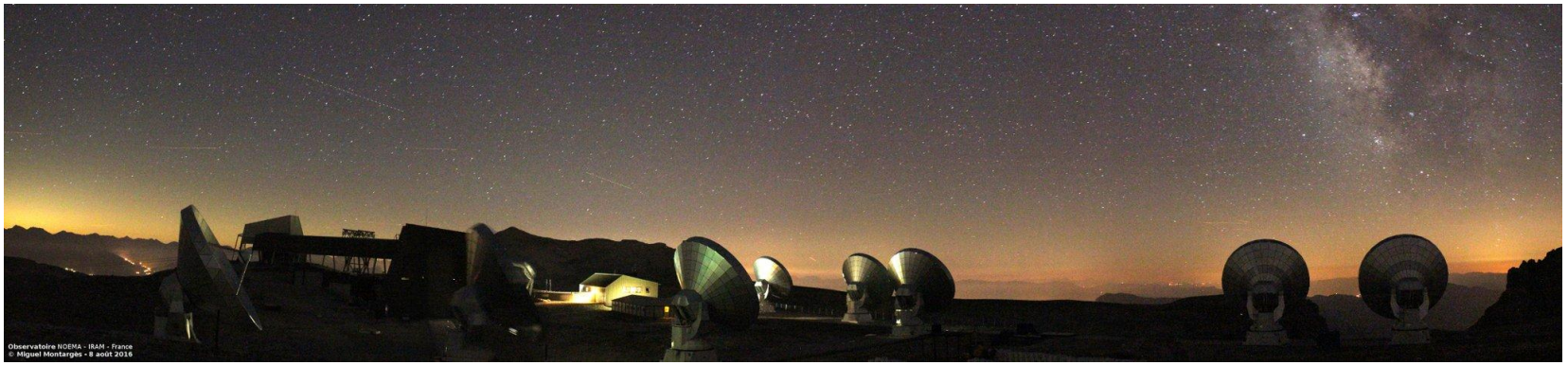
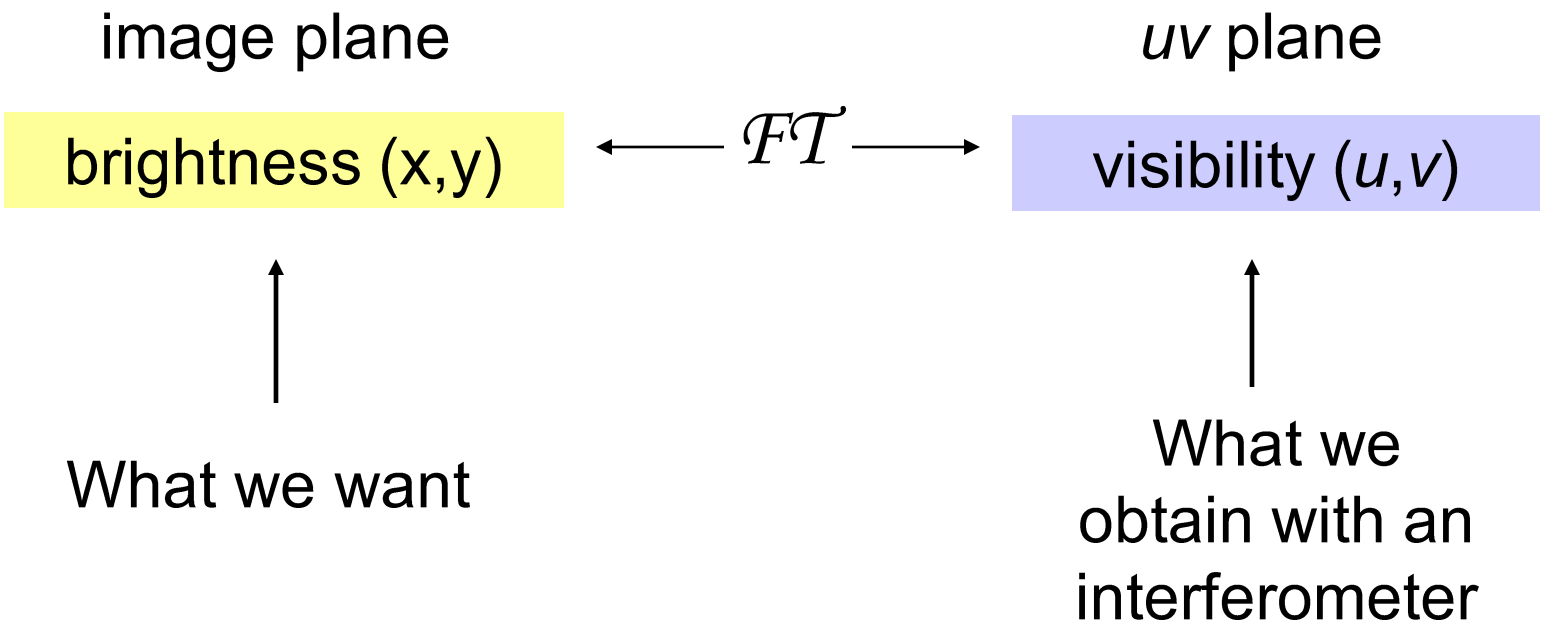
NOEMA *uv*-data analysis in practice



Miguel Montargès

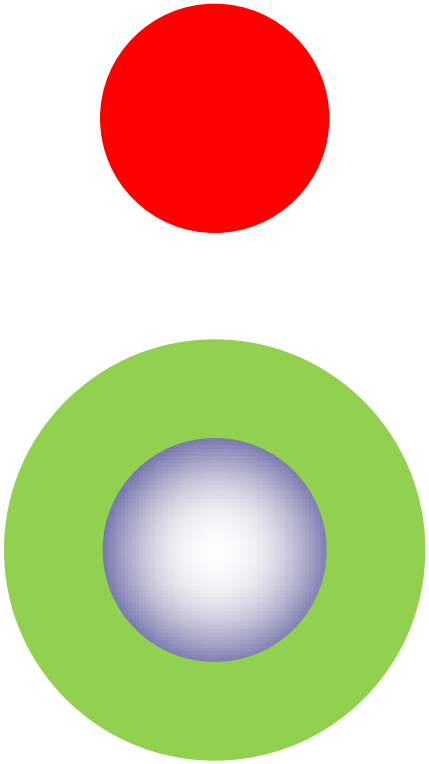
(slides available here, only today : **http://www.iram.fr/~montarges**)

General Picture

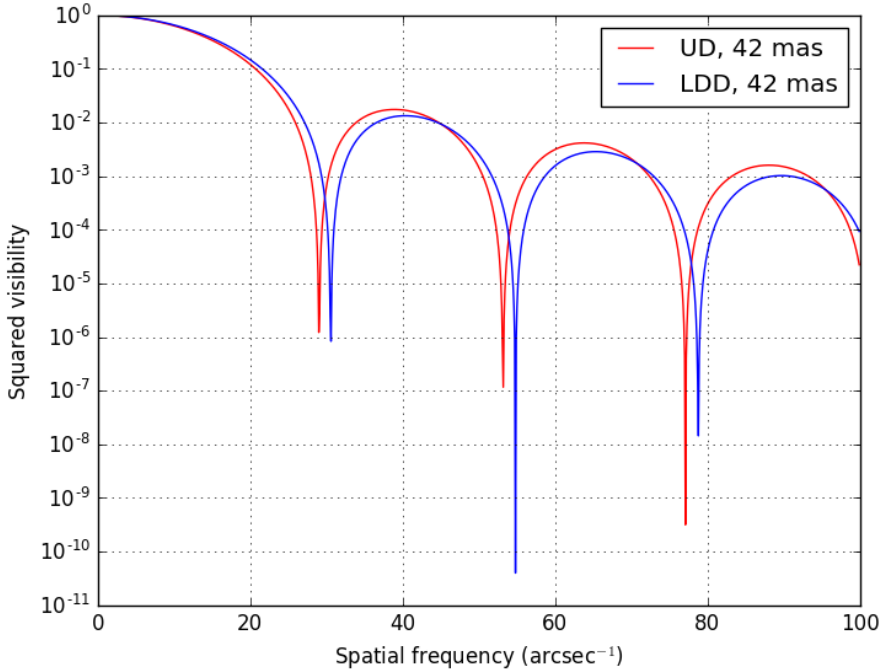


General Picture

image plane



uv plane



General Picture

image plane

brightness (x,y)

uv plane

visibility (*u*,*v*) instr — **IPB data**

Calibration

hpb files

visibility (*u*,*v*) obs — ***uv*-table**

Gridding

FFT

Cleaning

lmv* (gdf)

brightness (x,y) *uv*

• Data processed enough to have removed all instrumental contribution

• Data raw enough to access to observational characteristics: baseline, scan, weight, etc.

• Data not yet affected by the 'imaging process': assumptions, interpolations, computations, etc.

Structure of uv tables

Each visibility contains:

uv table [visib dimension, # visibilities]

visib dimension = 7 + 3 x (# channels)

- *u* in meters
- *v* in meters
- scan number
- observation date (CLASS number)
- time in seconds (since date above)
- start antenna in the baseline
- end antenna in the baseline

7 visib. characteristics

- real part for 1st channel
- imaginary part 1st channel
- weight 1st channel

data at 1st channel

- real part for 2nd channel
- imaginary part 2nd channel
- …

data at 2nd channel

Summary

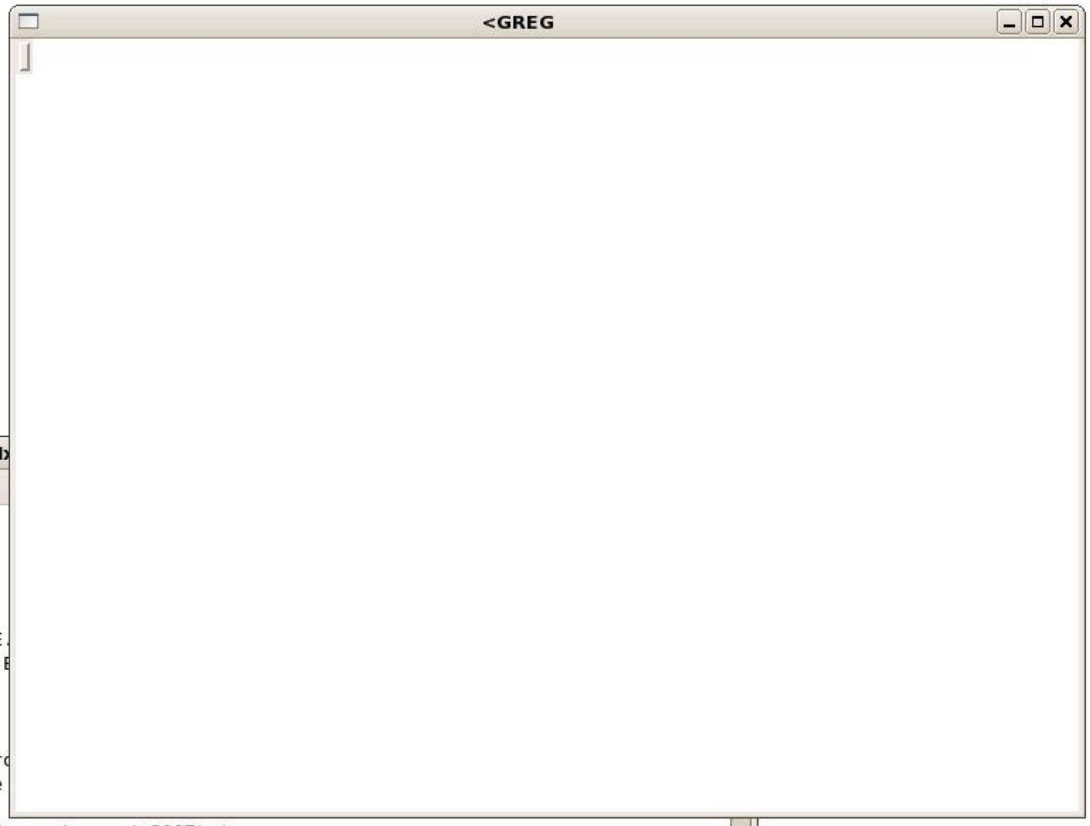
1. Let's create a uv-table, in CLIC
2. Data analysis, in MAPPING

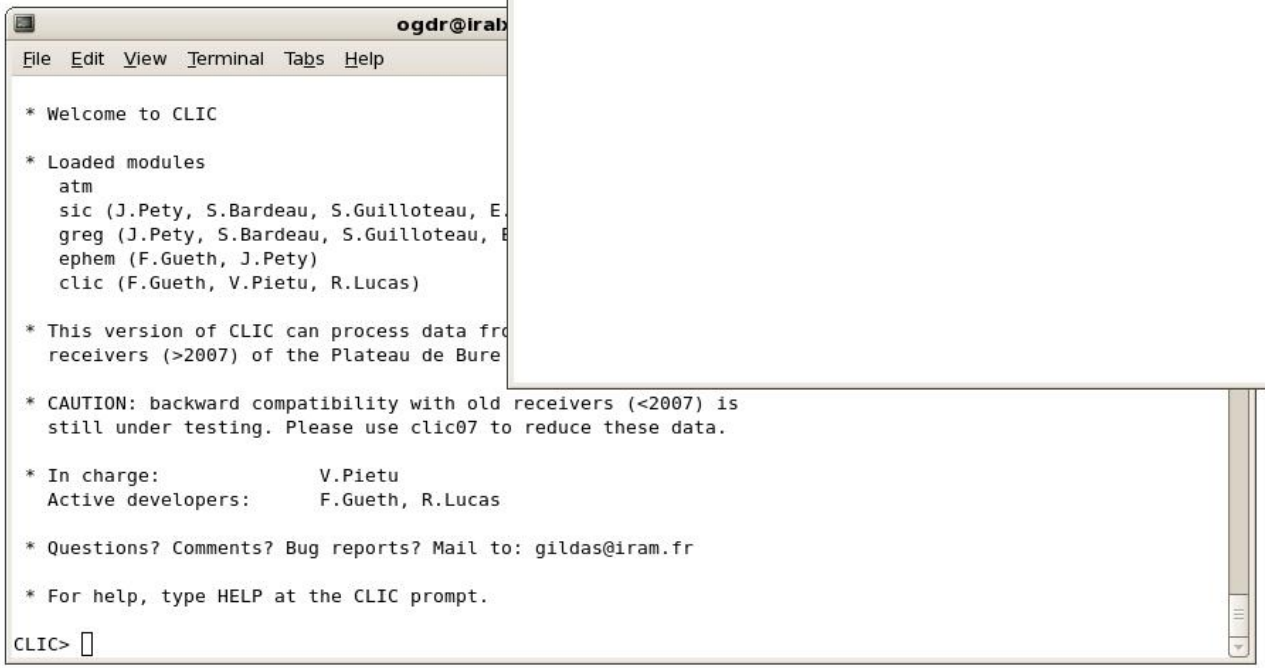
   - Data analysis in the *uv*-plane
   - An inspection of the *uv*-data needed

