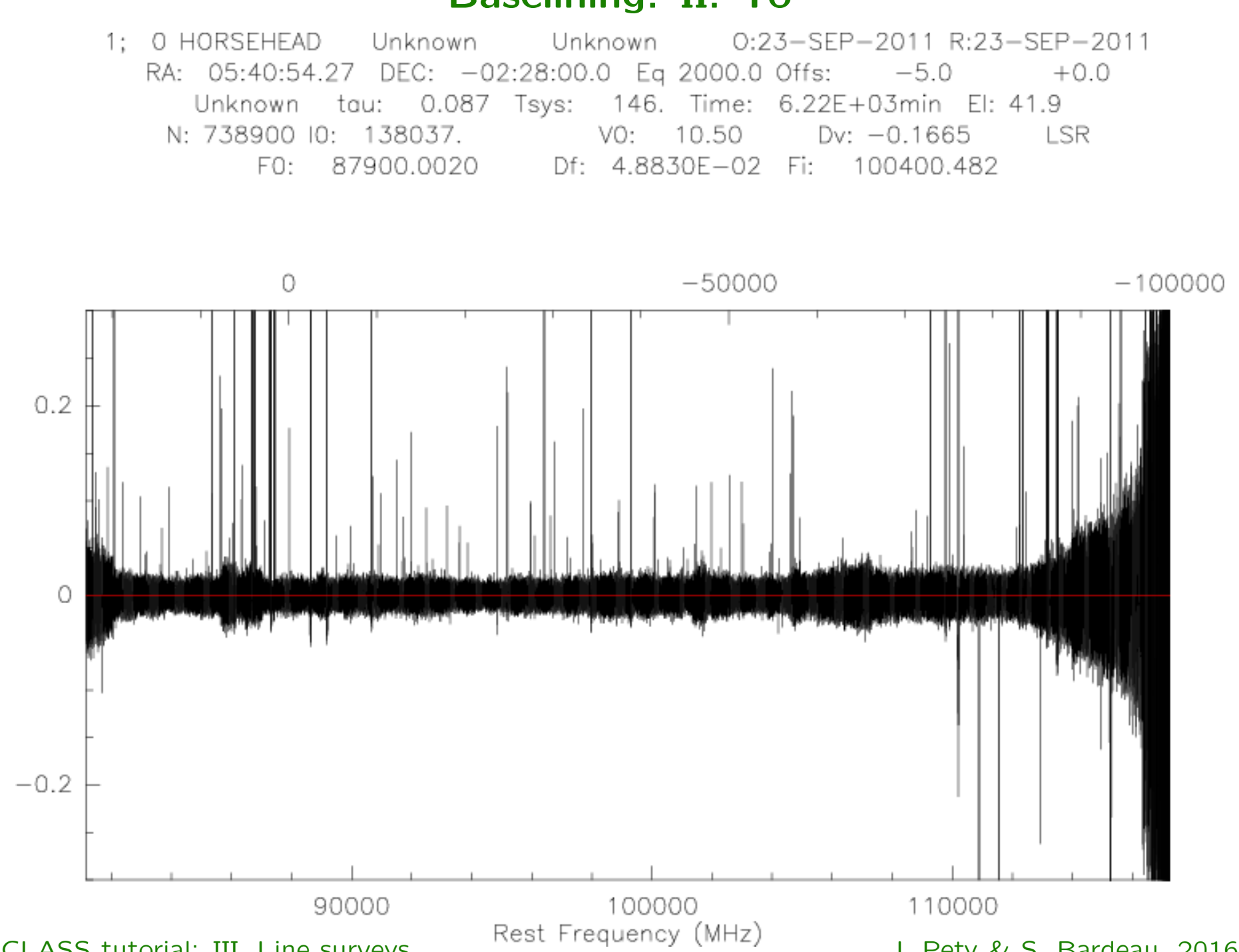
```
LAS> go browse
```



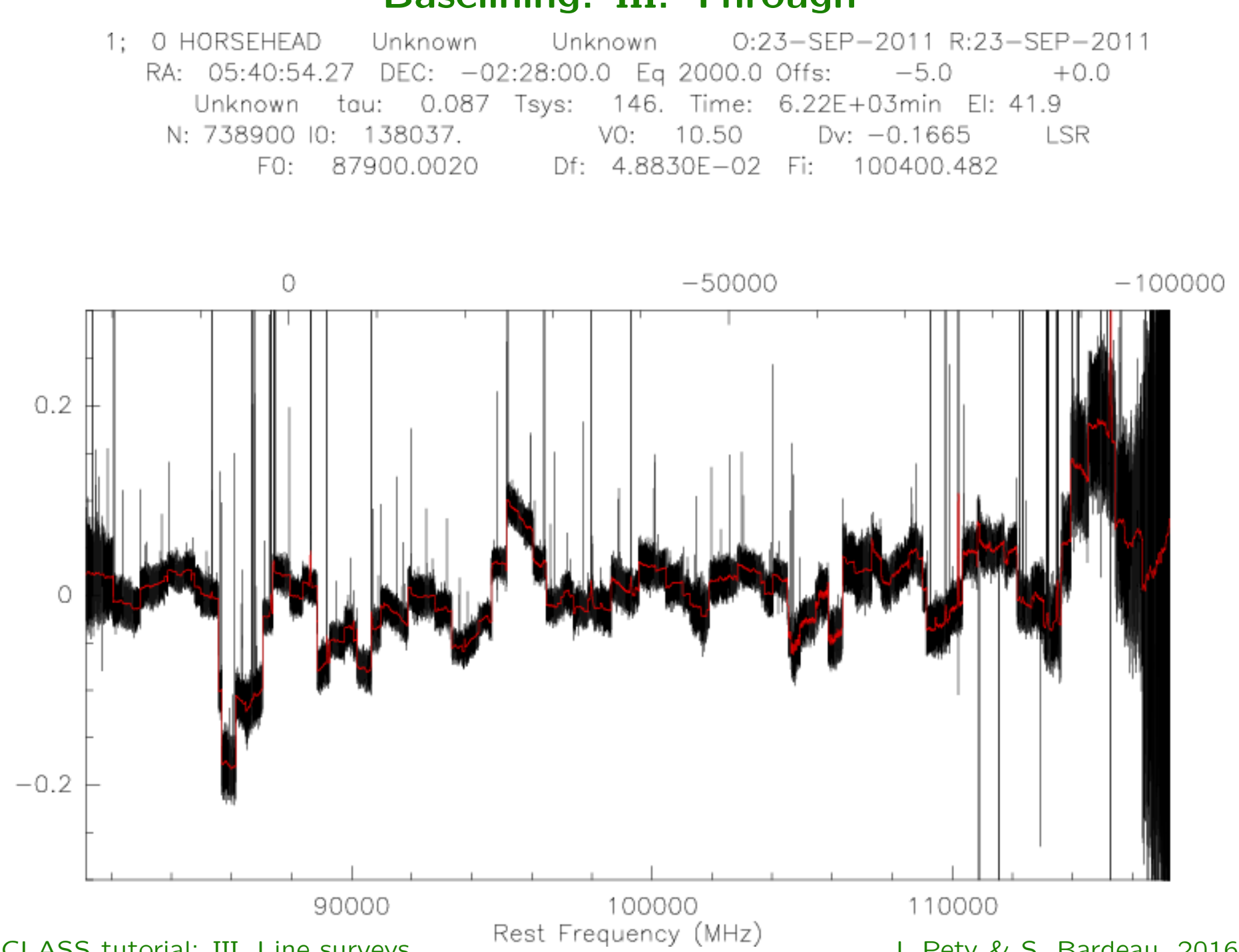
Baselining: I. From



Baselining: II. To



Baselining: III. Through

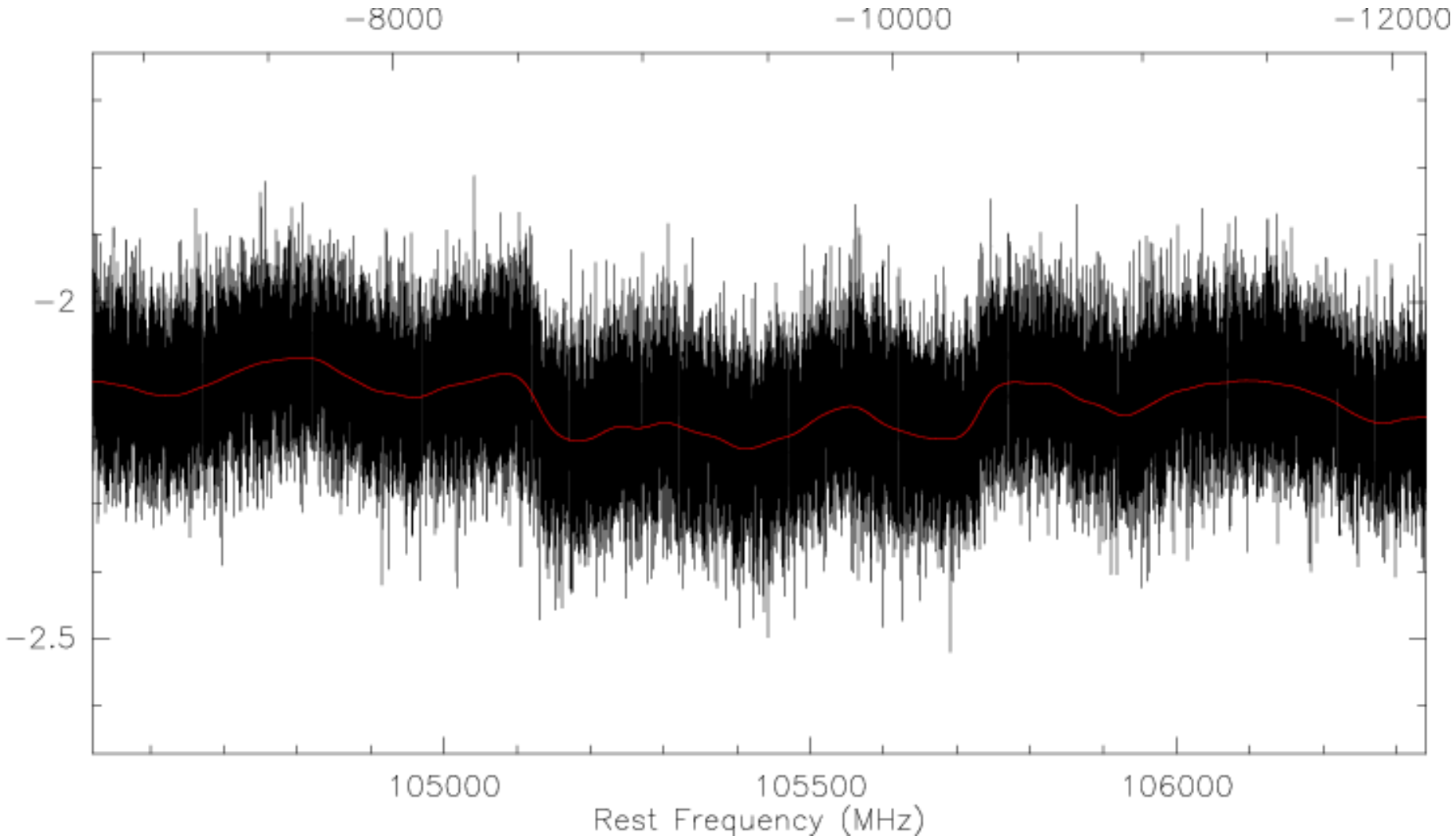


Baselining: IV. Wavelets (Experimental!)

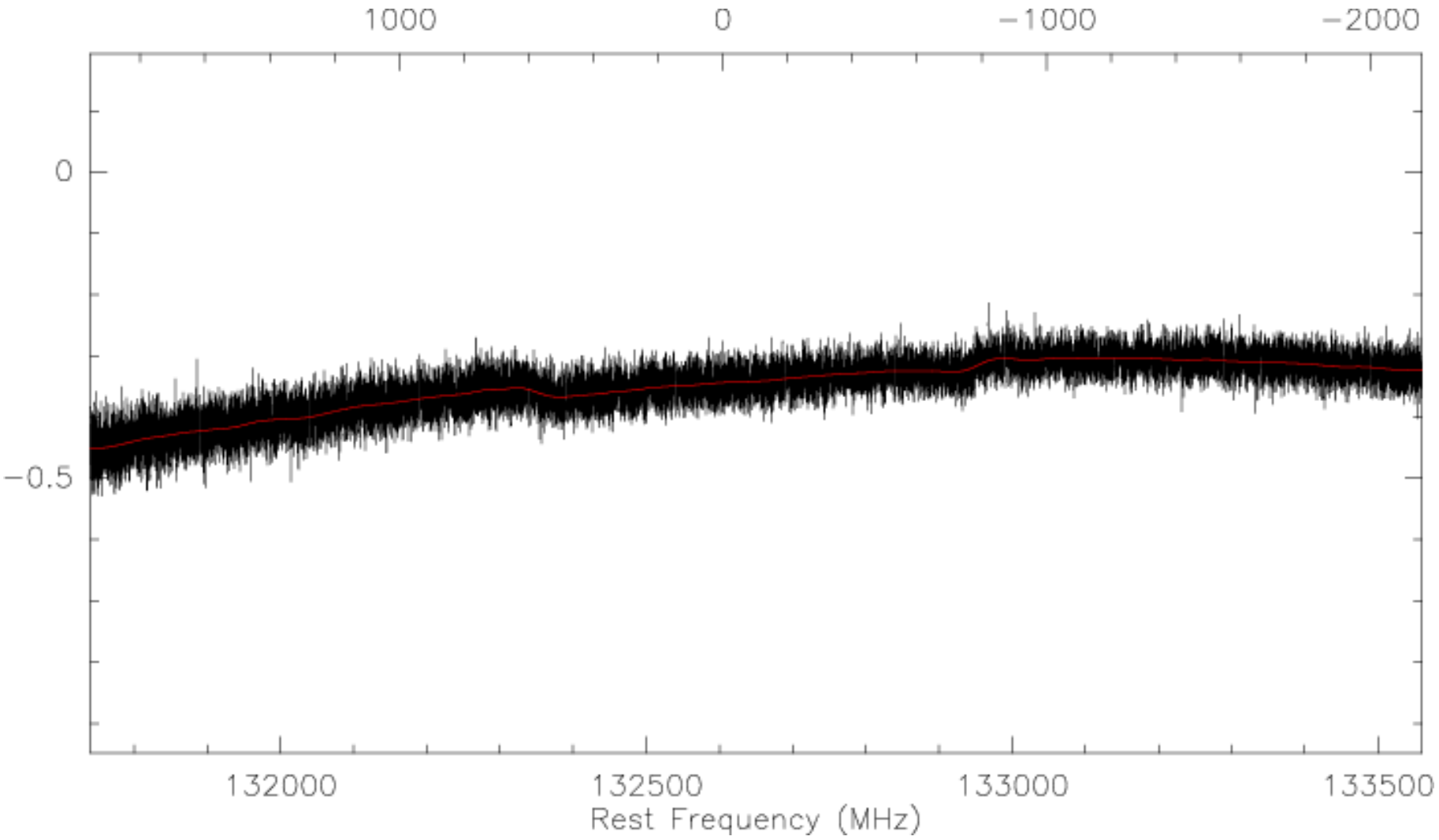
Hypotheses Lines and baselines have different spectral signatures

```
LAS> file out red/survey-5 single /over
LAS> file in  red/survey-3
LAS> find
LAS> quiet
LAS> for ient 1 to found
LAS>    get next
LAS>    wavelet /base 5
LAS>    write
LAS> next ient
LAS> verbose
```

