Analysis in the *uv*-plane

Arancha Castro-Carrizo

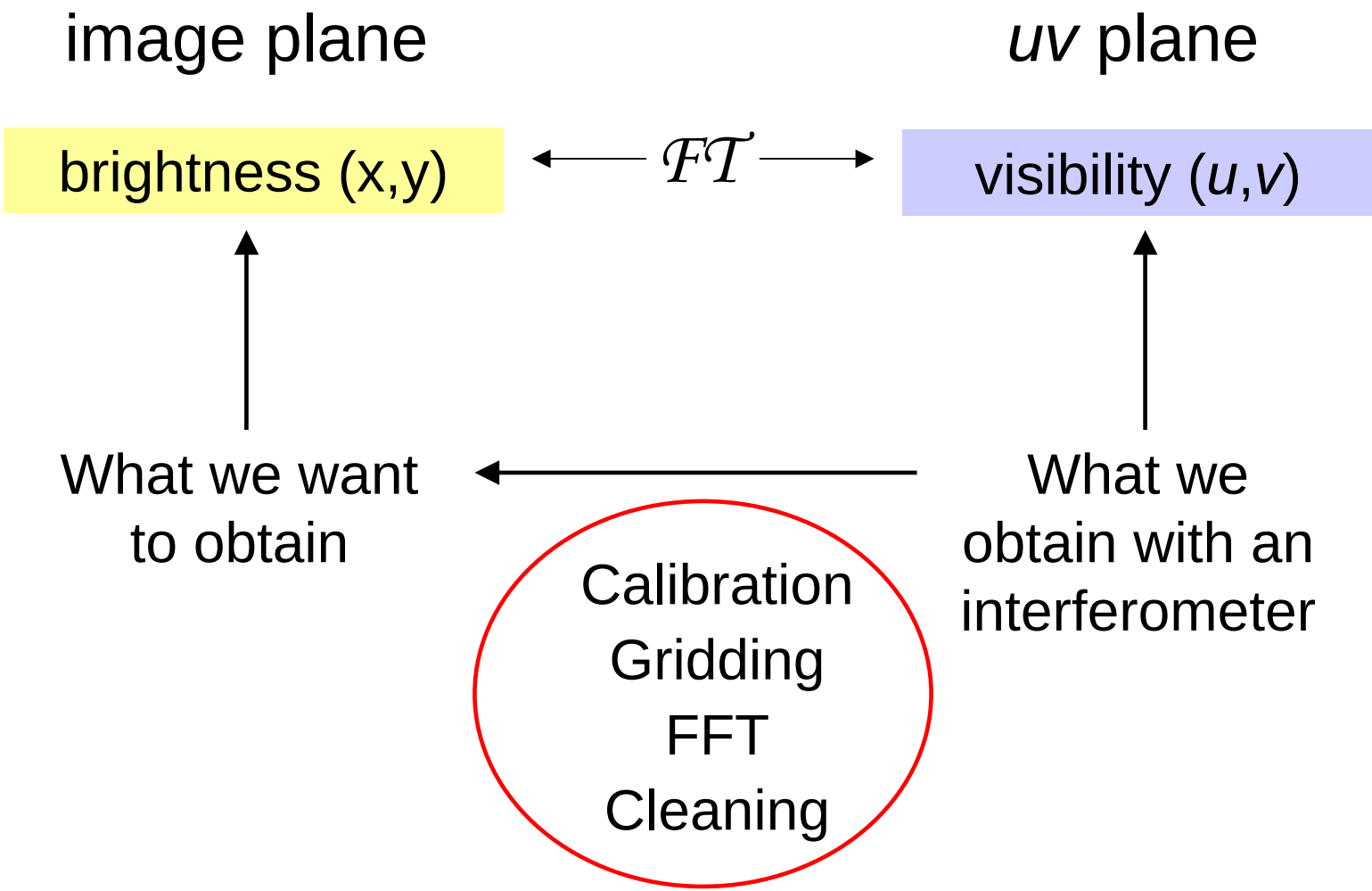


image plane
uv plane
brightness (x,y)
$\mathcal{FT}$
visibility (u,v)
What we want to obtain
What we obtain with an interferometer
Calibration
Gridding
FFT
Cleaning

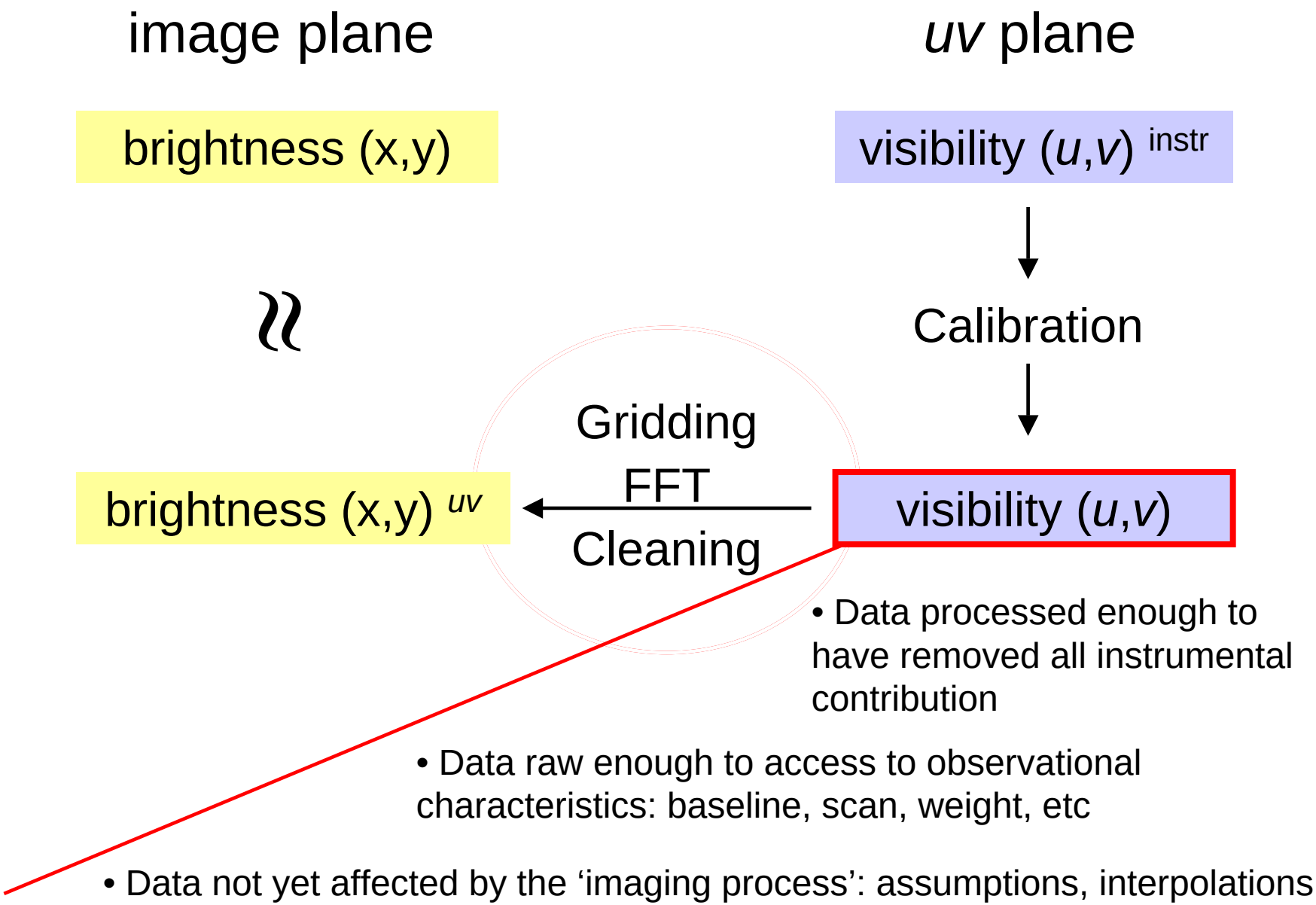
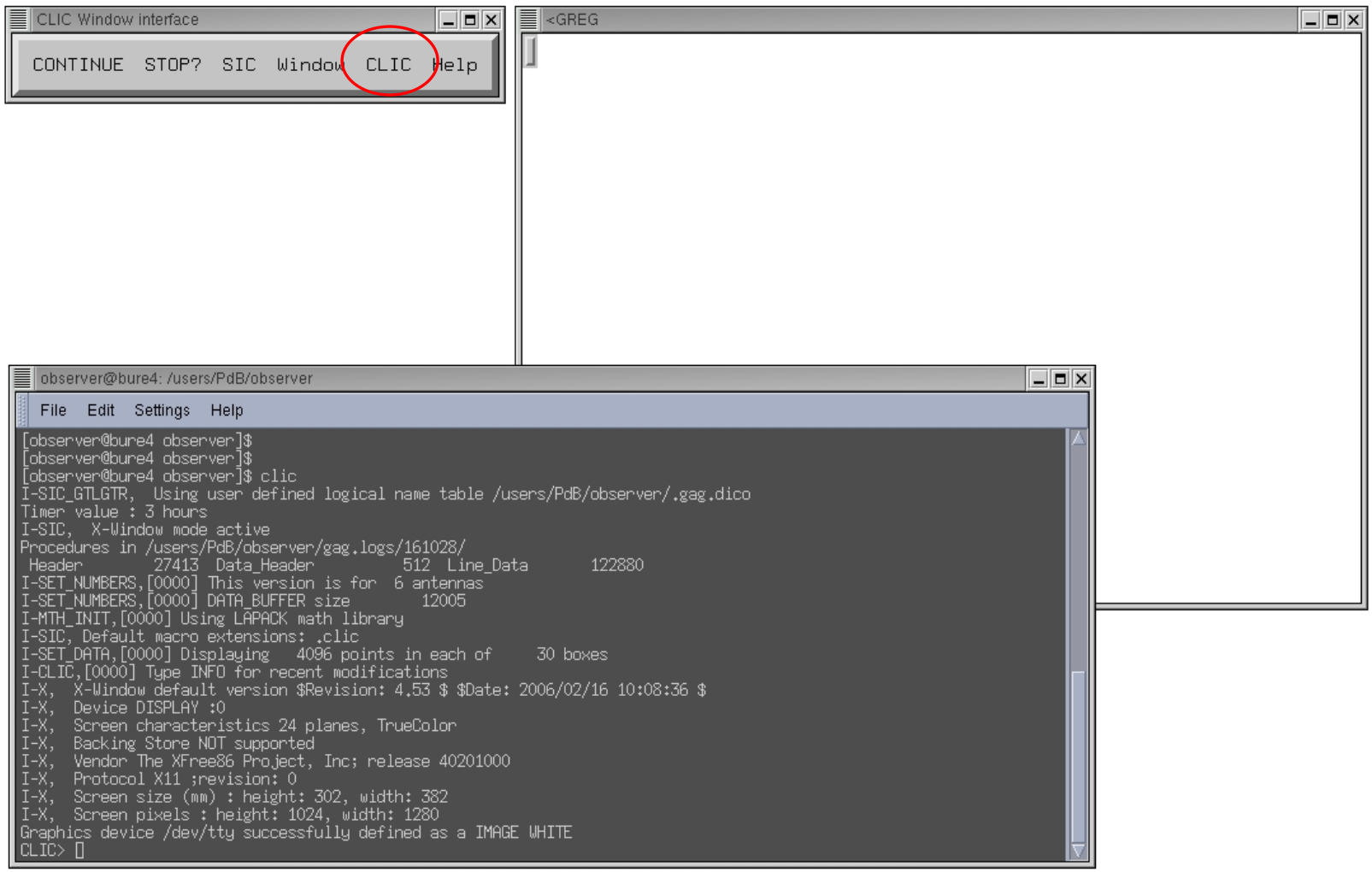


image plane
uv plane
brightness (x,y)
visibility (u,v) instr
Calibration
Gridding
FFT
Cleaning
brightness (x,y) uv
visibility (u,v)
• Data processed enough to have removed all instrumental contribution
• Data raw enough to access to observational characteristics: baseline, scan, weight, etc
• Data not yet affected by the 'imaging process': assumptions, interpolations, computations, etc