Let’s create a table (“mytable”.uvt),

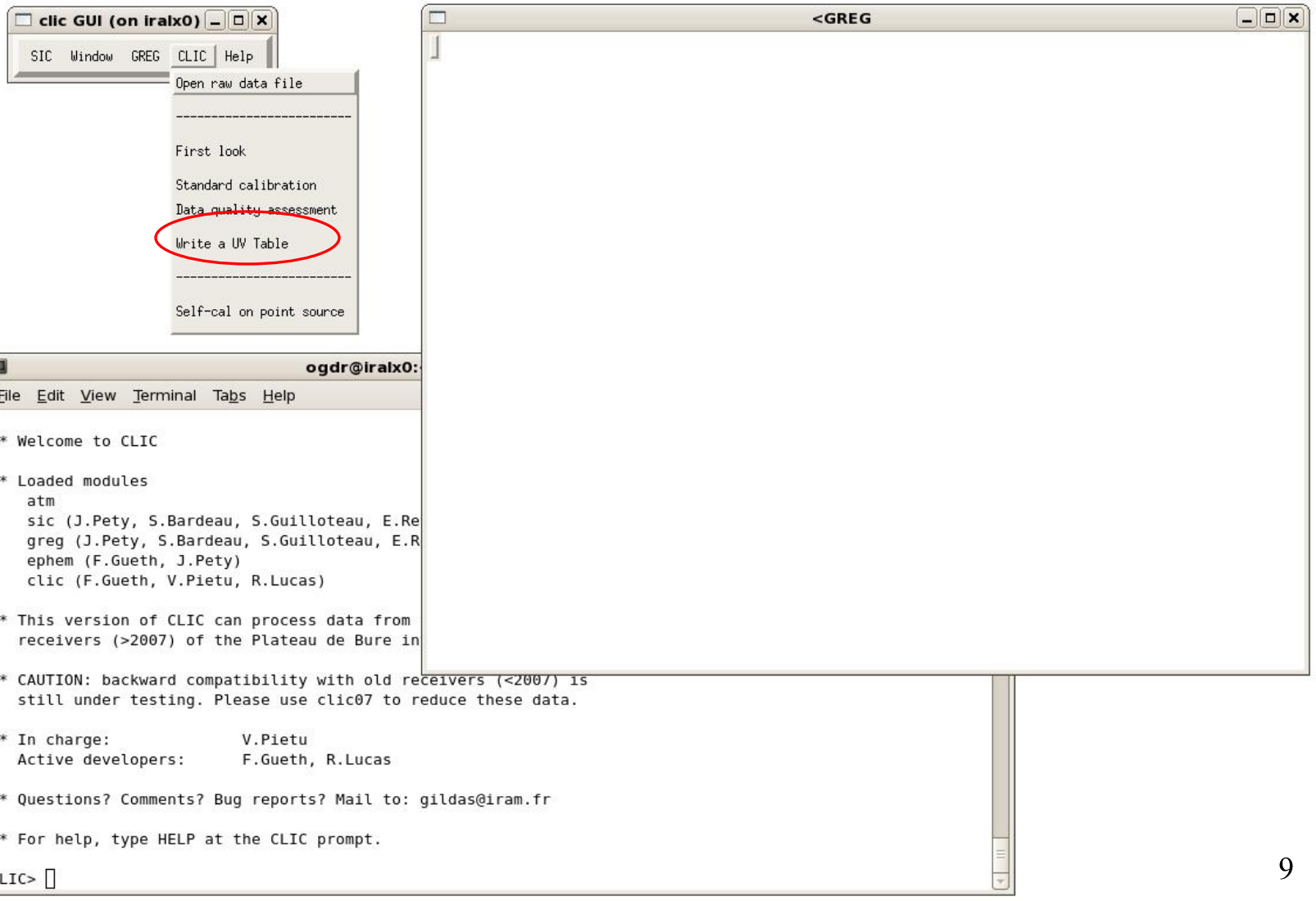
in CLIC

Creating a *uv*-table; **CLIC**

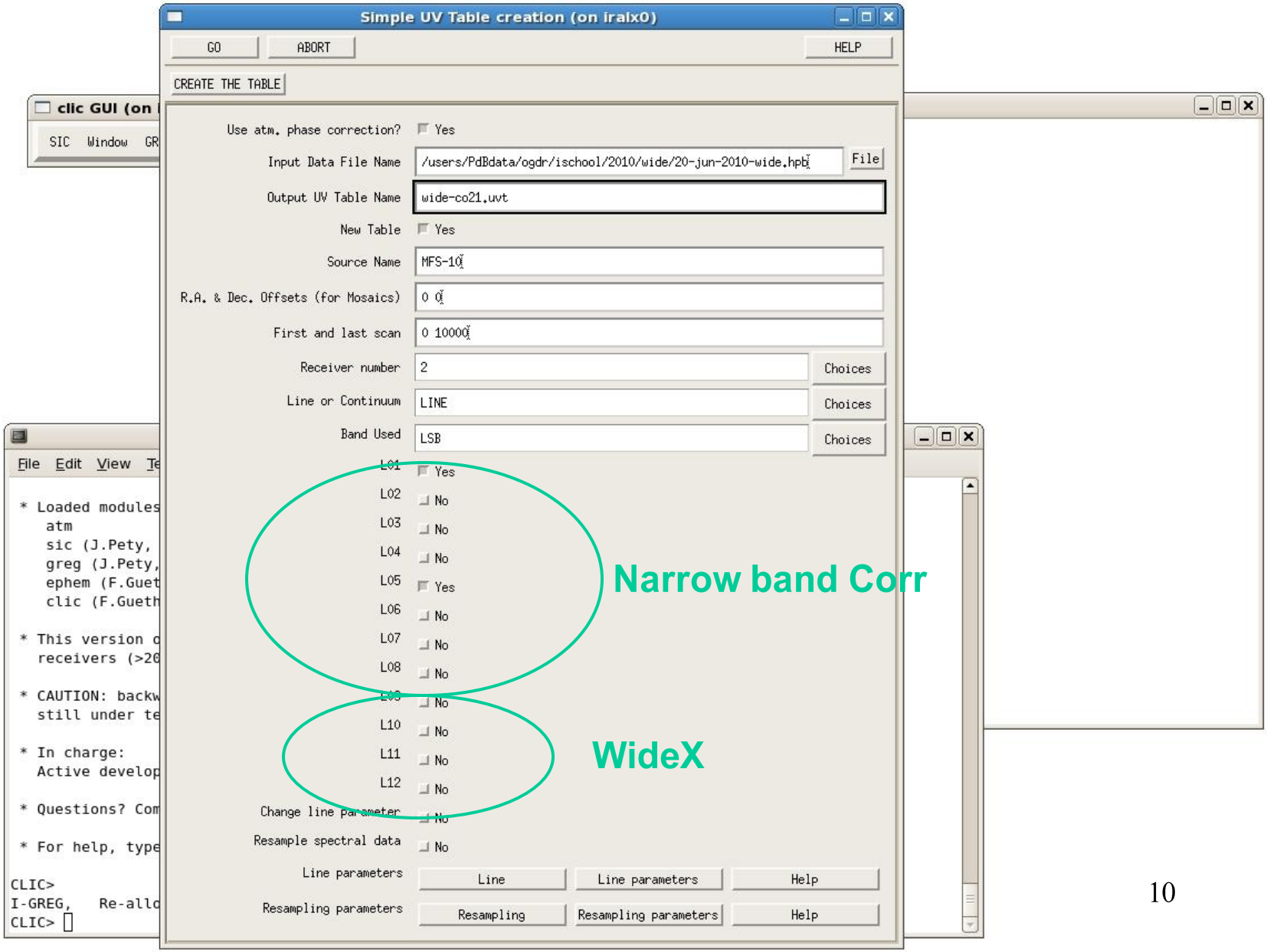




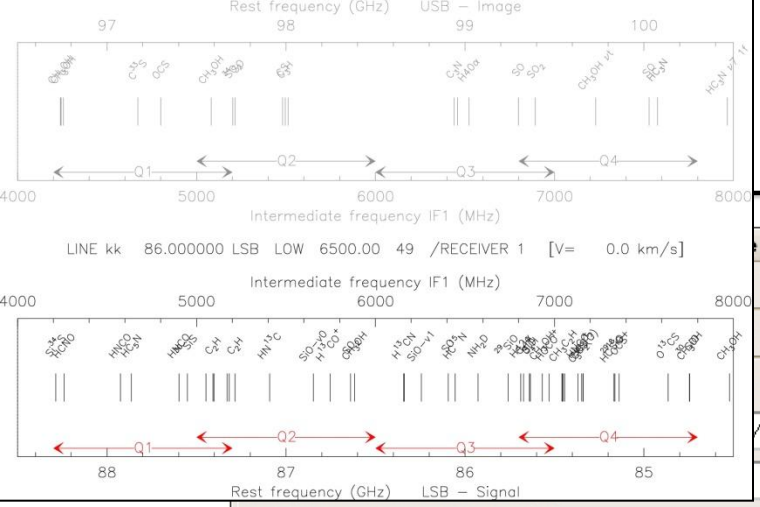
Creating a *uv*-table; CLIC

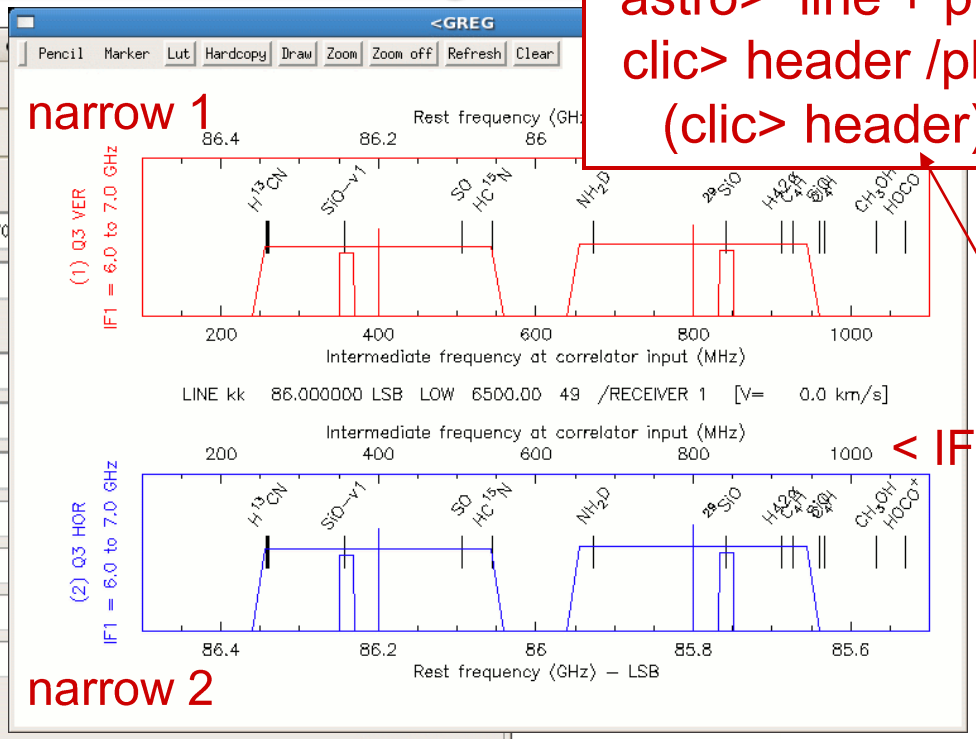


Creating a *uv*-table; CLIC



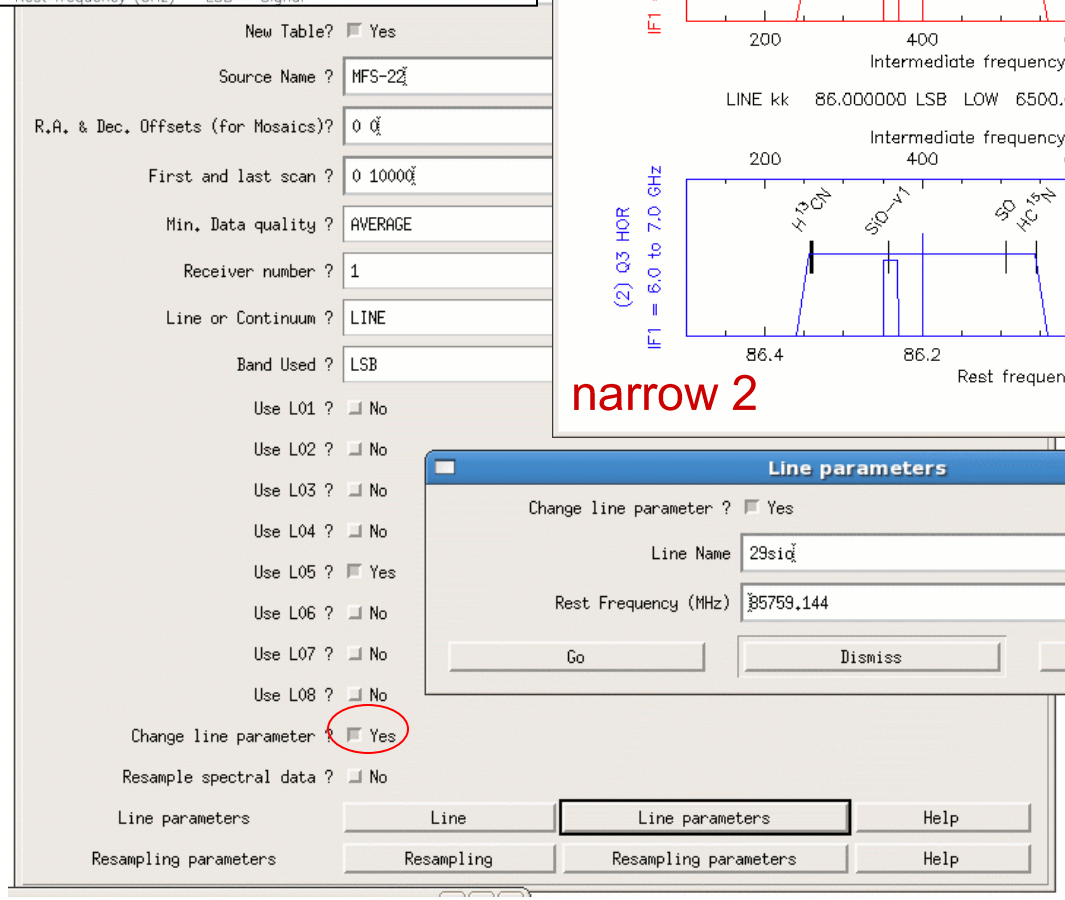
Creating a u

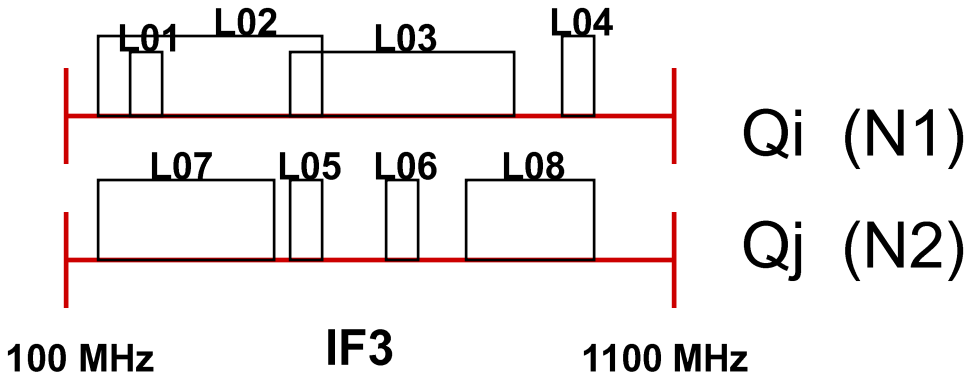




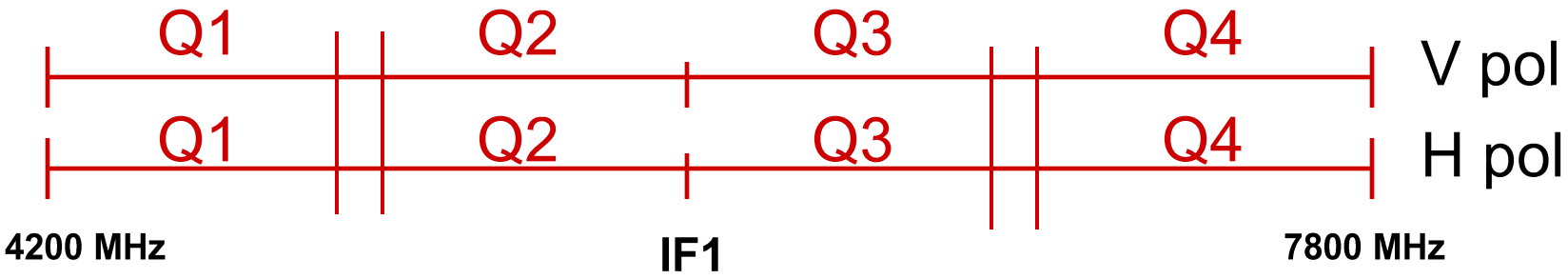
astro> line + plot
clic> header /plot
(clic> header)

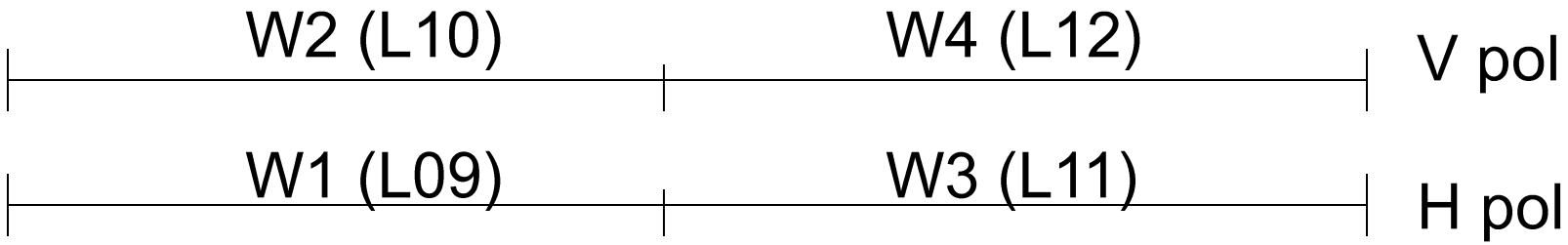
< IF3 units





Narrow Band Correlator CONFIG

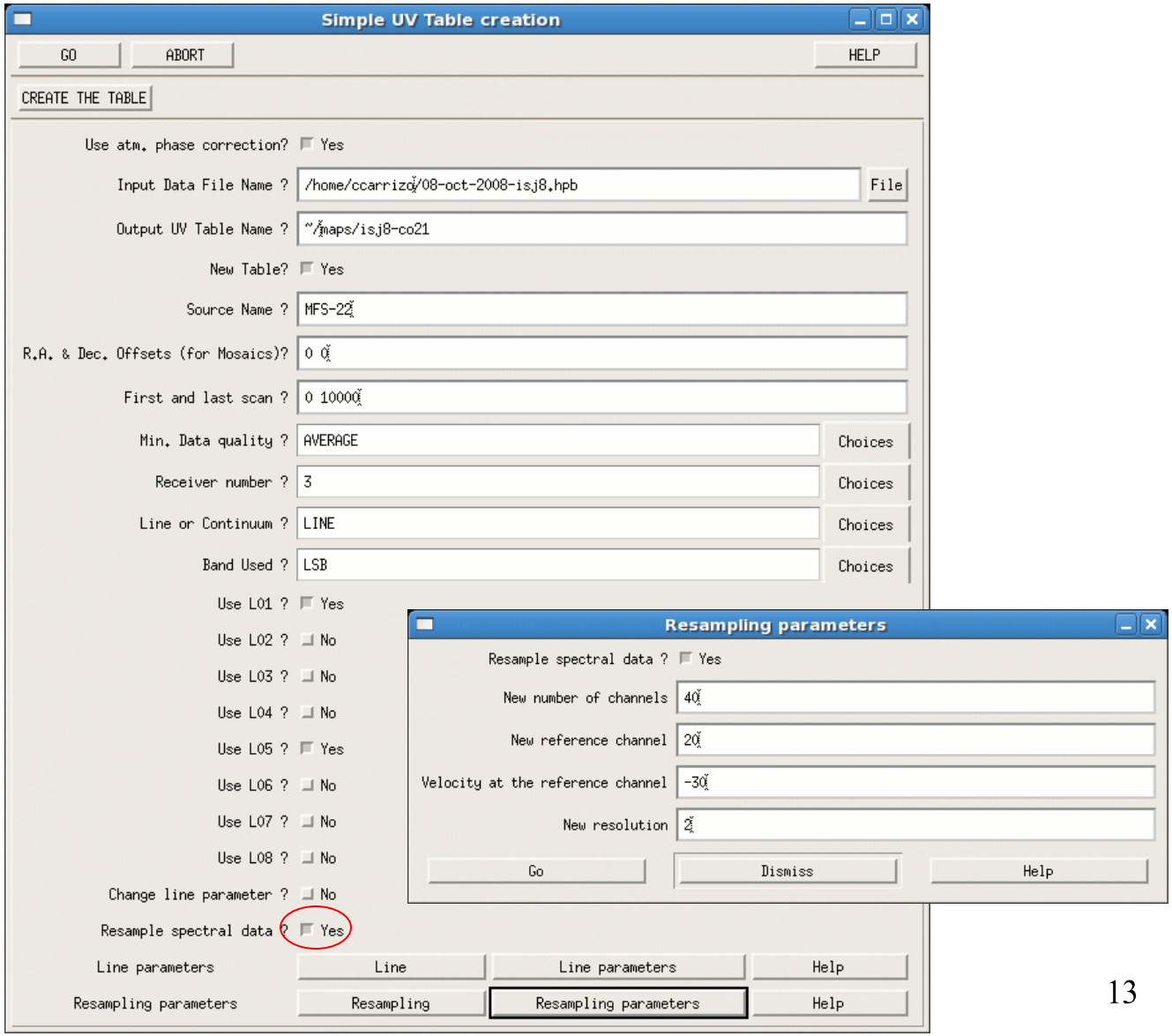




Wide Band Correlator FIXED

Talk of R. Neri yesterday

Creating a *uv*-table; CLIC



ogdr@iralx0:~/ischool/2010/isa8/reports

File Edit View Terminal Tabs Help

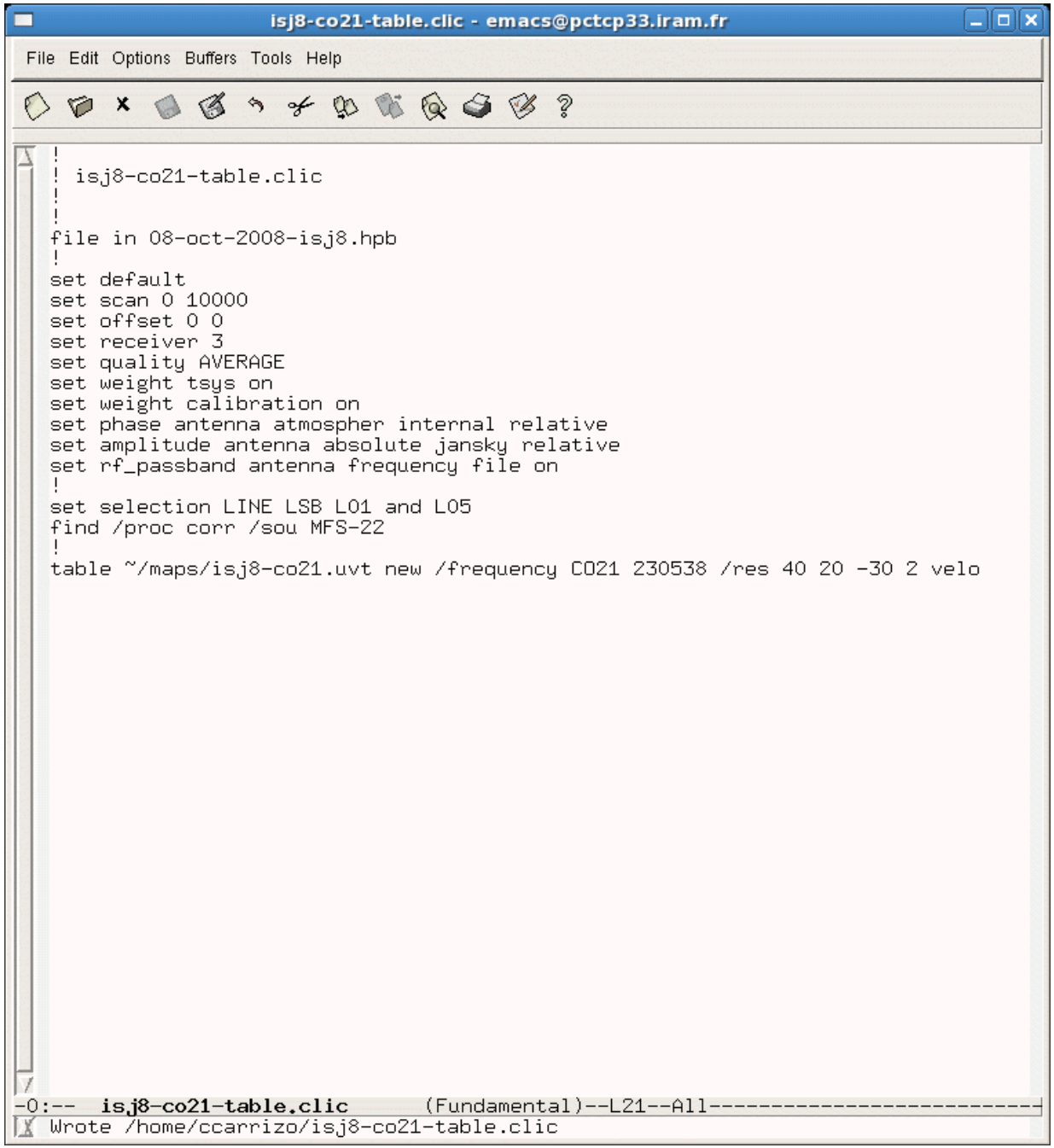
```
 Phases are Degrees Jumpy
 Amplitudes are relative to calibrator amplitude
 Amplitude Calibration is antenna-based
 Amplitudes are expressed in janskys
 RF Passband Calibration is applied
 RF Passband Calibration is frequency dependent
 RF Passband Calibration is antenna-based
 RF Passband Calibration from input file
 RF Passband Calibration is applied
 RF Passband Calibration is frequency dependent
 RF Passband Calibration is antenna-based
 RF Passband Calibration from input file
 Phases are relative to calibrator phase
 Phase Calibration is antenna-based
 Phase reference is internal (same receiver)

 Using real-time atmospheric phase correction, antennas  1 2 3 4 5 6
   (according to validation by STORE CORRECTION)
 Using no off-line atmospheric phase correction, antennas  1 2 3 4 5 6

 Phases are Degrees Jumpy
 Amplitudes are relative to calibrator amplitude
 Amplitude Calibration is antenna-based
 Amplitudes are expressed in janskys
I-FILE,[6868] Found file /users/PdBdata/ogdr/ischool/2010/isa8/reports/11-apr-2007-isa8.hpb
 Offset range :    0.0  to    0.0  and    0.0  to    0.0
 Selected data quality is   4 (Average)
I-CLIC_SET,[6868] SWITCHING ON SET AVERAGE SCAN METHOD
 Phases are Degrees Jumpy
 Amplitudes are relative to calibrator amplitude
 Amplitude Calibration is antenna-based
 Amplitudes are expressed in janskys
 RF Passband Calibration is applied
 RF Passband Calibration is frequency dependent
 RF Passband Calibration is antenna-based
 RF Passband Calibration from input file
 Selection is LINE, LSB     ,  L07
 All frequencies selected.
 I-CLIC,  Primary beam size    58.76925     "
W-TABLE,[7537] Spectrum resampling is needed, obs. #   844 Scan  7537
W-TABLE,[7537]  Frequency resolutions :   2.50000000000000      -0.858185138199841
W-TABLE,[7537]  Reference channels :   13.9744529724121        15.0000000000000
W-TABLE,[7537]  Number of channels :         116          30
I-TABLE,[6957] Table parameters for afgl-sio.uvt:
I-TABLE,[6957] X_LINE = sio          X_FREQ =    85759.144 X_VAL1 =    85743.342
I-TABLE,[6957] X_FRES =       -0.858 X_VRES =        3.000 X_VOFF =       99.000
I-TABLE,[6957]  NCHAN =           30 X_REF1 =      15.0000
I-TABLE,[6957]   5665 visibilities written (out of   5850 possible)
I-TABLE,[6957] Old size   5850 New   5665
CLIC>
```

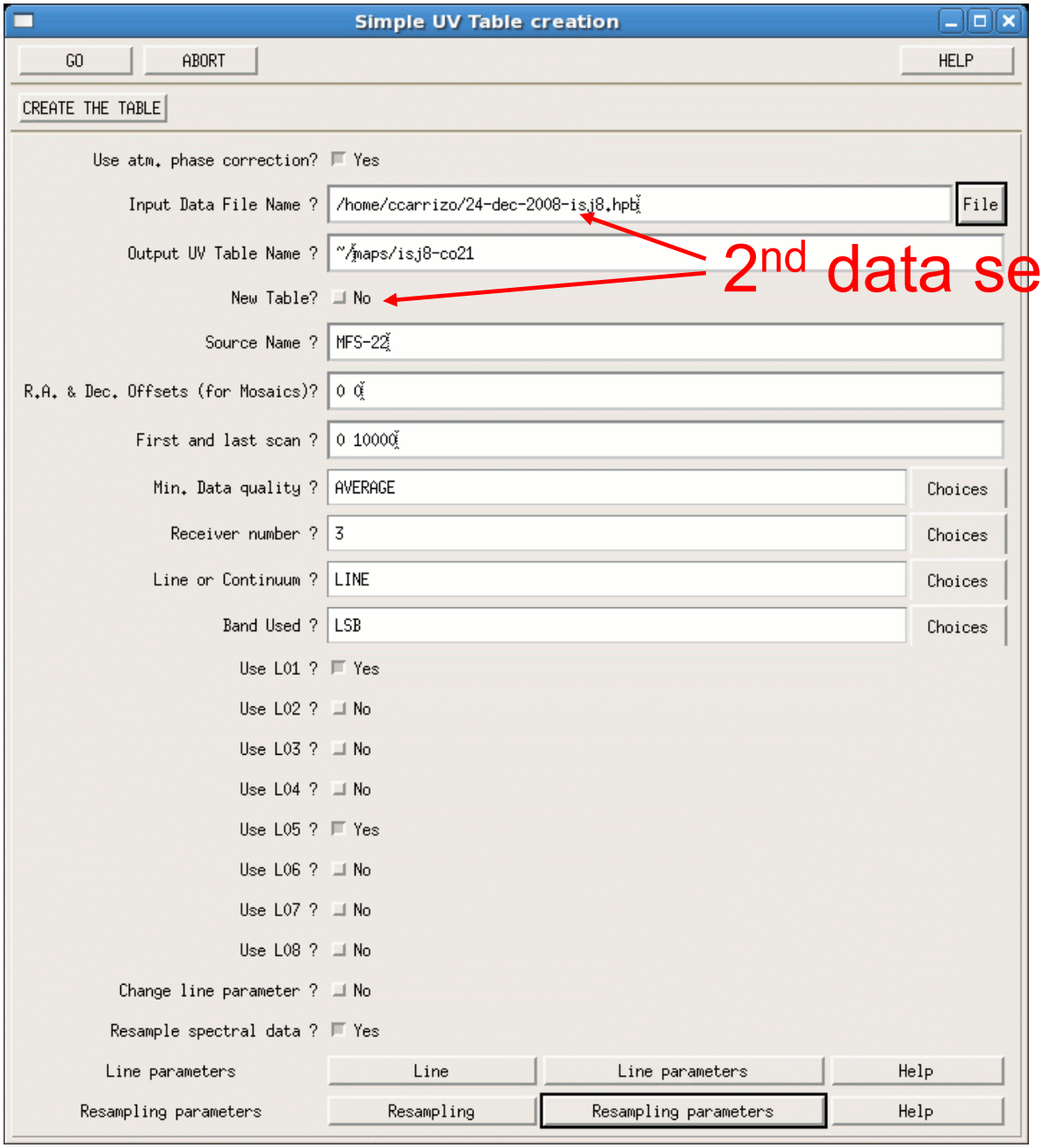
ogdr@iralx0:~/ischool/2010/isa8/reports

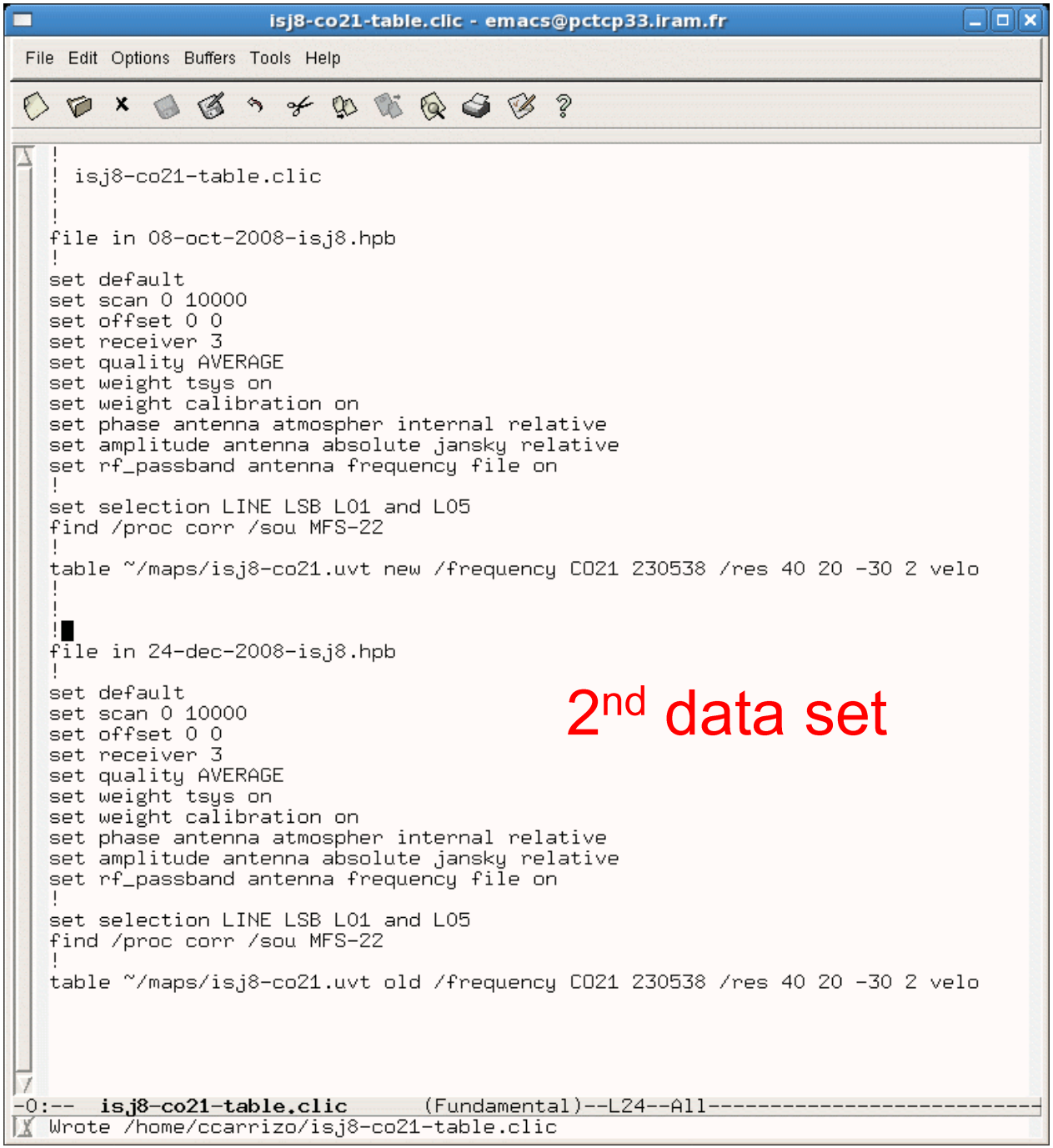
File Edit View Terminal Tabs Help

```
 RF Passband Calibration is applied
 RF Passband Calibration is frequency dependent
 RF Passband Calibration is antenna-based
 RF Passband Calibration from input file
 Phases are relative to calibrator phase
 Phase Calibration is antenna-based
 Phase reference is internal (same receiver)

 Using real-time atmospheric phase correction, antennas  1 2 3 4 5 6
   (according to validation by STORE CORRECTION)
 Using no off-line atmospheric phase correction, antennas  1 2 3 4 5 6

 Phases are Degrees Jumpy
 Amplitudes are relative to calibrator amplitude
 Amplitude Calibration is antenna-based
 Amplitudes are expressed in janskys
I-FILE,[6868] Found file /users/PdBdata/ogdr/ischool/2010/isa8/reports/11-apr-2007-isa8.hpb
 Offset range :    0.0  to    0.0  and    0.0  to    0.0
 Selected data quality is   4 (Average)
I-CLIC_SET,[6868] SWITCHING ON SET AVERAGE SCAN METHOD
 Phases are Degrees Jumpy
 Amplitudes are relative to calibrator amplitude
 Amplitude Calibration is antenna-based
 Amplitudes are expressed in janskys
 RF Passband Calibration is applied
 RF Passband Calibration is frequency dependent
 RF Passband Calibration is antenna-based
 RF Passband Calibration from input file
 Selection is LINE, LSB     ,  L07
 All frequencies selected.
 I-CLIC,  Primary beam size    58.76925     "
W-TABLE,[7537] Spectrum resampling is needed, obs. #   844 Scan
W-TABLE,[7537]  Frequency resolutions :   2.50000000000000      -
W-TABLE,[7537]  Reference channels :   13.9744529724121        15
W-TABLE,[7537]  Number of channels :         116          30
I-TABLE,[6957] Table parameters for afgl-sio.uvt:
I-TABLE,[6957] X_LINE = sio          X_FREQ =    85759.144 X_VAL1 =    85743.342
I-TABLE,[6957] X_FRES =       -0.858 X_VRES =        3.000 X_VOFF =       99.000
I-TABLE,[6957]  NCHAN =           30 X_REF1 =      15.0000
I-TABLE,[6957]   5665 visibilities written (out of   5850 possible)
I-TABLE,[6957] Old size   5850 New   5665
CLIC> sys
You are logged in on host iralx0.
Tue Oct  5 21:17:51 CEST 2010

Selecting GILDAS version: 27sep (27sep10 02:05 cest), executable tree, x86_64-fedora6-ifort

SIC# lrt *clic
-rw-r----- 1 ogdr project 534 Oct  5 21:14 afgl-sio.uvt-table.clic
SIC#
```