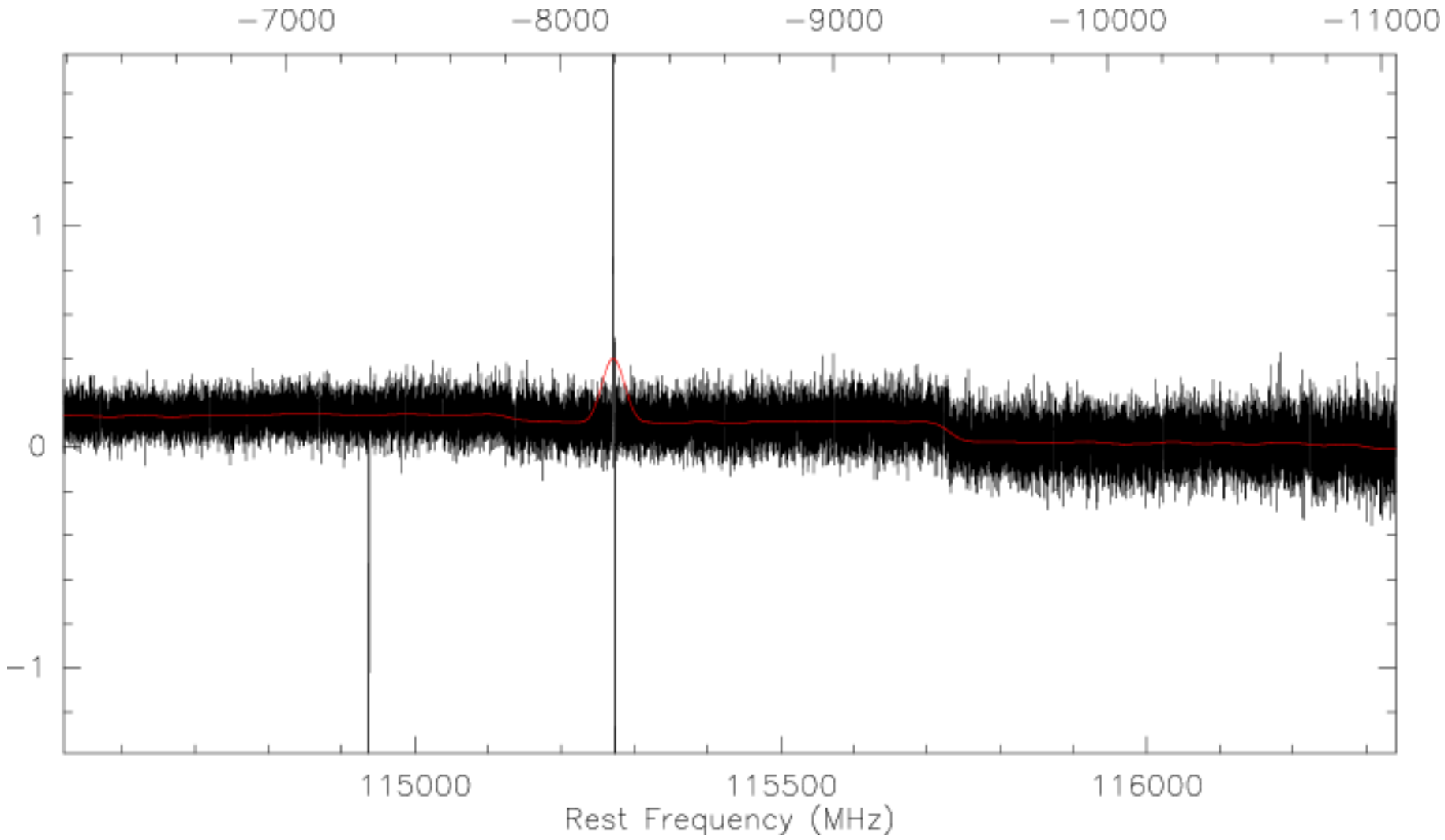
Baselining: V. Wavelet example #1



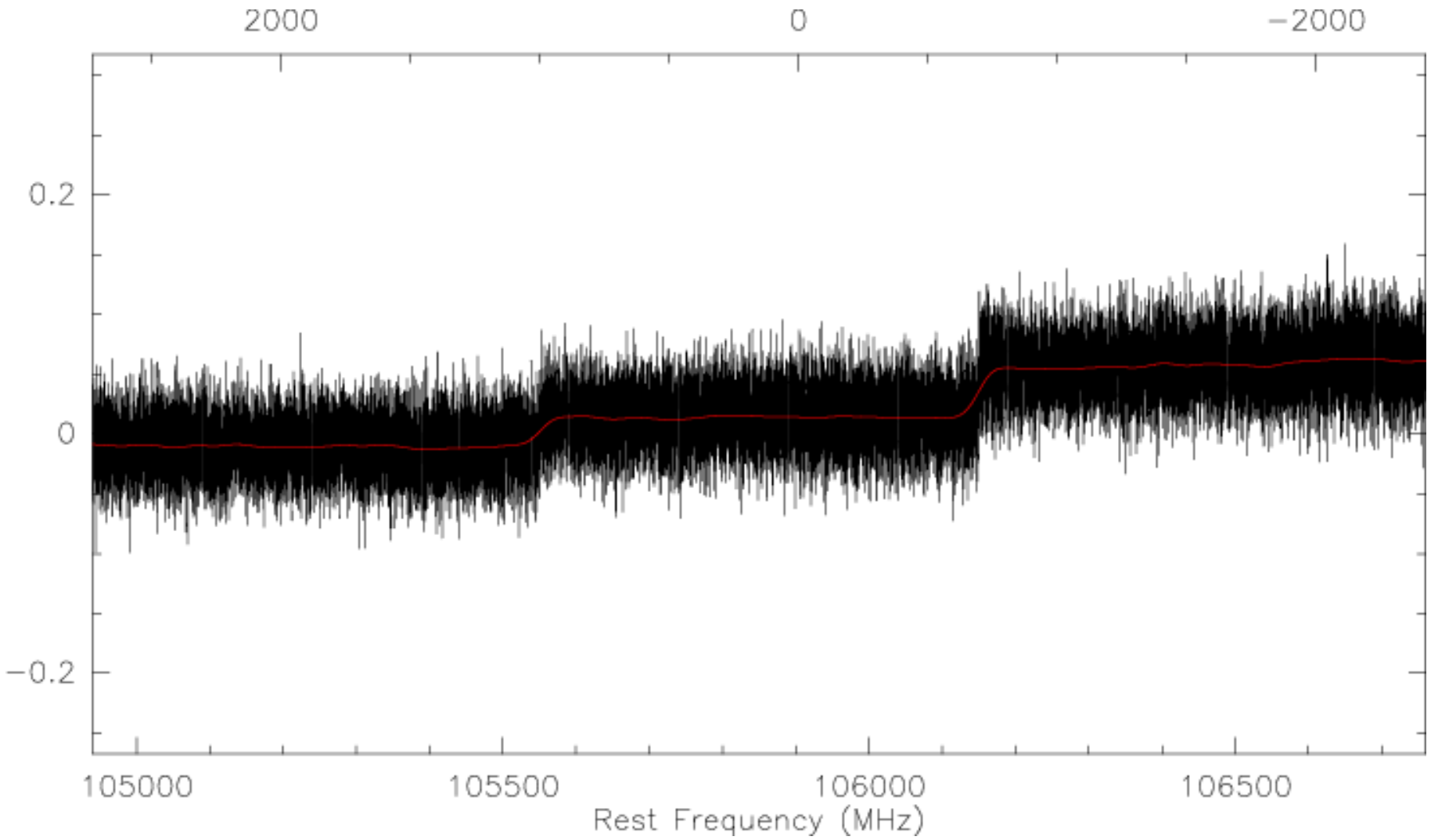
Baselining: V. Wavelet example #2



Baselining: V. Wavelet artefact #1



Baselining: V. Wavelet artefact #2



Other problems

Spikes.

Limited sideband rejection.

CLASS tutorial: IV. Interfacing GILDAS and line catalogs

Presentation by Sébastien BARDEAU
(IRAM/Grenoble)
Current LINEDB developers: Sébastien BARDEAU, Jérôme PETY
on behalf of the LINEDB developers over time

9th IRAM Millimeter Interferometry School
Oct. 10-14 2016, St Martin d'Hères

LINEDB and WEEDS

LINEDB GILDAS kernel language to query online or local spectroscopic databases (Developed by M. Lonjaret, S. Bardeau, S. Maret, & J. Pety). ⇒ see LINEDB demo.

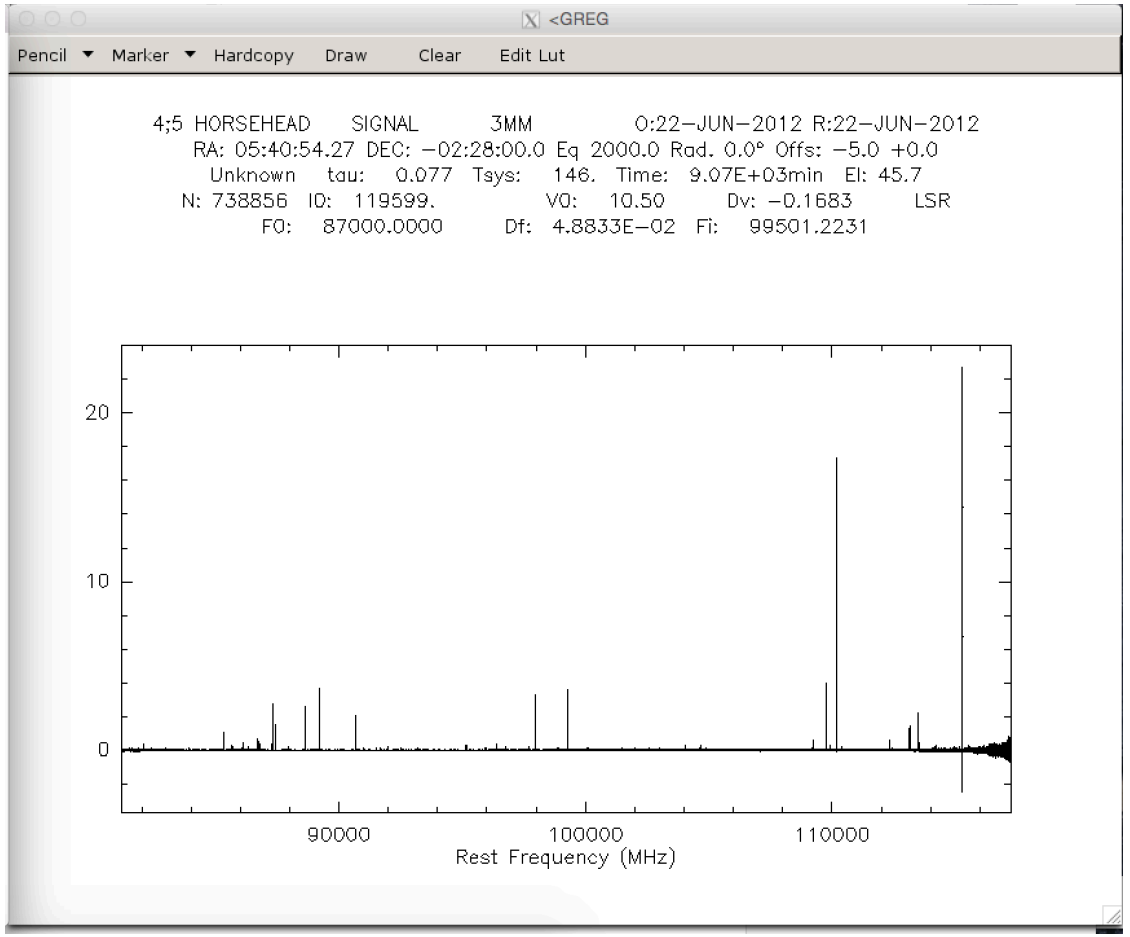
WEEDS Adaptation of LINEDB to the CLASS environment (see Maret et al. 2011, *A&A*, 256, 47). It offers

- Interactive use of line catalogs with CLASS spectra.
- LTE line modeling and production of synthetic spectra.

Compiled automatically if python (v≥ 2.6) and numpy are installed (including the development packages).