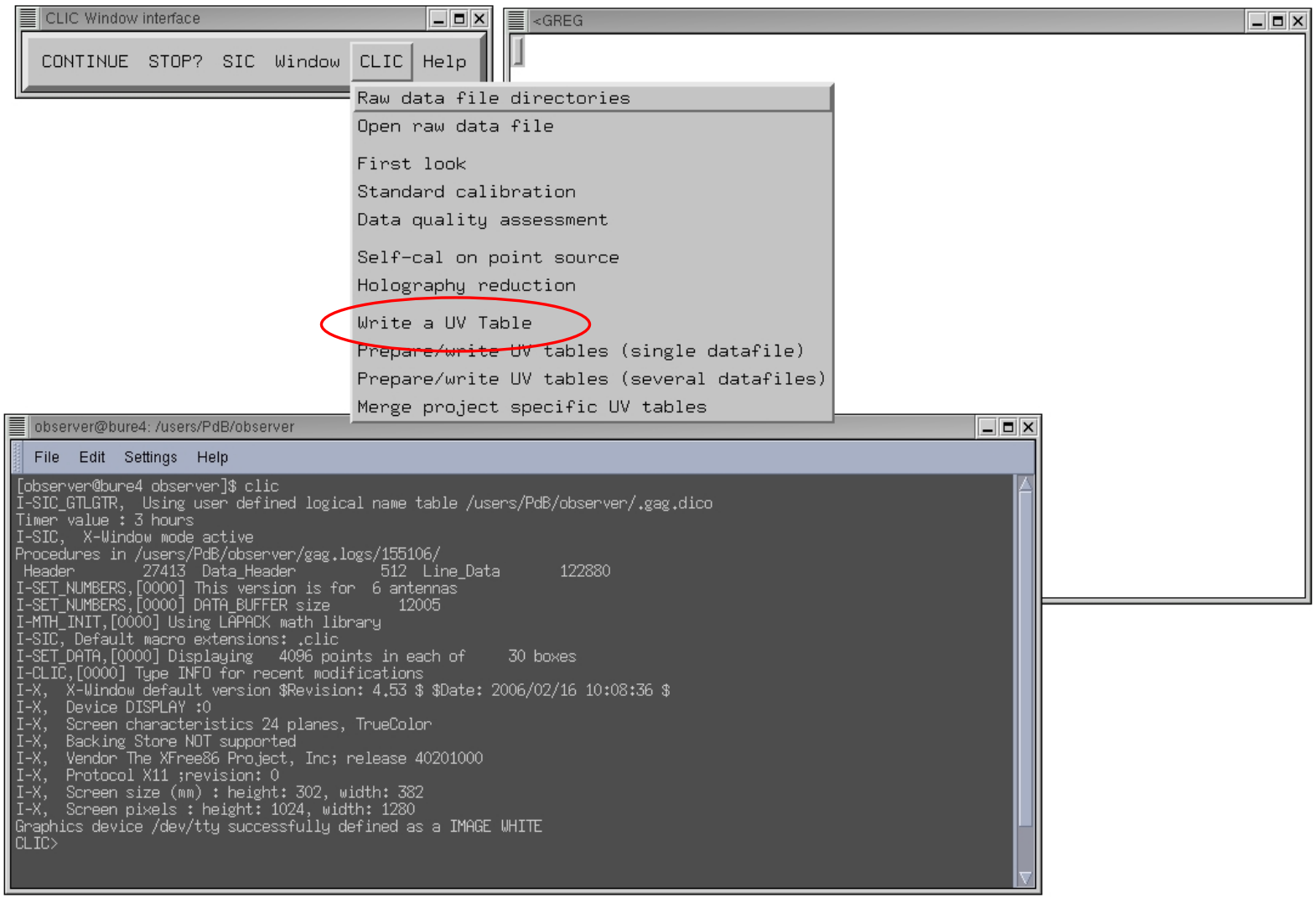
Let’s create a table (“mytable”.uvt),

in CLIC

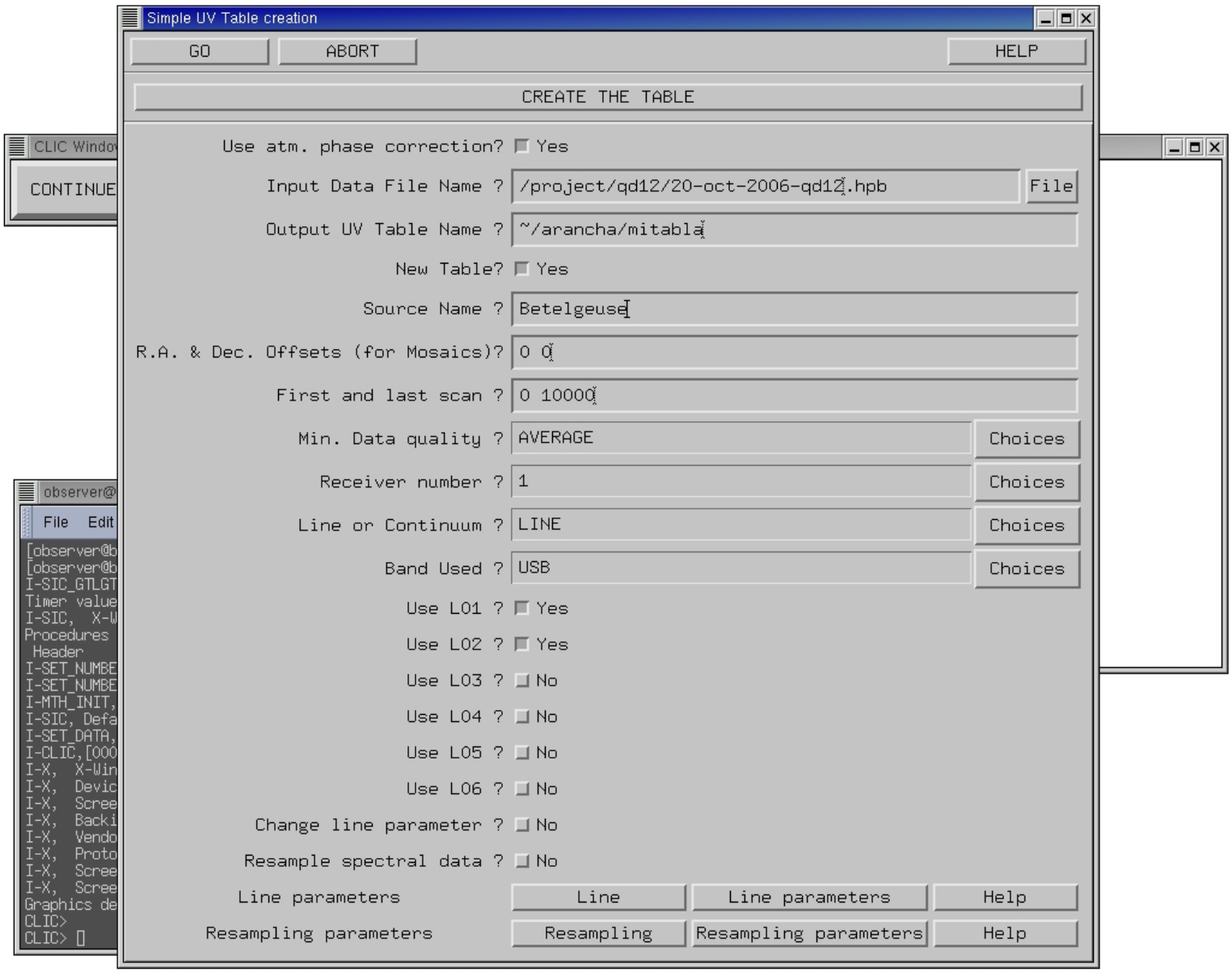
Creating a *uv*-table; **CLIC**

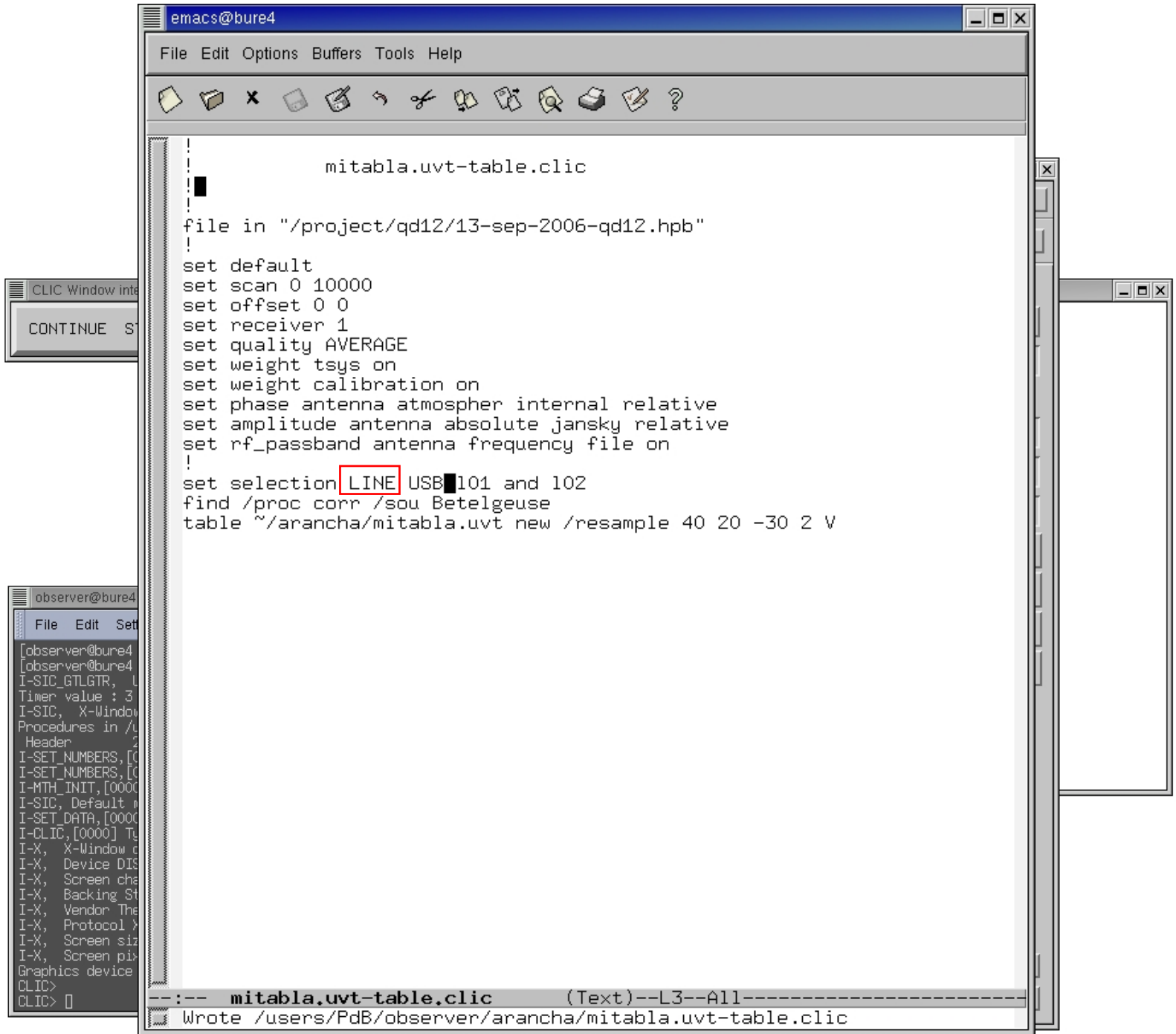


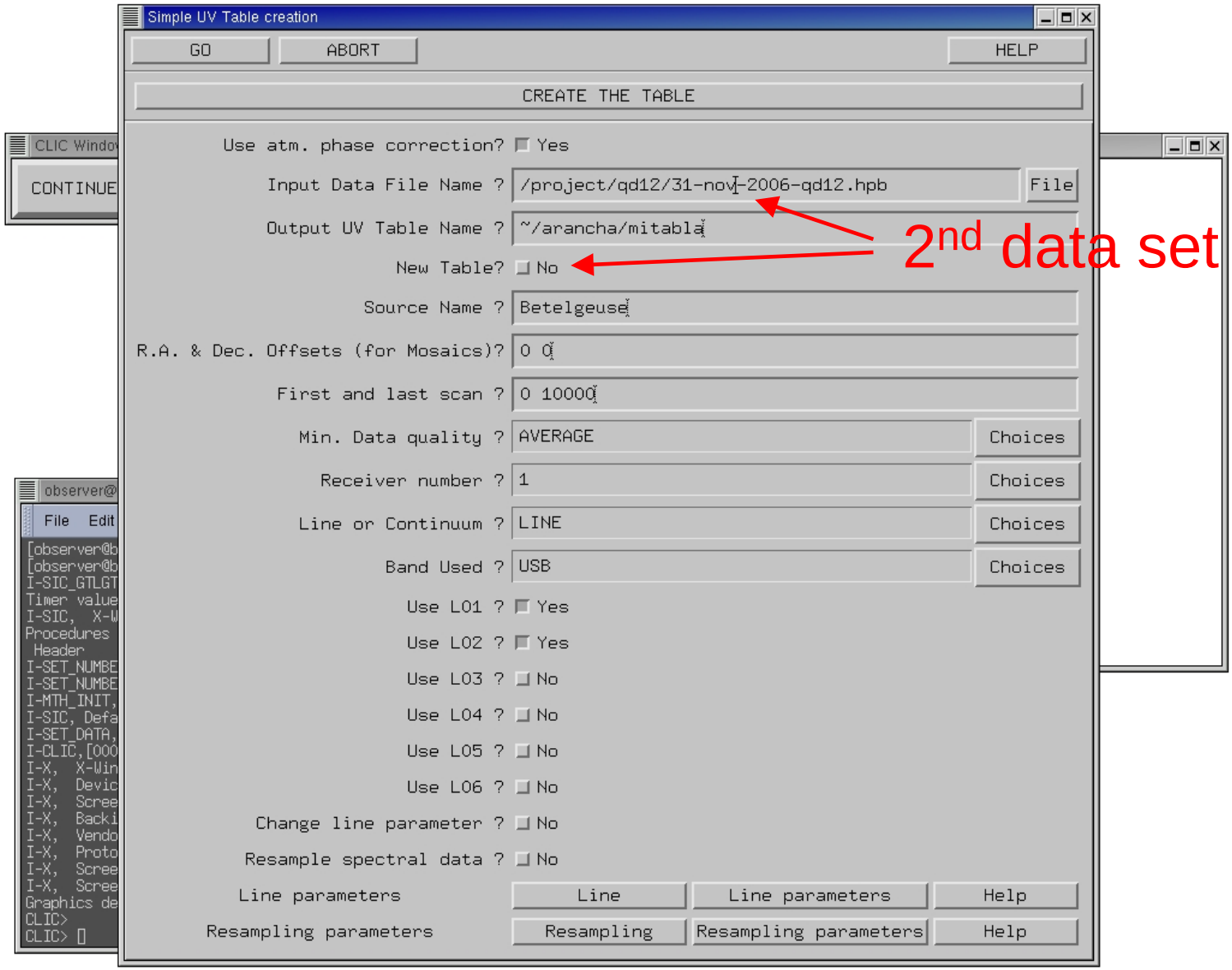
Creating a *uv*-table; CLIC

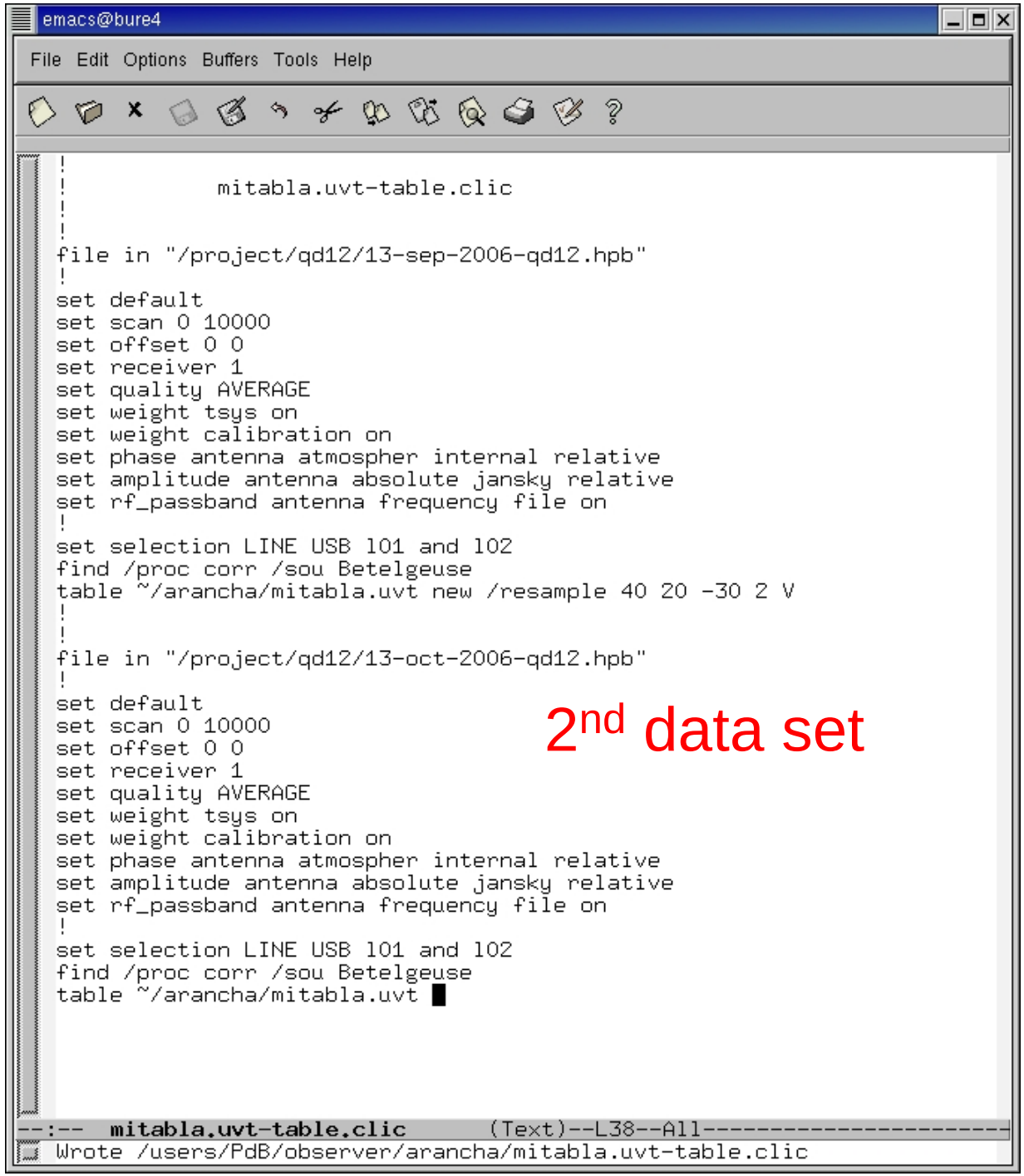


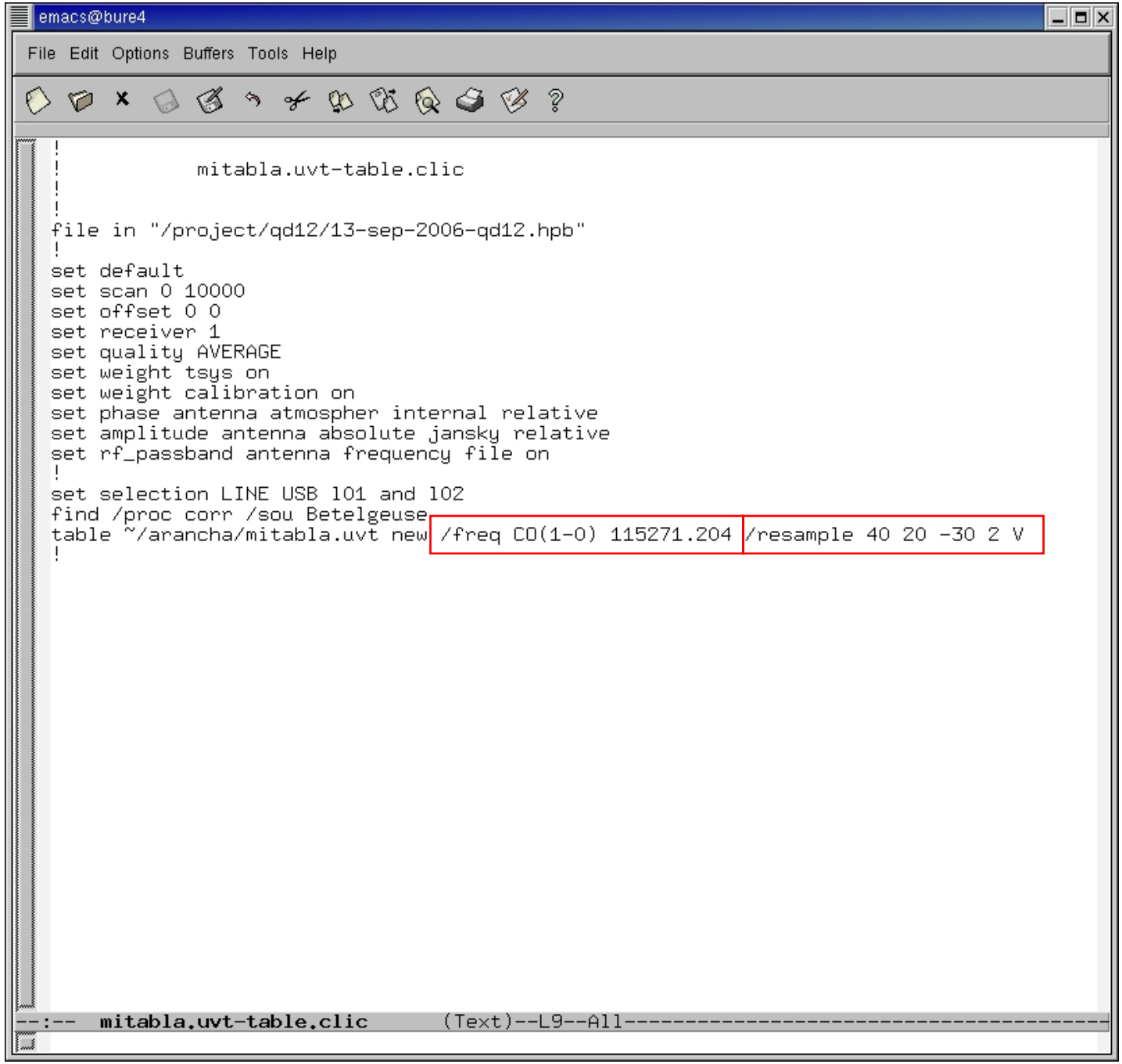
Creating a *uv*-table; CLIC




emacs@bure4
File Edit Options Buffers Tools Help
!
! mitabla.uvt-table.clic
!
!
file in "/project/qd12/13-sep-2006-qd12.hpb"
!
set default
set scan 0 10000
set offset 0 0
set receiver 1
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 USB 101 and 102
find /proc corr /sou Betelgeuse
table ~/arancha/mitabla.uvt new /resample 40 20 -30 2 V
--:-- mitabla.uvt-table.clic (Text)--L3--All
Wrote /users/PdB/observer/arancha/mitabla.uvt-table.clic
CLIC Window inte
CONTINUE
observer@bure4
File Edit Set
[observer@bure4
[observer@bure4
I-SIC_GTLGTR,
Timer value : 3
I-SIC, X-Windo
Procedures in /
Header
I-SET_NUMBERS,[
I-SET_NUMBERS,[
I-MTH_INIT,[000
I-SIC, Default
I-SET_DATA,[000
I-CLIC,[0000] Ty
I-X, X-Window
I-X, Device DIS
I-X, Screen cha
I-X, Backing St
I-X, Vendor The
I-X, Protocol
I-X, Screen siz
I-X, Screen pix
Graphics device
CLIC>
CLIC> []