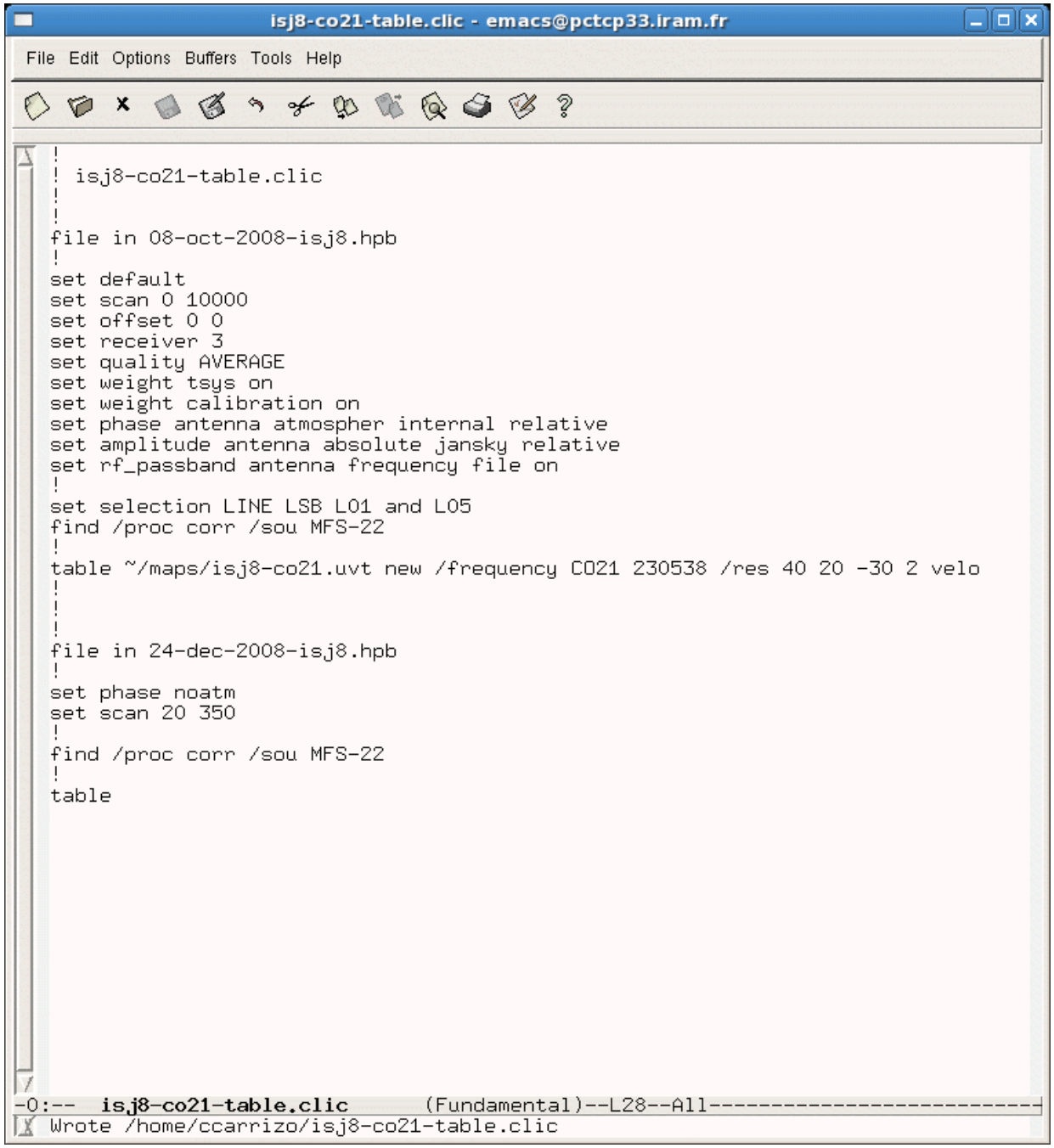
Easy and faster edit table script

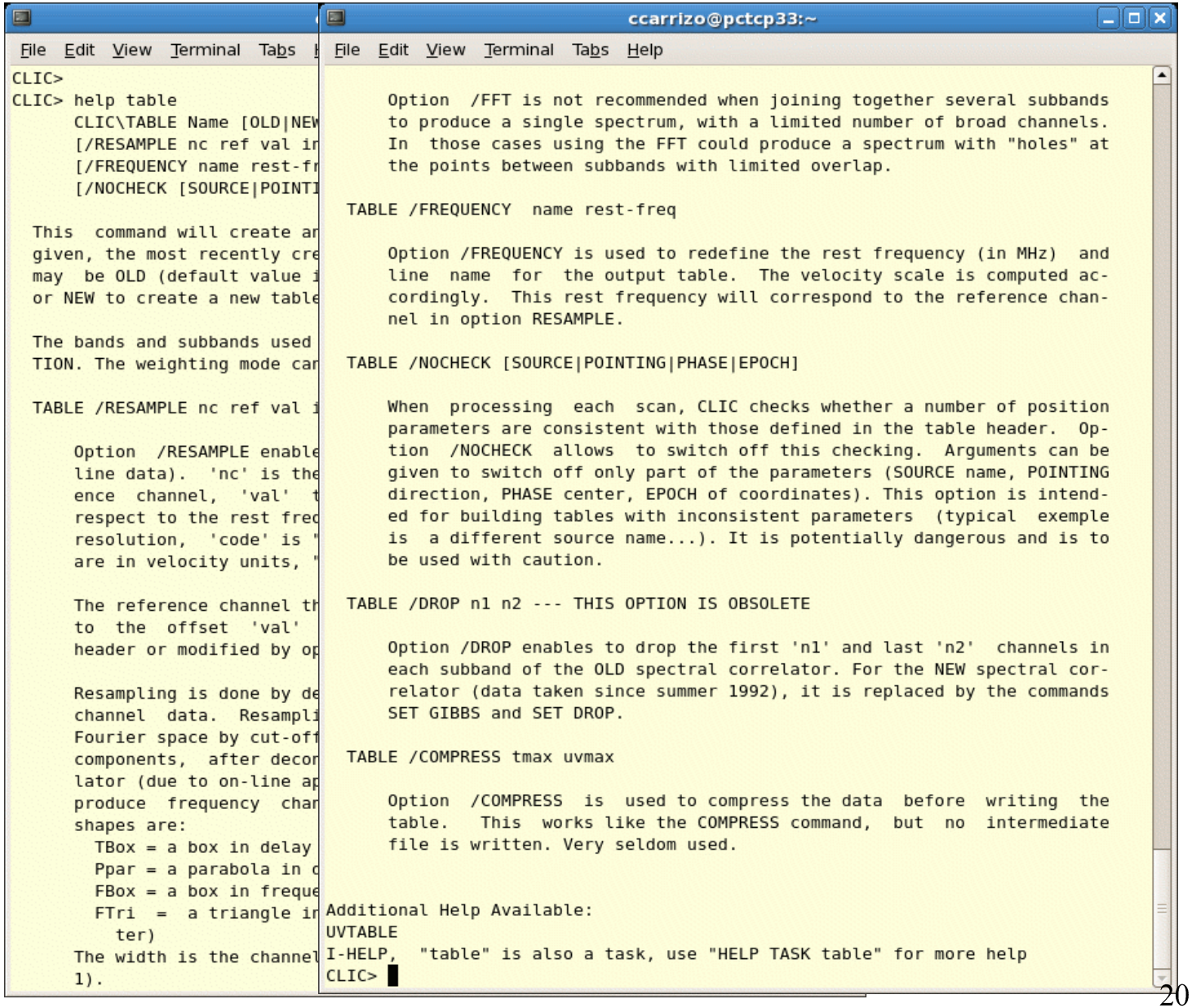

isj8-co21-table.clic - emacs@pctcp33.iram.fr
File Edit Options Buffers Tools Help
!
! isj8-co21-table.clic
!
!
file in 08-oct-2008-isj8.hpb
!
set default
set scan 0 10000
set offset 0 0
set receiver 3
set quality AVERAGE
set weight tsys on
set weight calibration on
set phase antenna atmospher internal relative
set amplitude antenna absolute jansky relative
set rf_passband antenna frequency file on
!
set selection LINE LSB L01 and L05
find /proc corr /sou MFS-22
!
table ~/maps/isj8-co21.uvt new /frequency CO21 230538 /res 40 20 -30 2 velo
-0:-- isj8-co21-table.clic (Fundamental)--L21--All
Wrote /home/ccarrizo/isj8-co21-table.clic

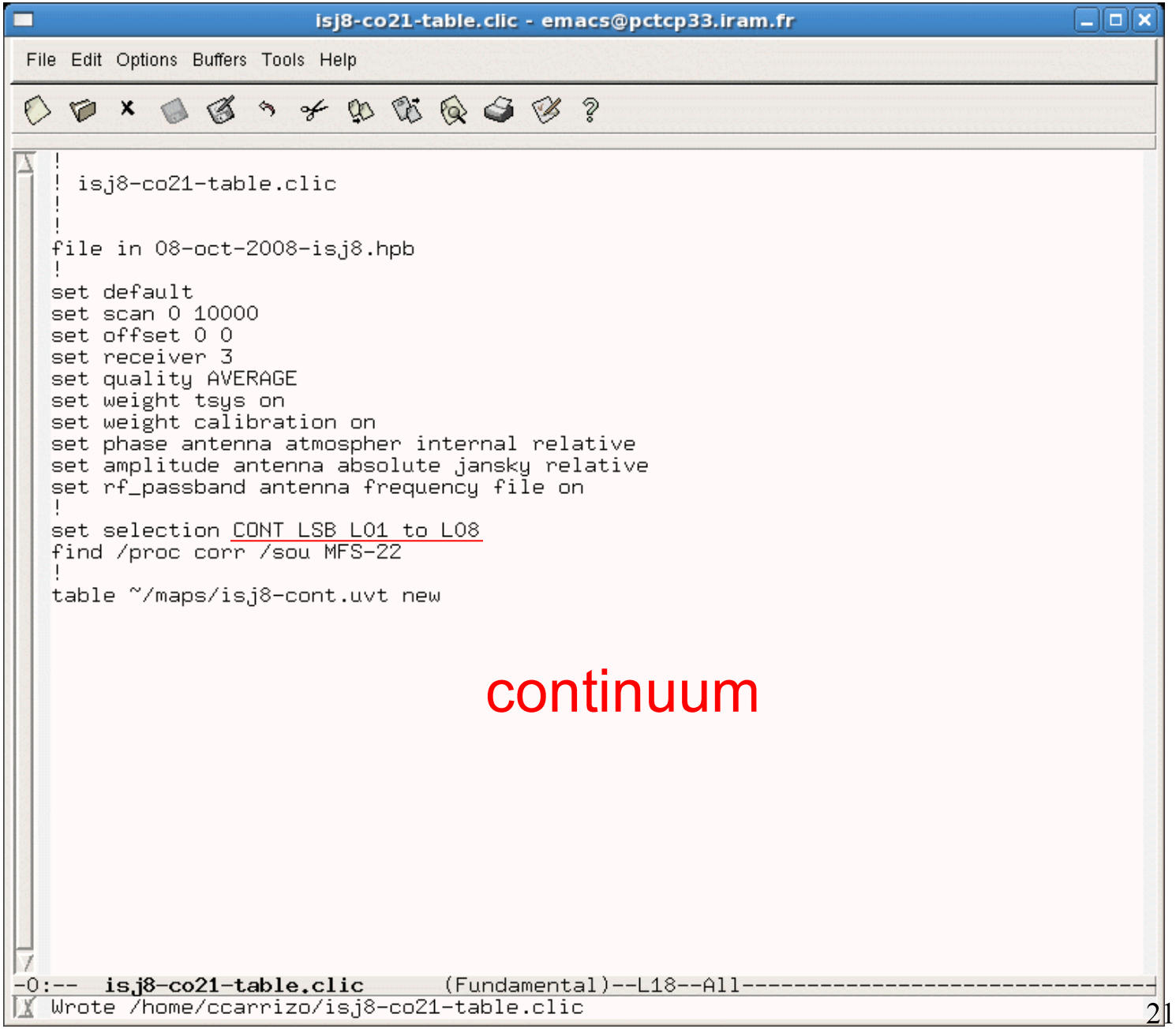

Simple UV Table creation
GO
ABORT
HELP
CREATE THE TABLE
Use atm. phase correction? Yes
Input Data File Name ? /home/ccarrizo/24-dec-2008-isj8.hpb
File
Output UV Table Name ? ~/maps/isj8-co21
New Table? No
Source Name ? MFS-22
R.A. & Dec. Offsets (for Mosaics)? 0 0
First and last scan ? 0 10000
Min. Data quality ? AVERAGE
Choices
Receiver number ? 3
Choices
Line or Continuum ? LINE
Choices
Band Used ? LSB
Choices
Use LO1 ? Yes
Use LO2 ? No
Use LO3 ? No
Use LO4 ? No
Use LO5 ? Yes
Use LO6 ? No
Use LO7 ? No
Use LO8 ? No
Change line parameter ? No
Resample spectral data ? Yes
Line parameters
Line
Line parameters
Help
Resampling parameters
Resampling
Resampling parameters
Help
2nd data set

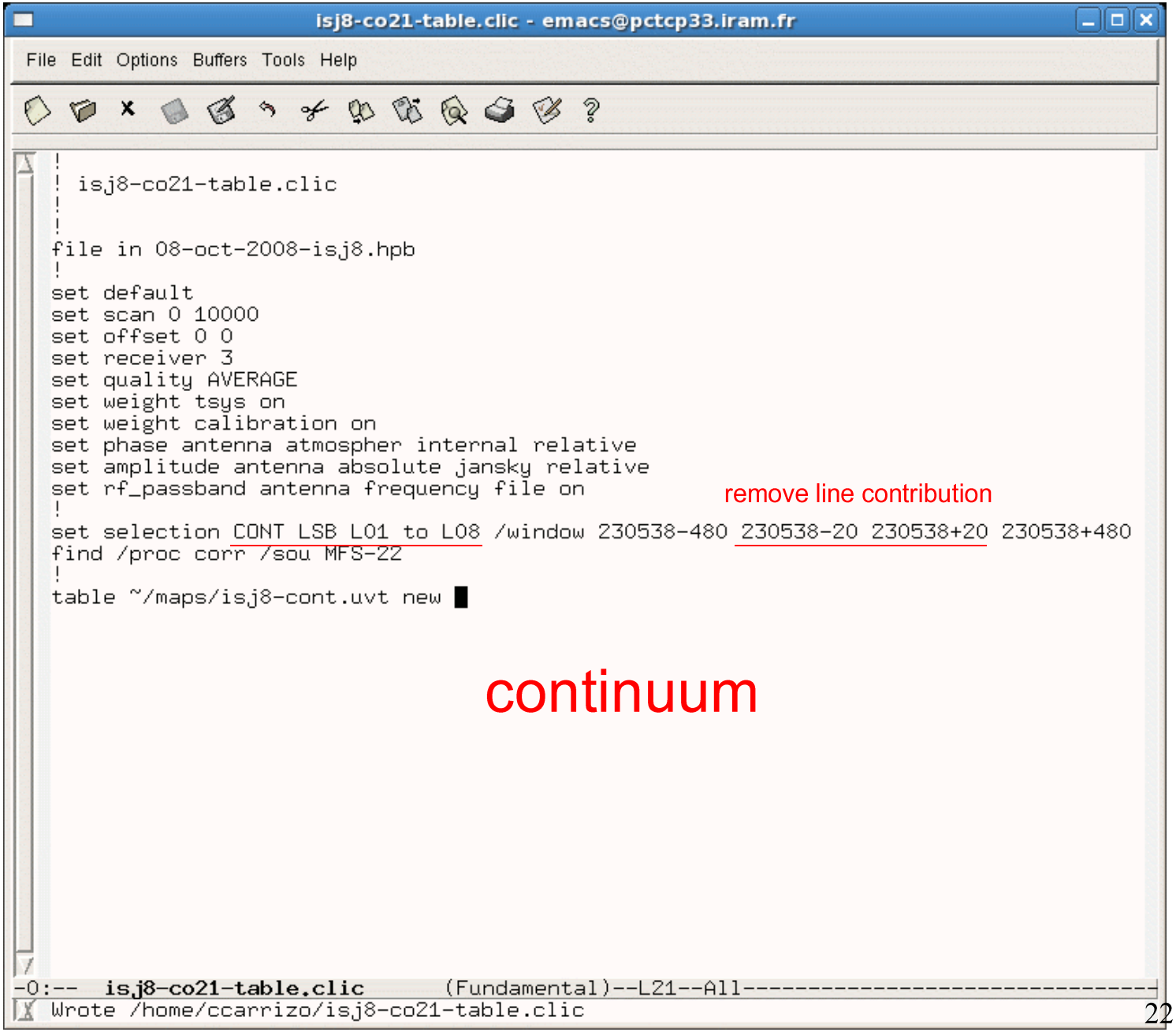

isj8-co21-table.clic - emacs@pctcp33.iram.fr
File Edit Options Buffers Tools Help
! isj8-co21-table.clic
!
!
file in 08-oct-2008-isj8.hpb
!
set default
set scan 0 10000
set offset 0 0
set receiver 3
set quality AVERAGE
set weight tsys on
set weight calibration on
set phase antenna atmospher internal relative
set amplitude antenna absolute jansky relative
set rf_passband antenna frequency file on
!
set selection LINE LSB L01 and L05
find /proc corr /sou MFS-22
!
table ~/maps/isj8-co21.uvt new /frequency CO21 230538 /res 40 20 -30 2 velo
!
!
!
file in 24-dec-2008-isj8.hpb
!
set default
set scan 0 10000
set offset 0 0
set receiver 3
set quality AVERAGE
set weight tsys on
set weight calibration on
set phase antenna atmospher internal relative
set amplitude antenna absolute jansky relative
set rf_passband antenna frequency file on
!
set selection LINE LSB L01 and L05
find /proc corr /sou MFS-22
!
table ~/maps/isj8-co21.uvt old /frequency CO21 230538 /res 40 20 -30 2 velo
-0:-- isj8-co21-table.clic (Fundamental)--L24--All
Wrote /home/ccarrizo/isj8-co21-table.clic

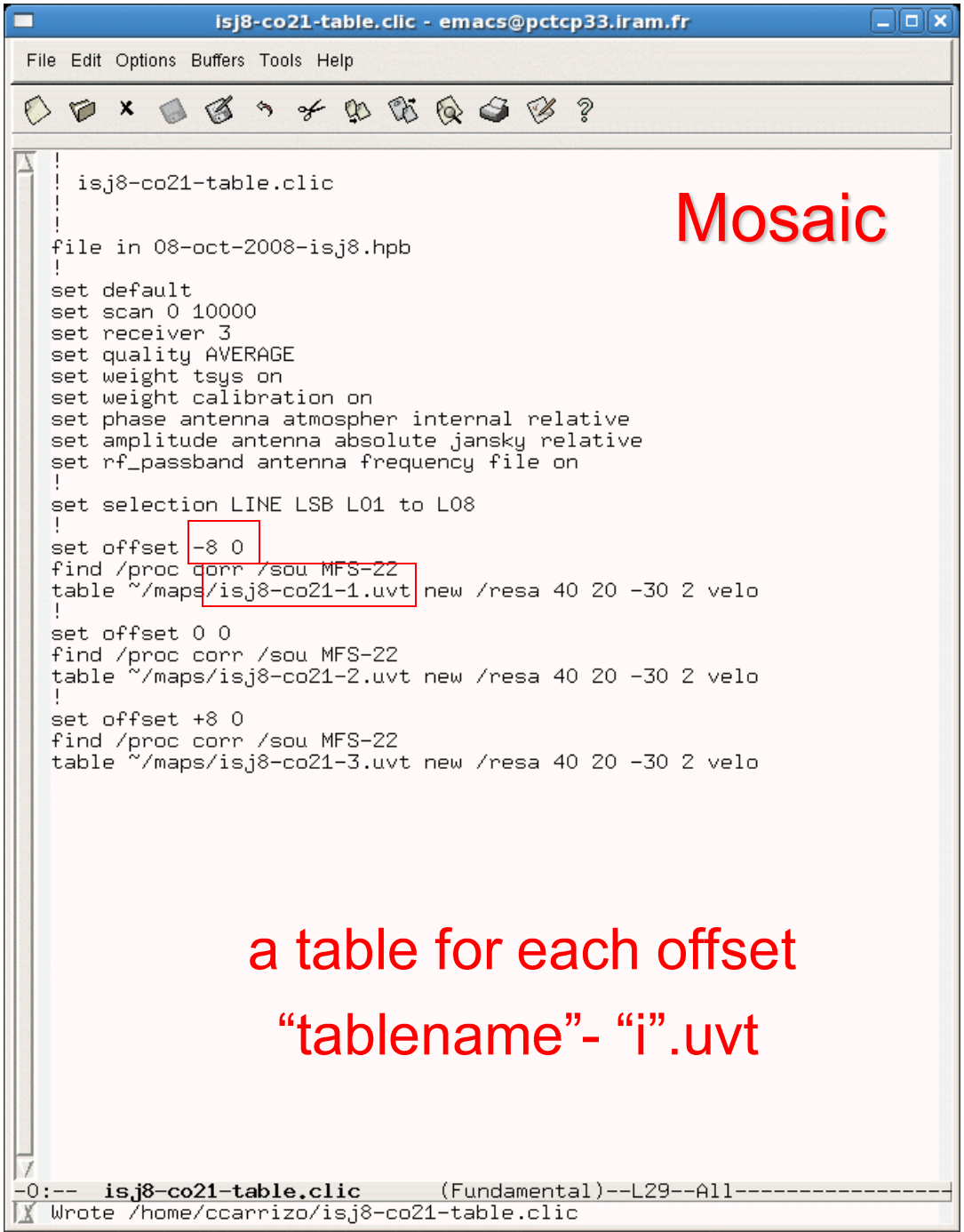
2nd data set


isj8-co21-table.clic - emacs@pctcp33.iram.fr
File Edit Options Buffers Tools Help
! isj8-co21-table.clic
!
!
file in 08-oct-2008-isj8.hpb
!
set default
set scan 0 10000
set offset 0 0
set receiver 3
set quality AVERAGE
set weight tsys on
set weight calibration on
set phase antenna atmospher internal relative
set amplitude antenna absolute jansky relative
set rf_passband antenna frequency file on
!
set selection LINE LSB LO1 and LO5
find /proc corr /sou MFS-22
!
table ~/maps/isj8-co21.uvt new /frequency CO21 230538 /res 40 20 -30 2 velo
!
!
!
file in 24-dec-2008-isj8.hpb
!
set phase noatm
set scan 20 350
!
find /proc corr /sou MFS-22
!
table
-0:-- isj8-co21-table.clic (Fundamental)--L28--All
Wrote /home/ccarrizo/isj8-co21-table.clic


File Edit View Terminal Tabs
CLIC>
CLIC> help table
CLIC\TABLE Name [OLD|NEW
[/RESAMPLE nc ref val in
[/FREQUENCY name rest-fr
[/NOCHECK [SOURCE|POINTI
This command will create an
given, the most recently cre
may be OLD (default value i
or NEW to create a new table
The bands and subbands used
TION. The weighting mode car
TABLE /RESAMPLE nc ref val i
Option /RESAMPLE enable
line data). 'nc' is the
ence channel, 'val' t
respect to the rest freq
resolution, 'code' is "
are in velocity units, "
The reference channel th
to the offset 'val'
header or modified by op
Resampling is done by de
channel data. Resampli
Fourier space by cut-off
components, after decor
lator (due to on-line ap
produce frequency char
shapes are:
TBox = a box in delay
Ppar = a parabola in d
FBox = a box in freque
FTri = a triangle in
ter)
The width is the channel
1).
ccarrizo@pctcp33:~
File Edit View Terminal Tabs Help
Option /FFT is not recommended when joining together several subbands
to produce a single spectrum, with a limited number of broad channels.
In those cases using the FFT could produce a spectrum with "holes" at
the points between subbands with limited overlap.
TABLE /FREQUENCY name rest-freq
Option /FREQUENCY is used to redefine the rest frequency (in MHz) and
line name for the output table. The velocity scale is computed ac-
cordingly. This rest frequency will correspond to the reference chan-
nel in option RESAMPLE.
TABLE /NOCHECK [SOURCE|POINTING|PHASE|EPOCH]
When processing each scan, CLIC checks whether a number of position
parameters are consistent with those defined in the table header. Op-
tion /NOCHECK allows to switch off this checking. Arguments can be
given to switch off only part of the parameters (SOURCE name, POINTING
direction, PHASE center, EPOCH of coordinates). This option is intend-
ed for building tables with inconsistent parameters (typical exemple
is a different source name...). It is potentially dangerous and is to
be used with caution.
TABLE /DROP n1 n2 --- THIS OPTION IS OBSOLETE
Option /DROP enables to drop the first 'n1' and last 'n2' channels in
each subband of the OLD spectral correlator. For the NEW spectral cor-
relator (data taken since summer 1992), it is replaced by the commands
SET GIBBS and SET DROP.
TABLE /COMPRESS tmax uvmax
Option /COMPRESS is used to compress the data before writing the
table. This works like the COMPRESS command, but no intermediate
file is written. Very seldom used.
Additional Help Available:
UVTABLE
I-HELP, "table" is also a task, use "HELP TASK table" for more help
CLIC>


isj8-co21-table.clic - emacs@pctcp33.iram.fr
File Edit Options Buffers Tools Help
!
! isj8-co21-table.clic
!
!
file in 08-oct-2008-isj8.hpb
!
set default
set scan 0 10000
set offset 0 0
set receiver 3
set quality AVERAGE
set weight tsys on
set weight calibration on
set phase antenna atmospher internal relative
set amplitude antenna absolute jansky relative
set rf_passband antenna frequency file on
!
set selection CONT LSB L01 to L08
find /proc corr /sou MFS-22
!
table ~/maps/isj8-cont.uvt new
continuum
-0:-- isj8-co21-table.clic (Fundamental)--L18--All
Wrote /home/ccarrizo/isj8-co21-table.clic