Prerequisite: Plotting a spectrum in CLASS

```
LAS> file in mydata.30m
LAS> find
LAS> get first
LAS> plot
```



Connecting the input line catalog(s)

If you want to:

- Select an online database (CDMS or JPL),
- Duplicate a (subset of) an online database in an offline catalog,
- Build a custom offline database,
- Insert or remove lines in an offline catalog

⇒ see `LINEDB` demo.

```
LAS> use in cdms      ! Online access to the CDMS database
I-USE,  cdms (online) selected
```

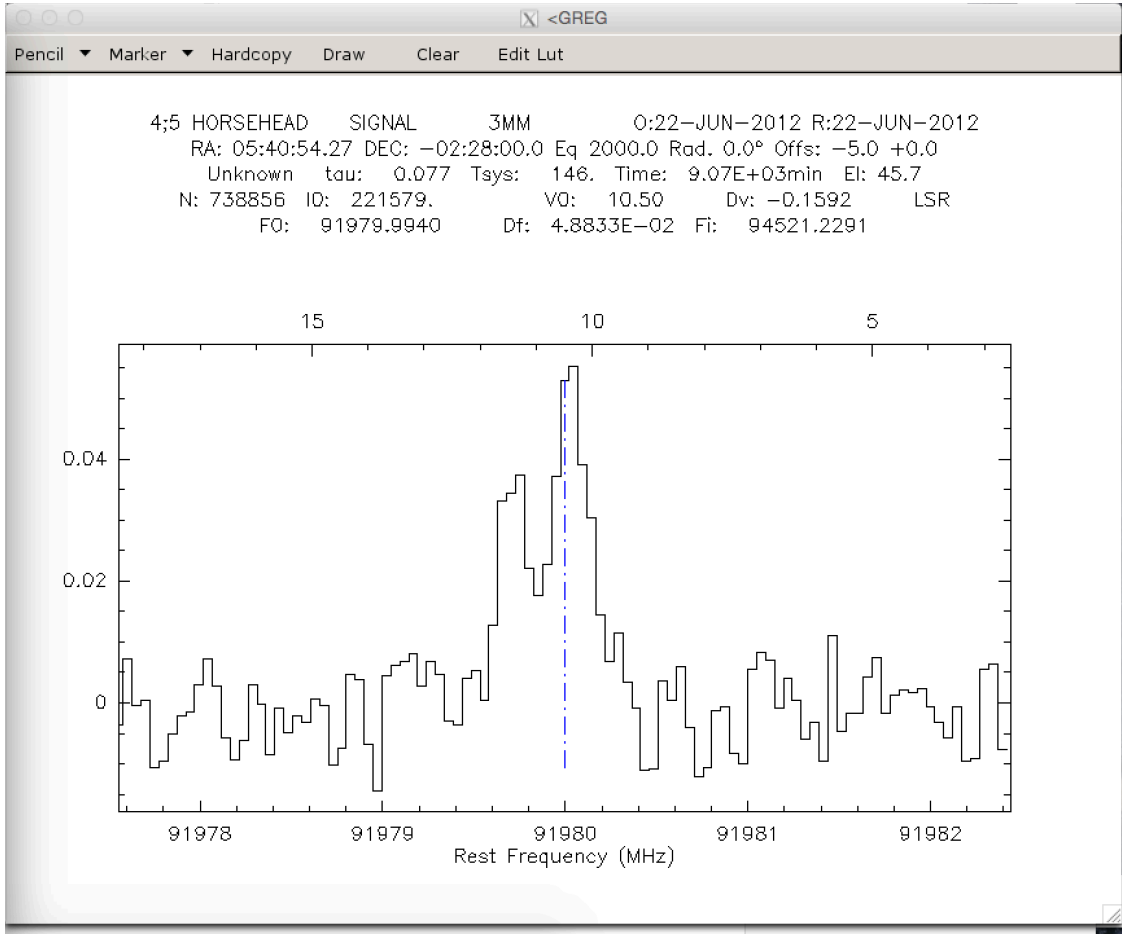
Find all the lines of a given species in the current connected line catalogs

```
LAS> lfind CH3CN   ! Create an index of all the lines associated of CH3CN
I-LFIND,  11 lines found in the frequency range 81159.6729337 to 117240.165713 MHz
LAS> llist         ! List them with their spectroscopic properties
```

#	Species	Freq[MHz]	Err[MHz]	Eup[K]	Gup	Aij[s-1]	Upper level -- Lower level	Origin
1	CH3CN	91958.726	0.000	127.5	22	2.28e-05	5 4 -- 4 4	jpl
2	CH3CN	91971.130	0.000	77.5	44	4.05e-05	5 3 -- 4 3	jpl
3	CH3CN	91979.994	0.000	41.8	22	5.32e-05	5 2 -- 4 2	jpl
4	CH3CN	91985.314	0.000	20.4	22	6.08e-05	5 1 -- 4 1	jpl
5	CH3CN	91987.088	0.000	13.2	22	6.33e-05	5 0 -- 4 0	jpl
6	CH3CN	110330.345	0.000	197.1	26	3.39e-05	6 5 -- 5 5	jpl
7	CH3CN	110349.470	0.000	132.8	26	6.17e-05	6 4 -- 5 4	jpl
8	CH3CN	110364.354	0.000	82.8	52	8.33e-05	6 3 -- 5 3	jpl
9	CH3CN	110374.989	0.000	47.1	26	9.87e-05	6 2 -- 5 2	jpl
10	CH3CN	110381.372	0.000	25.7	26	1.08e-04	6 1 -- 5 1	jpl
11	CH3CN	110383.500	0.000	18.5	26	1.11e-04	6 0 -- 5 0	jpl

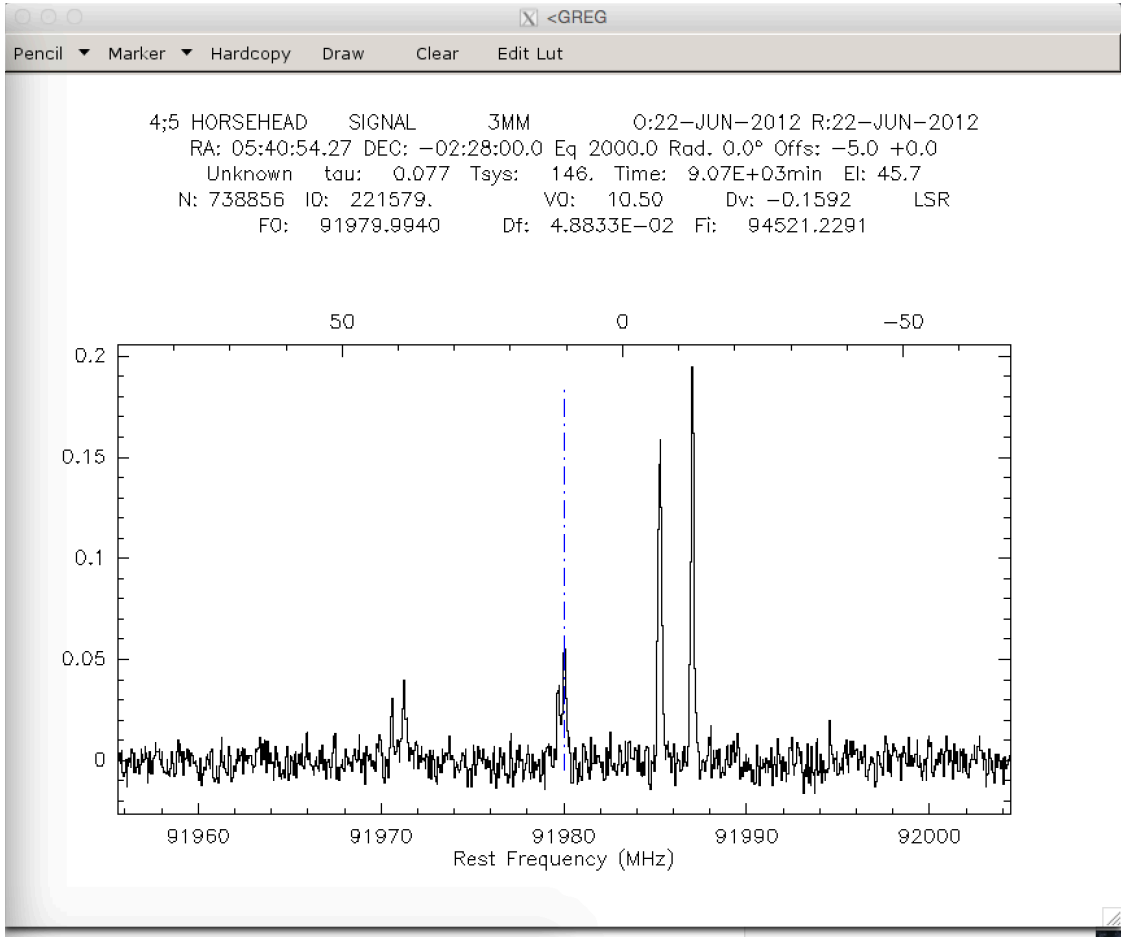
Plotting the frequency range associated to a single line of the current line index

```
LAS> lget 3    ! Get frequency range around line #3 of current index
I-LGET,  Found line frequency in the current scan
# Species Freq[MHz] Err[MHz] Eup[K]  Gup  Aij[s-1] Upper level -- Lower level Origin
1 CH3CN   91979.994   0.000    41.8   22  5.32e-05         5 2 -- 4 2            jpl
LAS> lplot     ! Plot the corresponding frequency range
```