Simple UV Table creation
GO
ABORT
HELP
CREATE THE TABLE
Use atm. phase correction? Yes
Input Data File Name ? /project/qd12/31-nov-2006-qd12.hpb
File
Output UV Table Name ? ~/arancha/mitabla
New Table? No
Source Name ? Betelgeuse
R.A. & Dec. Offsets (for Mosaics)? 0 0
First and last scan ? 0 10000
Min. Data quality ? AVERAGE
Choices
Receiver number ? 1
Choices
Line or Continuum ? LINE
Choices
Band Used ? USB
Choices
Use LO1 ? Yes
Use LO2 ? Yes
Use LO3 ? No
Use LO4 ? No
Use LO5 ? No
Use LO6 ? No
Change line parameter ? No
Resample spectral data ? No
Line parameters
Line
Line parameters
Help
Resampling parameters
Resampling
Resampling parameters
Help
2nd data set
CLIC Windo
CONTINUE
observer@
File Edit

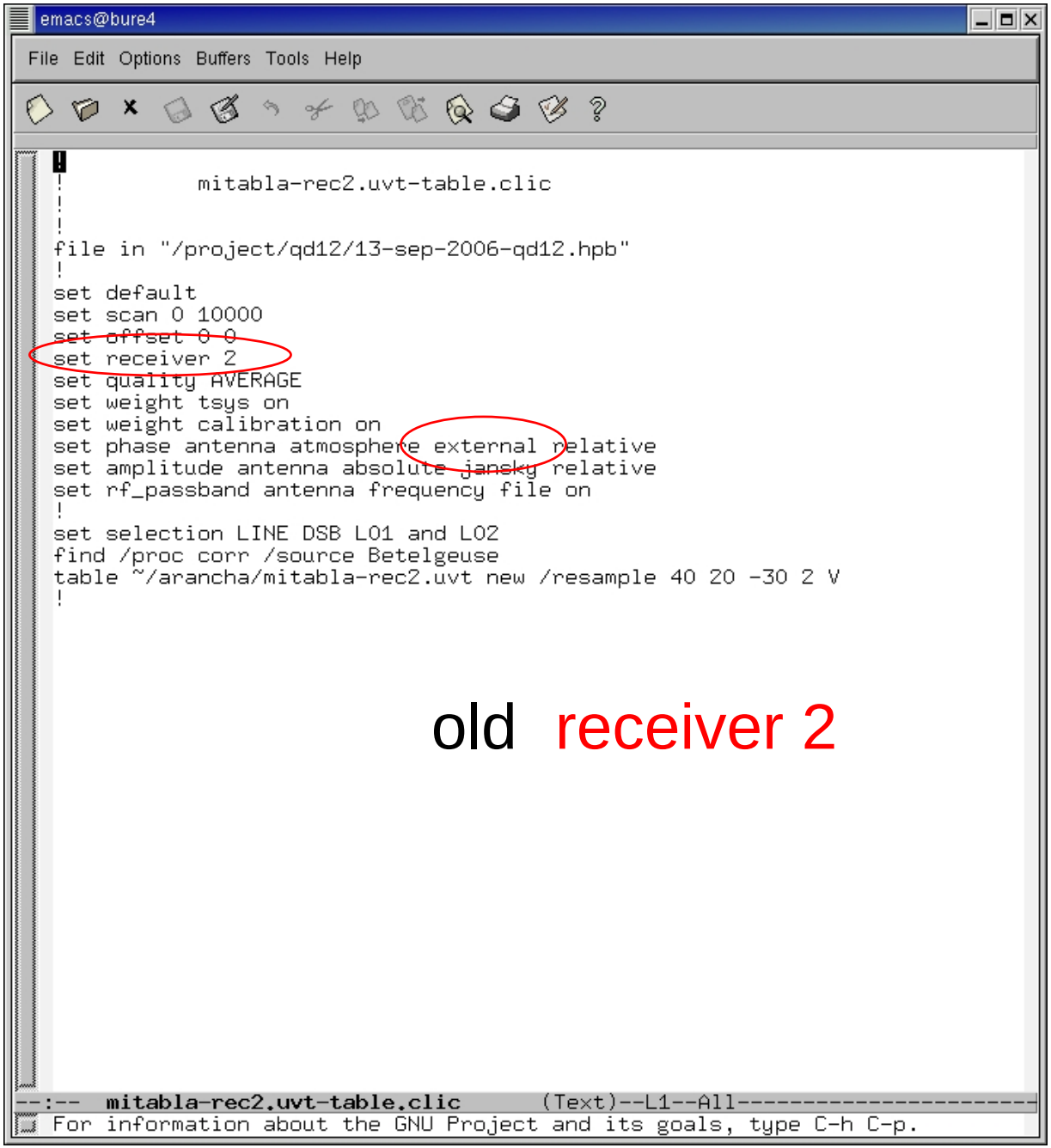

emacs@bure4
File Edit Options Buffers Tools Help
!
! mitabla.uvt-table.clic
!
!
file in "/project/qd12/13-sep-2006-qd12.hpb"
!
set default
set scan 0 10000
set offset 0 0
set receiver 1
set quality AVERAGE
set weight tsys on
set weight calibration on
set phase antenna atmospher internal relative
set amplitude antenna absolute jansky relative
set rf_passband antenna frequency file on
!
set selection LINE USB 101 and 102
find /proc corr /sou Betelgeuse
table ~/arancha/mitabla.uvt new /resample 40 20 -30 2 V
!
!
file in "/project/qd12/13-oct-2006-qd12.hpb"
!
set default
set scan 0 10000
set offset 0 0
set receiver 1
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 USB 101 and 102
find /proc corr /sou Betelgeuse
table ~/arancha/mitabla.uvt
2nd data set
--:-- mitabla.uvt-table.clic (Text)--L38--All
Wrote /users/PdB/observer/arancha/mitabla.uvt-table.clic

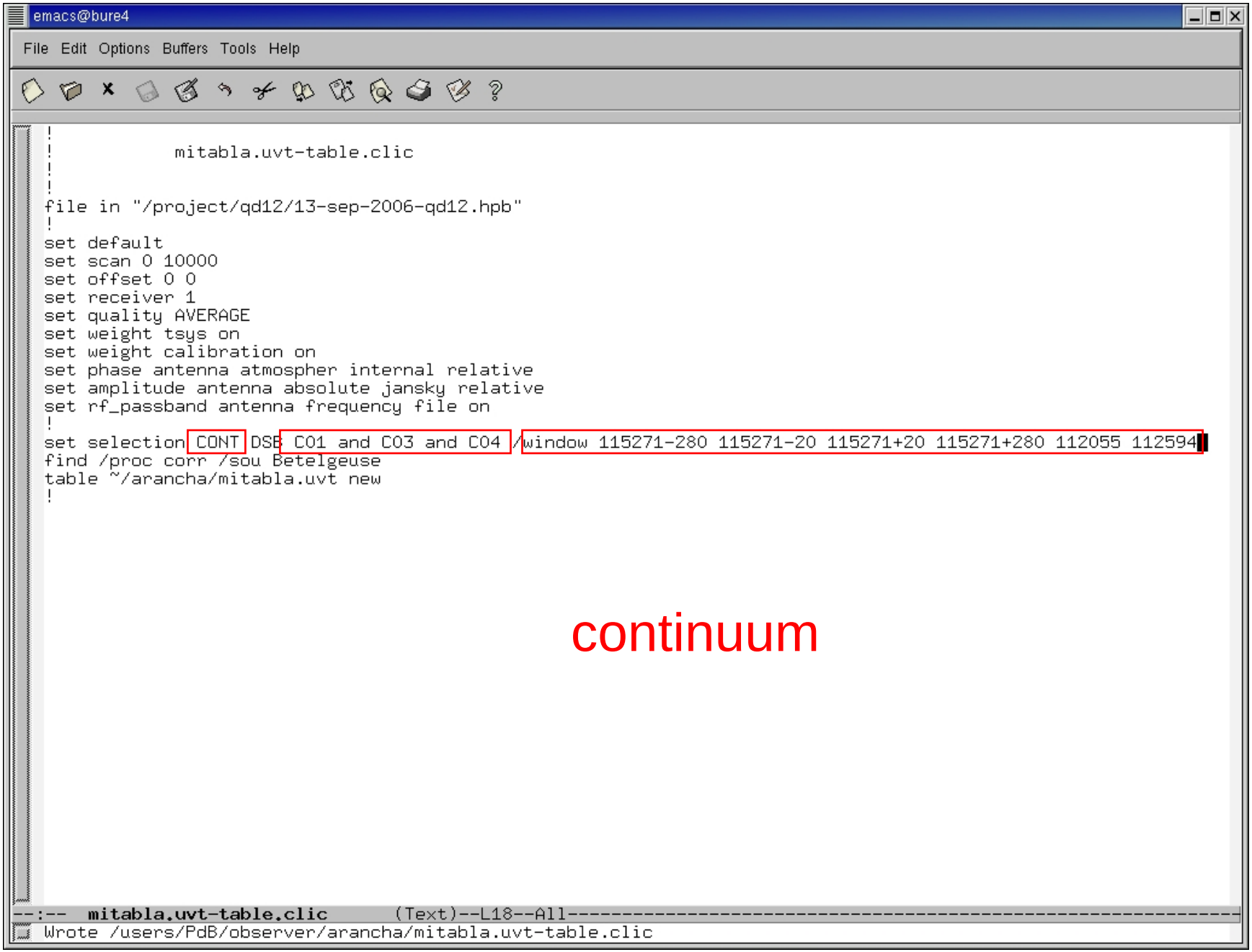

emacs@bure4
File Edit Options Buffers Tools Help
!
!   mitabla.uvt-table.clic
!
!
file in "/project/qd12/13-sep-2006-qd12.hpb"
!
set default
set scan 0 10000
set offset 0 0
set receiver 1
set quality AVERAGE
set weight tsys on
set weight calibration on
set phase antenna atmospher internal relative
set amplitude antenna absolute jansky relative
set rf_passband antenna frequency file on
!
set selection LINE USB l01 and l02
find /proc corr /sou Betelgeuse
table ~/arancha/mitabla.uvt new /freq CO(1-0) 115271.204 /resample 40 20 -30 2 V
!
--:-- mitabla.uvt-table.clic   (Text)--L9--All

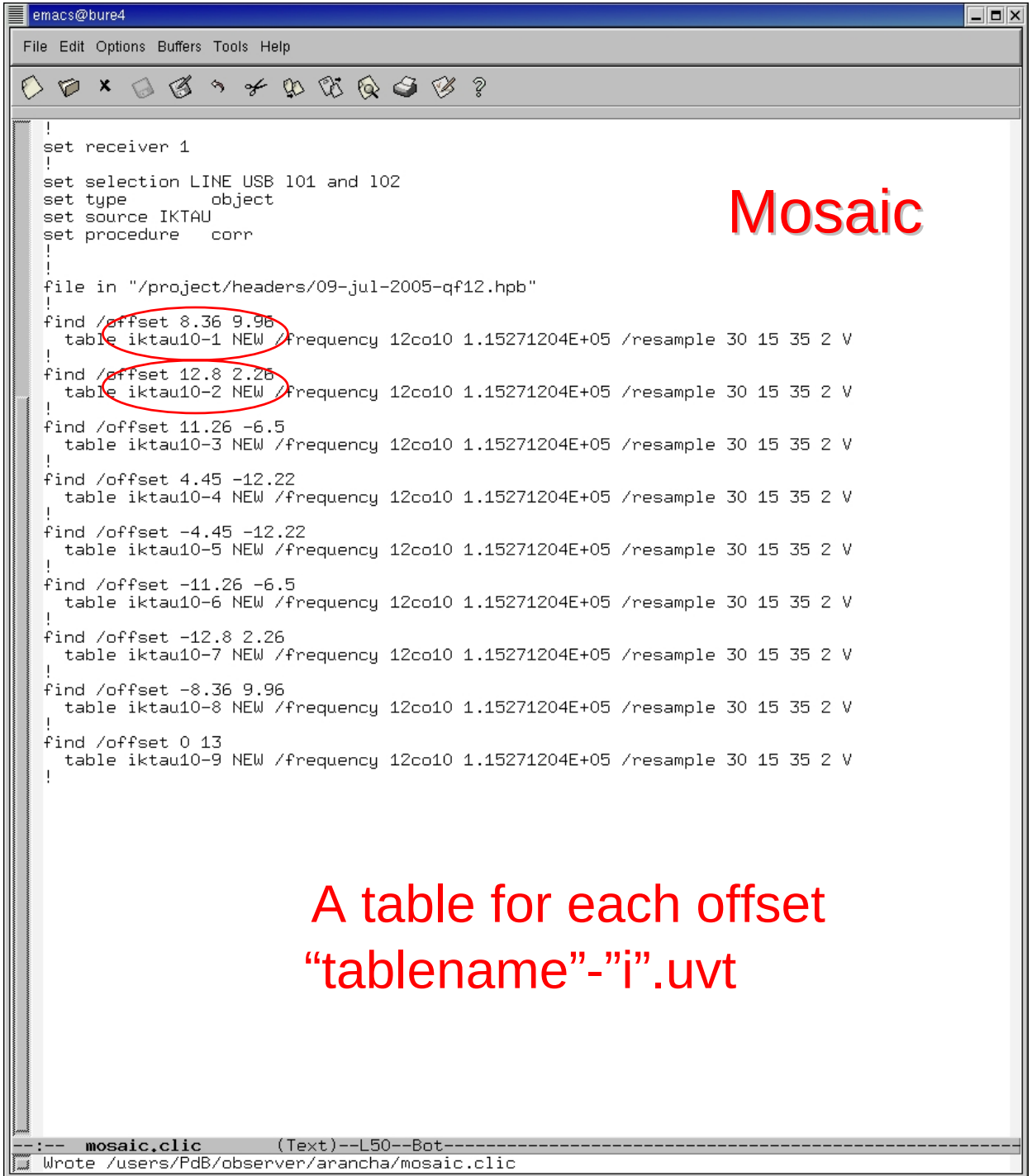
observer@bure4: /project/qa26

File Edit Settings Help

```
CLIC> help table
        CLIC\TABLE Name [OLD|NEW] [/COMPRESS tmax uvmax]
        [/RESAMPLE nc ref val inc code shape width]  [/FFT]
        [/FREQUENCY name rest-freq] [/DROP  n1 n2]
        [/NOCHECK [SOURCE|POINTING|PHASE|EPOCH]]

    This  command  will  create an UV data Table from the current index.  is
    not given, the most recently created table will be extended.  Next argu-
    ment  may be OLD (default value if not specified) to extend and existing
    table, or NEW to create a new table.

    The bands and subbands used must have been given by the command SET  SE-
    LECTION.  The weighting mode can be modified by the command SET WEIGHTS.

    TABLE /RESAMPLE nc ref val inc code [shape width /FFT]

        Option /RESAMPLE enables to resample data on  a  new  spectral  grid
        (for  line  data).  'nc' is the output number of channels, 'ref' the
        reference channel, 'val' the value of velocity or  frequency  offset
        (with respect to the rest frequency) at the reference channel, 'inc'
        the resolution, 'code' is "V" if the value 'val' and the  resolution
        'inc' are in velocity units, "F" for frequency units.

        The  reference channel thus corresponds to the given 'val' velocity,
        or to the offset 'val' in MHz from the rest frequency present in the
        header or modified by option /FREQUENCY.

        Resampling  is done by default through linear interpolation of input
        channel data. Resampling may also be done  (using  option  /FFT)  in
        Fourier space by cut-off or extrapolation (by zeroes) of the Fourier
        components, after deconvolution by the channel response of the  cor-
        relator  (due to on-line apodization), and followed by reconvolution
        to produce frequency channels of the given 'shape' and 'width'.  Al-
        lowed shapes are:
          TBox = a box in delay space (unapodized correlator)
          Ppar  =  a  parabola in delay space (apodized correlator) (the de-
            fault)
          FBox = a box in frequency space (square filter)
          FTri = a triangle in frequency space (Hanning smoothed square fil-
            ter)
        The  width  is the channel width in units of channel separation (de-
        fault 1).

        Option /FFT is not recommended when joining  together  several  sub-
        bands  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
        accordingly.   This  rest frequency will correspond to the reference
        channel in option RESAMPLE.

    TABLE /NOCHECK [SOURCE|POINTING|PHASE|EPOCH]

        When processing each scan, CLIC checks whether a number of  position
```