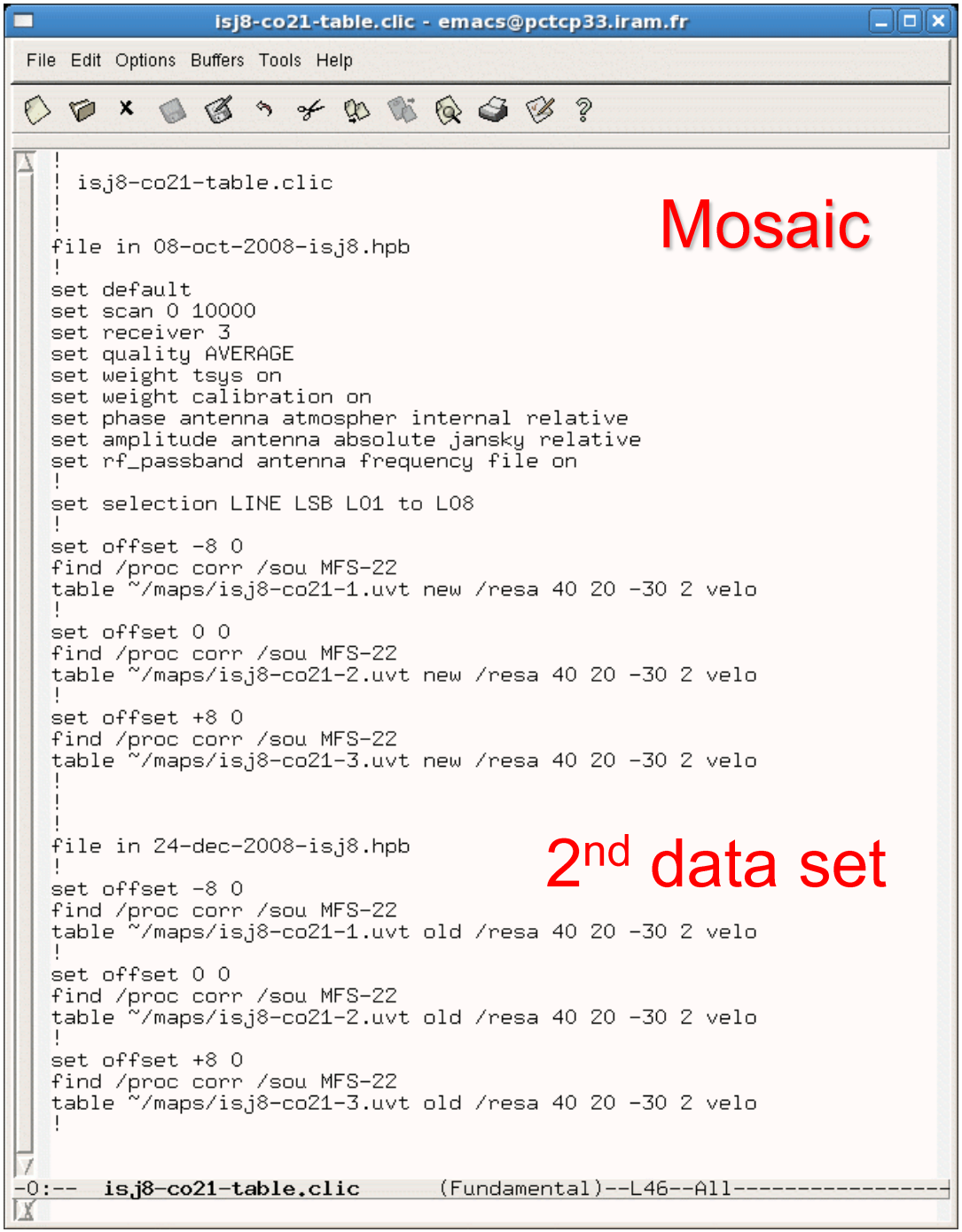

isj8-co21-table.clic - emacs@pctcp33.iram.fr
File Edit Options Buffers Tools Help
!
! isj8-co21-table.clic
!
!
file in 08-oct-2008-isj8.hpb
!
set default
set scan 0 10000
set offset 0 0
set receiver 3
set quality AVERAGE
set weight tsys on
set weight calibration on
set phase antenna atmospher internal relative
set amplitude antenna absolute jansky relative
set rf_passband antenna frequency file on
!
set selection CONT LSB L01 to L08 /window 230538-480 230538-20 230538+20 230538+480
find /proc corr /sou MFS-22
!
table ~/maps/isj8-cont.uvt new
remove line contribution
continuum
-0:-- isj8-co21-table.clic (Fundamental)--L21--All
Wrote /home/ccarrizo/isj8-co21-table.clic



Mosaic

a table for each offset

“tablename”- “i”.uvt

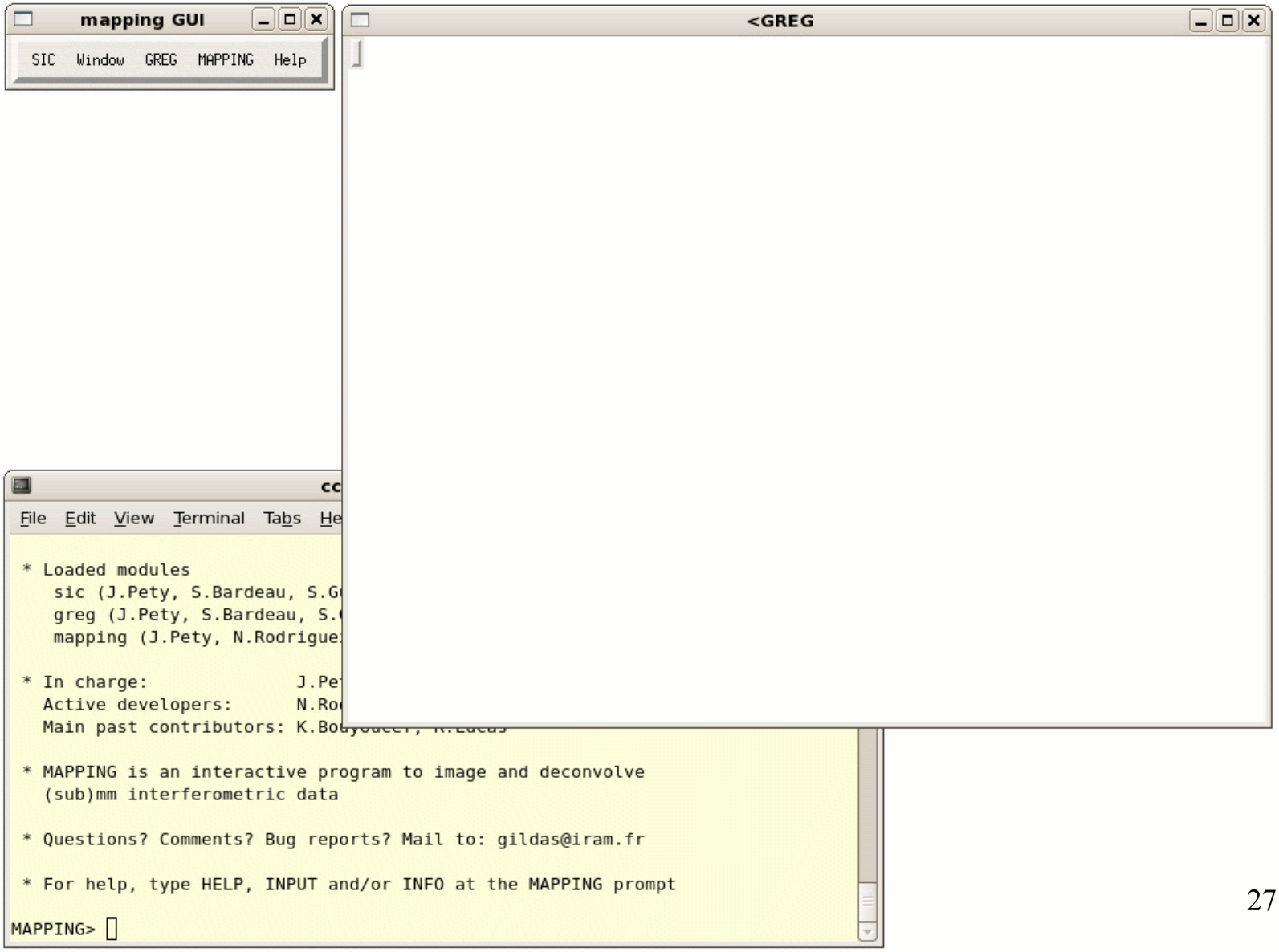

isj8-co21-table.clic - emacs@pctcp33.iram.fr
File Edit Options Buffers Tools Help
!
! isj8-co21-table.clic
!
!
file in 08-oct-2008-isj8.hpb
!
set default
set scan 0 10000
set receiver 3
set quality AVERAGE
set weight tsys on
set weight calibration on
set phase antenna atmospher internal relative
set amplitude antenna absolute jansky relative
set rf_passband antenna frequency file on
!
set selection LINE LSB L01 to L08
!
set offset -8 0
find /proc corr /sou MFS-22
table ~/maps/isj8-co21-1.uvt new /resa 40 20 -30 2 velo
!
set offset 0 0
find /proc corr /sou MFS-22
table ~/maps/isj8-co21-2.uvt new /resa 40 20 -30 2 velo
!
set offset +8 0
find /proc corr /sou MFS-22
table ~/maps/isj8-co21-3.uvt new /resa 40 20 -30 2 velo
!
!
!
file in 24-dec-2008-isj8.hpb
!
set offset -8 0
find /proc corr /sou MFS-22
table ~/maps/isj8-co21-1.uvt old /resa 40 20 -30 2 velo
!
set offset 0 0
find /proc corr /sou MFS-22
table ~/maps/isj8-co21-2.uvt old /resa 40 20 -30 2 velo
!
set offset +8 0
find /proc corr /sou MFS-22
table ~/maps/isj8-co21-3.uvt old /resa 40 20 -30 2 velo
!
-0:-- isj8-co21-table.clic (Fundamental)--L46--All
Mosaic
2nd data set

Created “mytable”.uvt, in CLIC

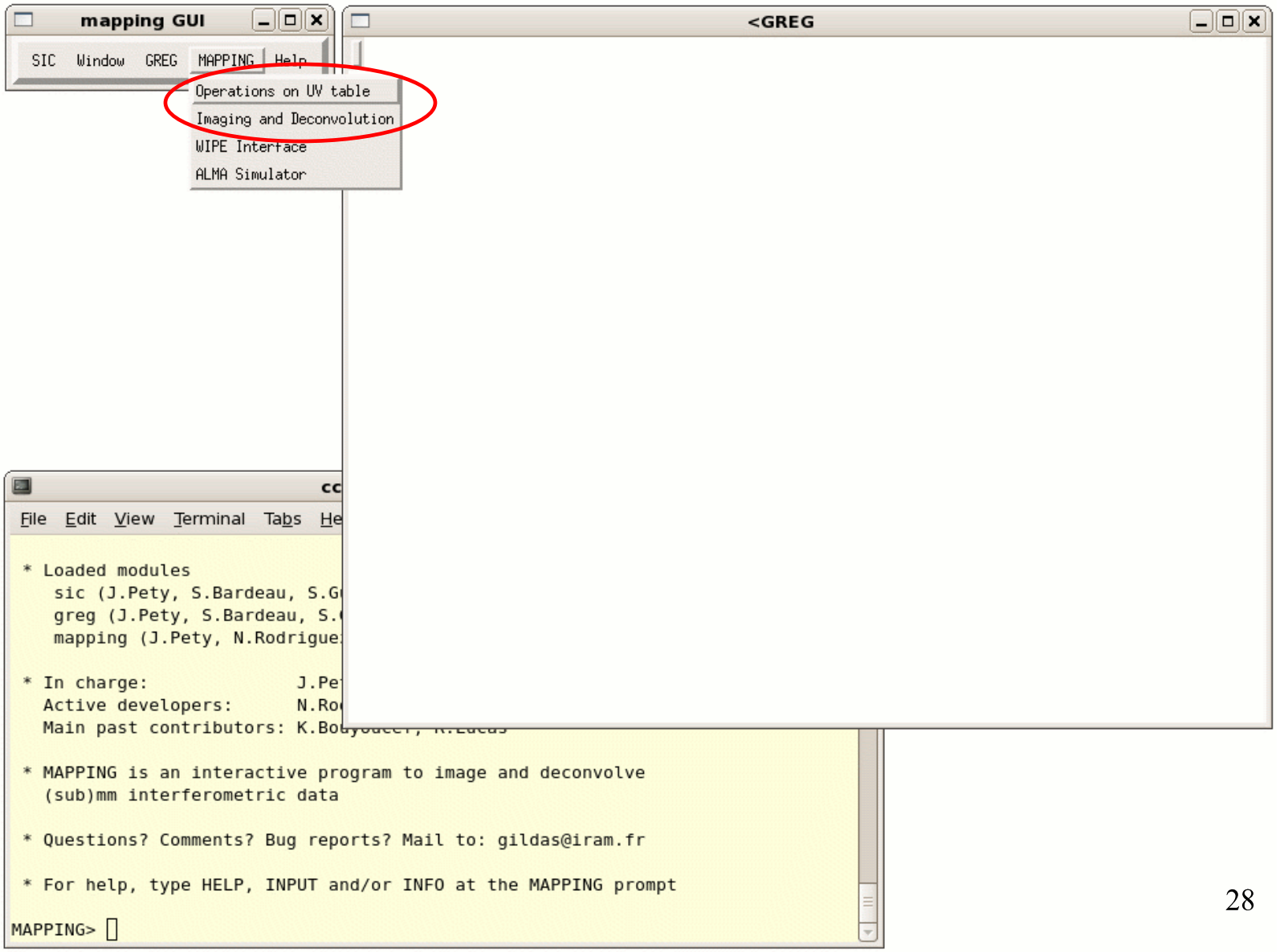
Analyze the data, in MAPPING

1. Data analysis in the *uv*-plane

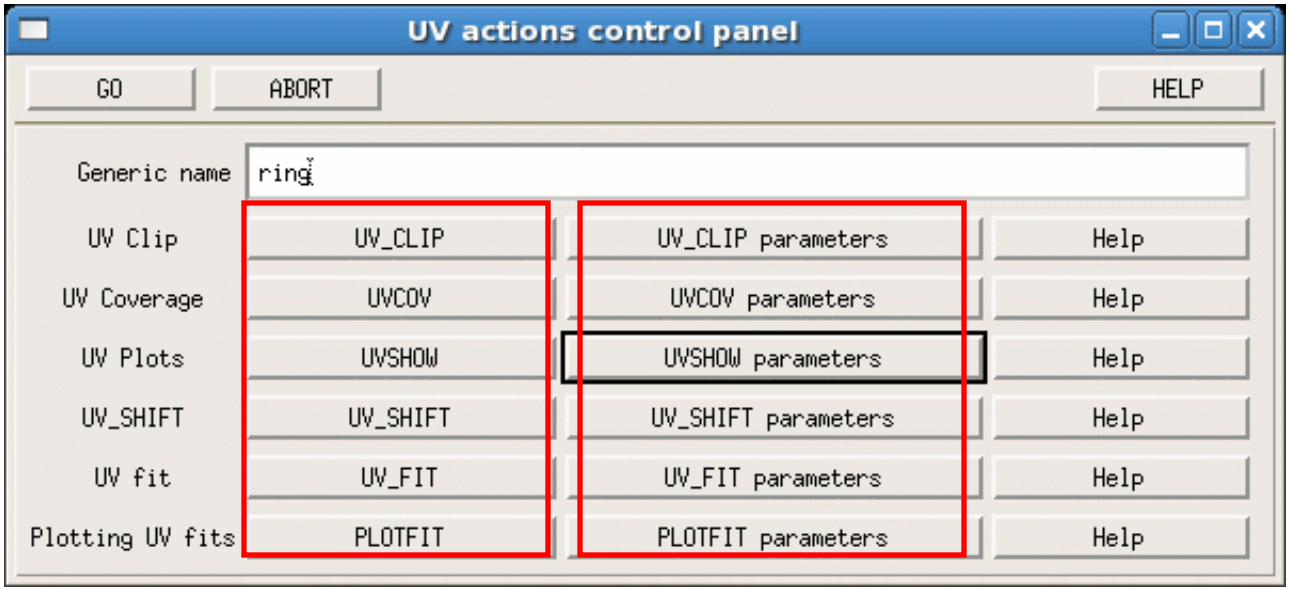
Data analysis in the *uv*-plane; **MAPPING**