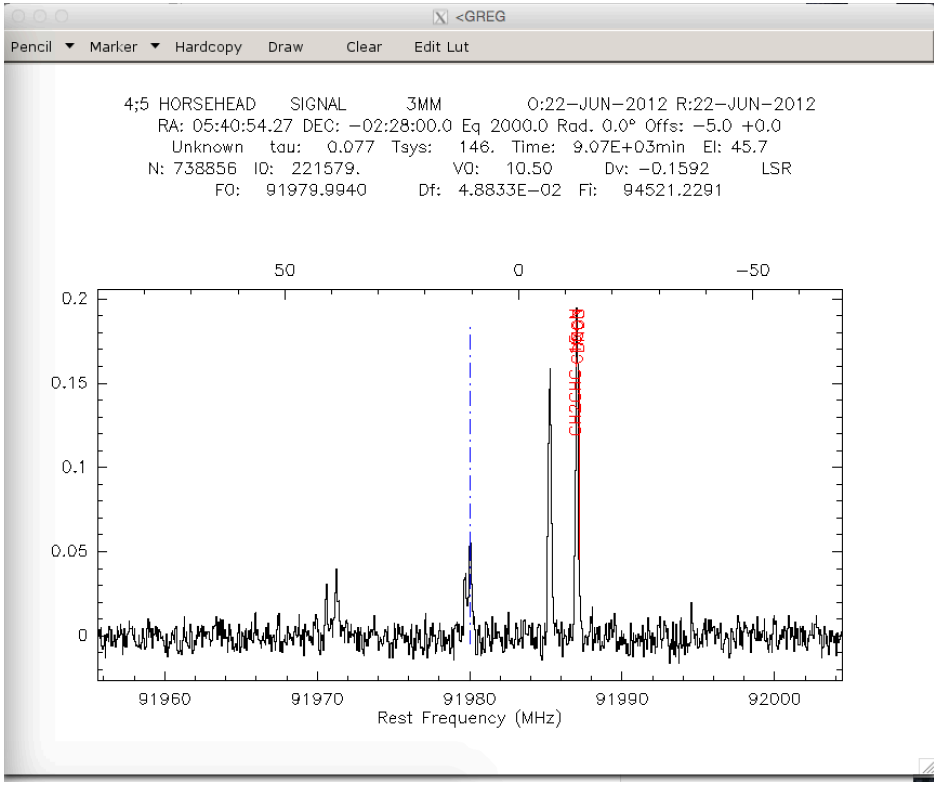
Enlarge the plotted frequency range

```
LAS> lplot 1000    ! Plot 1000 channels instead of the default 100 channels
```



Identifying a line on an already plotted spectrum

```
LAS> lid    ! Call the interactive cursor and list the lines in the current
            ! index that are nearby the selected frequency
I-LID,  9 lines found in the frequency range 91986.7037371 to 91987.1920663 MHz
  # Species              Freq[MHz] Err[MHz] Eup[K]  Gup  Aij[s-1] Upper level -- Lower level Origin
  1 H2CCHCN-15           91986.955   0.001    32.9   21  6.03e-05      10 2 9 -- 9 2 8         cdms
  2 CH2CHC-15-N          91986.955   0.001    32.9   21  5.85e-05      10 2 9 -- 9 2 8          jpl
  3 ag-diethyl ether     91987.000   0.006    52.7   39  7.06e-07      19 416 -- 18 415        cdms
  4 CH3CN, v=0           91987.088   0.000    13.2   22  6.33e-05         5 0 -- 4 0           cdms
  5 CH3CN                91987.088   0.000    13.2   22  6.33e-05         5 0 -- 4 0            jpl
  6 Phenol               91987.100   0.002    64.9  175  1.58e-06    1714 3 0 -- 1713 4 1      cdms
  7 Phenol               91987.100   0.002    64.9  175  1.58e-06    1714 4 0 -- 1713 5 1      cdms
  8 CH3C-13-H2CN, v=0    91987.124   0.003    53.5   31  2.05e-06      15 114 -- 14 213        cdms
  9 DNO3                 91987.192   0.035   511.2   61  9.29e-08      3022 8 -- 3021 9         jpl
```