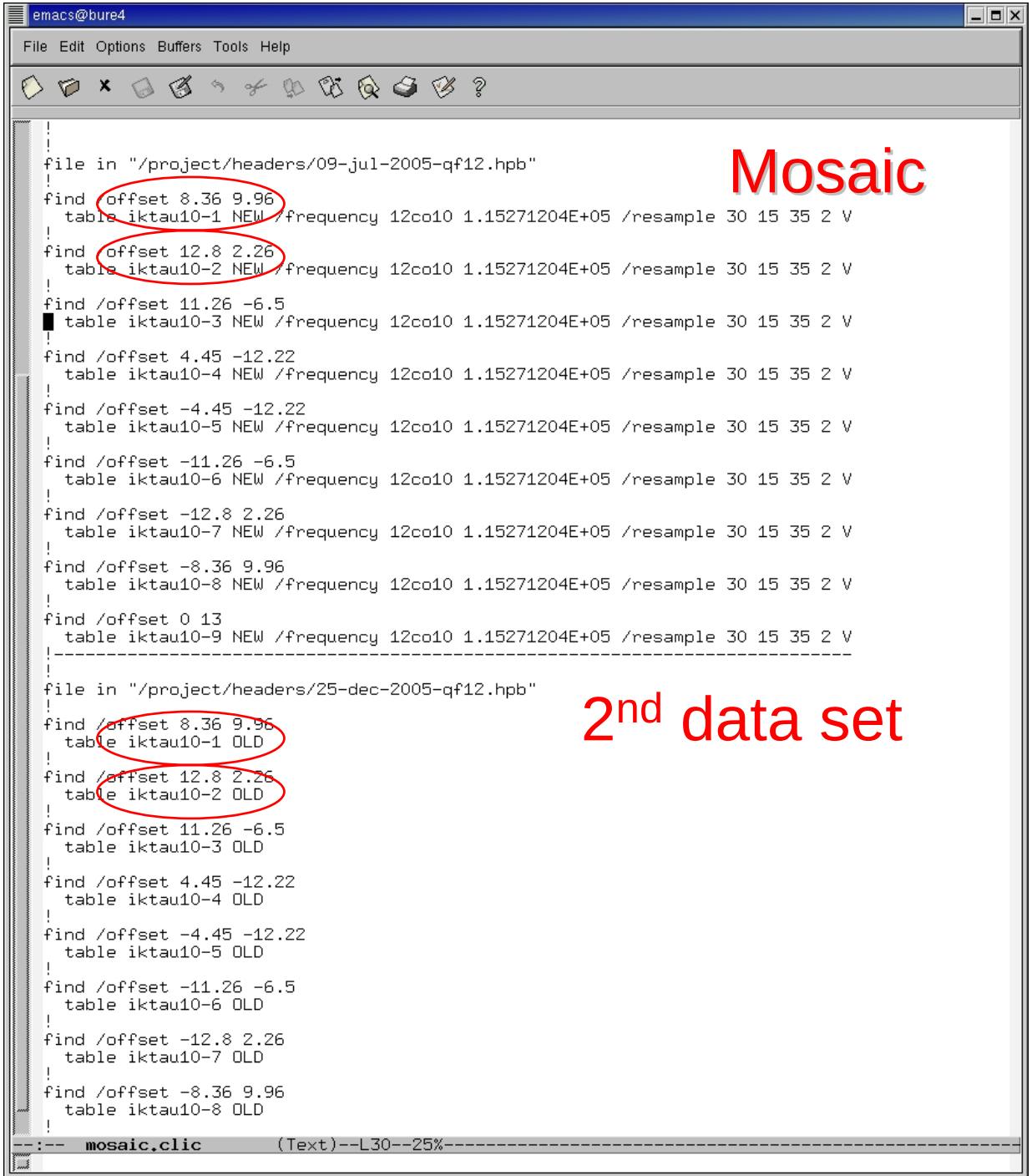

emacs@bure4
File Edit Options Buffers Tools Help
!
!   mitabla-rec2.uvt-table.clic
!
!
file in "/project/qd12/13-sep-2006-qd12.hpb"
!
set default
set scan 0 10000
set offset 0 0
set receiver 2
set quality AVERAGE
set weight tsys on
set weight calibration on
set phase antenna atmosphere external relative
set amplitude antenna absolute jansky relative
set rf_passband antenna frequency file on
!
set selection LINE DSB LO1 and LO2
find /proc corr /source Betelgeuse
table ~/arancha/mitabla-rec2.uvt new /resample 40 20 -30 2 V
!
old receiver 2
--:-- mitabla-rec2.uvt-table.clic   (Text)--L1--All----------
For information about the GNU Project and its goals, type C-h C-p.


emacs@bure4
File Edit Options Buffers Tools Help
!
!   mitabla.uvt-table.clic
!
!
file in "/project/qd12/13-sep-2006-qd12.hpb"
!
set default
set scan 0 10000
set offset 0 0
set receiver 1
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 DSB C01 and C03 and C04 /window 115271-280 115271-20 115271+20 115271+280 112055 112594
find /proc corr /sou Betelgeuse
table ~/arancha/mitabla.uvt new
!
continuum
--:-- mitabla.uvt-table.clic   (Text)--L18--All
Wrote /users/PdB/observer/arancha/mitabla.uvt-table.clic



Mosaic

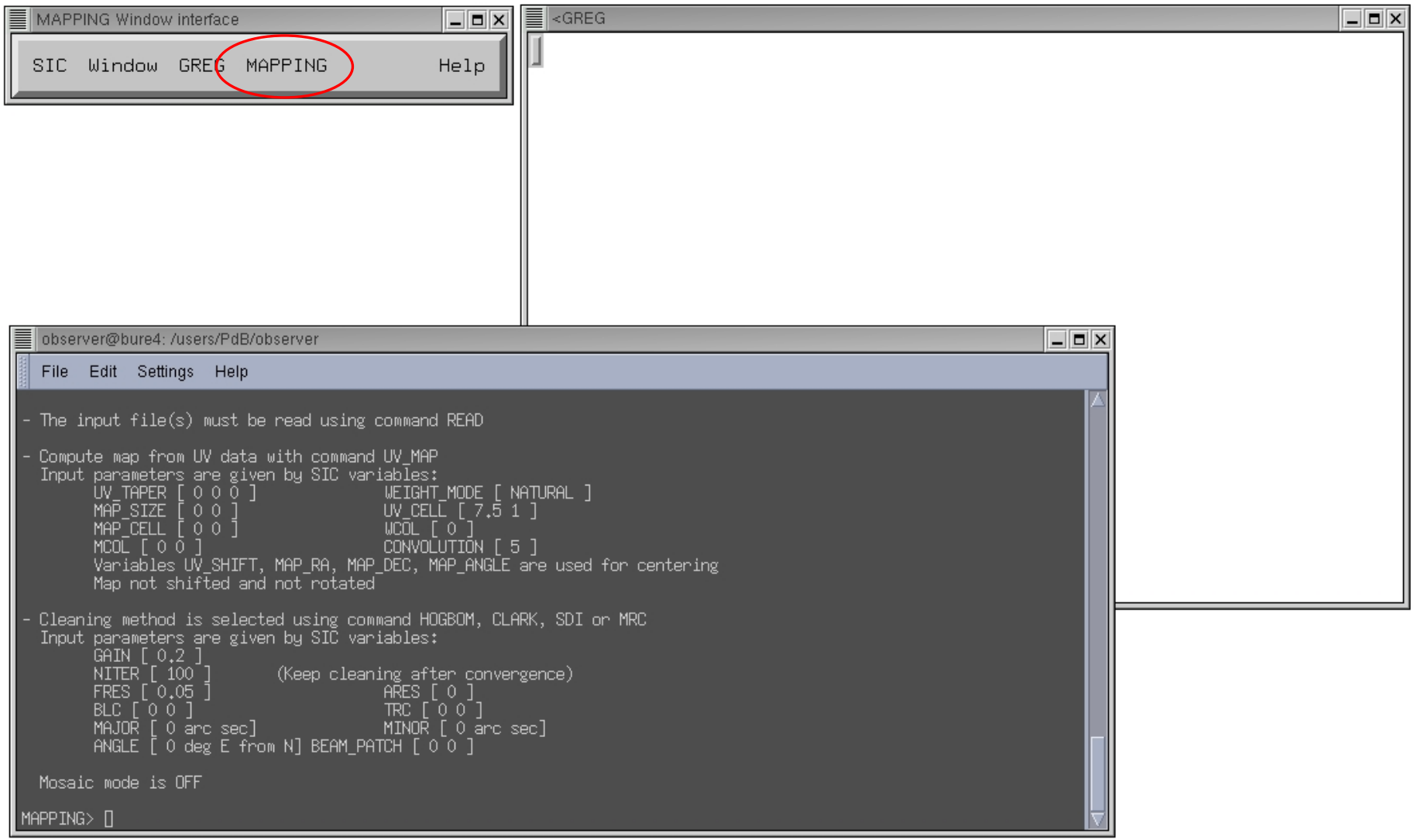
A table for each offset
“tablename”-”i”.uvt


emacs@bure4
File Edit Options Buffers Tools Help
!
!
file in "/project/headers/09-jul-2005-qf12.hpb"
!
find /offset 8.36 9.96
table iktau10-1 NEW /frequency 12co10 1.15271204E+05 /resample 30 15 35 2 V
!
find /offset 12.8 2.26
table iktau10-2 NEW /frequency 12co10 1.15271204E+05 /resample 30 15 35 2 V
!
find /offset 11.26 -6.5
table iktau10-3 NEW /frequency 12co10 1.15271204E+05 /resample 30 15 35 2 V
!
find /offset 4.45 -12.22
table iktau10-4 NEW /frequency 12co10 1.15271204E+05 /resample 30 15 35 2 V
!
find /offset -4.45 -12.22
table iktau10-5 NEW /frequency 12co10 1.15271204E+05 /resample 30 15 35 2 V
!
find /offset -11.26 -6.5
table iktau10-6 NEW /frequency 12co10 1.15271204E+05 /resample 30 15 35 2 V
!
find /offset -12.8 2.26
table iktau10-7 NEW /frequency 12co10 1.15271204E+05 /resample 30 15 35 2 V
!
find /offset -8.36 9.96
table iktau10-8 NEW /frequency 12co10 1.15271204E+05 /resample 30 15 35 2 V
!
find /offset 0 13
table iktau10-9 NEW /frequency 12co10 1.15271204E+05 /resample 30 15 35 2 V
!----------
!
file in "/project/headers/25-dec-2005-qf12.hpb"
!
find /offset 8.36 9.96
table iktau10-1 OLD
!
find /offset 12.8 2.26
table iktau10-2 OLD
!
find /offset 11.26 -6.5
table iktau10-3 OLD
!
find /offset 4.45 -12.22
table iktau10-4 OLD
!
find /offset -4.45 -12.22
table iktau10-5 OLD
!
find /offset -11.26 -6.5
table iktau10-6 OLD
!
find /offset -12.8 2.26
table iktau10-7 OLD
!
find /offset -8.36 9.96
table iktau10-8 OLD
!
--:-- mosaic.clic (Text)--L30--25%----------
Mosaic
2nd data set