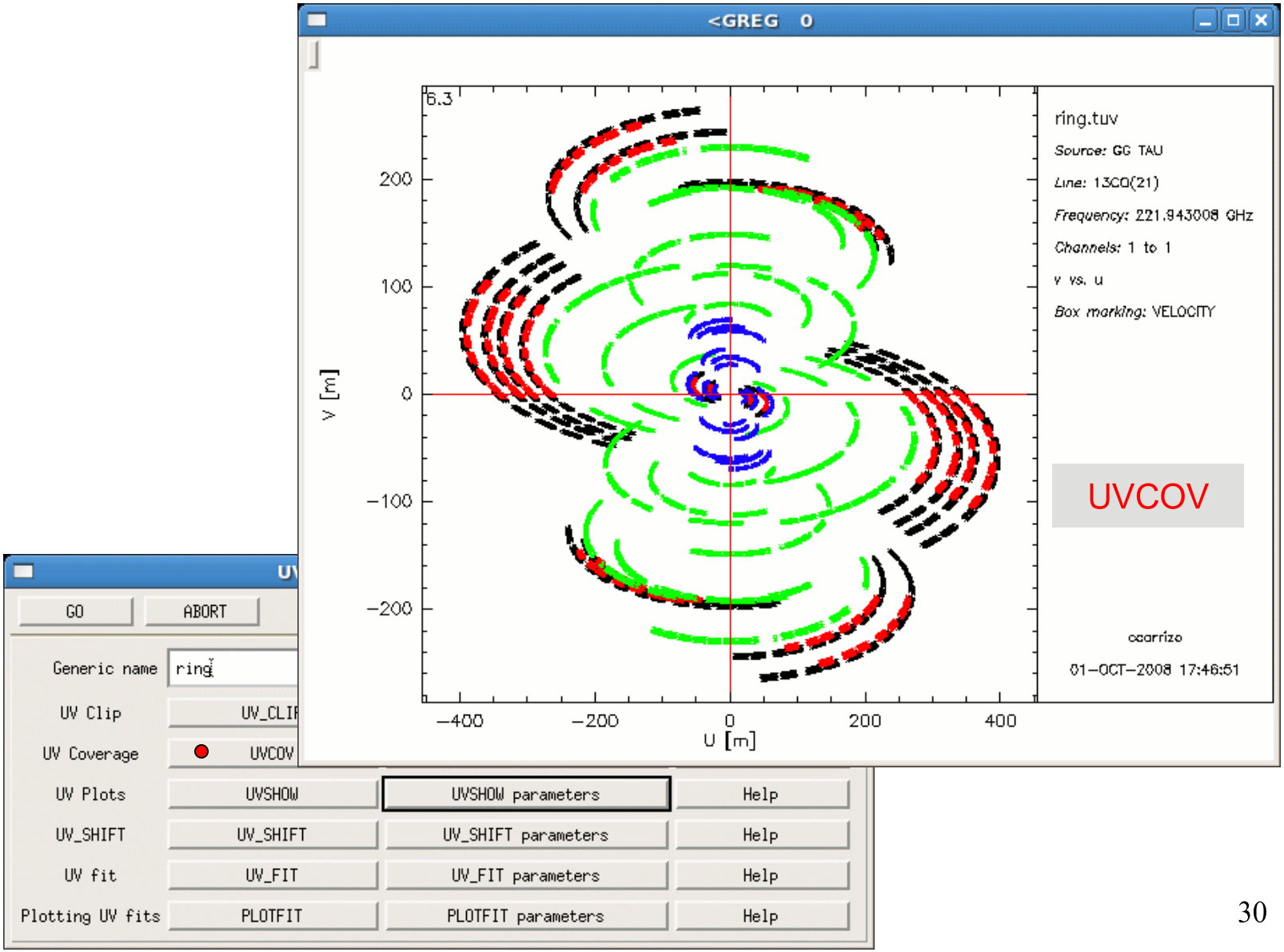
Data analysis in the *uv*-plane



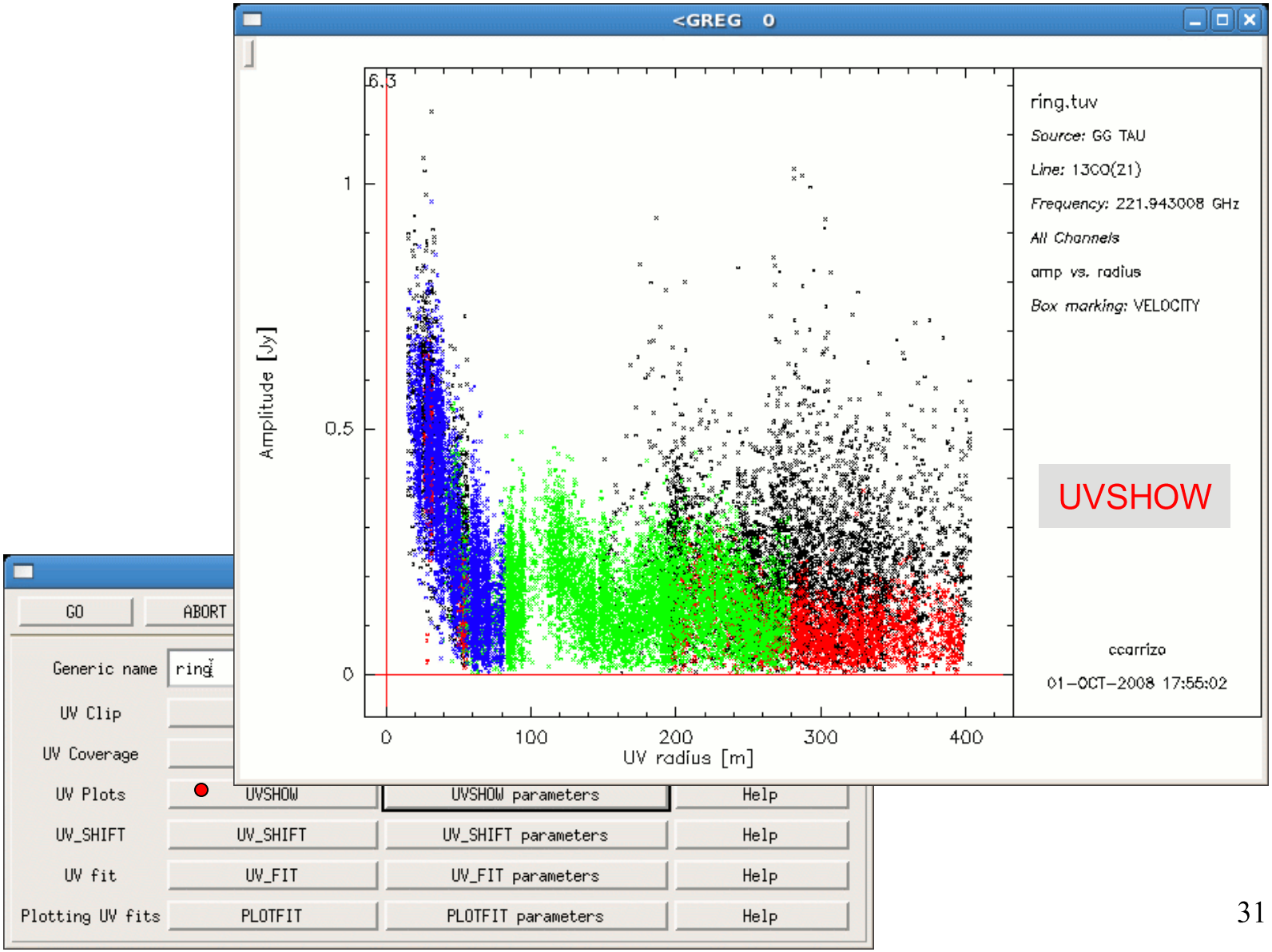
Data analysis in the *uv*-plane



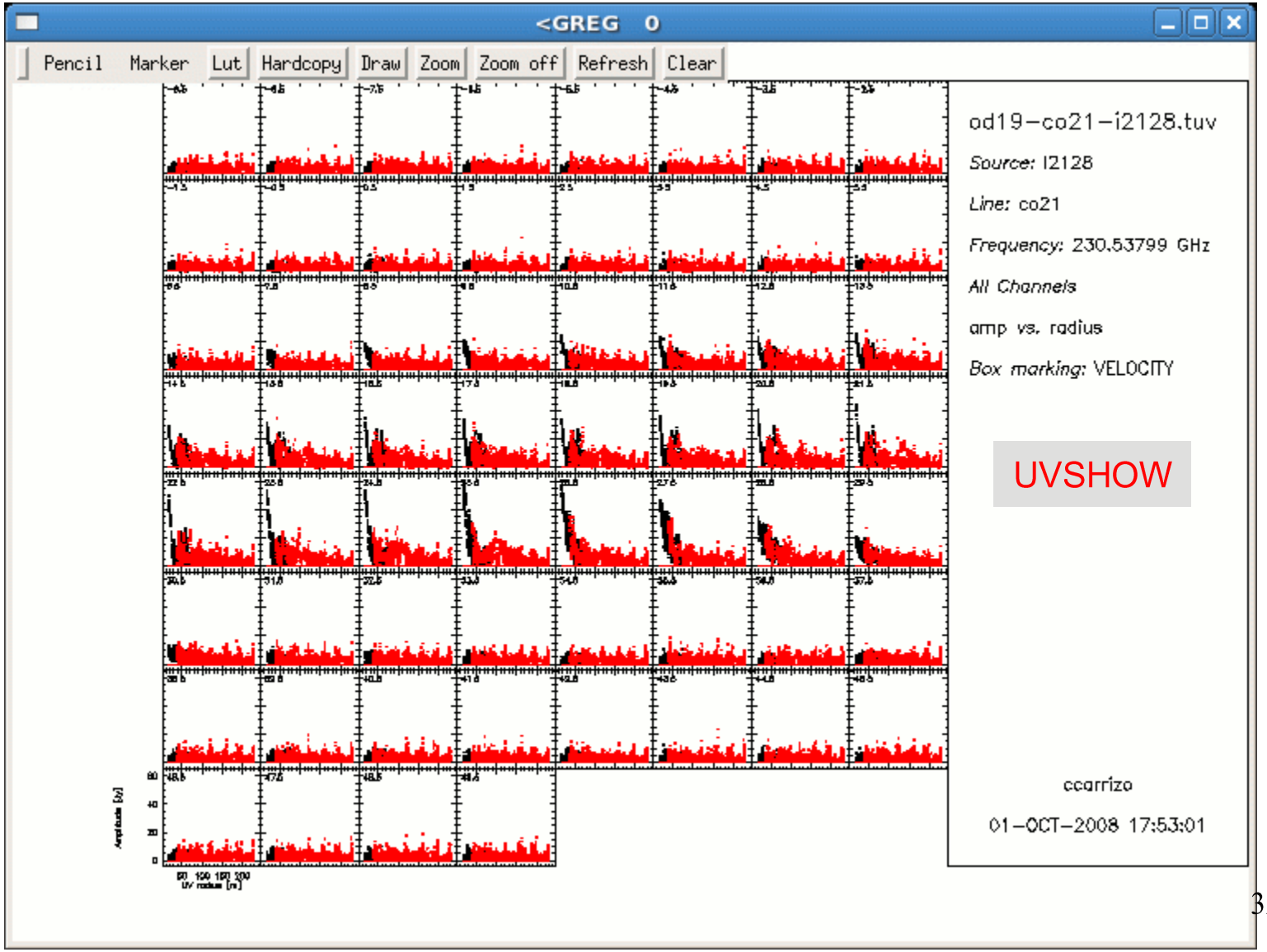
Data analysis in the *uv*-plane



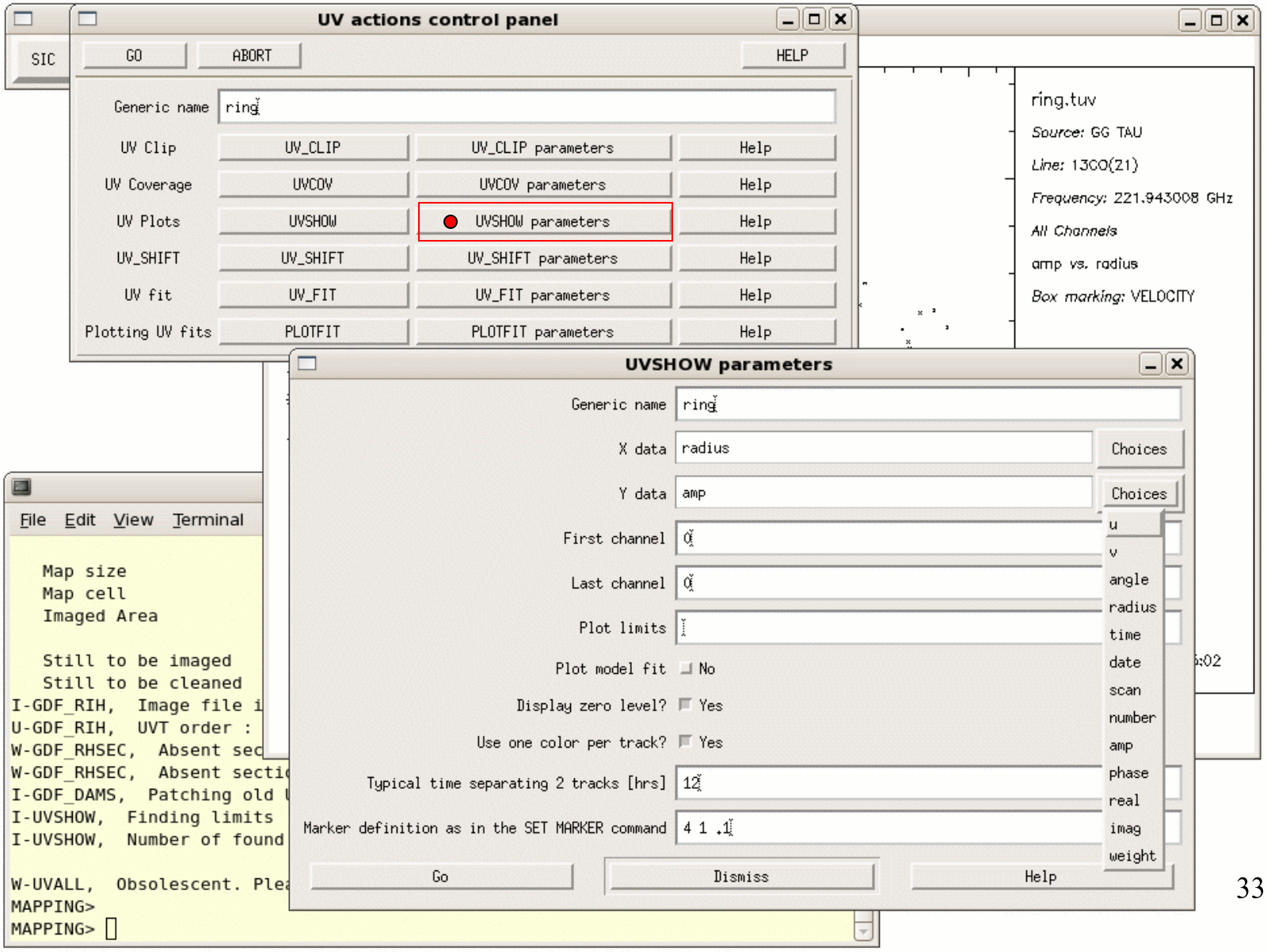
Data analysis in the *uv*-plane



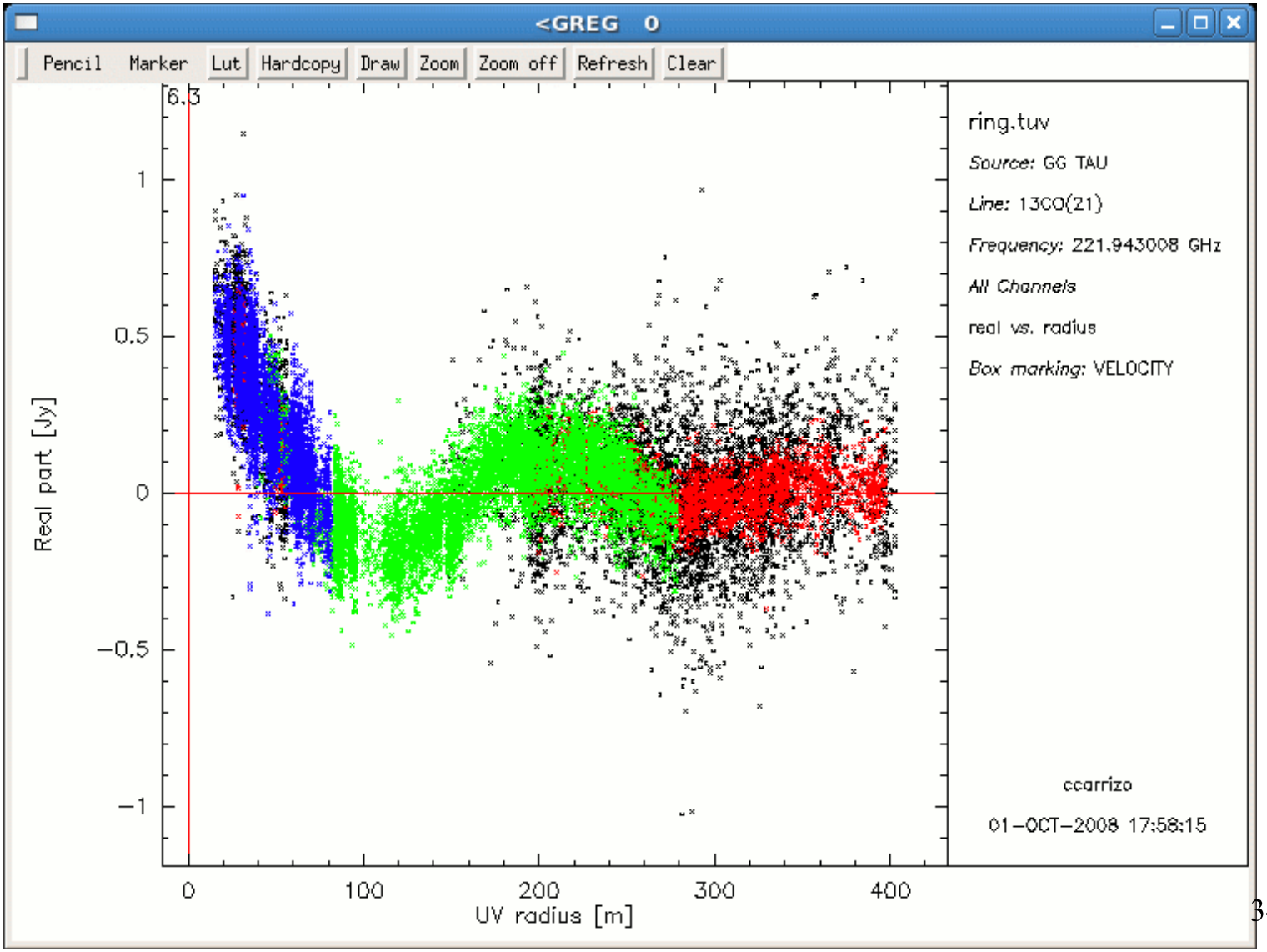
Data analysis in the *uv*-plane



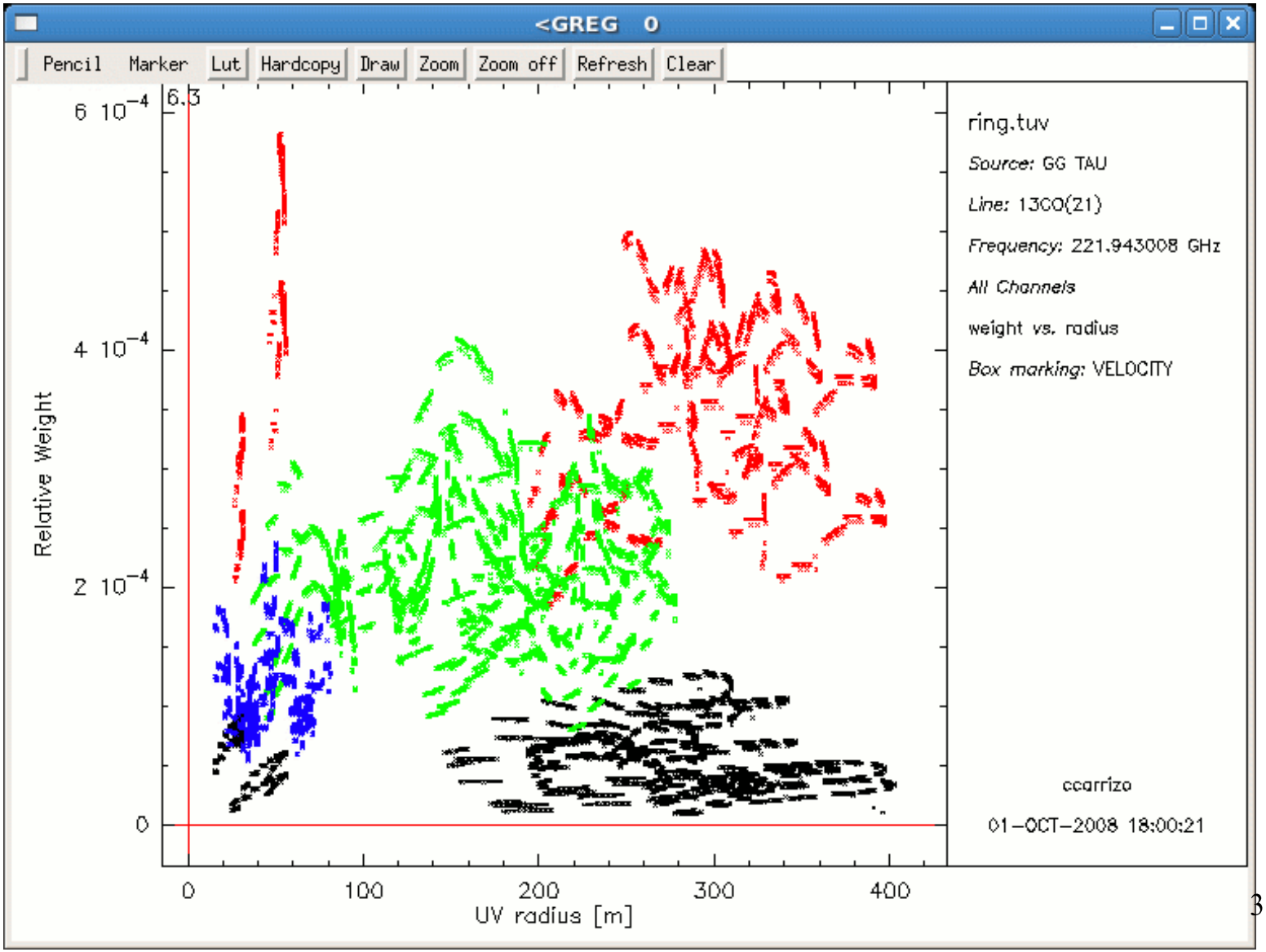
Data analysis in the *uv*-plane



Data analysis in the *uv*-plane



Data analysis in the *uv*-plane



Data analysis in the *uv*-plane

With commands:

MAPPING> let first 12

MAPPING> let last 12

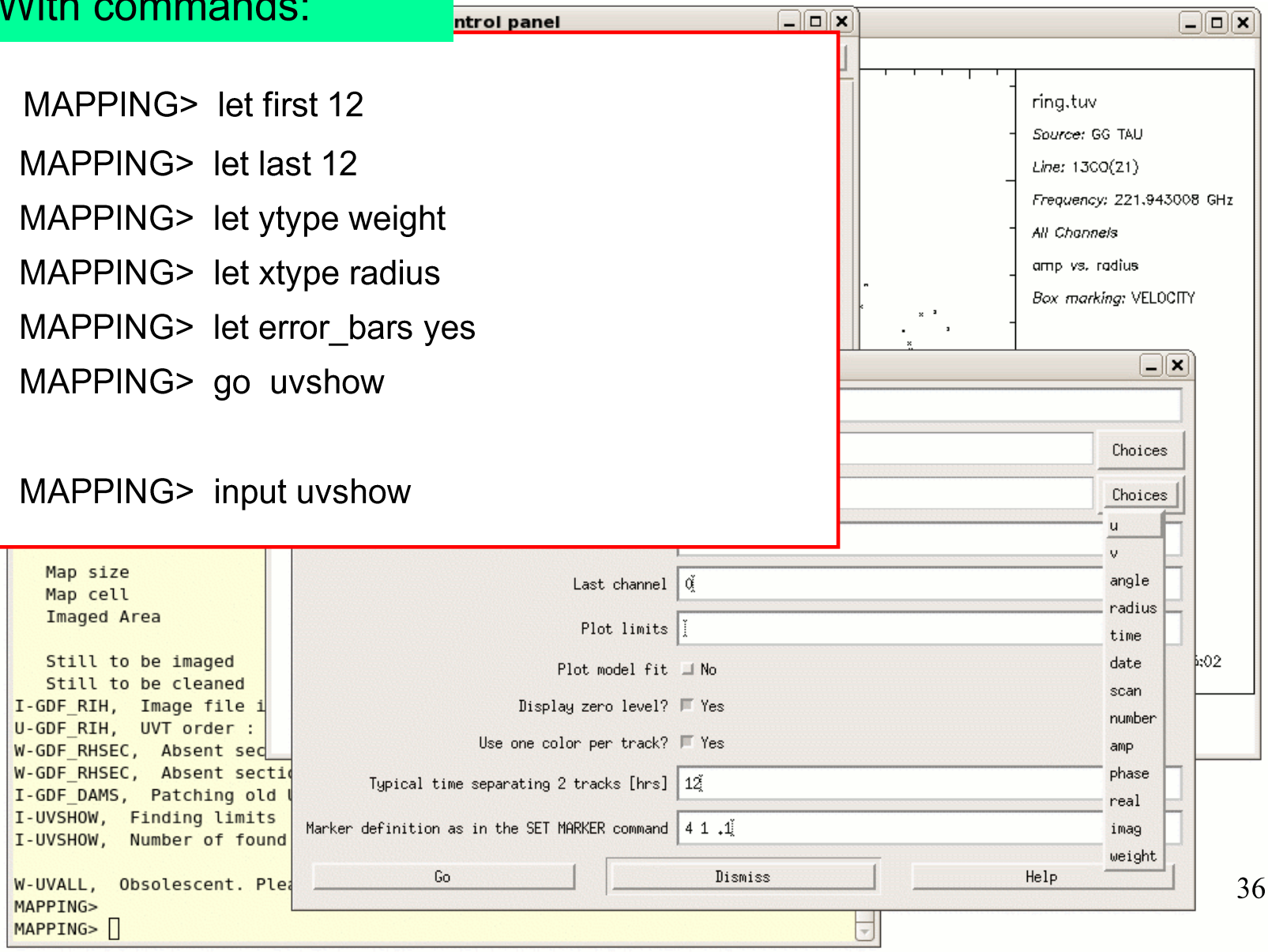
MAPPING> let ytype weight

MAPPING> let xtype radius

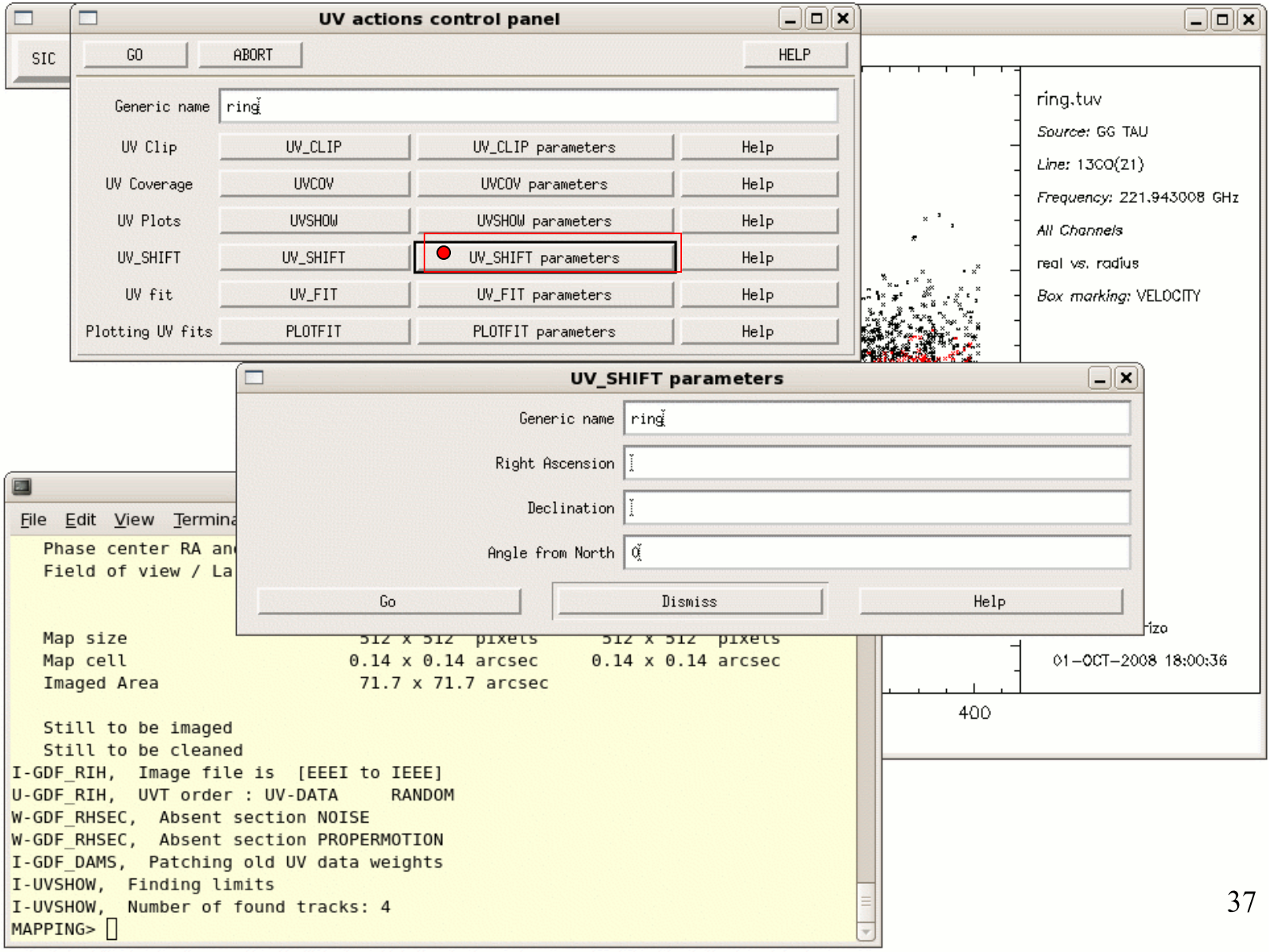
MAPPING> let error_bars yes

MAPPING> go uvshow

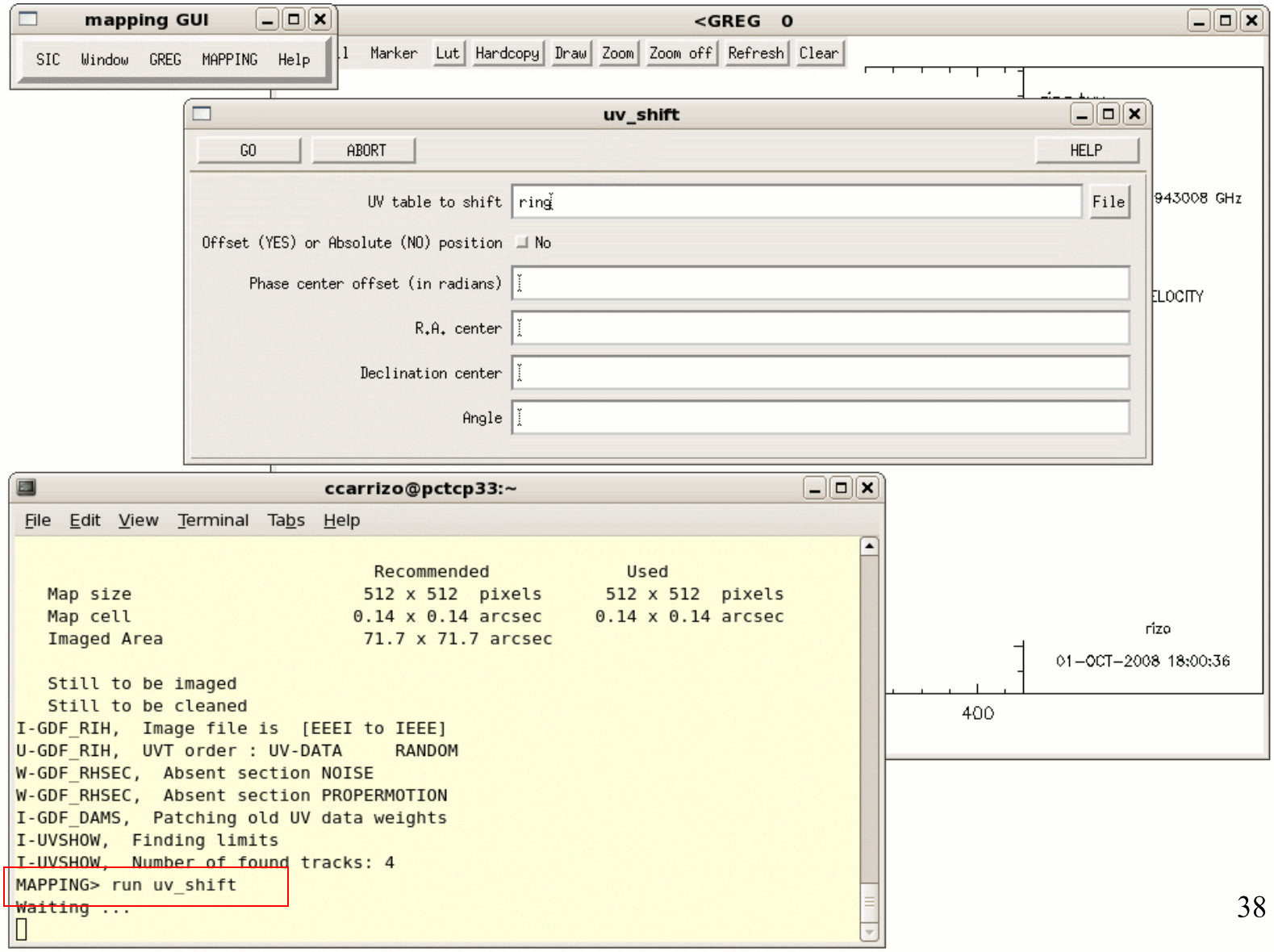
MAPPING> input uvshow



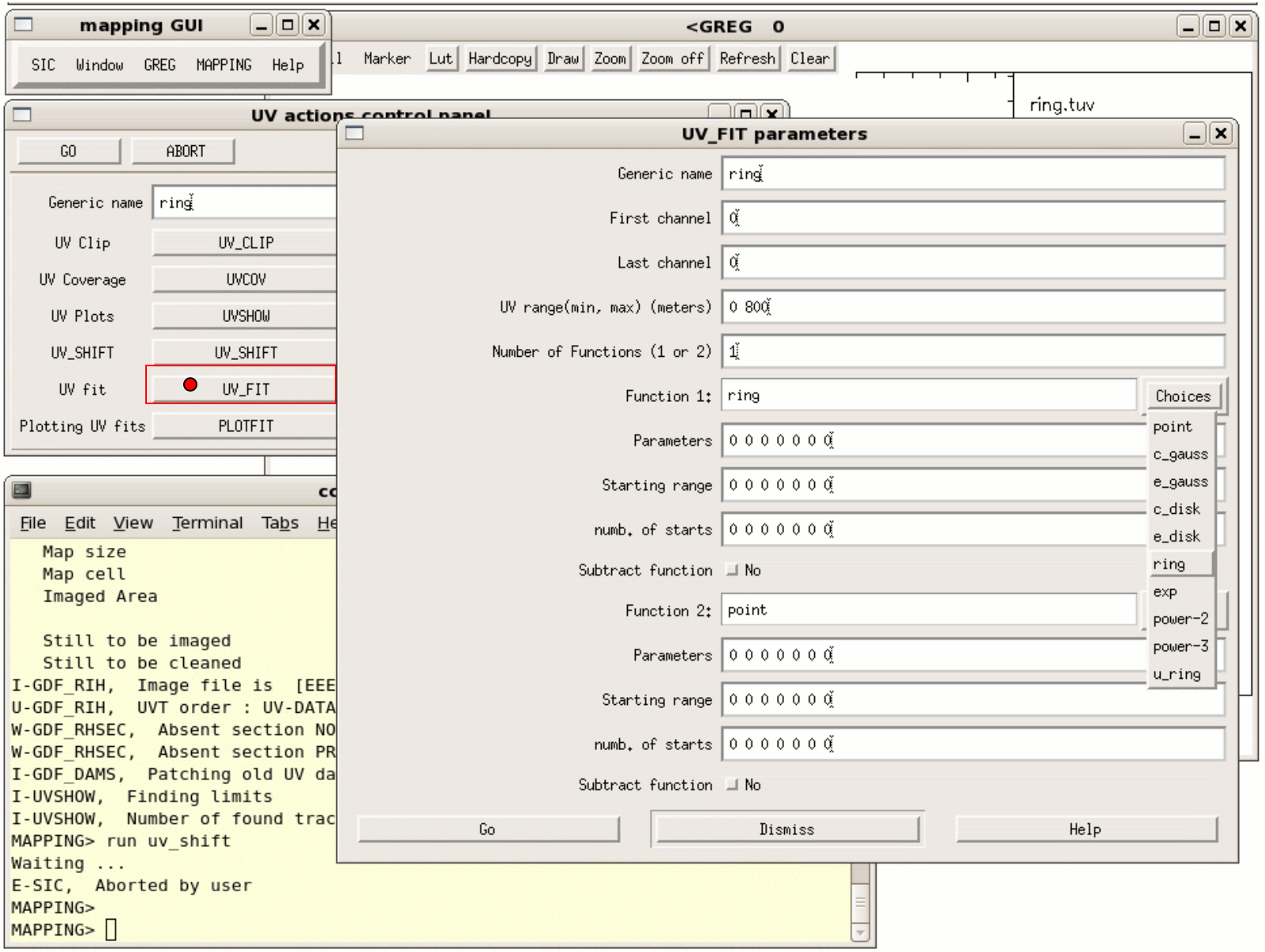
Data analysis in the *uv*-plane



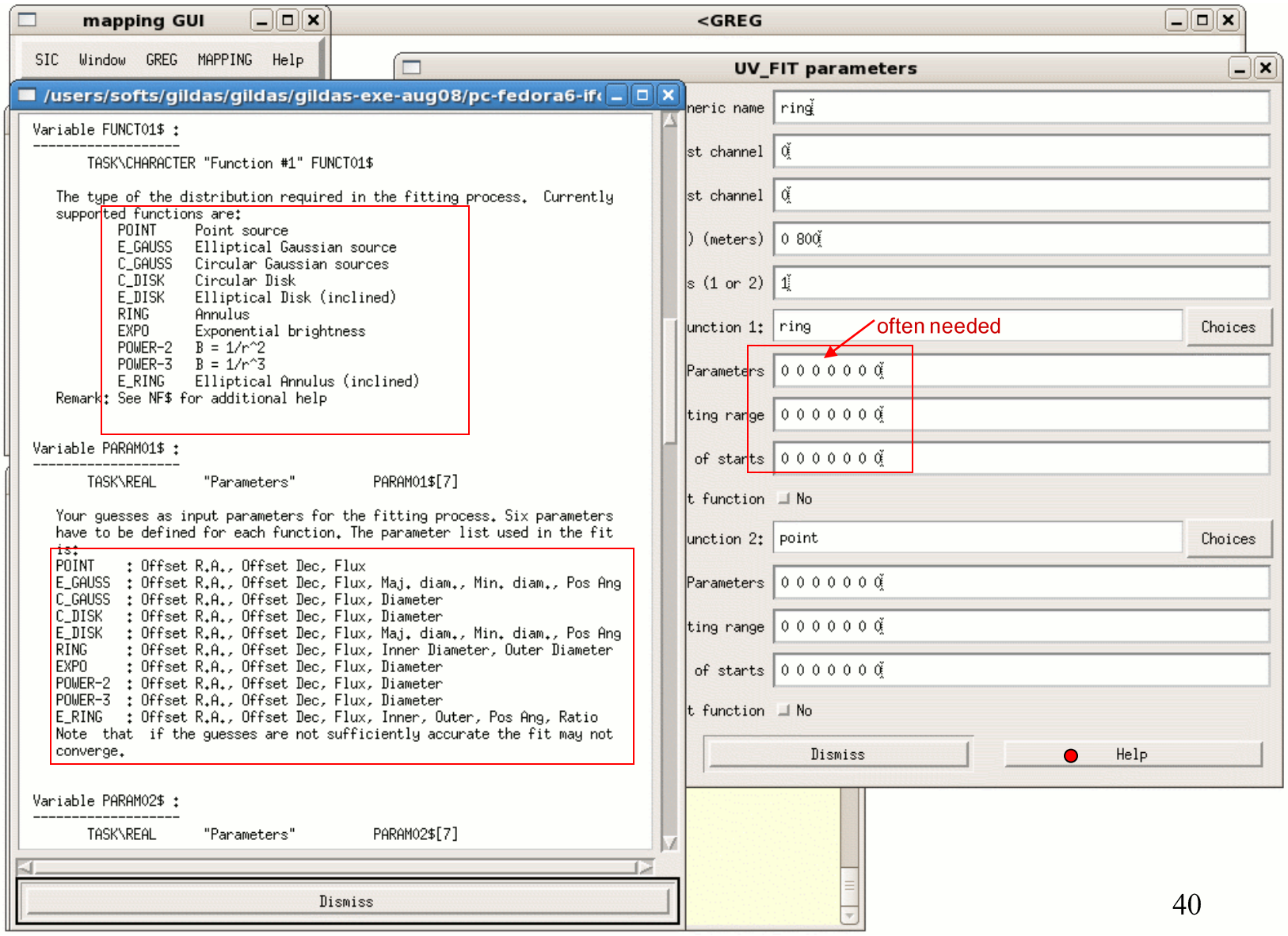
Data analysis in the *uv*-plane



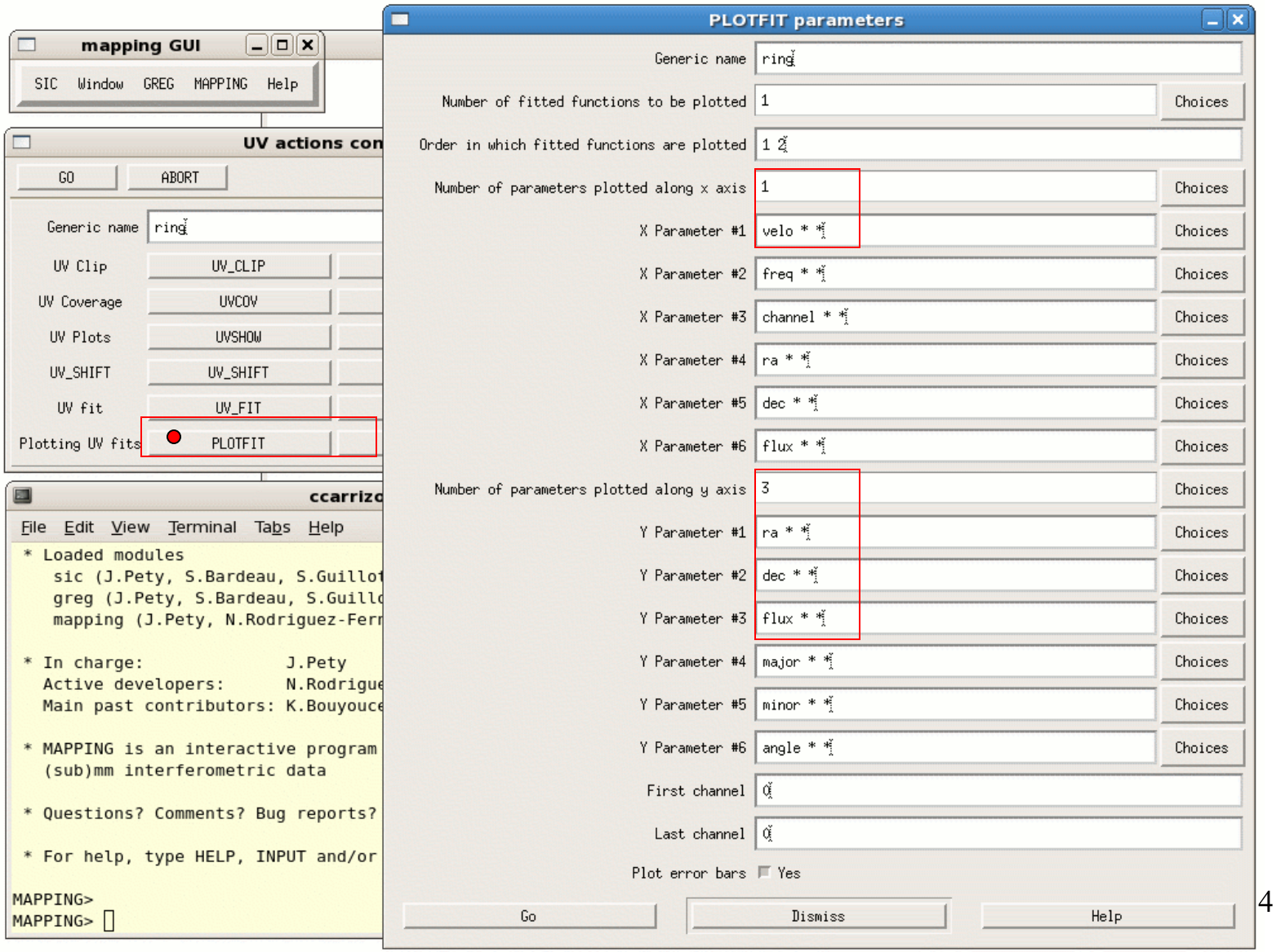
Data analysis in the *uv*-plane



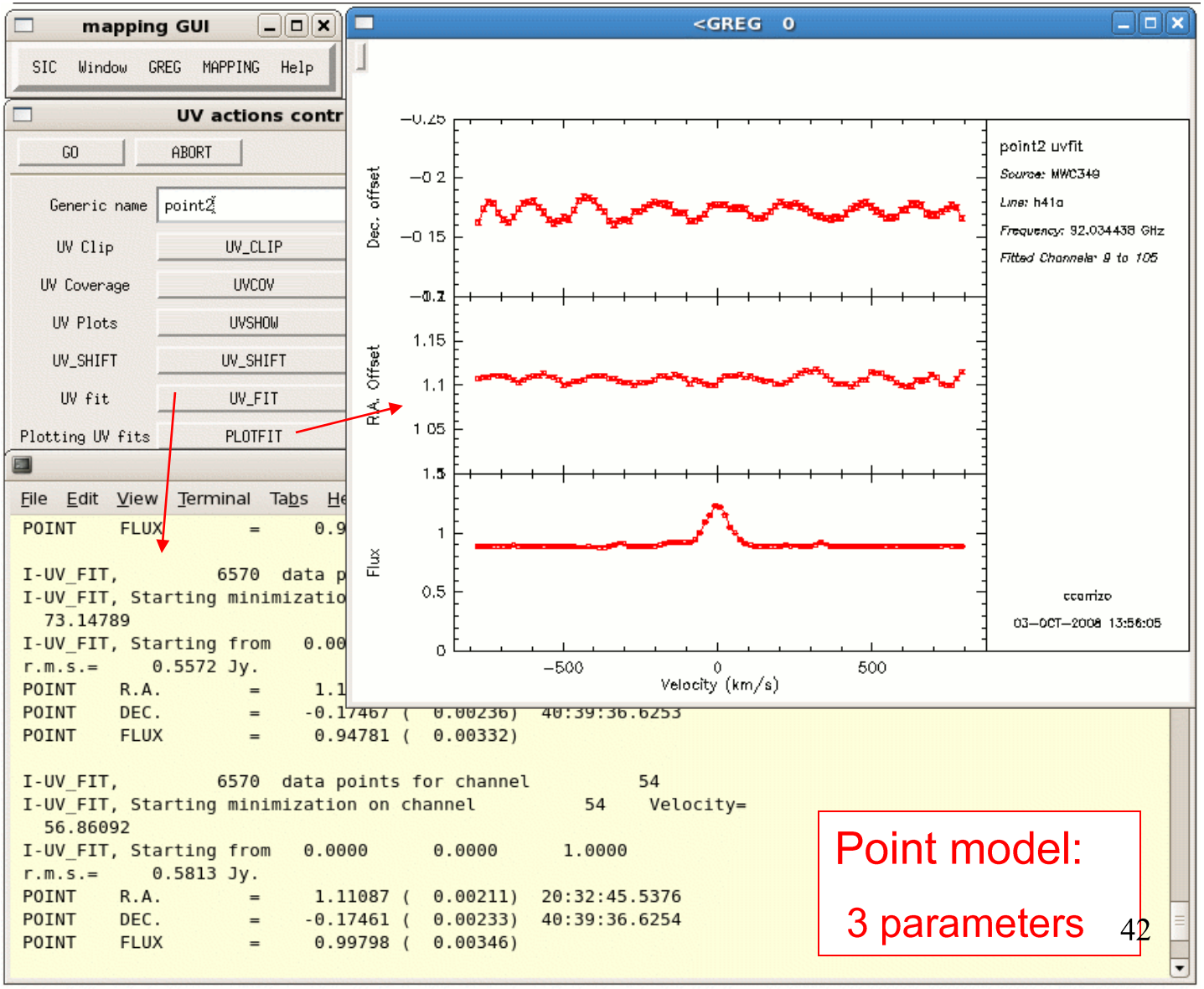
Data analysis in the *uv*-plane



Data analysis in the *uv*-plane



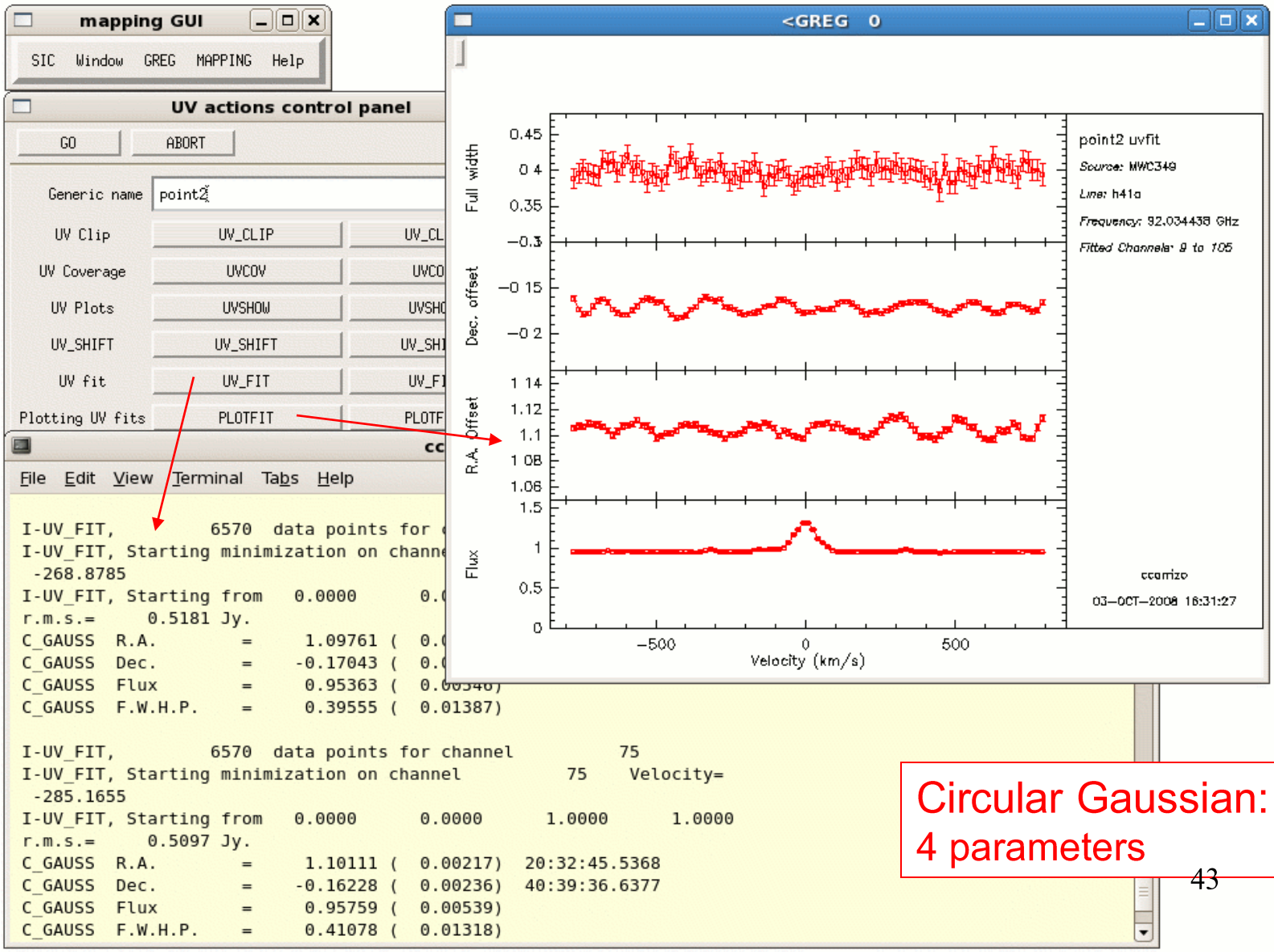
Data analysis in the *uv*-plane



Point model:

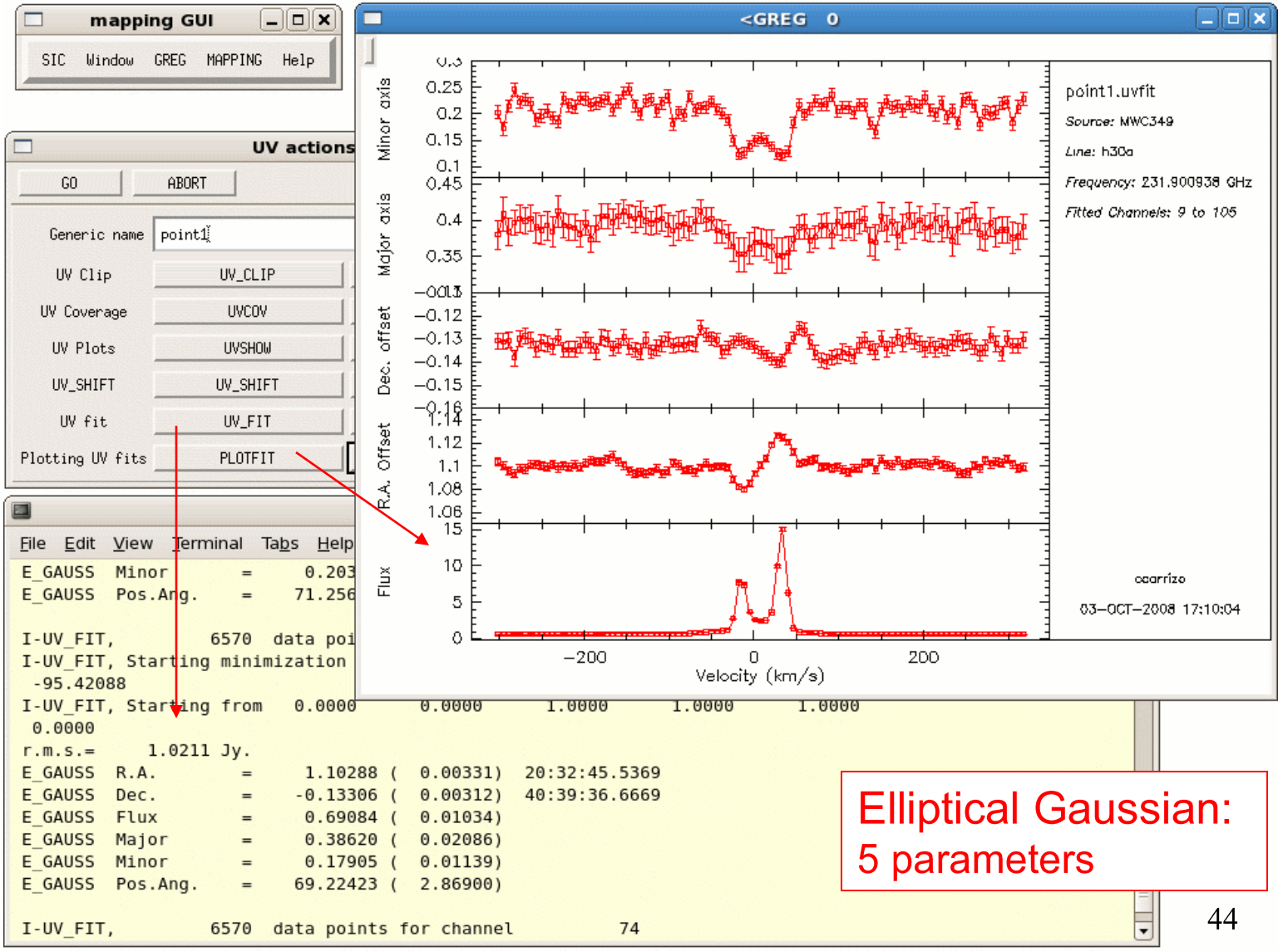
3 parameters

Data analysis in the *uv*-plane



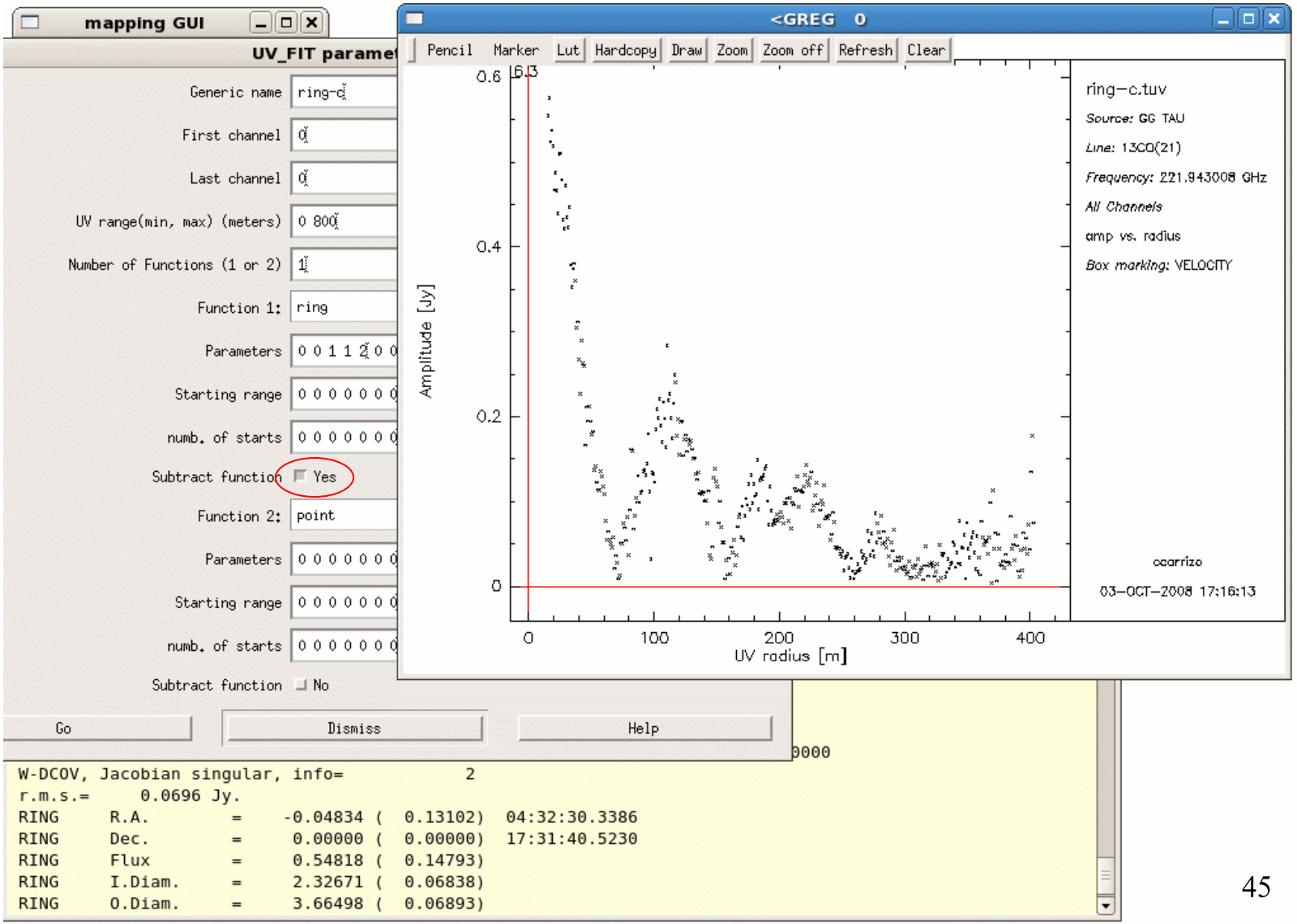
Circular Gaussian:
4 parameters

Data analysis in the *uv*-plane

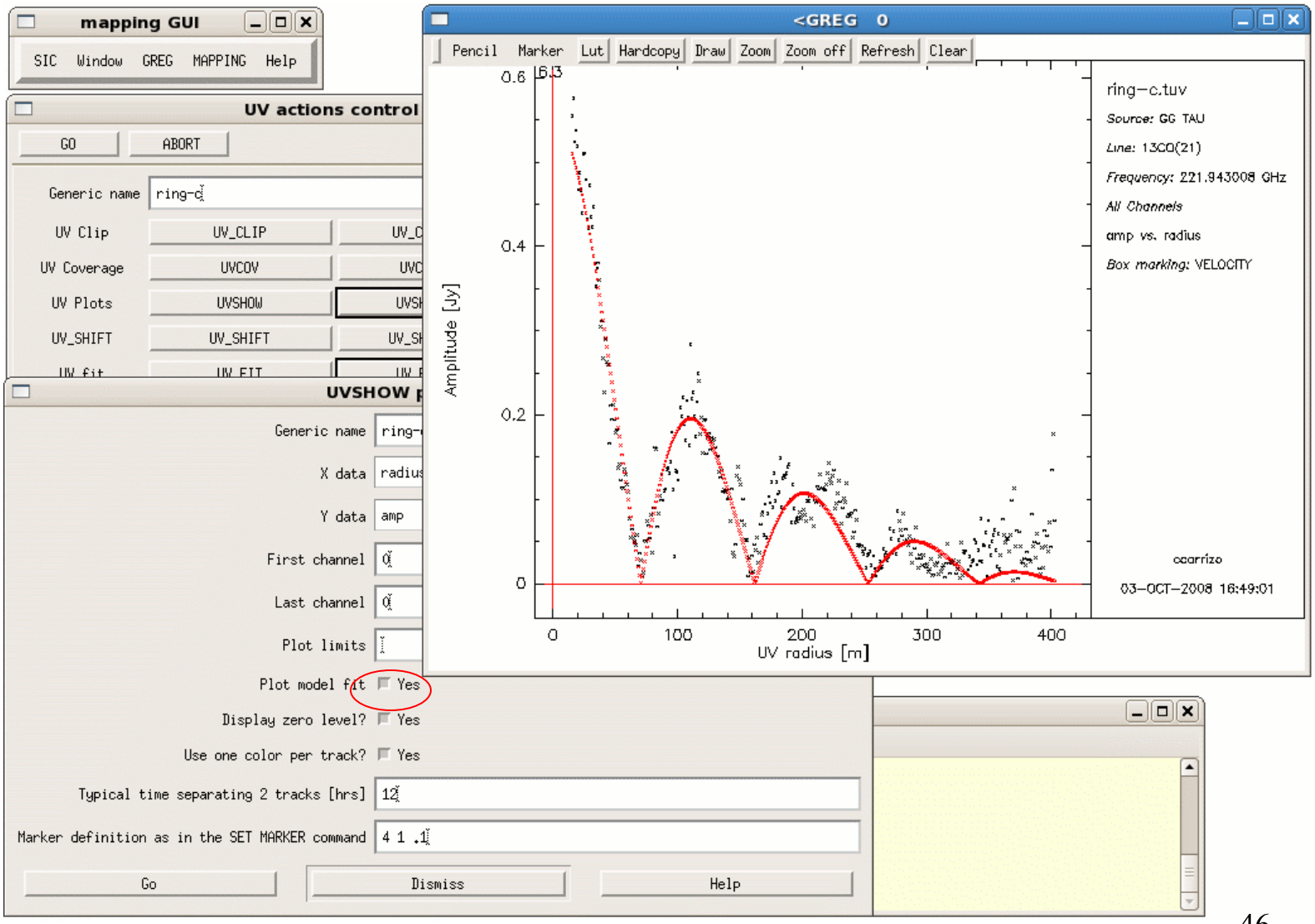


Elliptical Gaussian:
5 parameters

Data analysis in the *uv*-plane

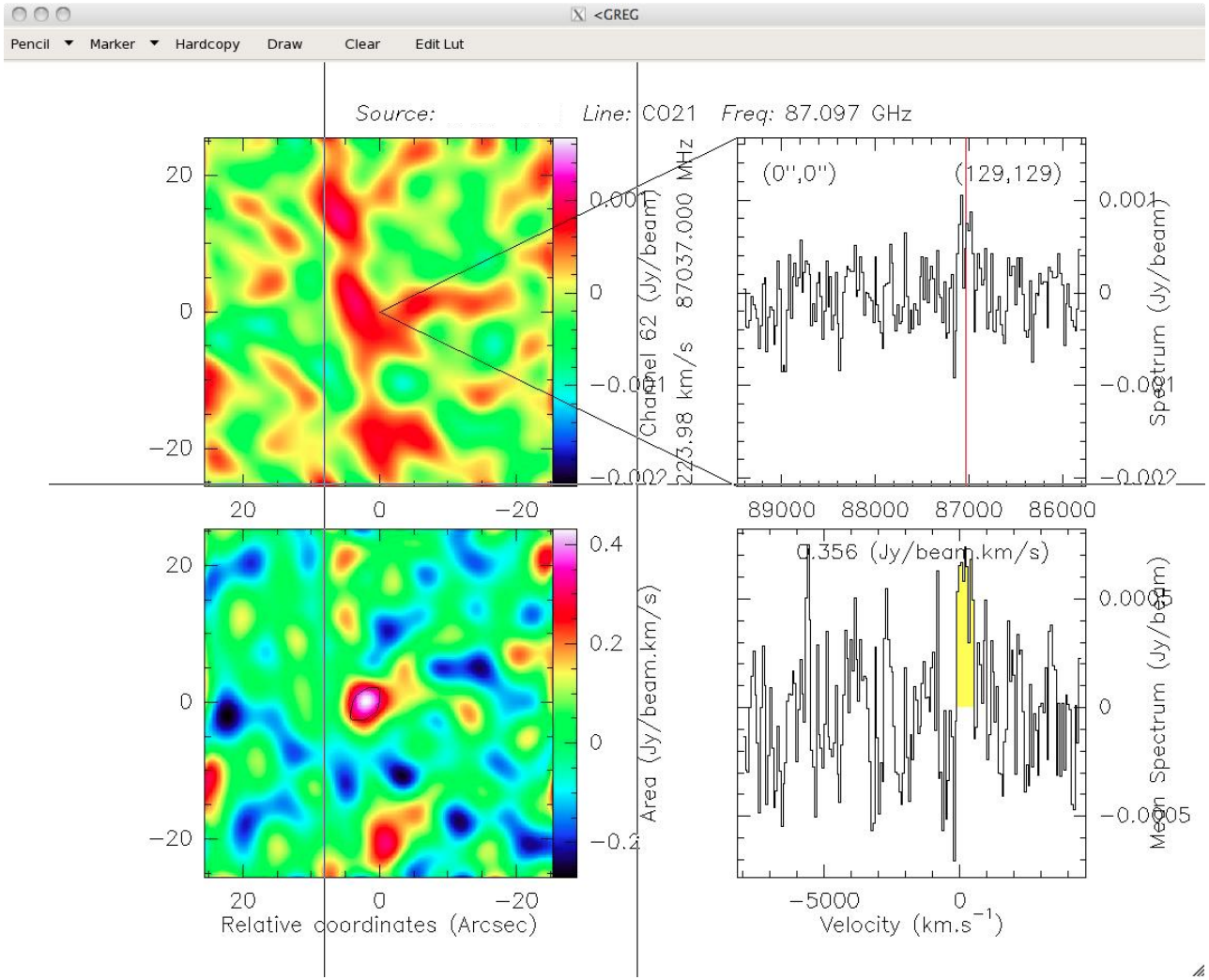


Data analysis in the *uv*-plane

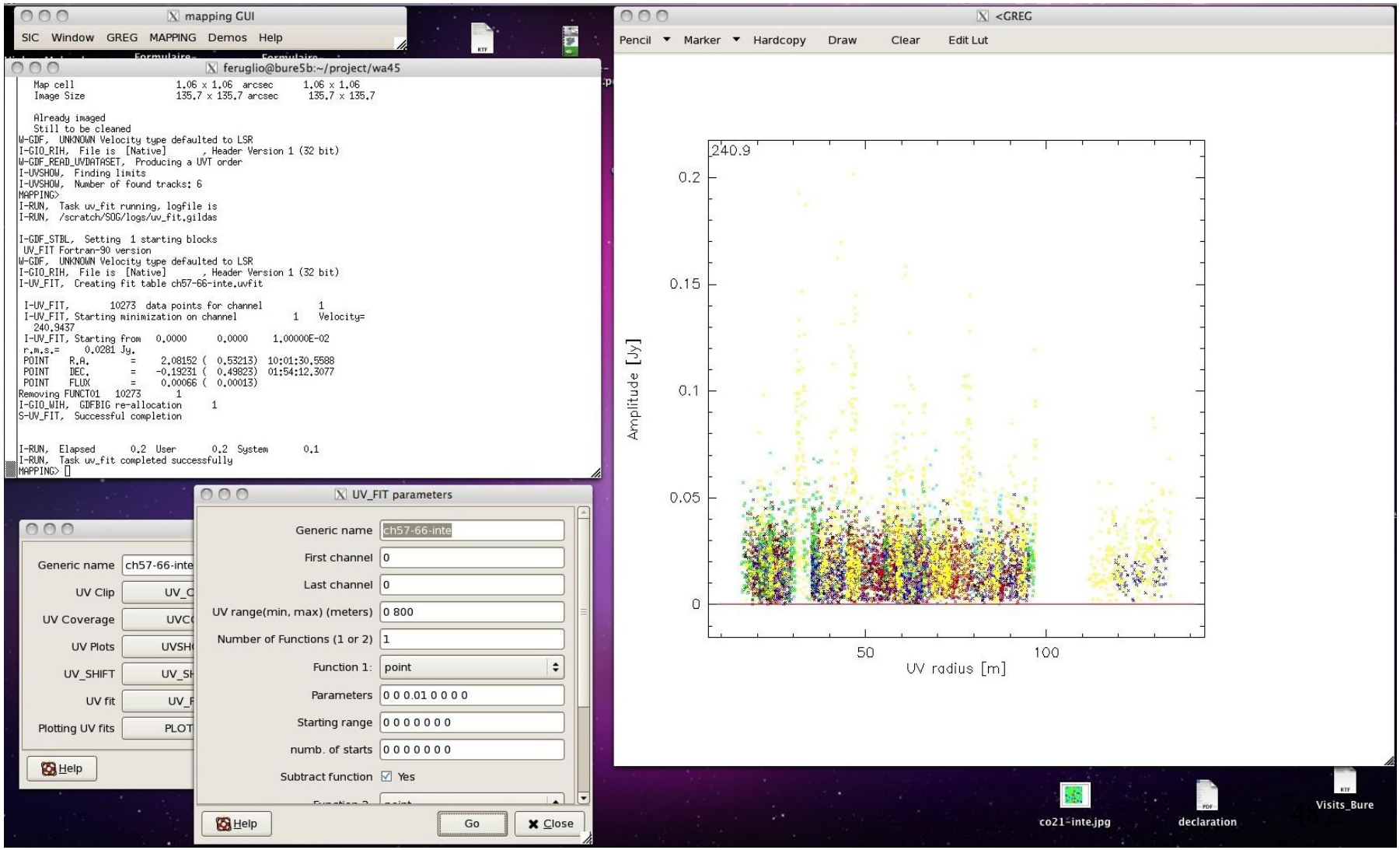


Data analysis in the *uv*-plane

Example: detection project of distant galaxy (unresolved)



Data analysis in the *uv*-plane



MAPPING procedures / tasks

```
MAPPING>  go …
MAPPING>  input …
```

also

```
MAPPING>  run …
MAPPING>  help …
```

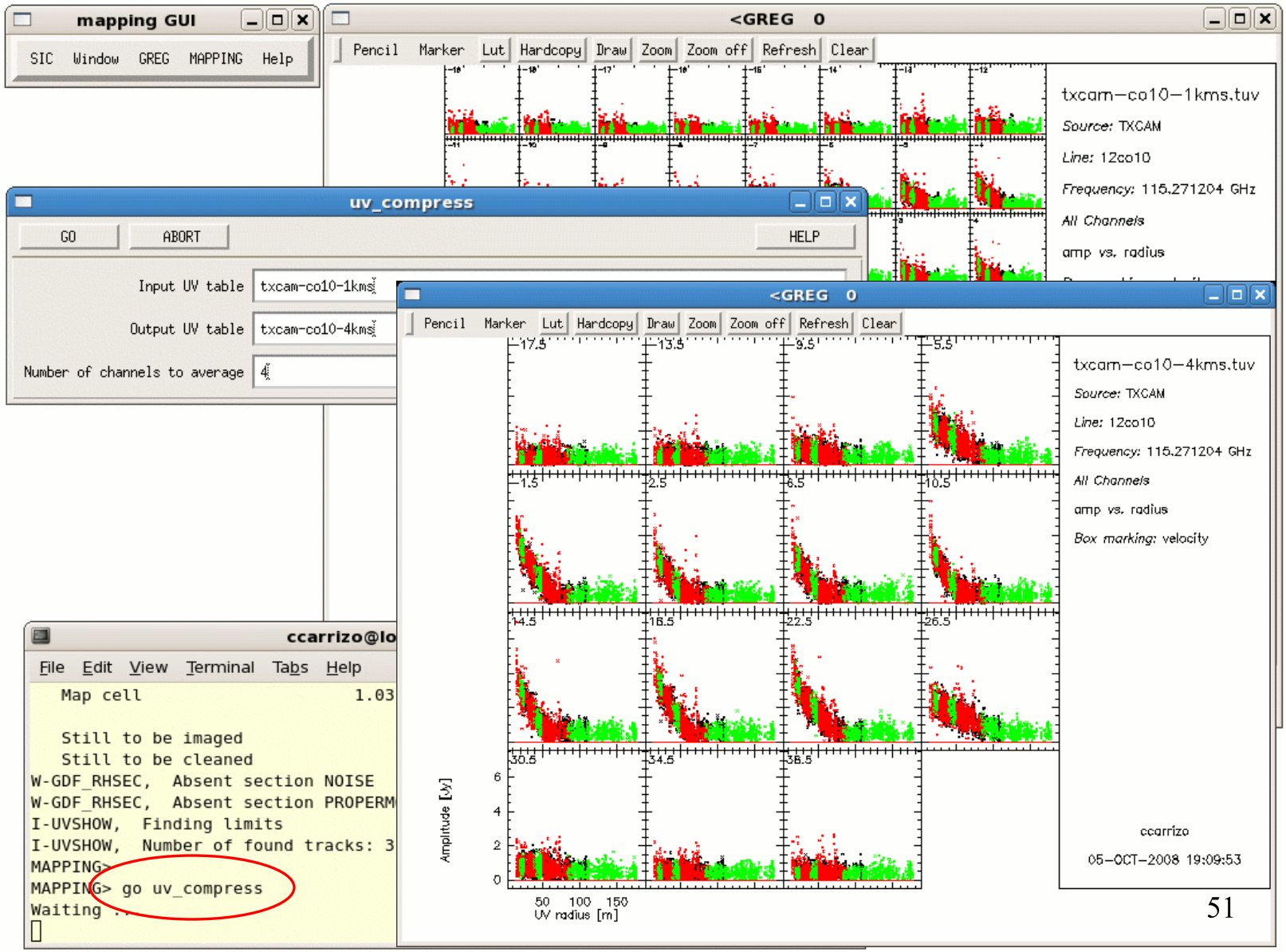
Data analysis in the *uv*-plane

MAPPING> go … or run …

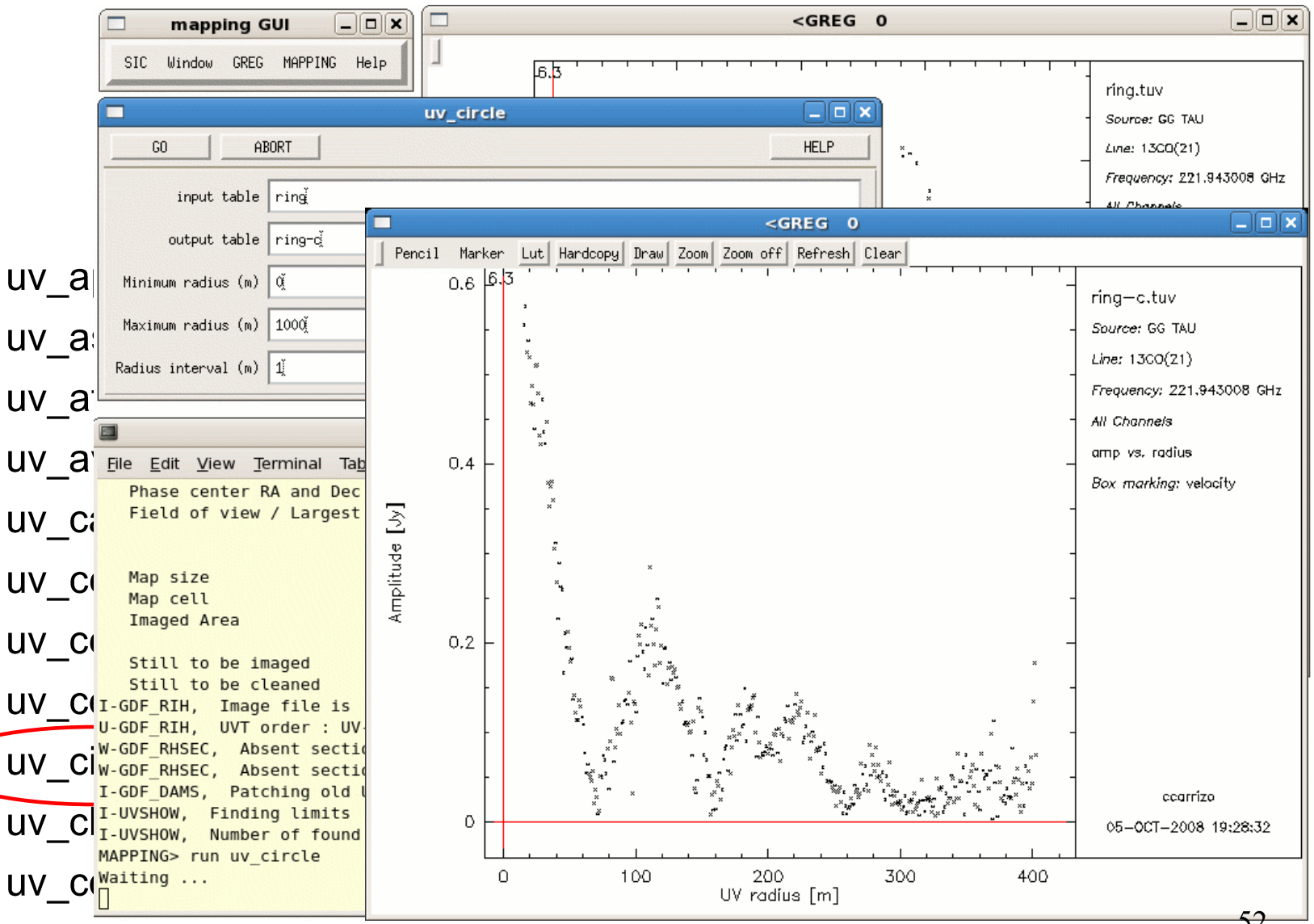
MAPPING> input … or help …

uv_applyphase	uv_dft	uv_merge	uv_solve
uv_ascal	uv_extract	uv_mflag	uv_sort
uv_atm	uv_fidelity	uv_model	uv_splitfield
uv_average	uv_fit-s	uv_mult	uv_stat
uv_cal	uv_flag	uv_noise	uv_substract
uv_ccmodel	uv_fmodel	uv_observe	uv_table
uv_cct	uv_gain	uv_pointing	uv_timeaverage
uv_center	uv_hanning	uv_selfcal	uv_timebase
uv_circle	uv_hybrid	uv_shift	uv_track
uv_clip	uv_list	uv_short	uv_track_phase
uv_compress	uv_map	uv_single	uv_zero
uv_cuts	uv_mcal	uv_sinusphase	

Data analysis in the *uv*-plane



Data analysis in the *uv*-plane

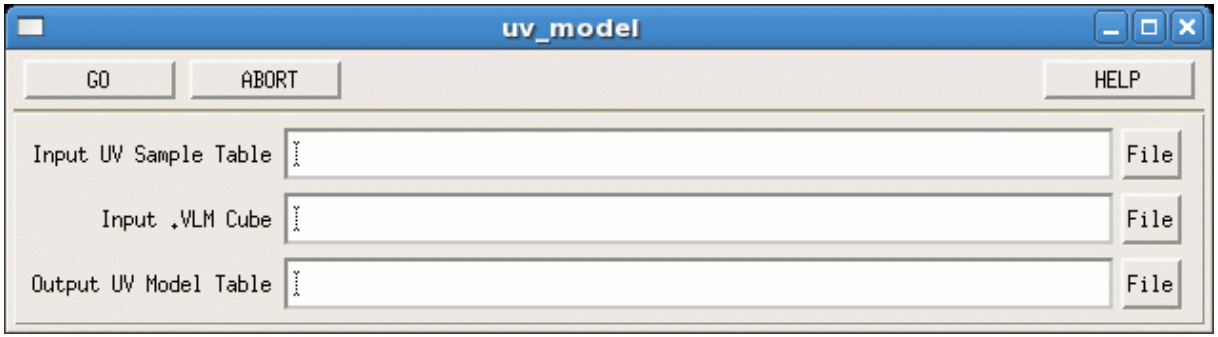


uv_a
uv_a
uv_a
uv_a
uv_c
uv_c
uv_c
uv_ci
uv_cl
uv_c
uv_cuts uv_mcal uv_sinusphase

Data analysis in the *uv*-plane

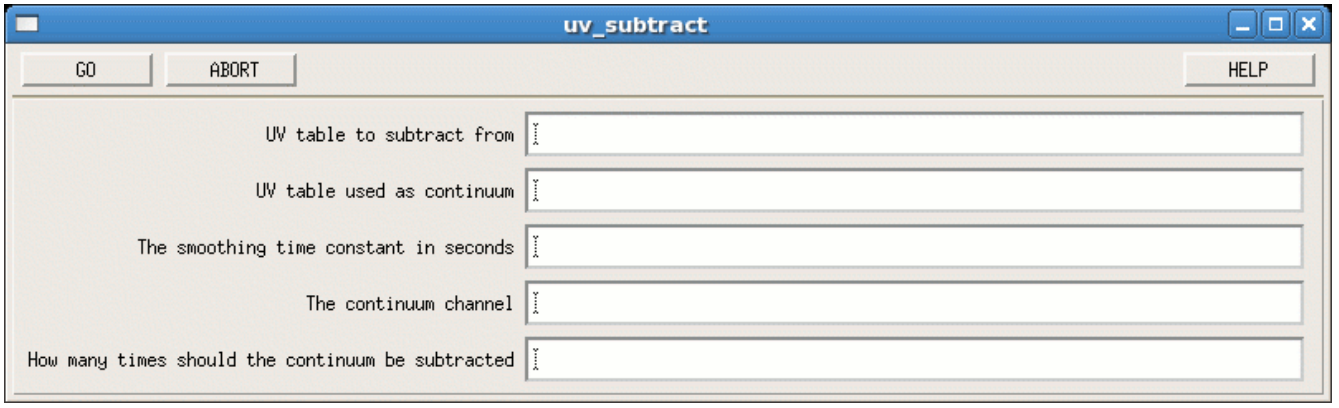
MAPPING>	go …	or	run …
MAPPING>	input …	or	help …

uv_applyphase	uv_dft	uv_merge	uv_solve
uv_ascal	uv_extract	uv_mflag	uv_sort
uv_atm	uv_fidelity	uv_model	uv_splitfield
uv_avera			
uv_cal			
uv_ccmo			
uv_cct			
uv_cente			
uv_circle			
uv_clip			
uv_compress	uv_map	uv_single	uv_zero
uv_cuts	uv_mcal	uv_sinusphase	



To create a *uv* table from an image, e.g. a model

Data analysis in the *uv*-plane

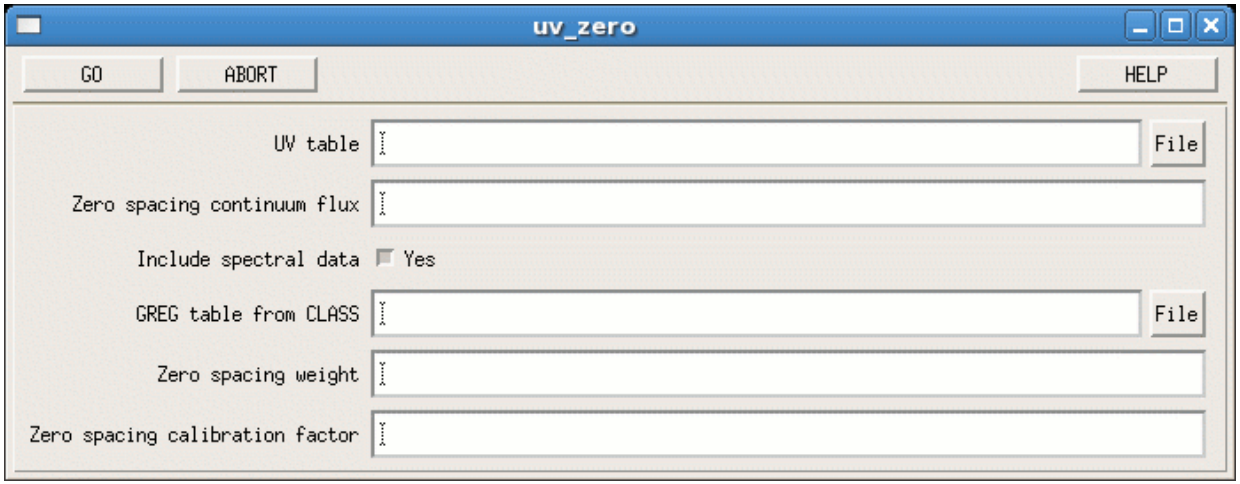


To substract a time-averaged continuum *uv* table

uv_cal	uv_flag	uv_noise	uv_subtract
uv_ccmodel	uv_fmodel	uv_observe	uv_table
uv_cct	uv_gain	uv_pointing	uv_timeaverage
uv_center	uv_hanning	uv_selfcal	uv_timebase
uv_circle	uv_hybrid	uv_shift	uv_track
uv_clip	uv_list	uv_short	uv_track_phase
uv_compress	uv_map	uv_single	uv_zero
uv_cuts	uv_mcal	uv_sinusphase	

Data analysis in the *uv*-plane

MAPPING> go … or run …
MAPPING> input … or help …



To add a single-dish zero-spacing spectrum

_solve
_sort
_splitfield
_stat
_subtract
_table
_timeaverage
_timebase
_track
uv_clip uv_list uv_short uv_track_phase
uv_compress uv_map uv_single uv_zero
uv_cuts uv_mcal uv_sinusphase

Data analysis in the *uv*-plane

uv tables are fully editable

Each visibility contains:

- *u* in meters
- *v* in meters
- scan number
- observation date (CLASS number)
- time in seconds (since date above)
- start antenna in the baseline
- end antenna in the

- real part fo
- imaginary part
- weight

- real part fo
- imaginary part
- …

uv table [visib dimension, # visibilities]

visib dimension = 7 + 3 x (# channels)

7 visib. characteristics

```
mapping>  define table aa mytable.uvt write
mapping>  let  aa[8,2380]  6000
mapping>  delete /variable aa
```