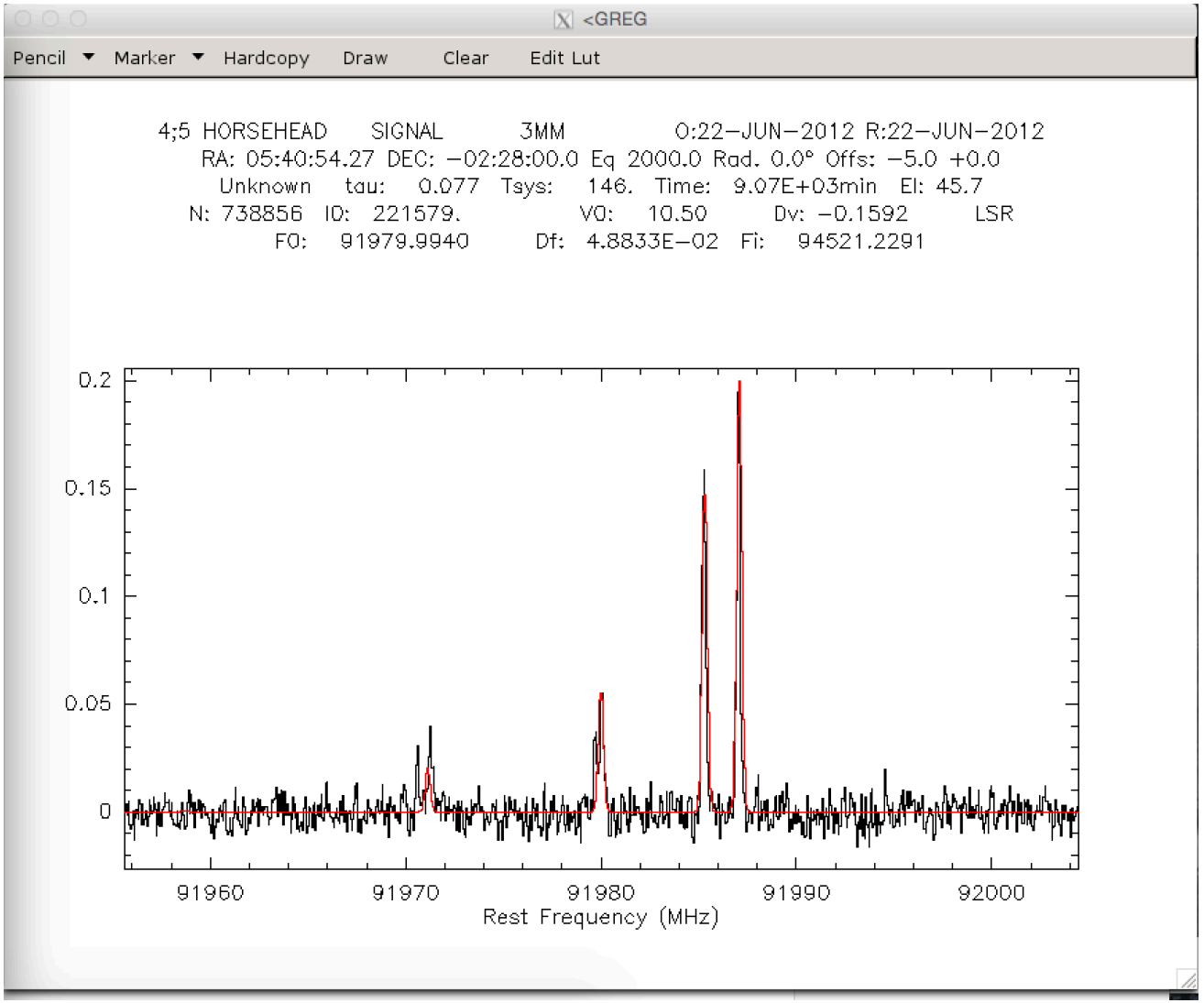


Creating a synthetic LTE spectrum

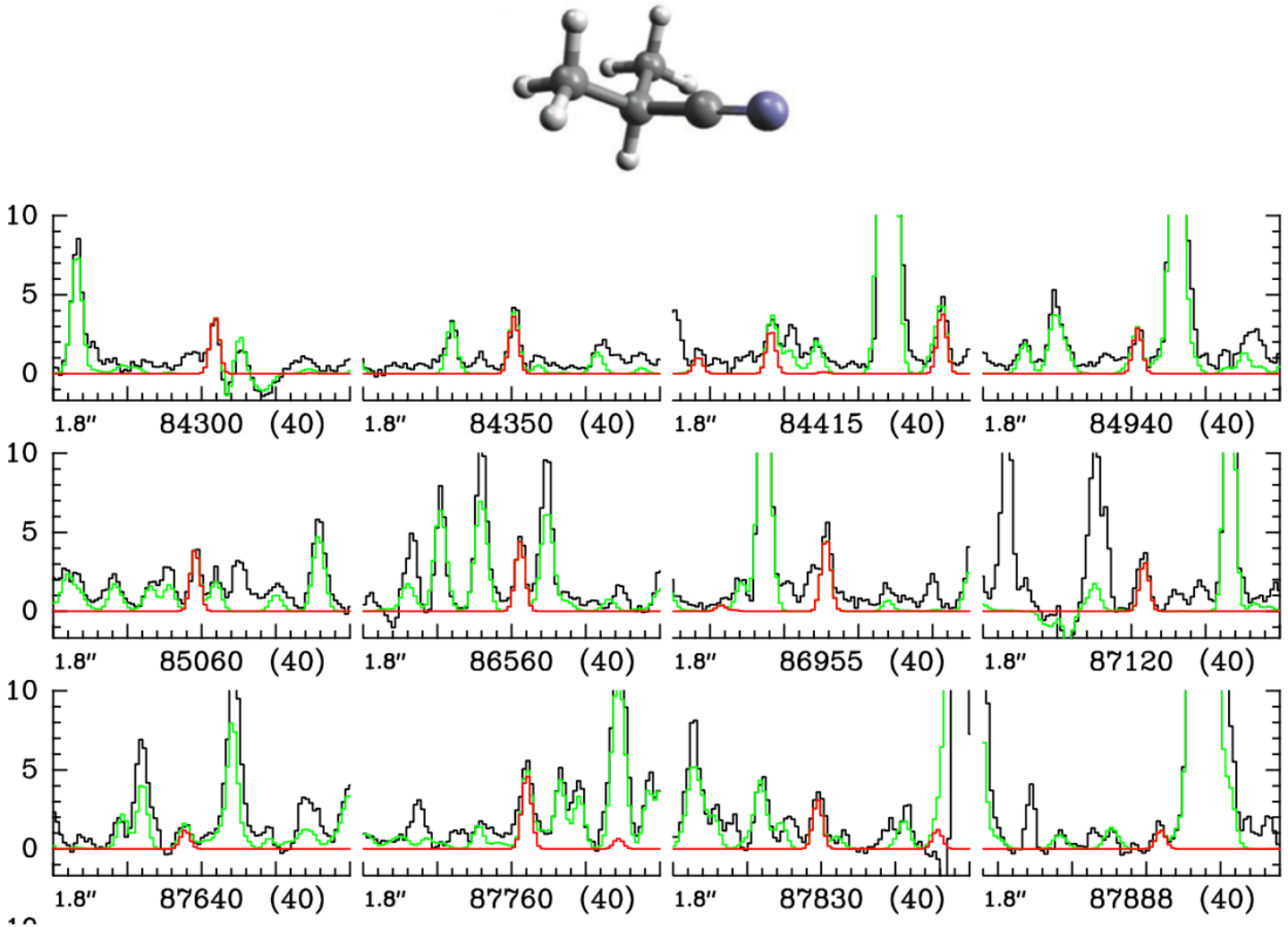
```
LAS> type ch3cn.mod                    ! Display the content of the ch3cn.mod file
! species  dcol     Tex    size     Voff     DV
!          (cm-2)  (K)    (")      (km/s)   (km/s)
  CH3CN    1e13    25     10       0        1
LAS> modsource ch3cn.mod 30 /verbose   ! Create the synthetic spectrum
I-MODSOURCE,  5 lines found in the frequency range 91955.5781255 to 92004.414063 MHz
I-MODSOURCE,   5 CH3CN lines found in the frequency range
I-MODSOURCE,  log10 of the partition function at 25.0 K from jpl is 2.3969
  # Species Freq[MHz] Err[MHz] Eup[K]  Gup  Aij[s-1]    Upper level -- Lower level Origin Tau
  1 CH3CN   91958.726   0.000   127.5   22  2.28e-05           5 4 -- 4 4         jpl 3.05e-04
  2 CH3CN   91971.130   0.000    77.5   44  4.05e-05           5 3 -- 4 3         jpl 8.03e-03
  3 CH3CN   91979.994   0.000    41.8   22  5.32e-05           5 2 -- 4 2         jpl 2.20e-02
  4 CH3CN   91985.314   0.000    20.4   22  6.08e-05           5 1 -- 4 1         jpl 5.90e-02
  5 CH3CN   91987.088   0.000    13.2   22  6.33e-05           5 0 -- 4 0         jpl 8.20e-02
I-MODEL,   Blanking value:   -1000.00000
I-RESAMPLE,  Frequency resolution: .04883 MHz (observatory), .04883 MHz (rest frame)
I-MODSOURCE,  Model has been stored in memory
```

Overplotting a synthetic LTE spectrum

```
LAS> modshow                ! Overplot the synthetic spectrum
```



WEEDS was used to detect the first branched alkyl (isopropylcyanide) in the ISM with ALMA data (Belloche et al. 2014, Science, 345)



CLASS tutorial: Dealing with cubes in CLASS

Presentation by Sébastien BARDEAU
(IRAM/Grenoble)
Current CLASS developers: Sébastien BARDEAU, Jérôme PETY,
& Stéphane GUILLOTEAU
on behalf of the CLASS developers over time

9th IRAM Millimeter Interferometry School
Oct. 10-14 2016, St Martin d'Hères

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Opening a cube

Opening a cube: I. Prerequisite

From LMV: cubes are usually Position-Position-Velocity (lmv): efficient for plane (image) access and use in GREG

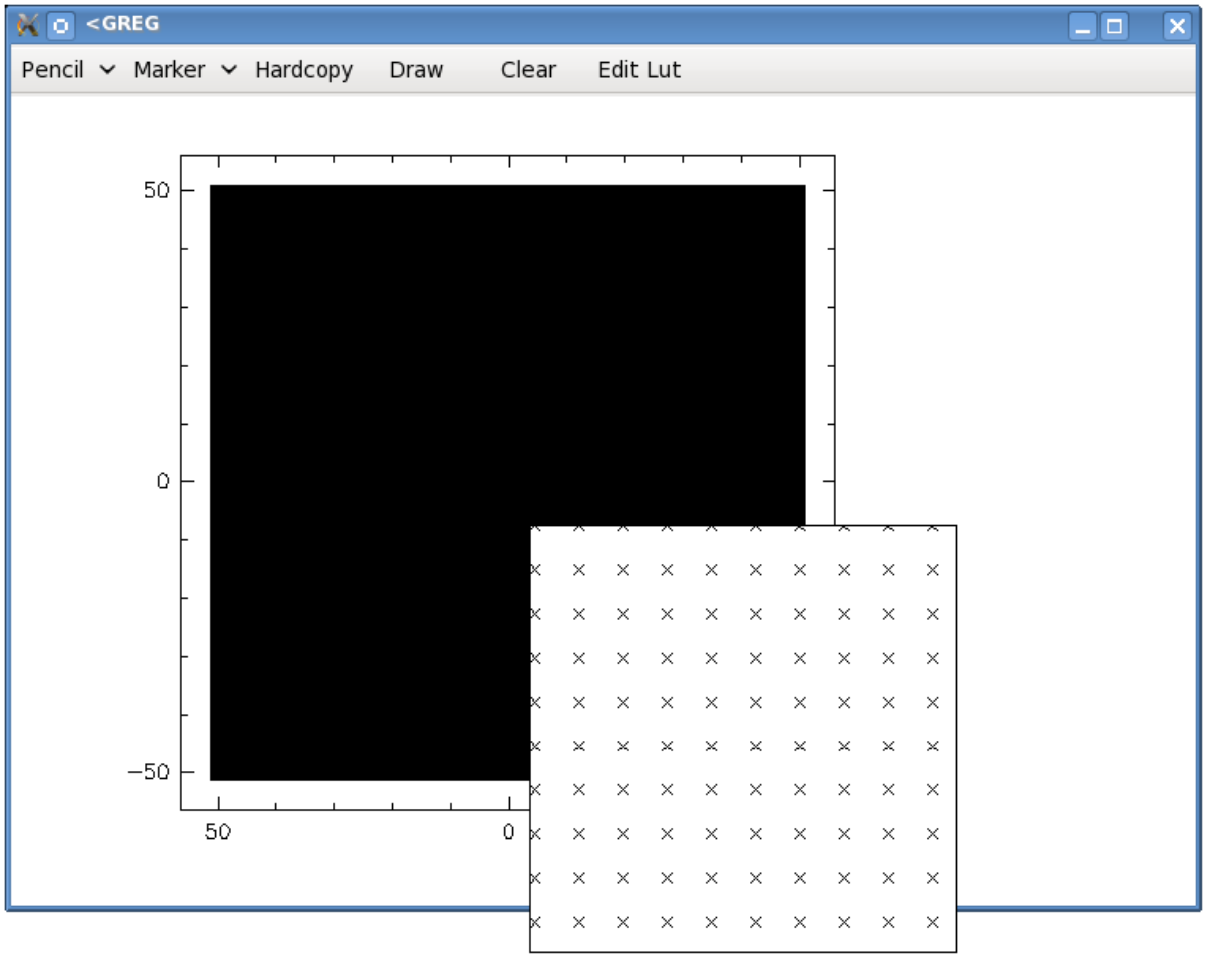
To VLM: spectrum access in CLASS needs Velocity-Position-Position (vlm) cubes ⇒ need transposition

```
LAS> TRANSPOSE lj-meth1.lmv-clean lj-meth1.vlm-clean 312
```

⊕ Efficient access,
⊖ Redondant files, double disk usage.