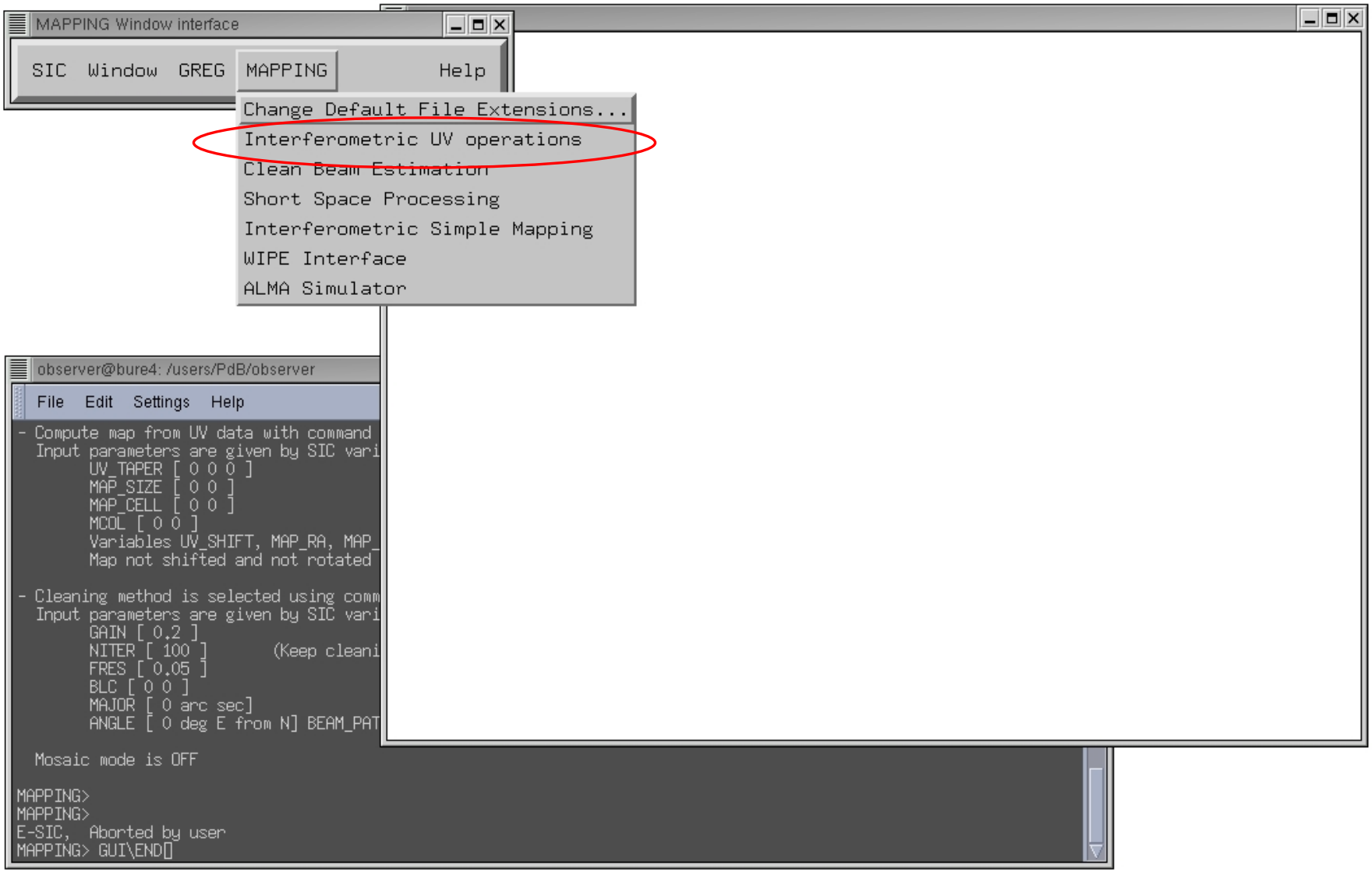
Created “mytable”.uvt, in CLIC

Analyze the data, in MAPPING

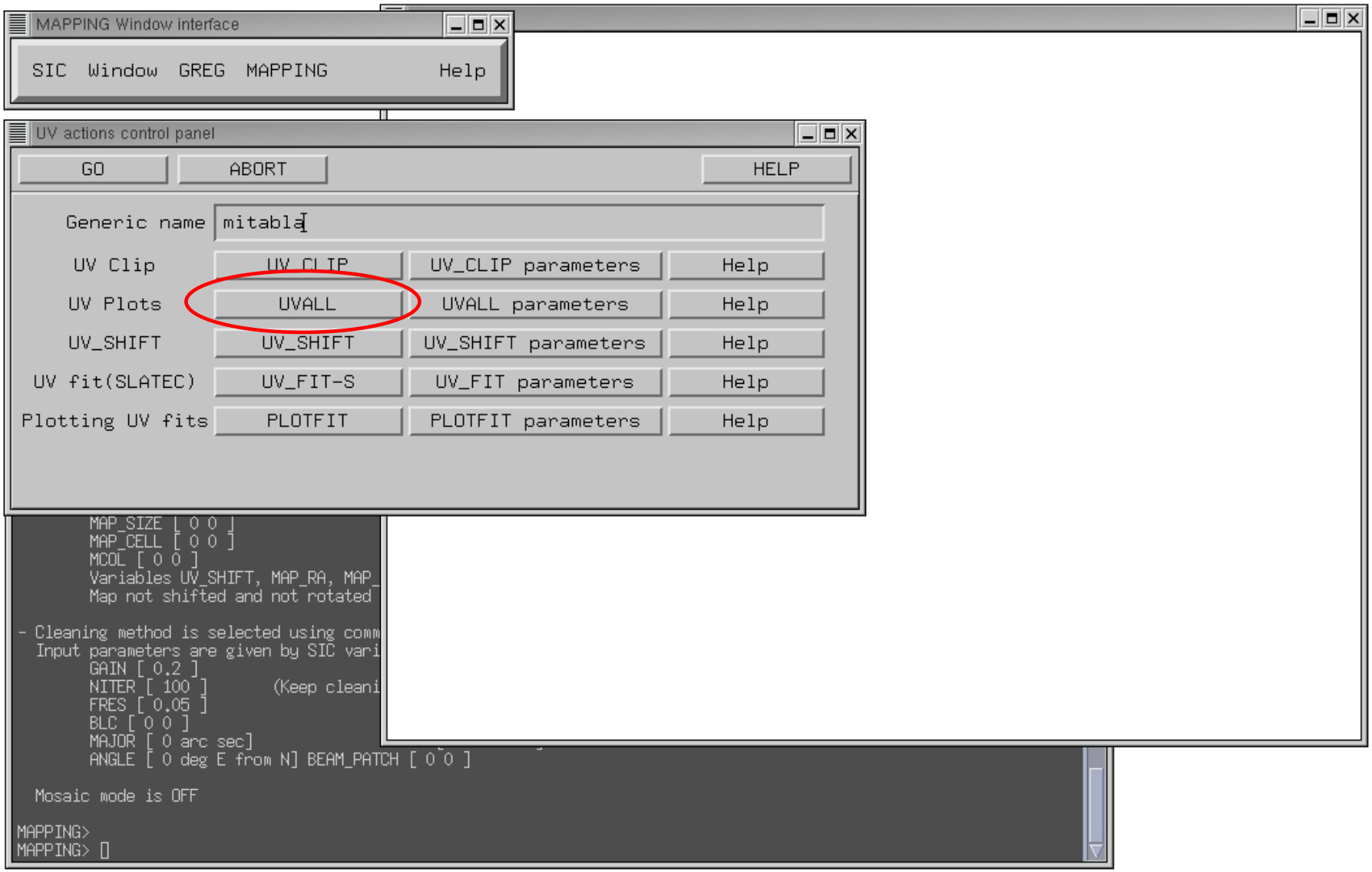
Data analysis in the *uv*-plane; **MAPPING**



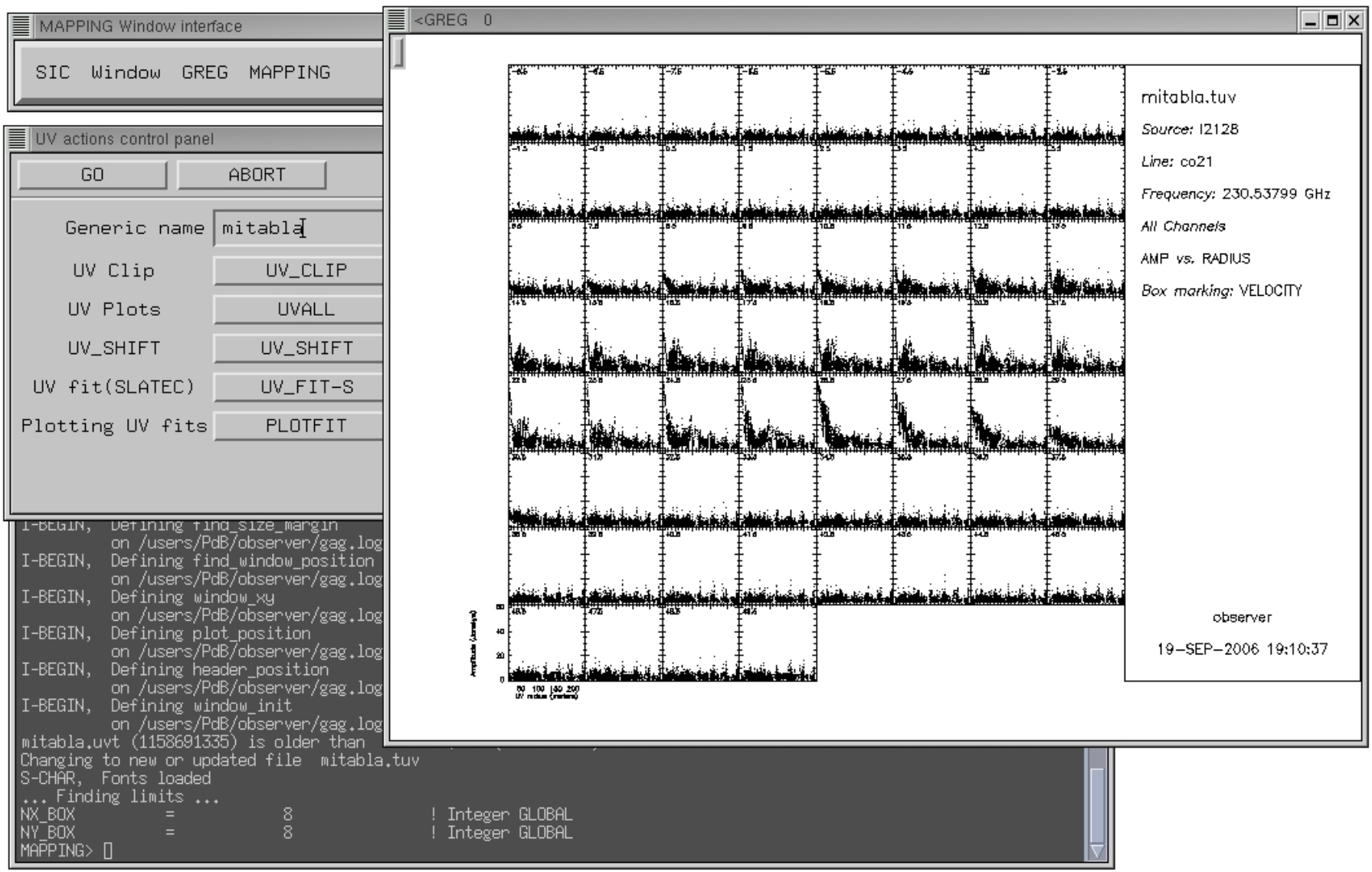
Data analysis in the *uv*-plane



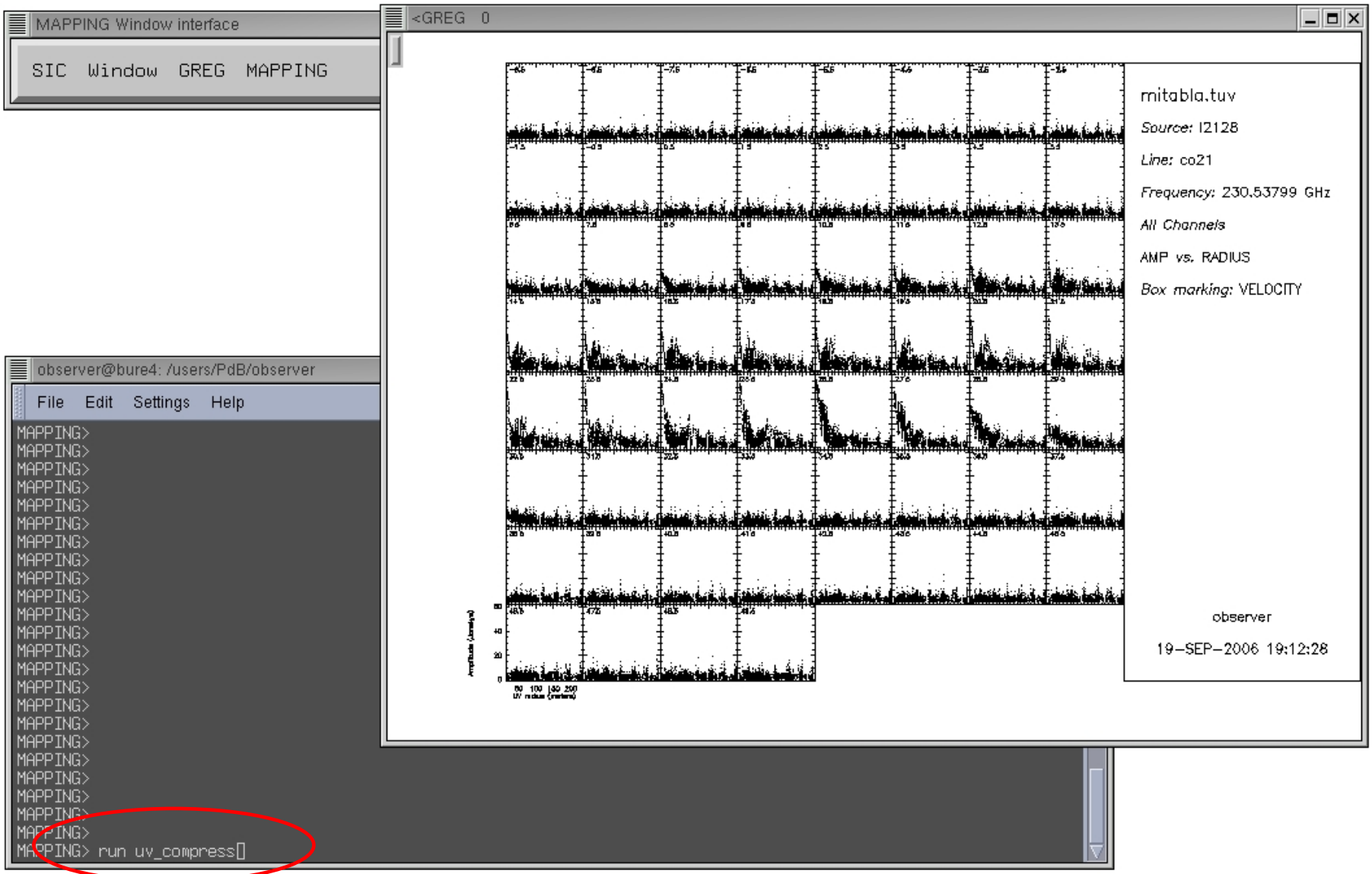
Inspection of the data in the *uv*-plane



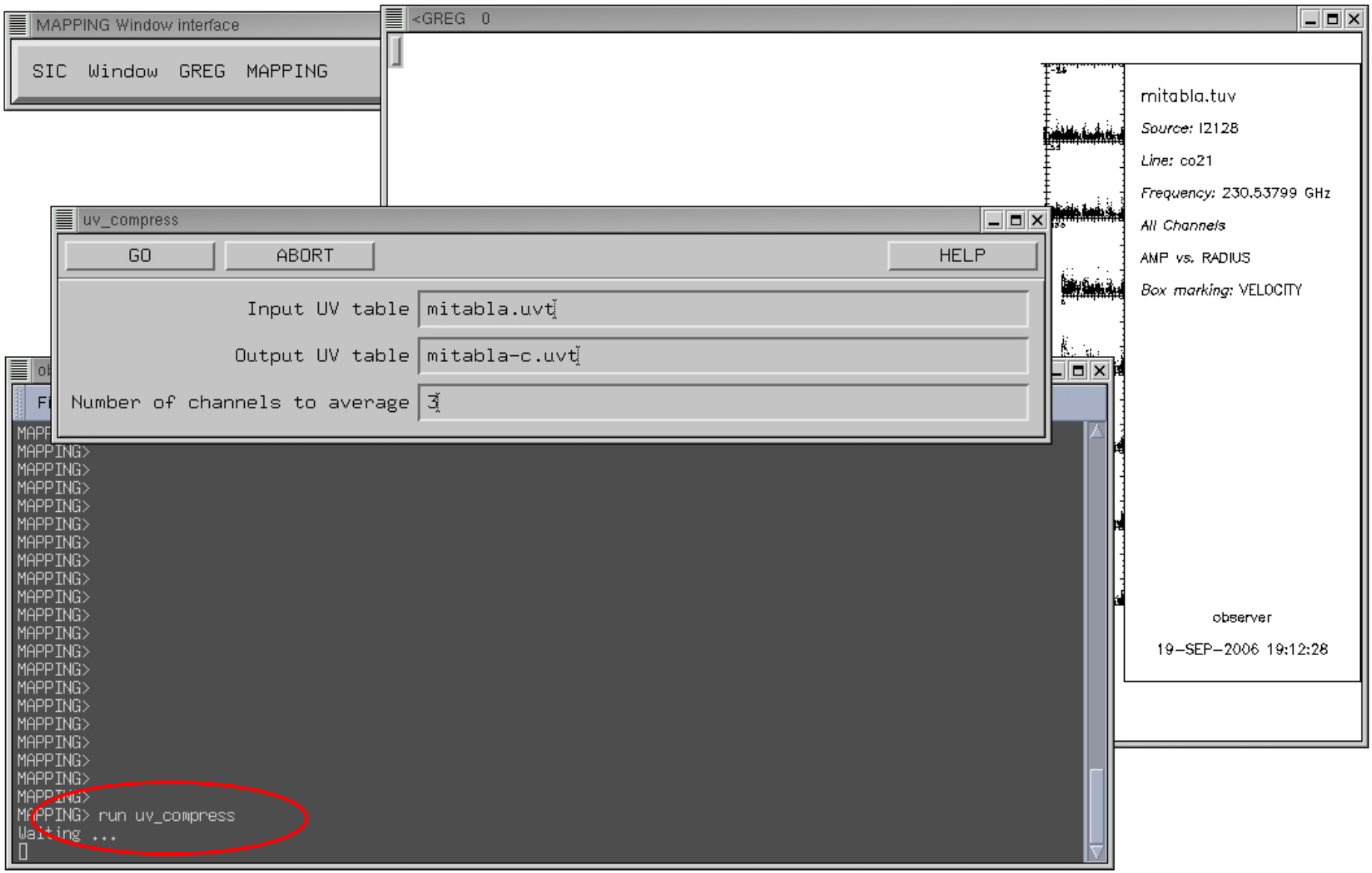
Inspection of the data in the *uv*-plane



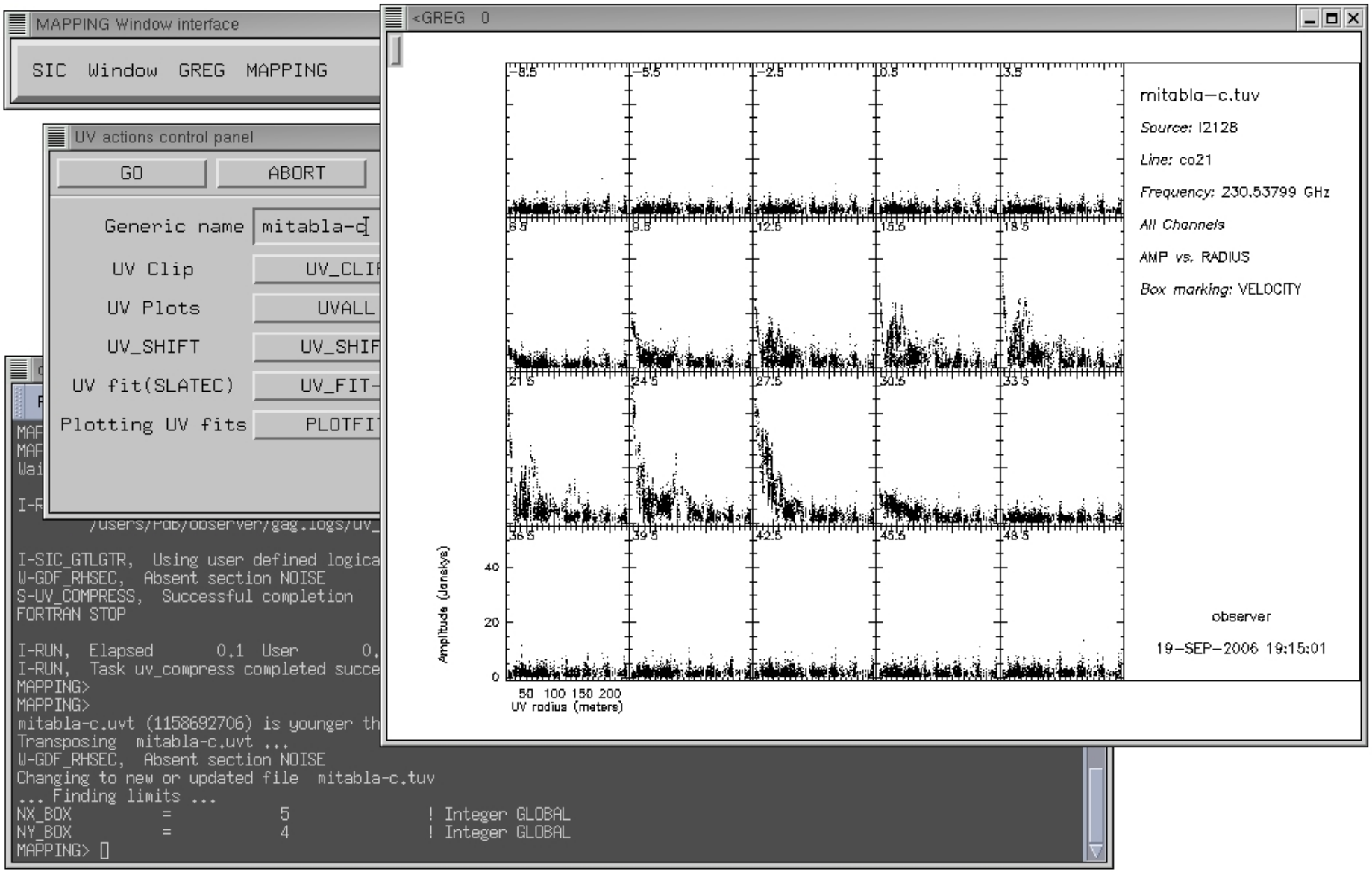
Inspection of the data in the *uv*-plane