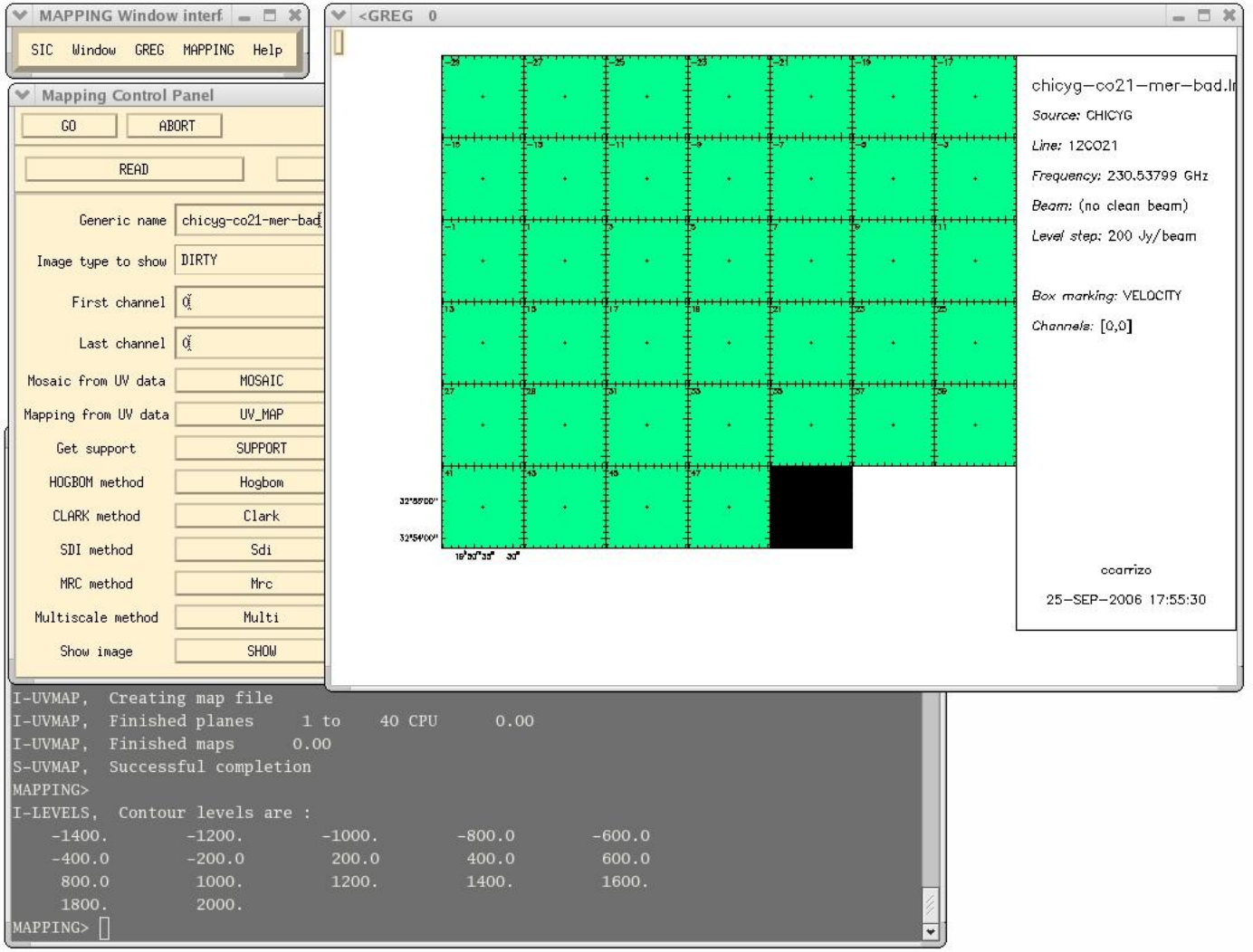
2nd channel

data at 2nd channel

3. An inspection of the data in the *uv*-plane is recommended

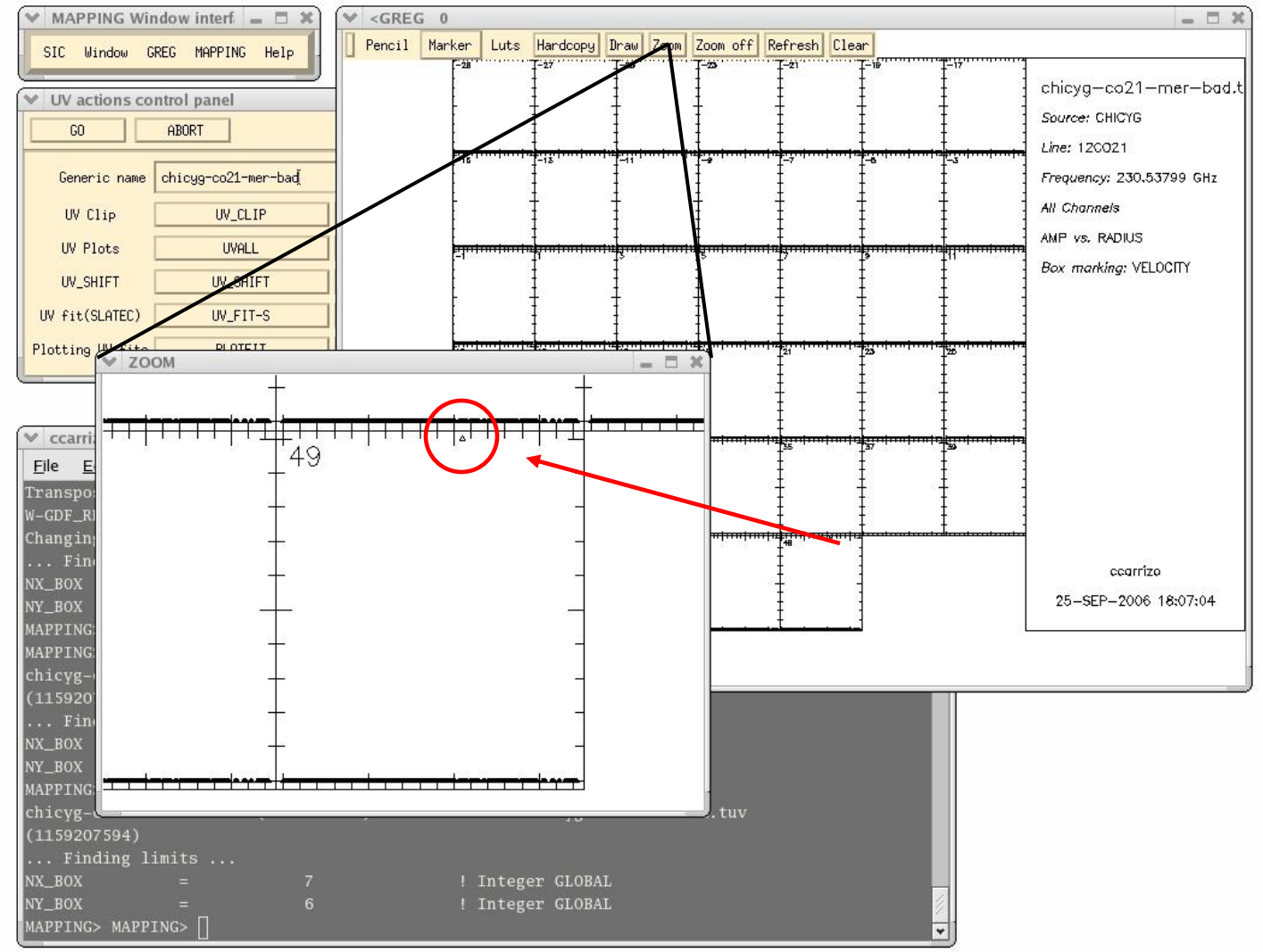
(1) Passing directly from hpb → mapping

It may happen…



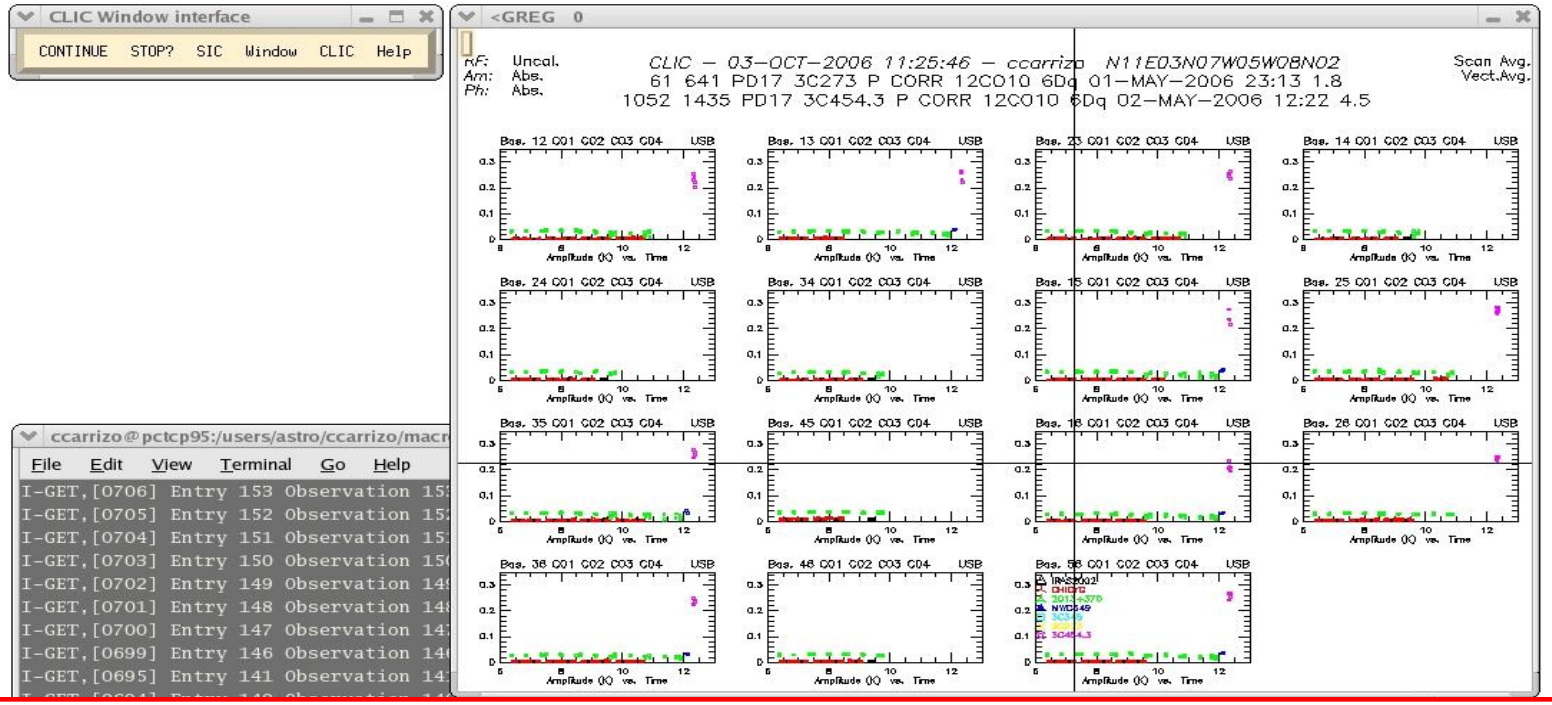
(1) Passing directly from hpb → mapping

It may happen…



(1) Passing directly from hpb → mapping

It may happen… that there remain some wrong visibilities

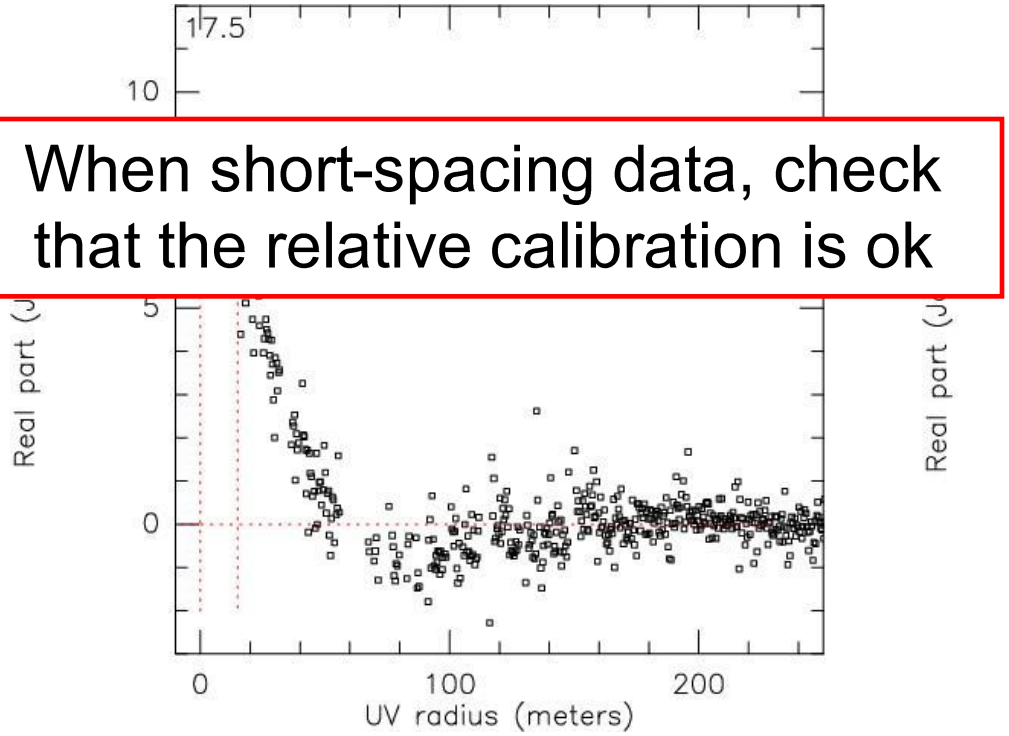


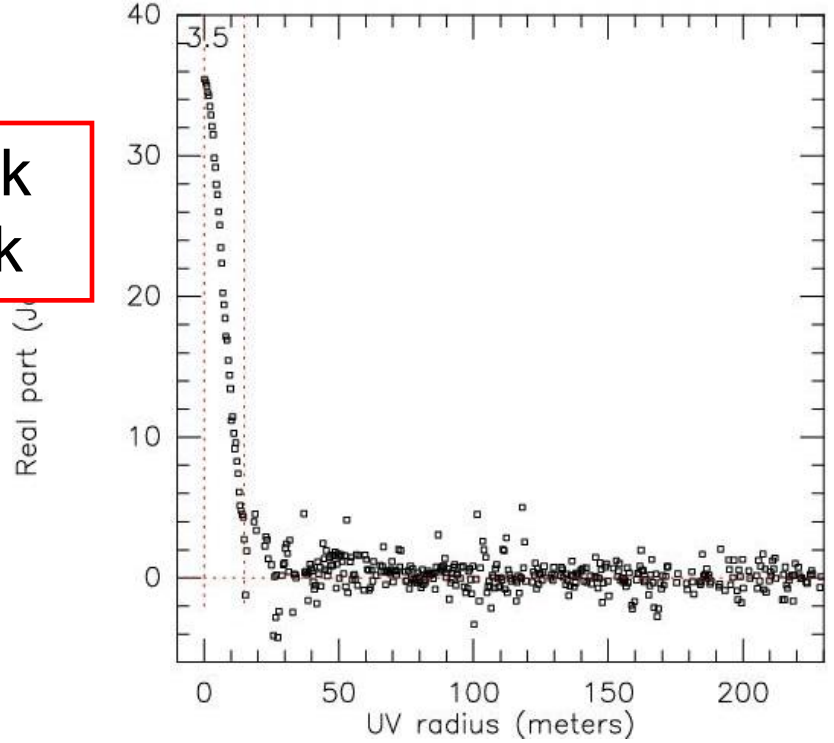
CLIC> find /proc corr /sou Betel /rece 2 /scans 1245 1255

CLIC> store quality 9

(2) Passing directly from hpb → mapping

When short-spacing data, check that the relative calibration is ok

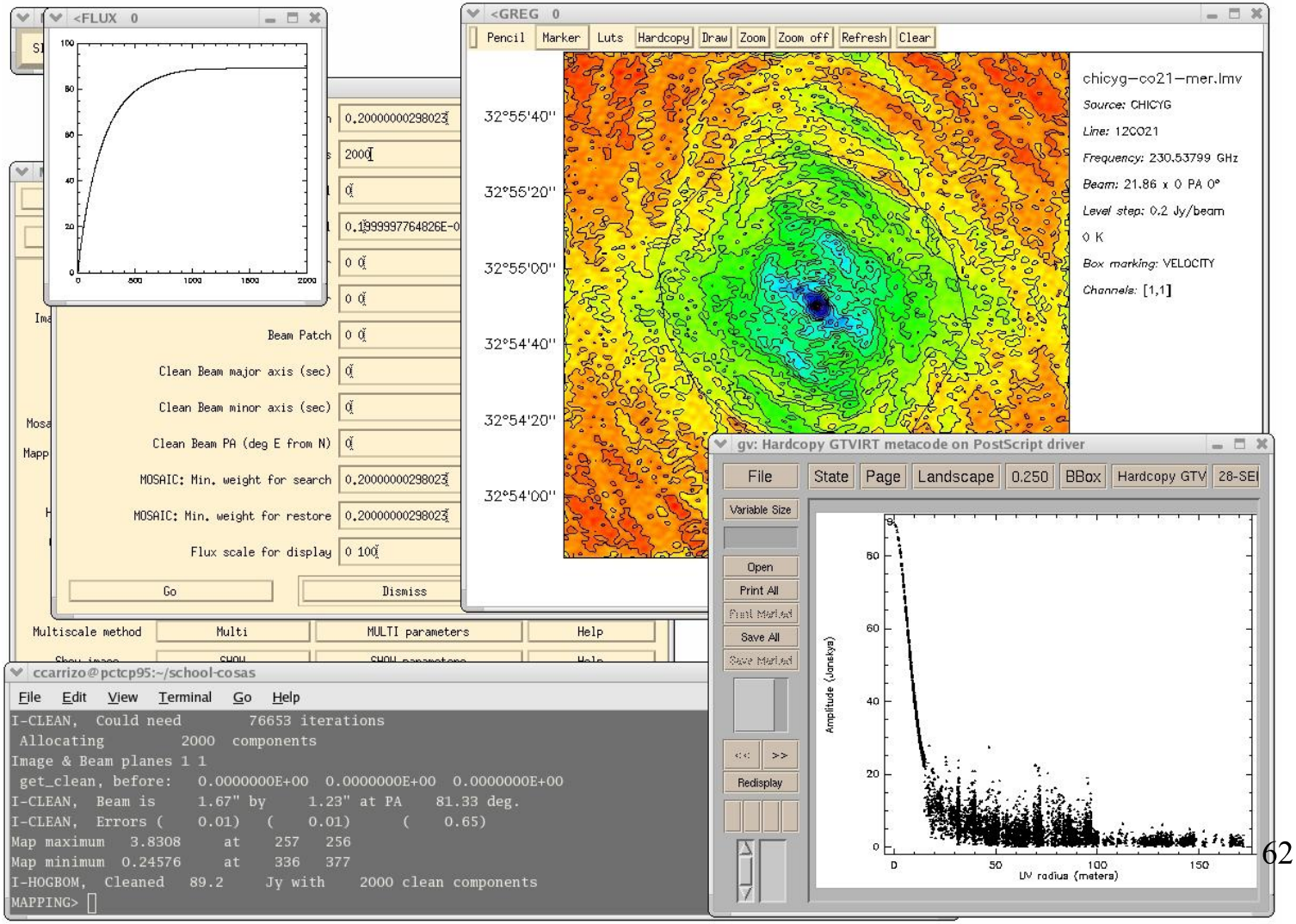




+ Short-spacing data

(3) Passing directly from hpb → mapping

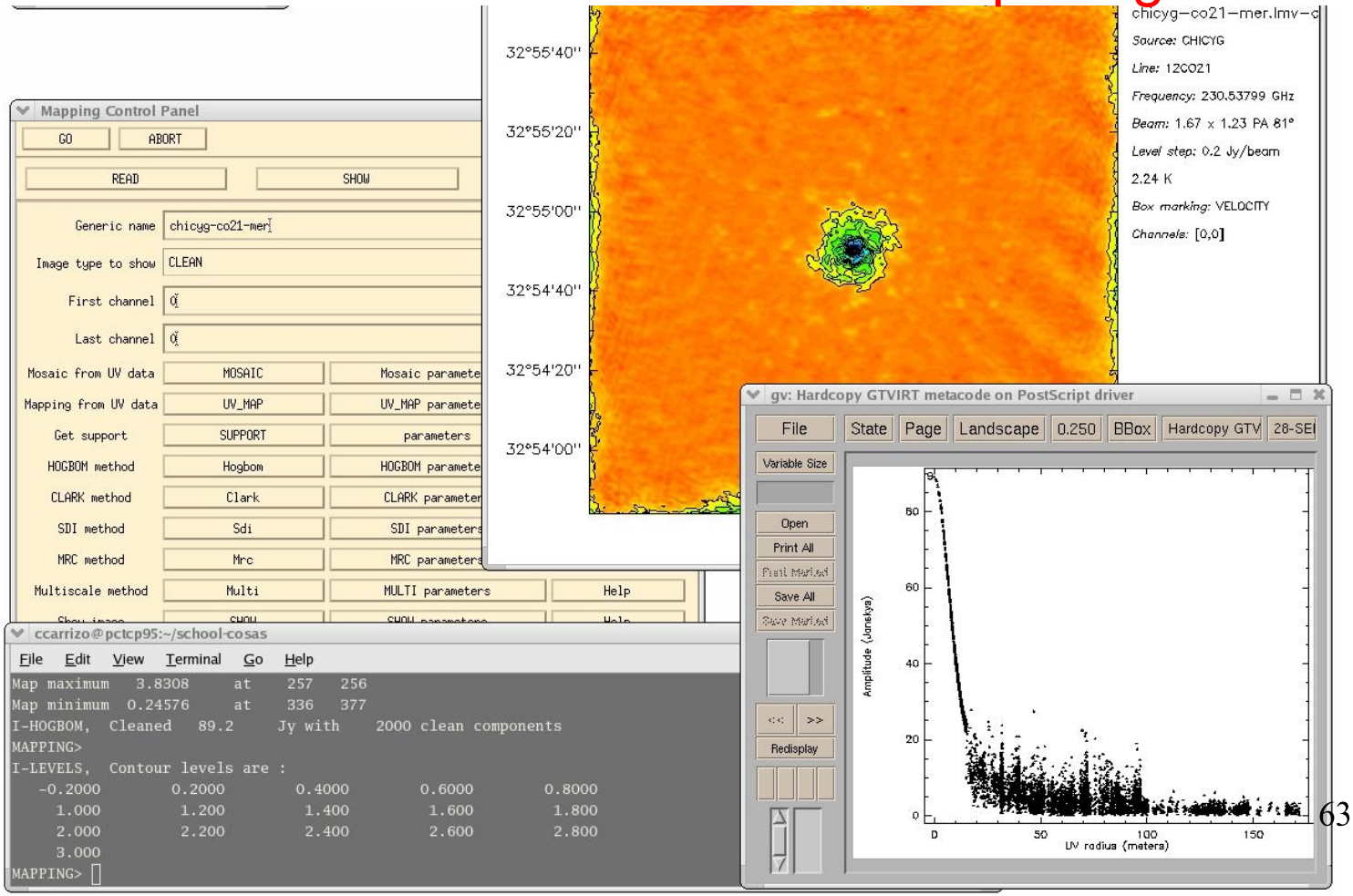
Good practice: When cleaning (extended sources)…



(3) Passing directly from hpb → mapping

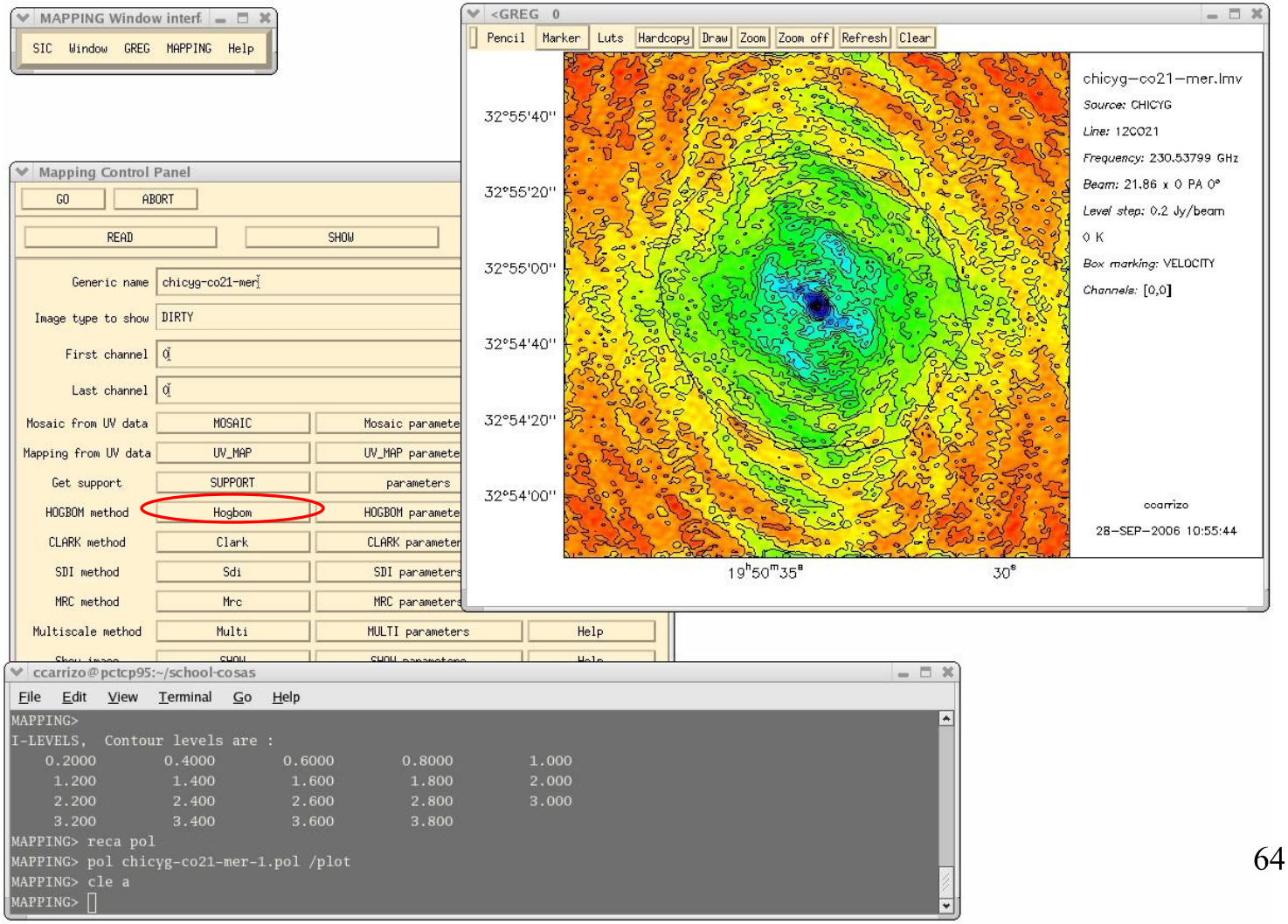
Good practice: When cleaning (extended sources)

verify that the flux obtained in the image plane coincides with that at the zero-spacing



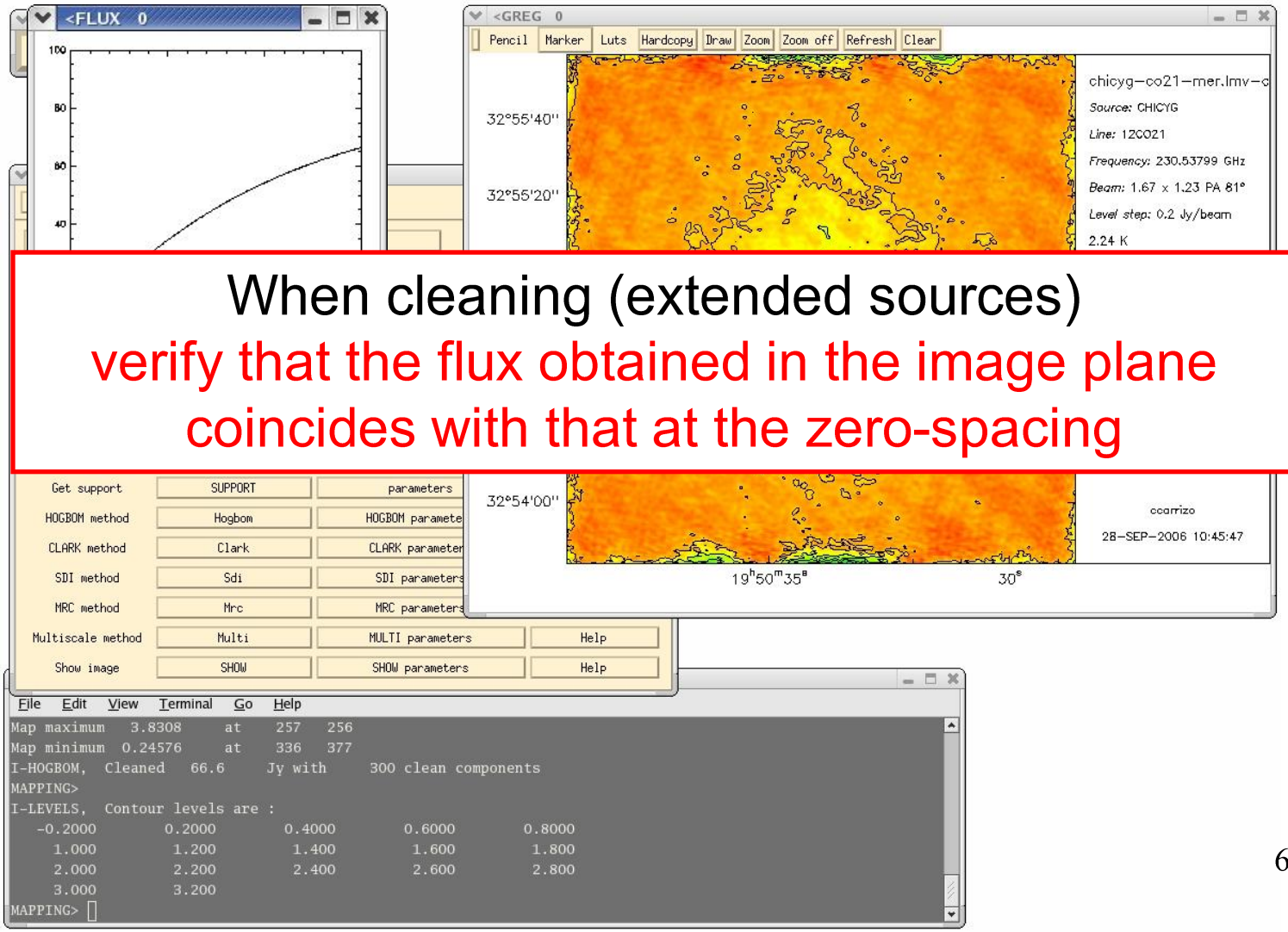
(3) Passing directly from hpb → mapping

If not, it may happen…



(3) Passing directly from hpb → mapping

It may happen…



When cleaning (extended sources)

verify that the flux obtained in the image plane coincides with that at the zero-spacing

To conclude:

- An inspection of data in the *uv*-plane is recommended for all the projects

- A detailed analysis in the *uv*-plane: detection, modeling of simple shapes, to check relative calibration, etc…