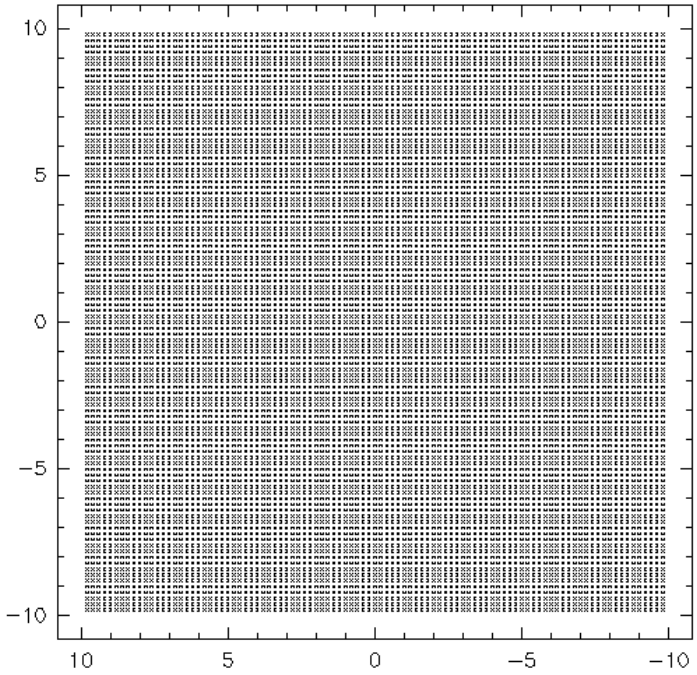
Opening a cube: II. Selecting all pixels

```
LAS> file in lj-meth1.vlm-clean  ! Open the file
I-GIO_RIH,  GDFBIG re-allocation      2
I-INPUT,  lj-meth1.vlm-clean successfully opened
LAS> find                        ! Select all the spectra/pixels
I-FIND,  262144 observations found
LAS> go where                    ! Where are the selected pixels?
```

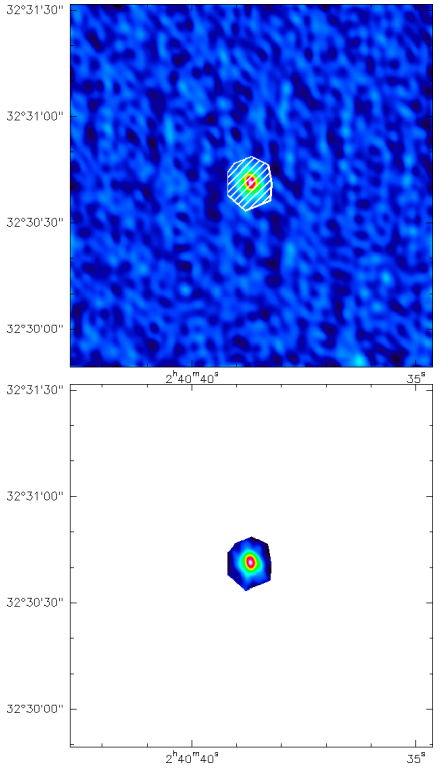


Opening a cube: III. Selecting a subset

```
LAS> set angle sec      ! Set angle unit (second is the default)
LAS> set match 10       ! Matching tolerance, in current angle unit
LAS> find /offset 0 0   ! Find spectra/pixels at the source center, with above tolerance
I-FIND,  9801 observations found
LAS> go where           ! Check selection
```



Opening a cube: IV. Selecting with custom mask

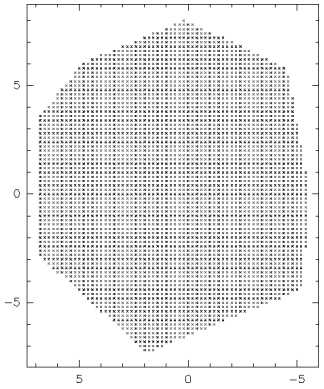


Use GREG commands (g\...) to create a mask file:

```
LAS> g\clear
LAS> g\set /def
LAS> g\image lj-meth1.lmv-clean /plane 135
LAS> g\limits /rg
LAS> g\set box match
LAS> g\plot
LAS> g\box /absolute
LAS> g\polygon /plot /hatch  ! Custom selection with cursor

LAS> g\mask out  ! Mask pixels out of the polygon
LAS> g\clear
LAS> g\plot
LAS> g\box /absolute

LAS> let rg 1 /where rg.ne.blanking[1]  ! Enable pixels in the polygon
LAS> g\write image lj-meth1-mask.lm     ! Save the mask in image file
```



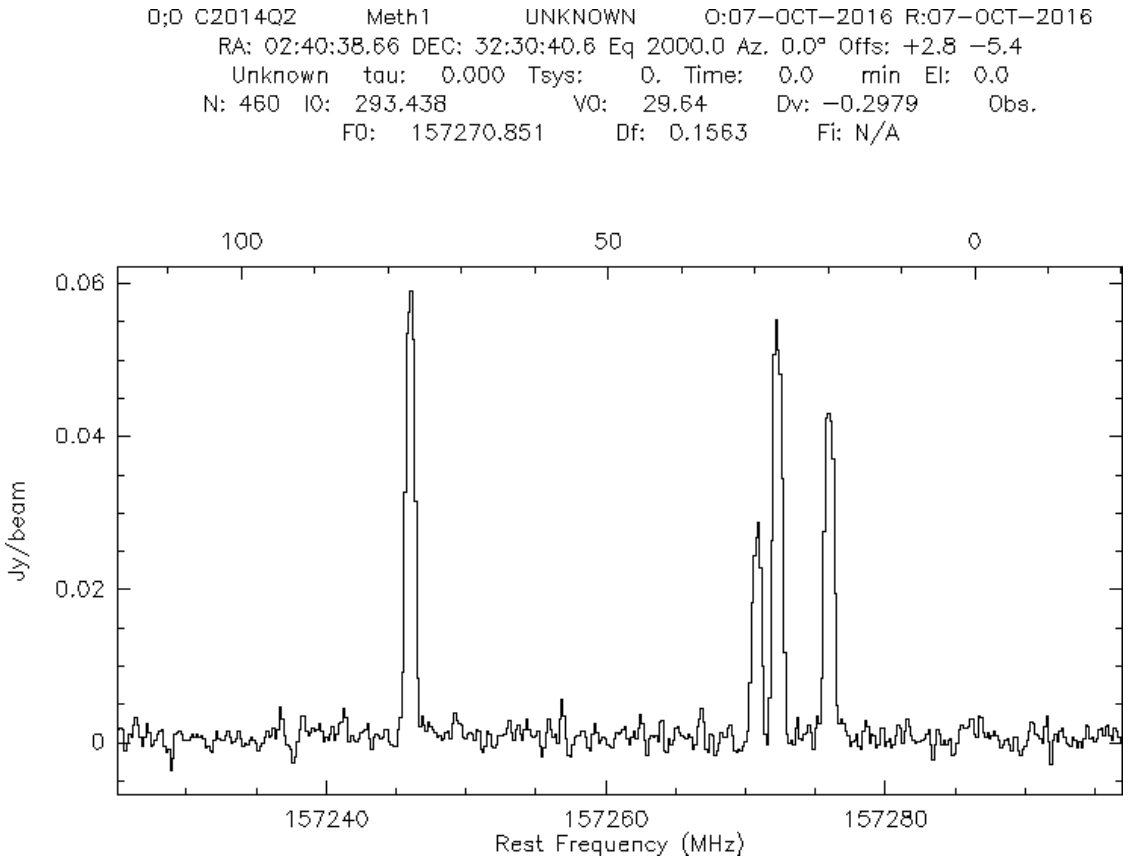
Use this mask file in CLASS for custom selection:

```
LAS> file in lj-meth1.vlm-clean
LAS> find /mask lj-meth1-mask.lm  ! Use the mask image file
LAS> go where
```

Data reduction

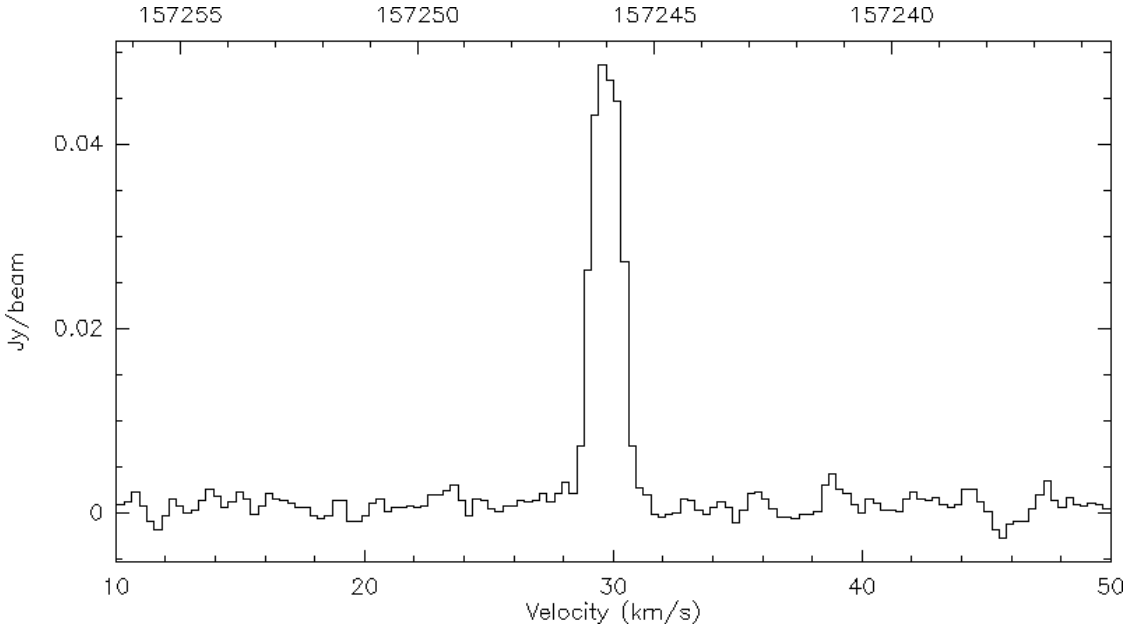
Data reduction: I. Averaging

```
LAS> set weight equal          ! Spectra have equal weight
LAS> average /nocheck offset   ! Average the selected spectra altogether, result in R buffer
...
Channel alignment, no resampling:
...
LAS> plot                      ! Plot the R buffer
```