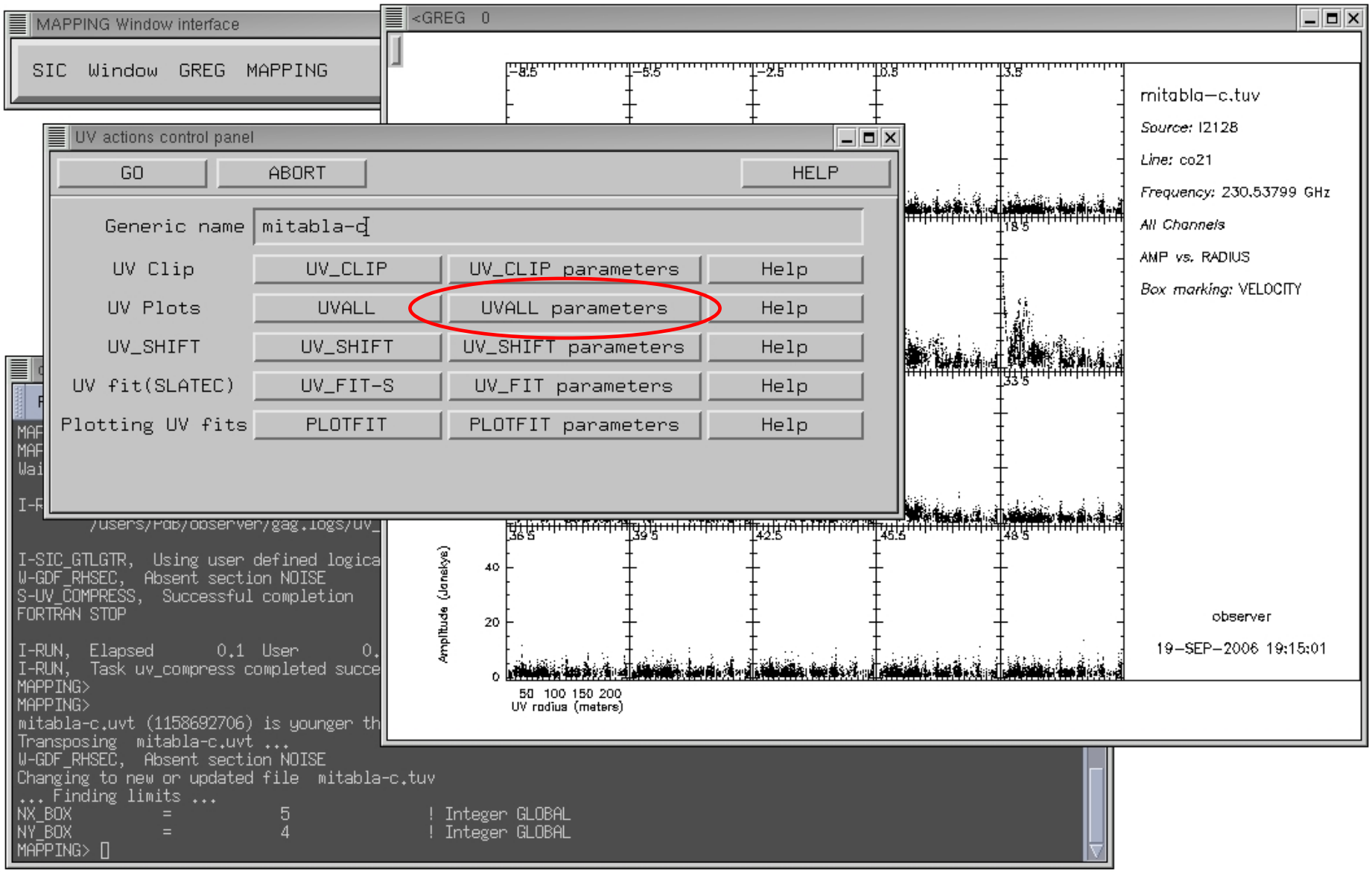
Inspection of the data in the *uv*-plane



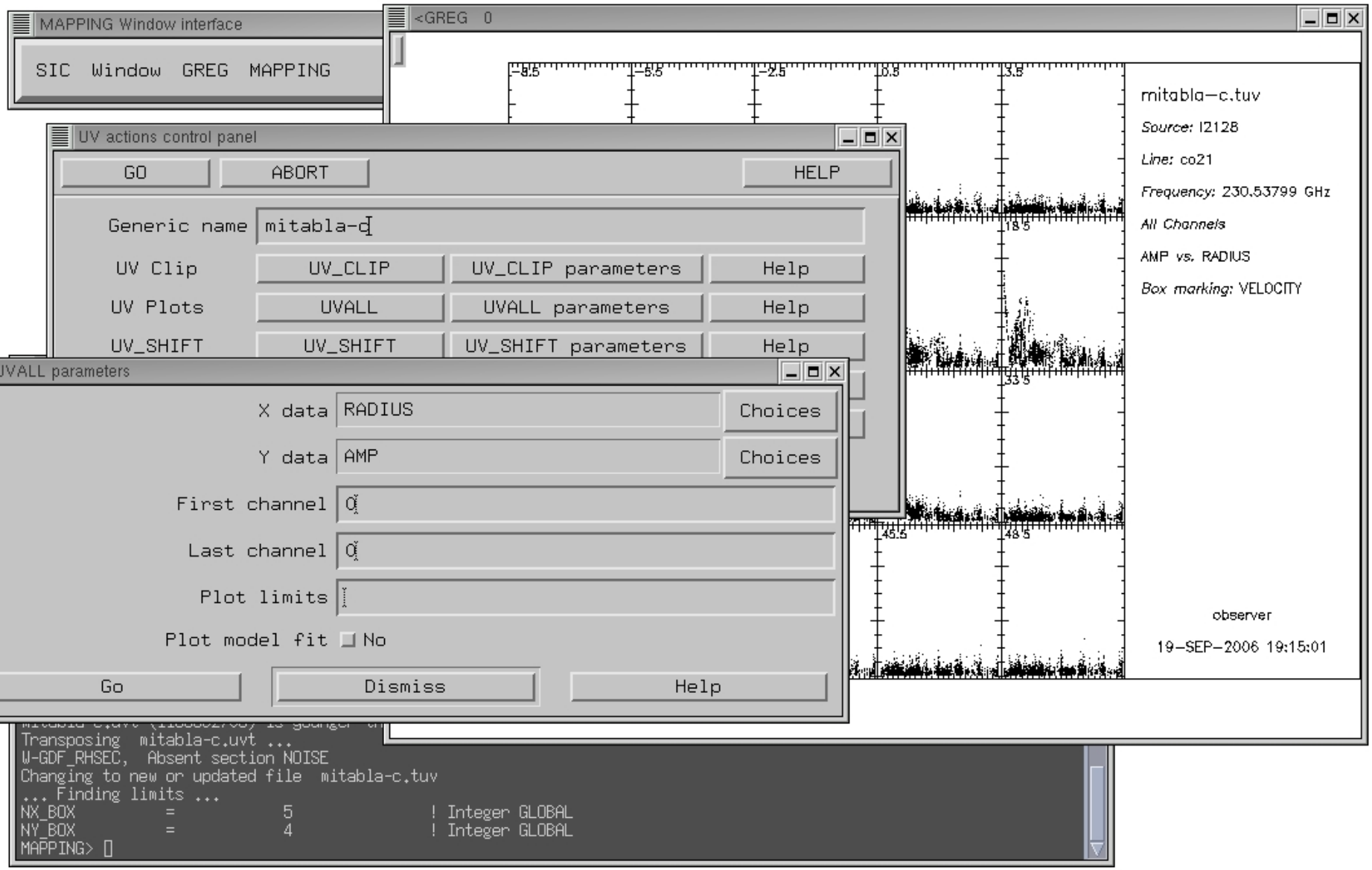
Inspection of the data in the *uv*-plane



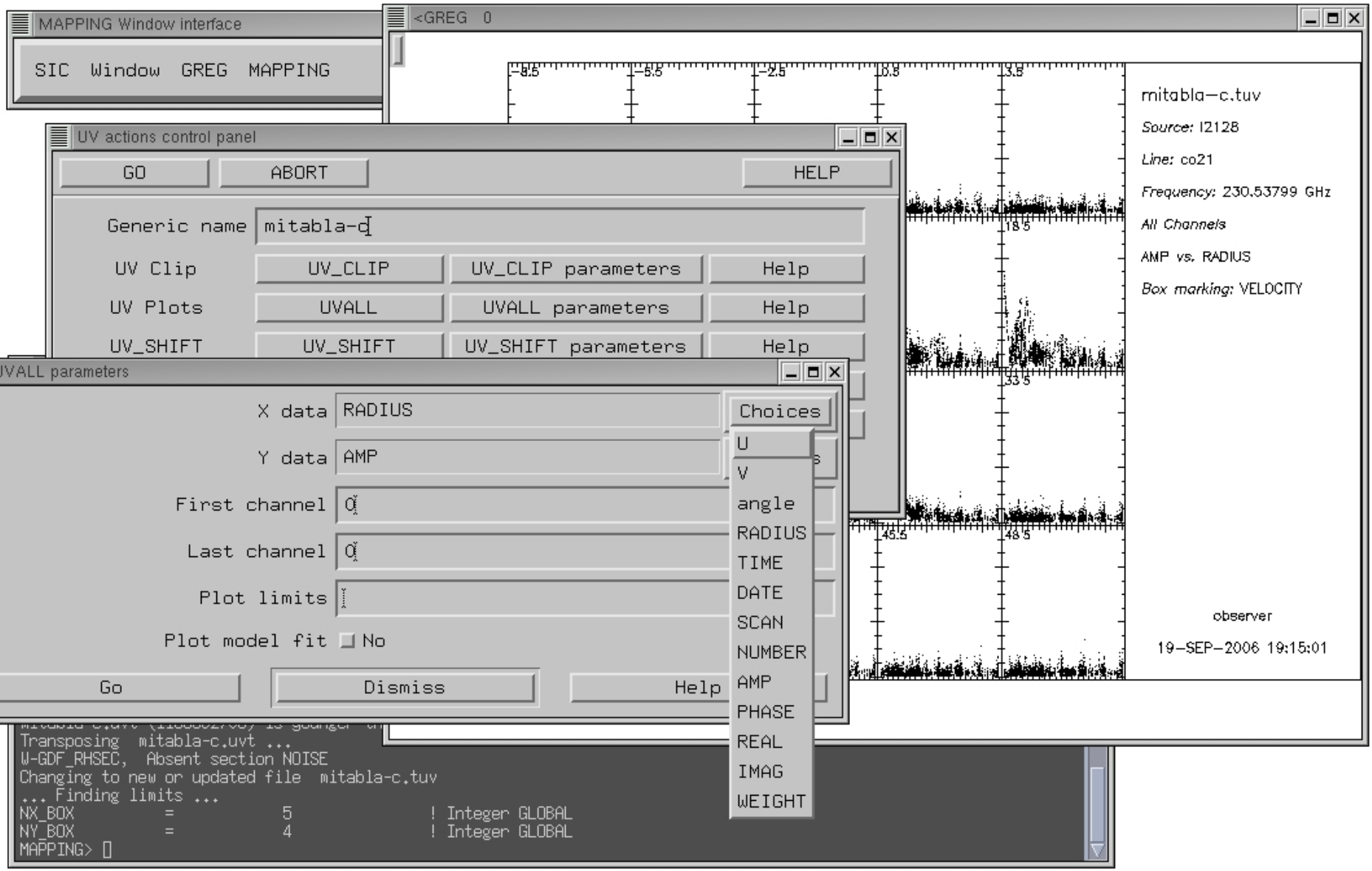
Inspection of the data in the *uv*-plane



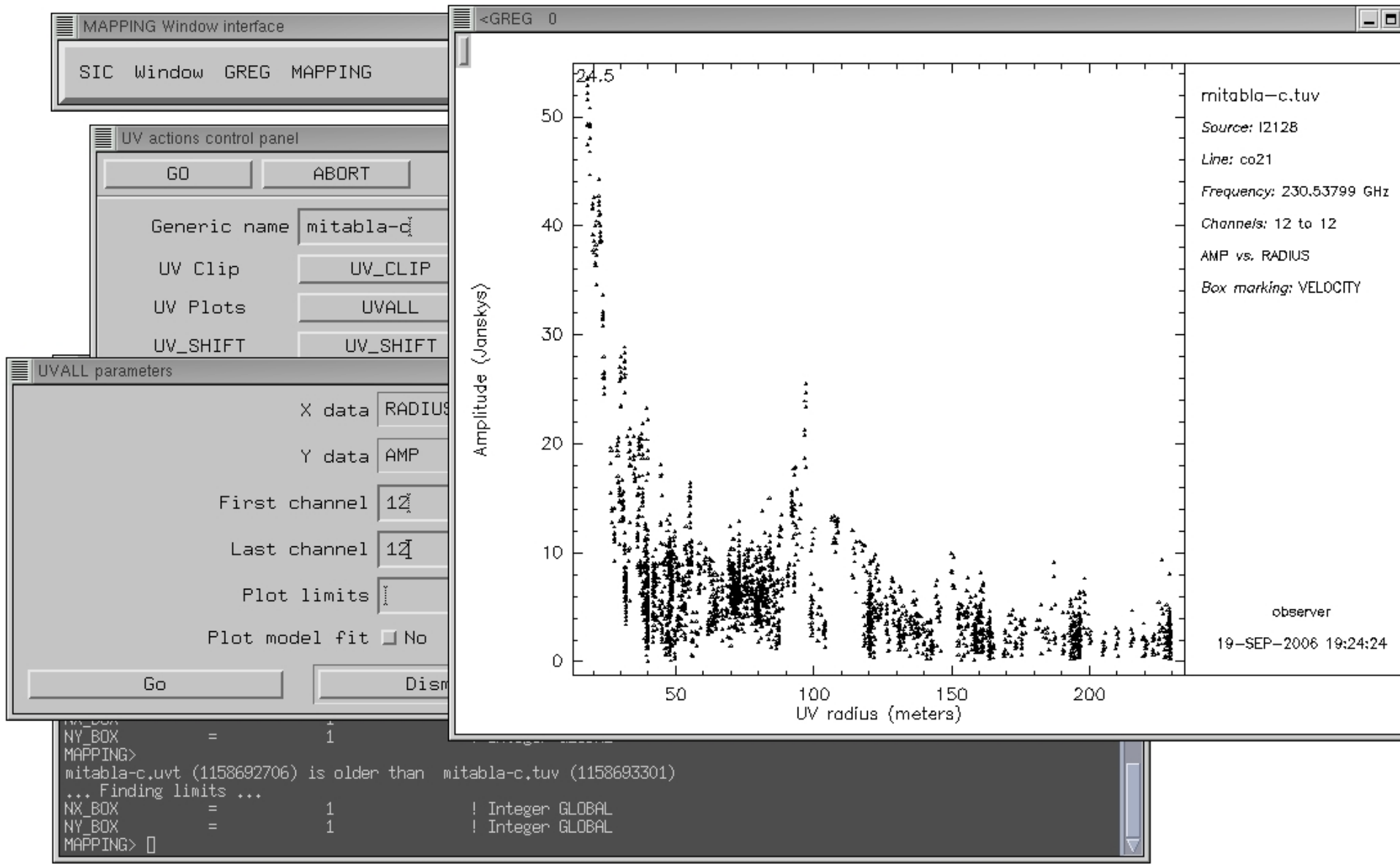
Inspection of the data in the *uv*-plane



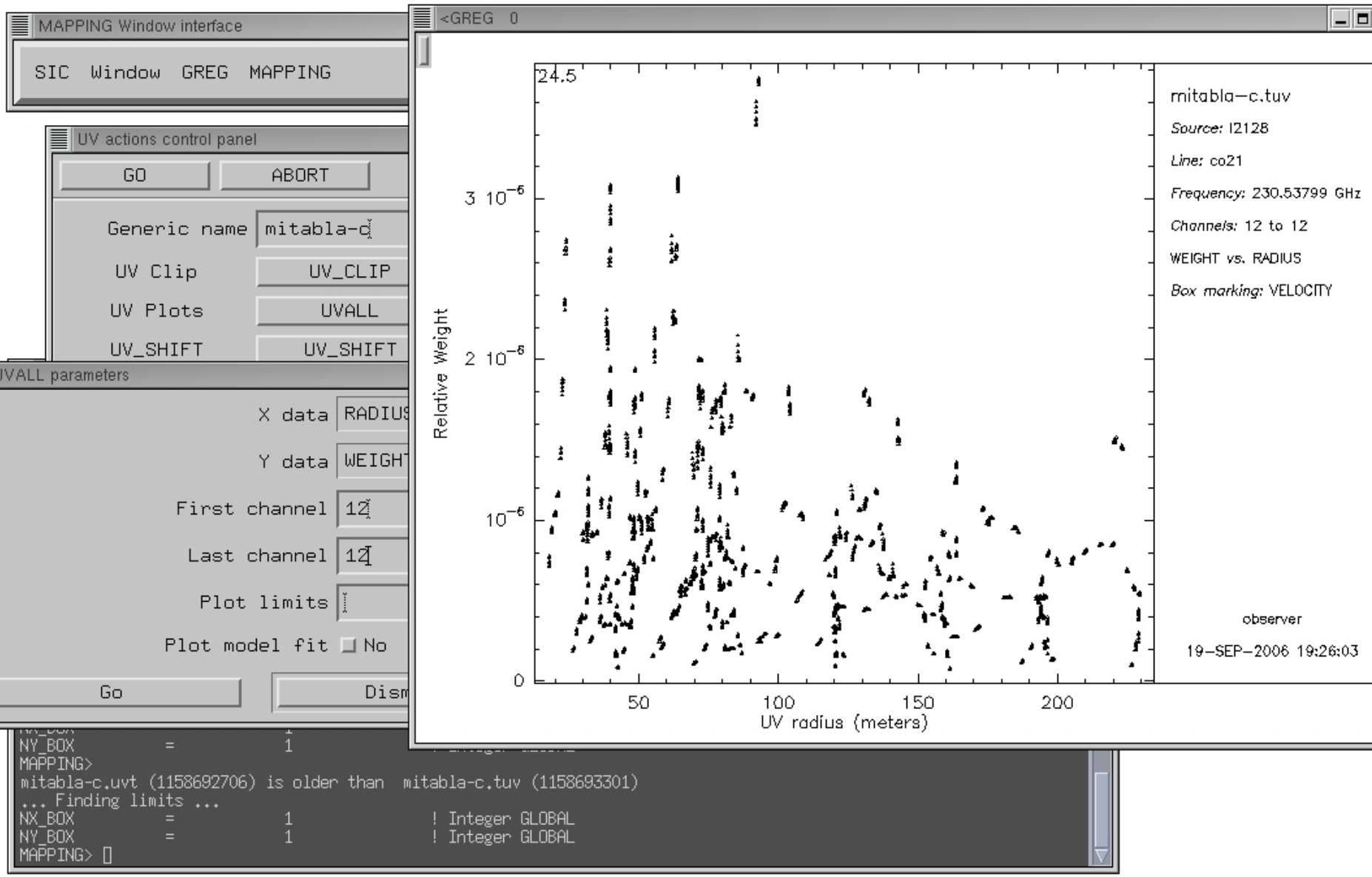
Inspection of the data in the *uv*-plane



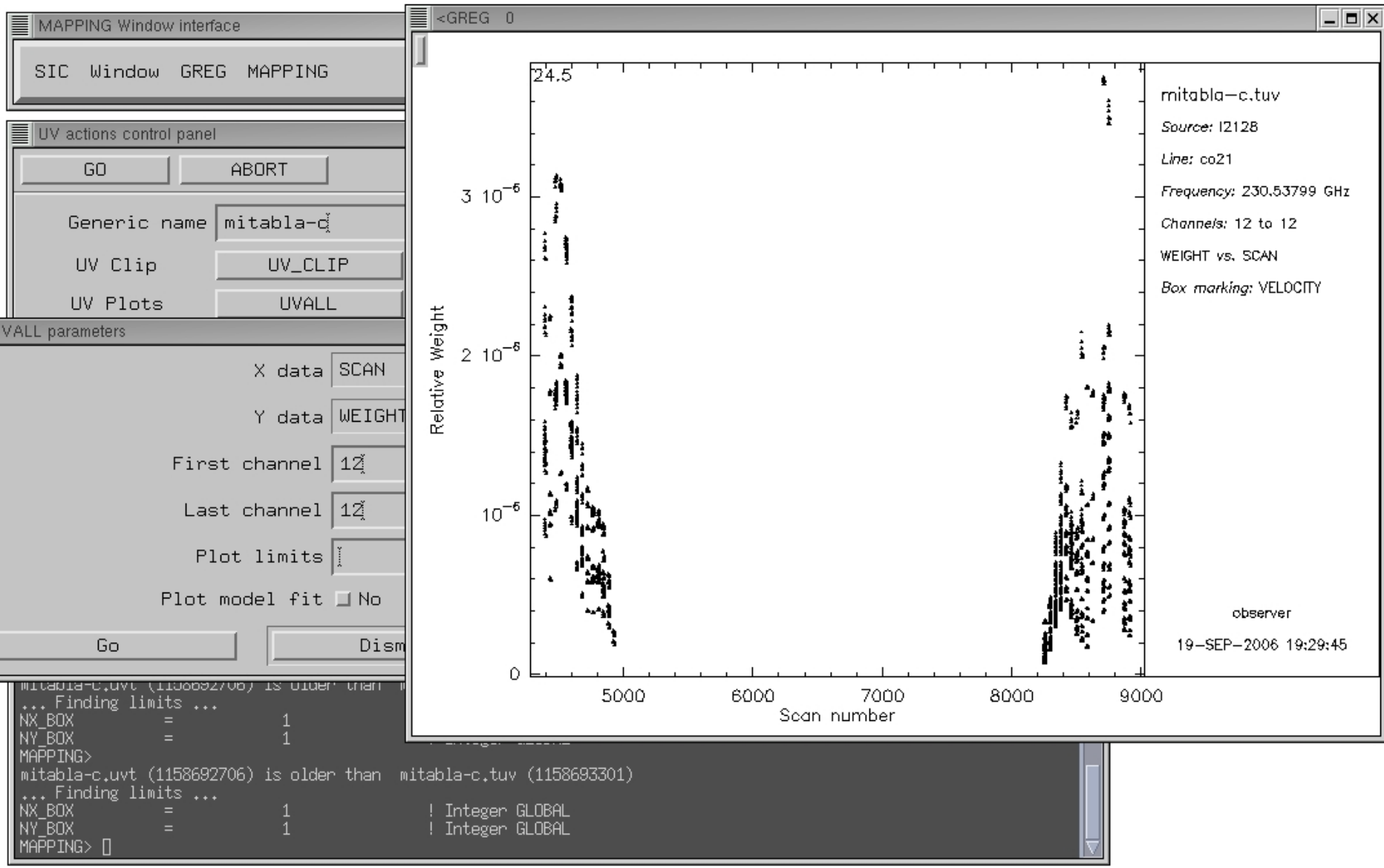
Inspection of the data in the *uv*-plane



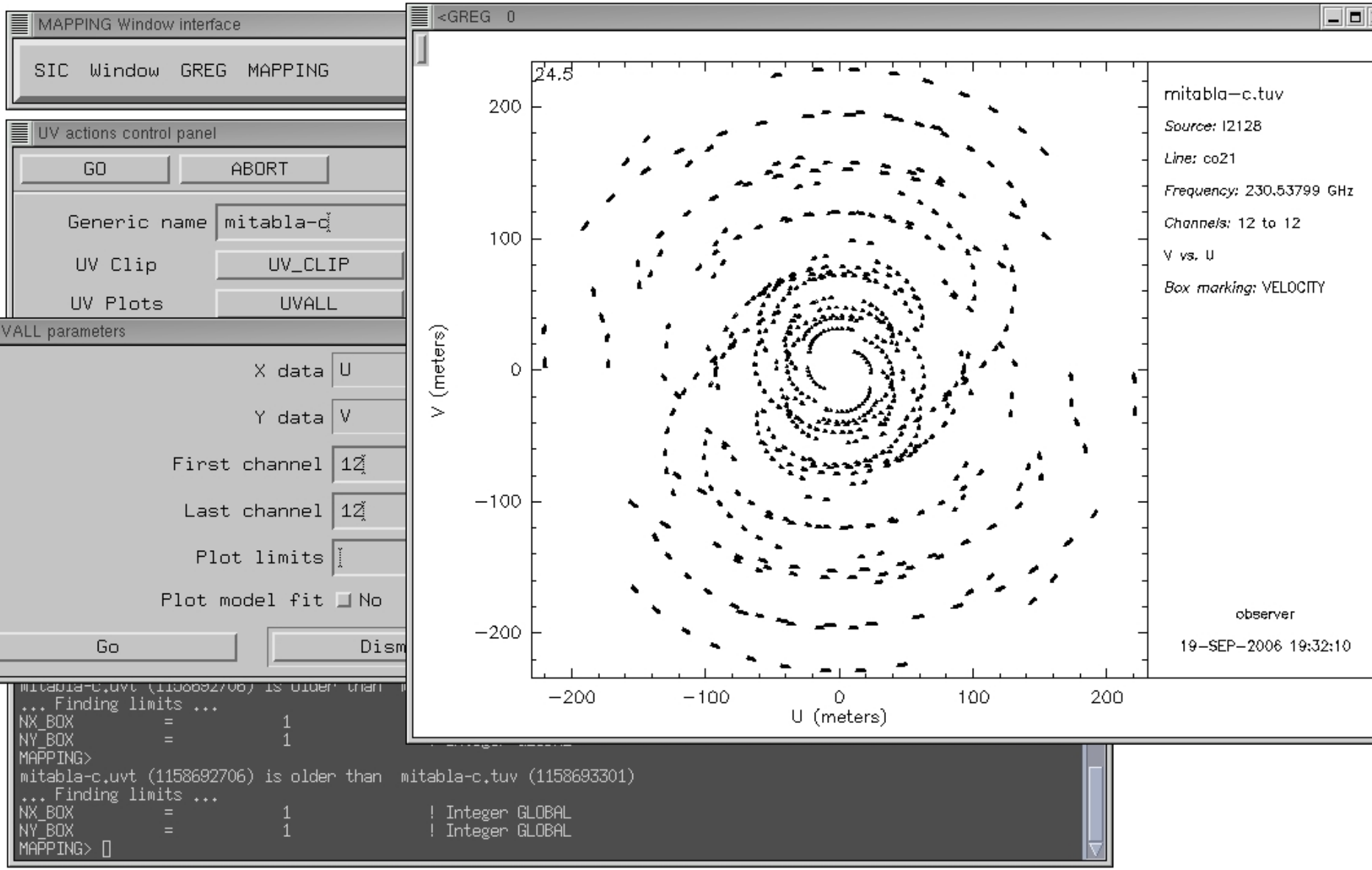
Inspection of the data in the *uv*-plane



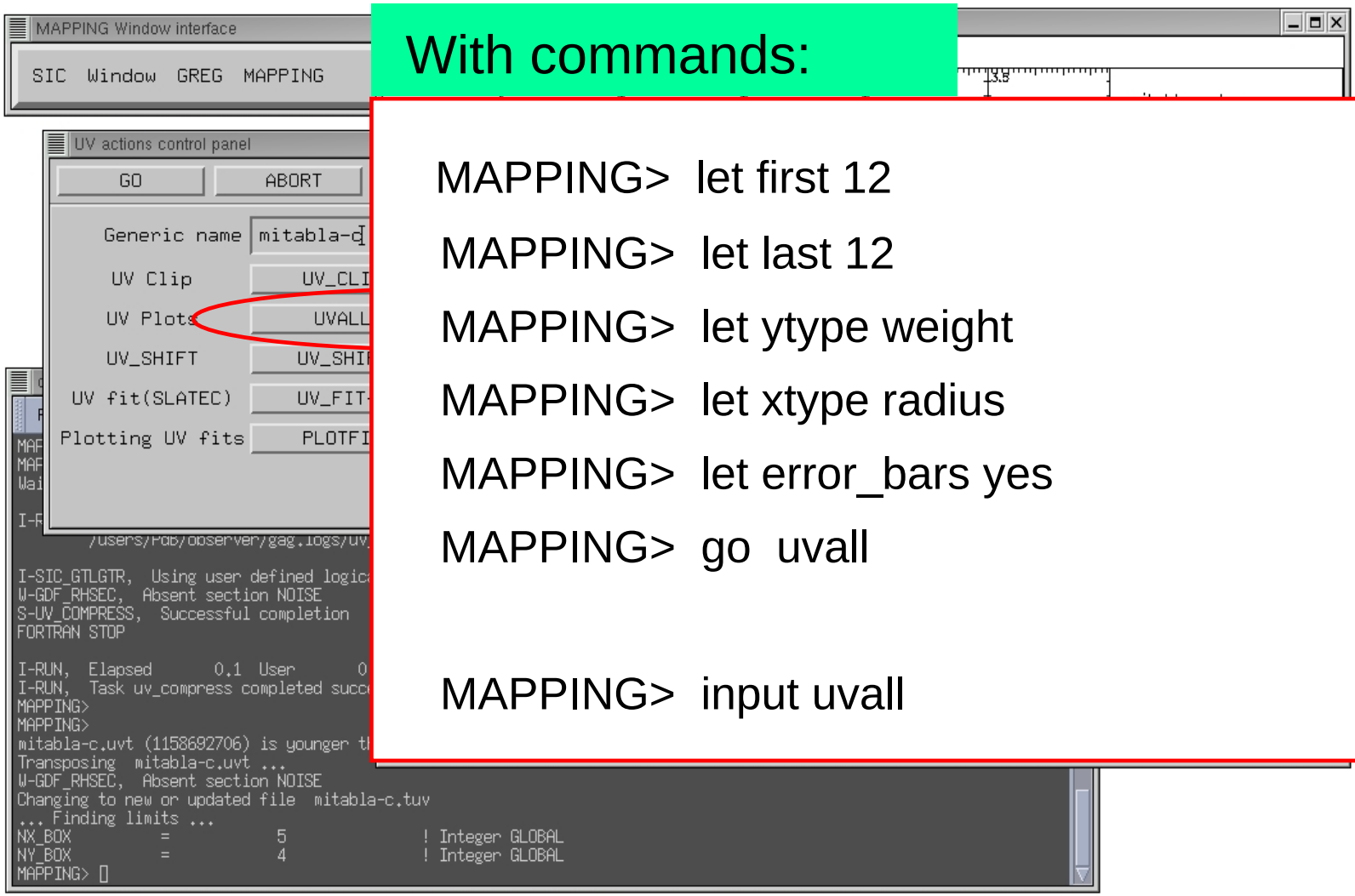
Inspection of the data in the *uv*-plane