Data reduction: II. Fitting a line on single spectrum

```
LAS> modify frequency 157246.056  ! Align velocity axis for analyzing this methanol line
LAS> set unit v f                 ! Lower axis velocity => fit results in velocity units
LAS> set mode x 10 50             ! Plot and fit only in range 10 to 50 km/s
LAS> plot
```



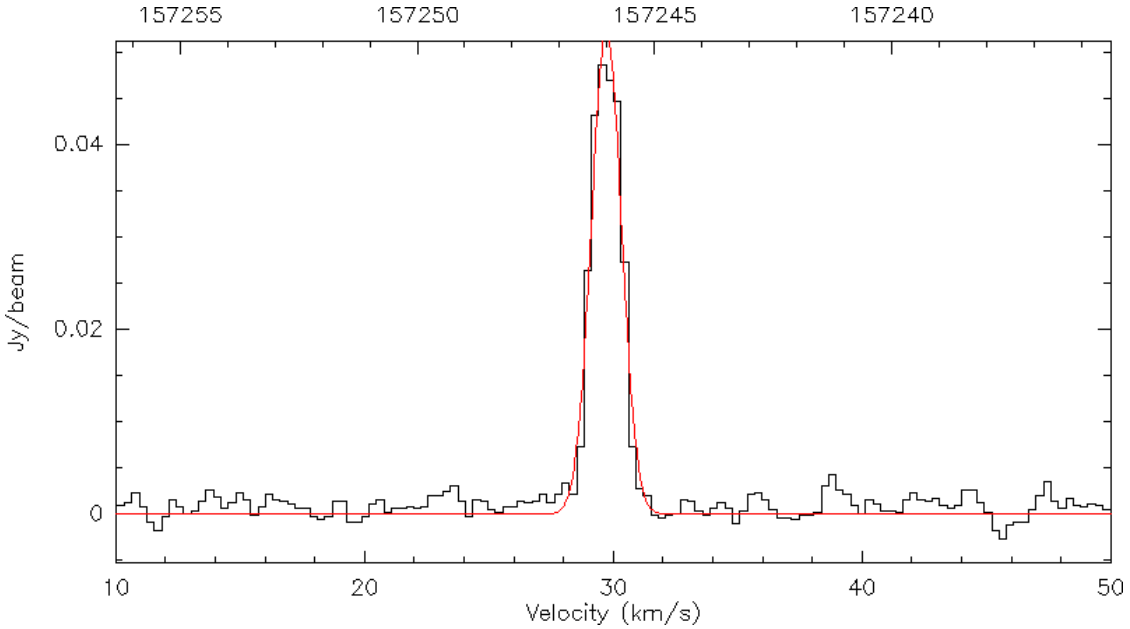

```
LAS> method gauss                 ! Will fit gaussian profile(s)
I-METHOD,   GAUSS        selected
LAS> lines 1 "0 0.1  0 30  0 2"   ! 1 gaussian, initial guesses for intensity, position, width
LAS> minimize /nocheck baseline   ! Minimization, assume there is no baseline to remove
...
 Line      Area                    Position           Width              Tpeak
 1    9.51483E-02 (  0.002)    29.717 (  0.012)     1.404 (  0.025)  6.36587E-02
```

Data reduction: II. Fitting a line on single spectrum (cont'd)

```
LAS> minimize /nocheck baseline      ! Minimization, assume there is no baseline to remove
...
 Line      Area                    Position            Width              Tpeak
 1    7.89793E-02 (  0.001)    29.720 (  0.012)     1.410 (  0.027)  5.26357E-02

LAS> examine r%head%gau%result[1:3]  ! Fitting results saved in R buffer
R%HEAD%GAU%RESULT[1:3] is a real Array     of dimensions  3
  7.8979328E-02   29.72018       1.409616
LAS> examine r%head%gau%error[1:3]   ! Fitting errors saved in R buffer
R%HEAD%GAU%ERROR[1:3] is a real Array     of dimensions  3
  1.3531410E-03  1.2194340E-02  2.6825795E-02

LAS> visualize /pen 1                ! Overplot the fitted profile
```



Data reduction: III. Fitting a line on all pixels

Same operation on each individual spectrum/pixel. Save results in a CLASS file.

```
LAS> file in lj-meth1.vlm-clean
LAS> set match 5
LAS> find /offset 0 0                  ! Square selection => will produce square maps

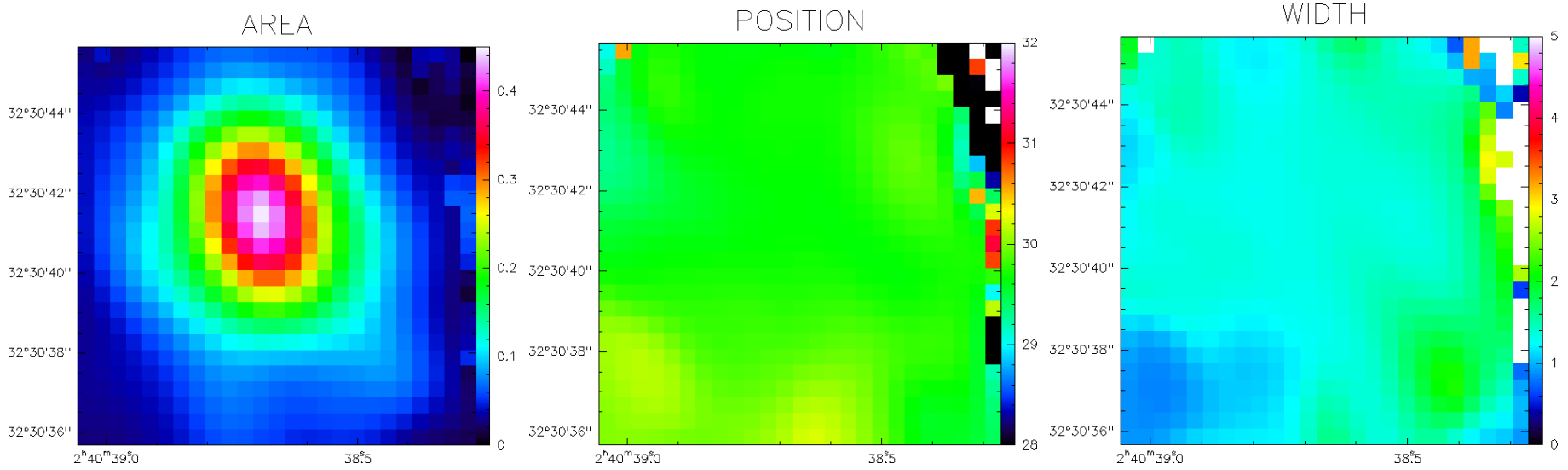
LAS> file out lj-meth1.bin single      ! Will save spectra + fitting results in this file
LAS> set unit v f                      ! Lower axis velocity => fit results in velocity units
LAS> set mode x 10 50                  ! Fit only in range 10 to 50 km/s
LAS> method gauss                      ! Will fit gaussian profile(s)

LAS> for i 1 to found                  ! Loop on all selected spectra
LAS>   get next                        ! Read next spectrum in index
LAS>   modify frequency 157246.056
LAS>   lines 1 "0 0.1  0 30  0 2"      ! 1 gaussian, initial guesses for intensity, position, width
LAS>   minimize /nocheck baseline
LAS>   write                           ! Write this spectrum + fitting results
LAS> next i

LAS> $ls -l lj-meth1.bin
-rw------- 1 bardeau astro 6148096 Oct 10 10:42 lj-meth1.bin
```

Data reduction: IV. Maps of parameters

```
LAS> file in lj-meth1.bin      ! Retrieve the fitted spectra
LAS> find
LAS> set weight equal          ! Spectra have equal weight

LAS> table lj-meth1 new /math R%HEAD%GAU%RESULT[1] R%HEAD%GAU%RESULT[2] R%HEAD%GAU%RESULT[3]

LAS> xy_map lj-meth1 /nogrid   ! Create cube from table, no gridding (spectra already inplace)
...
Field of View:     -10.0" x      10.0"
Pixel size:      -0.4" x       0.4"
Spatial resolution:       3.2"
Telescope Beam:       3.0" (from table header)
I-XY_MAP,  Creating file: lj-meth1.lmv
I-XY_MAP,  Creating file: lj-meth1.wei
```