Inspection of the data in the *uv*-plane



Inspection of the data in the *uv*-plane



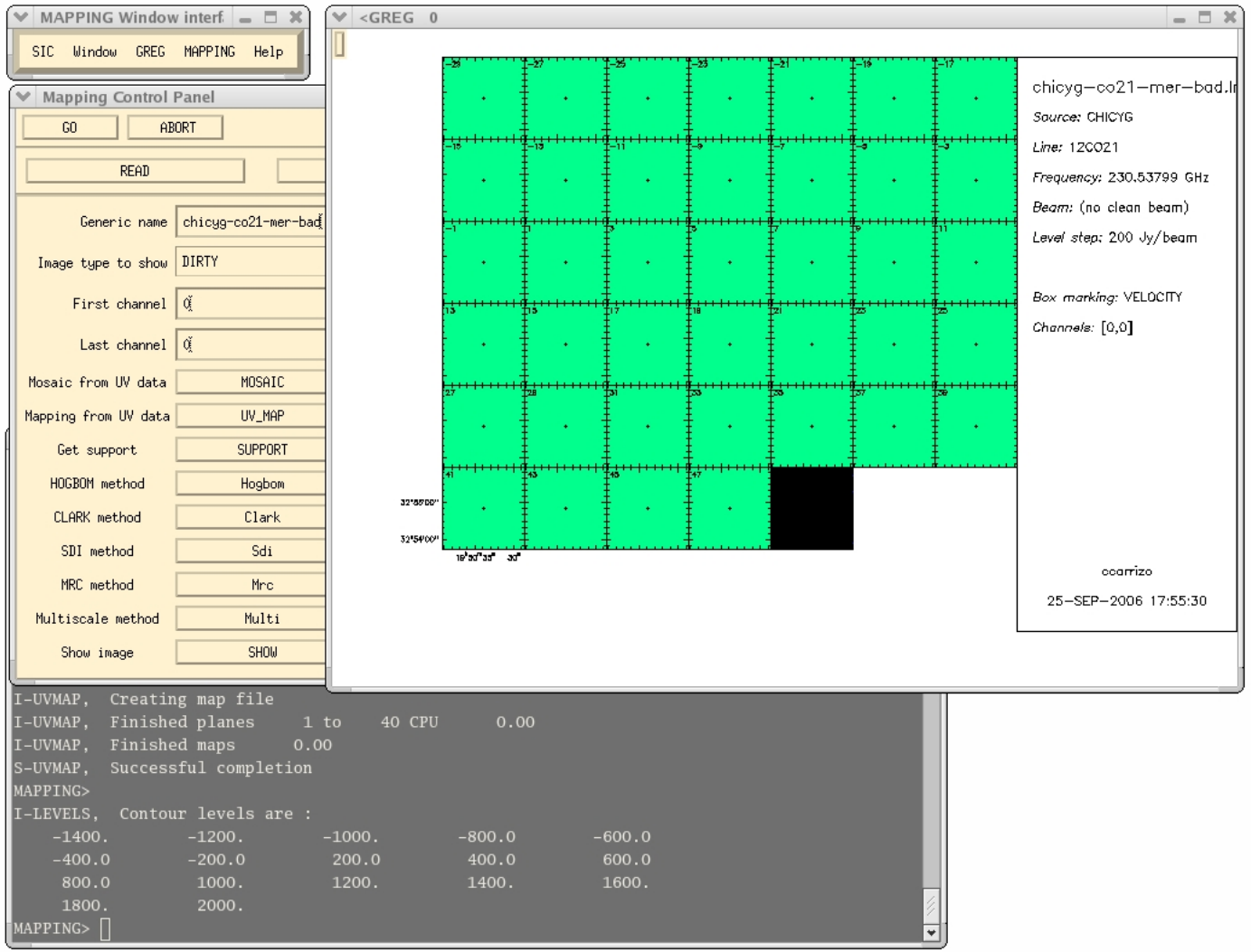
With commands:

```
MAPPING>  let first 12
MAPPING>  let last 12
MAPPING>  let ytype weight
MAPPING>  let xtype radius
MAPPING>  let error_bars yes
MAPPING>  go  uvall

MAPPING>  input uvall
```

Mapping takes shorter
if previously
we have had a look at the data in
the *uv*-plane

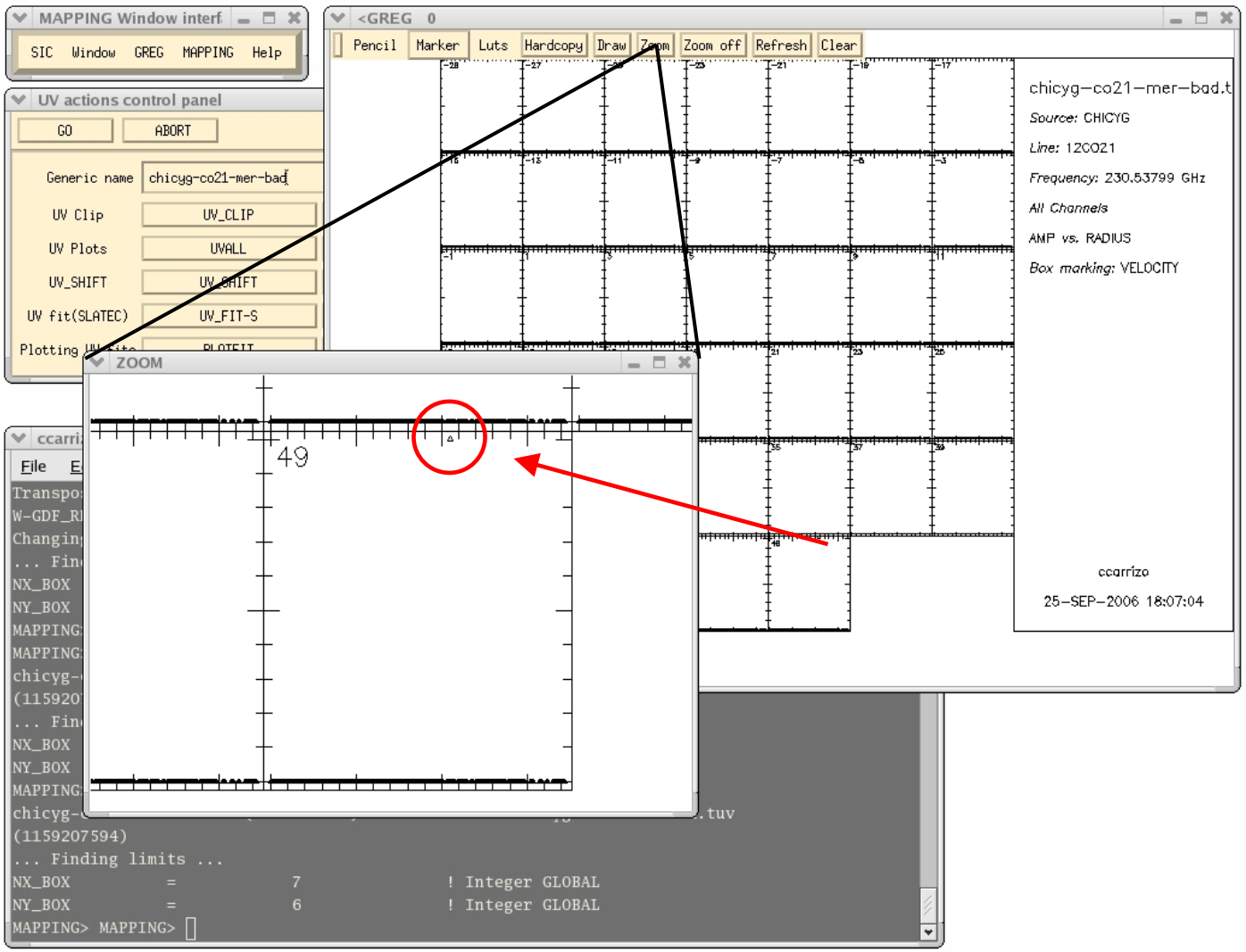
(1) Passing directly from hpb → mapping

It may happen…



(1) Passing directly from hpb → mapping

It may happen…



(1) Passing directly from hpb → mapping

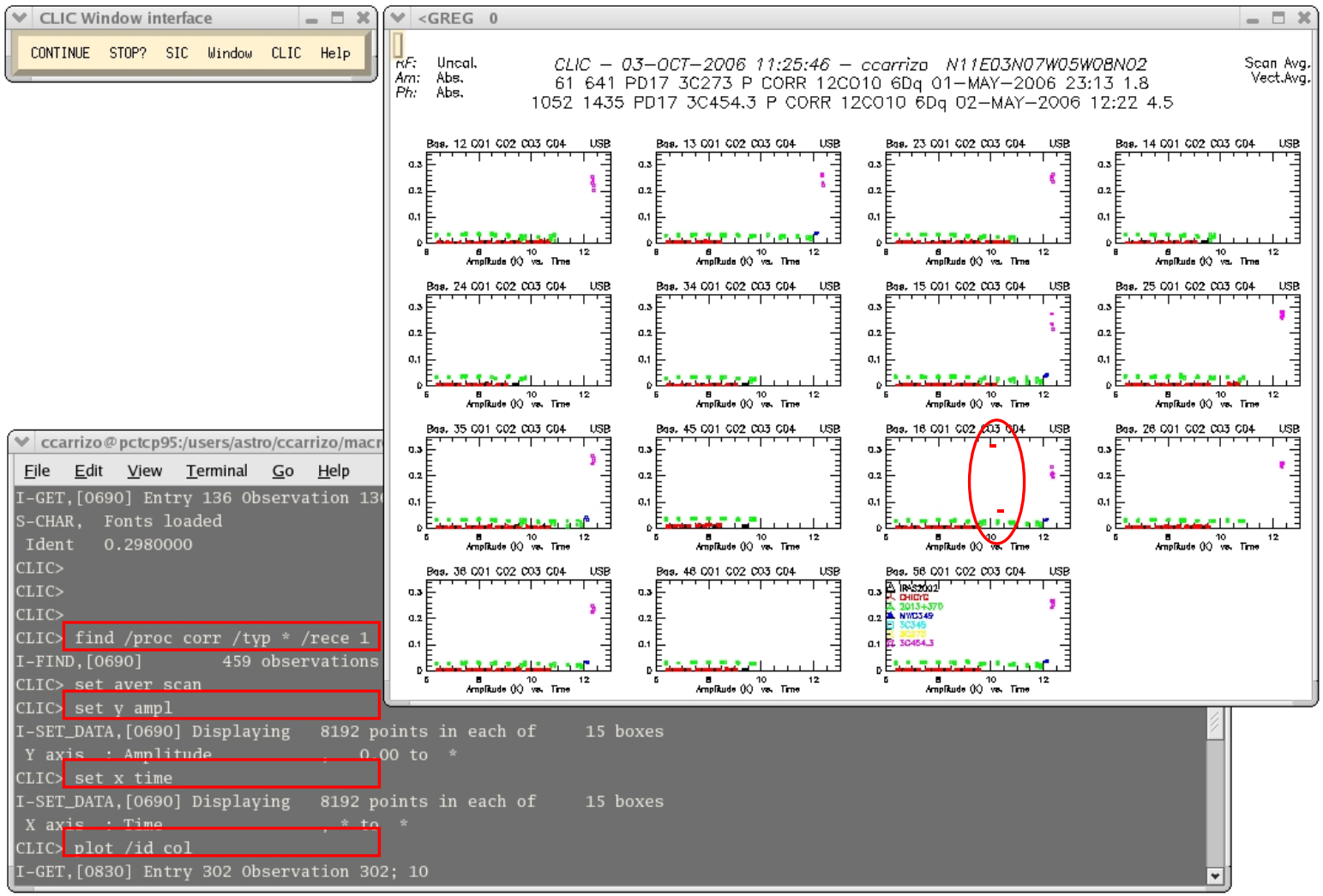
It may happen… that it remains a wrong visibility

MAPPING> uv_flag

Return to CLIC to identify the wrong visibility(ies) and flag them in the hpb file

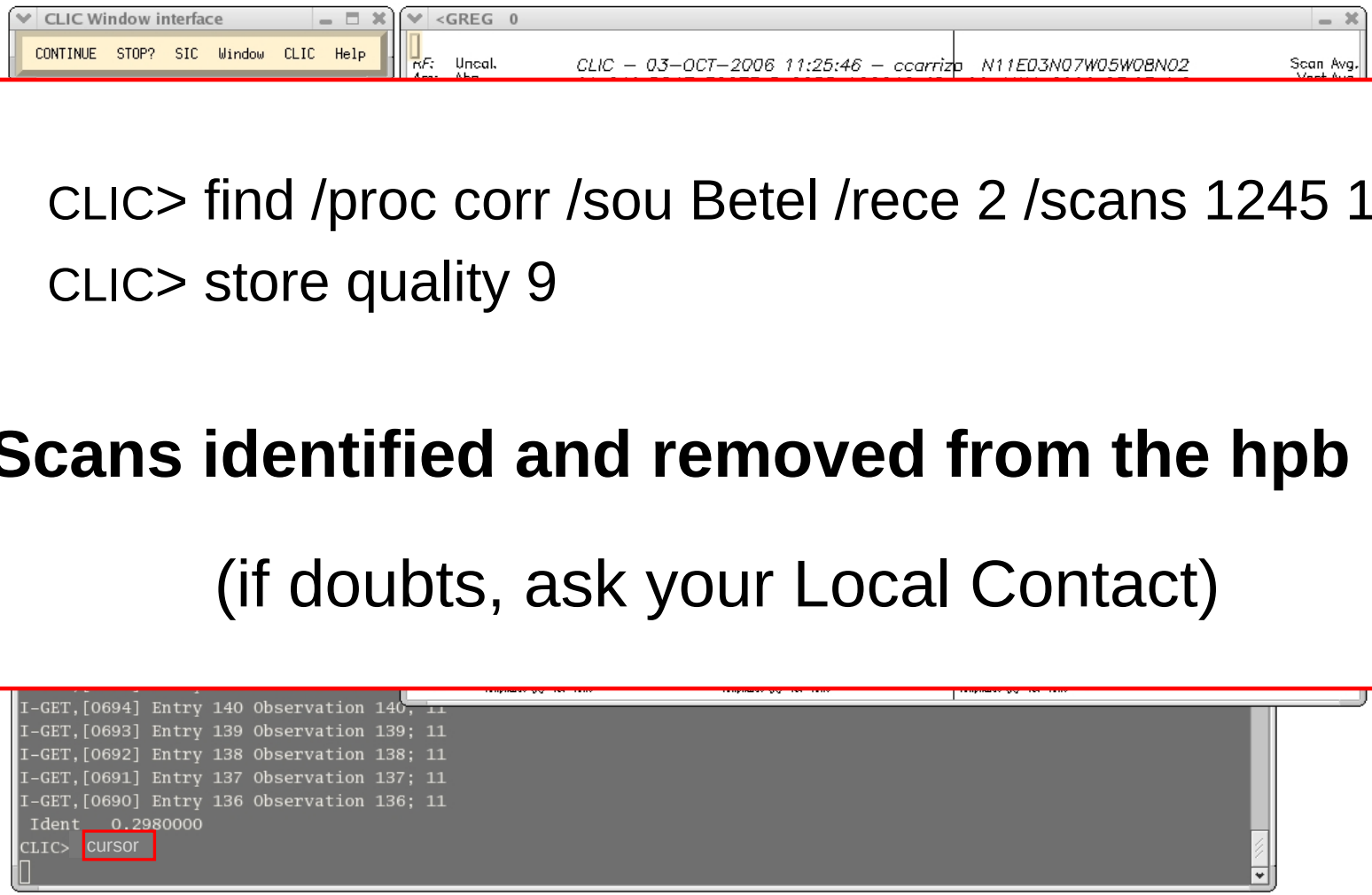
(1) Passing directly from hpb → mapping

It may happen… that you must go back



(1) Passing directly from hpb → mapping

It may happen… that you must go back



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

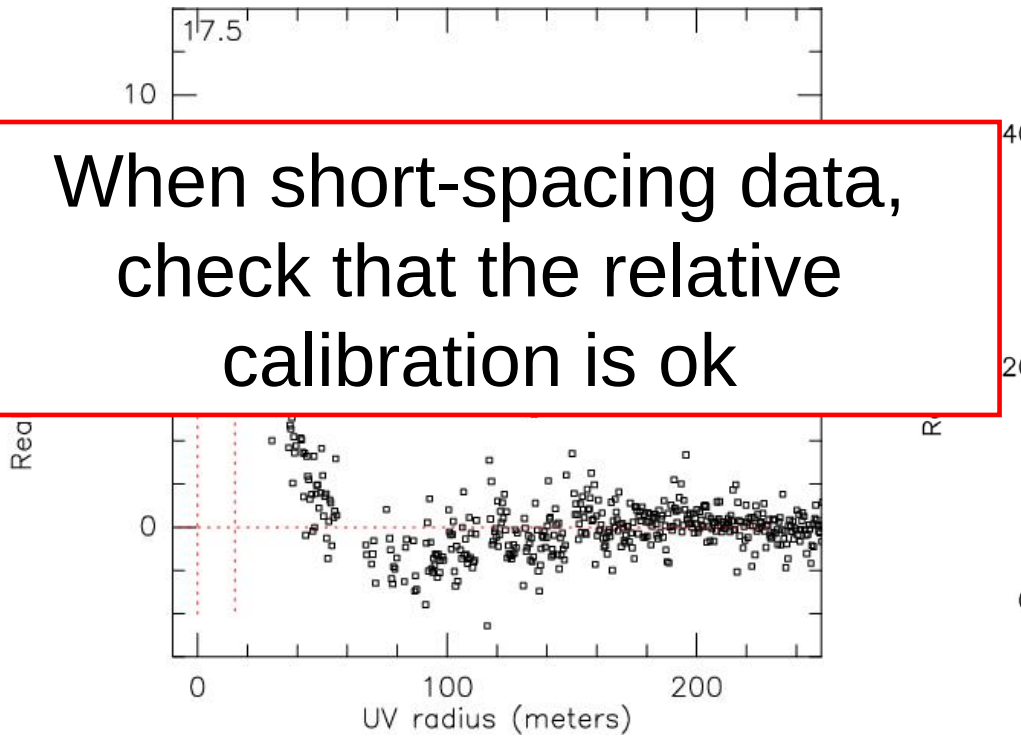
CLIC> store quality 9

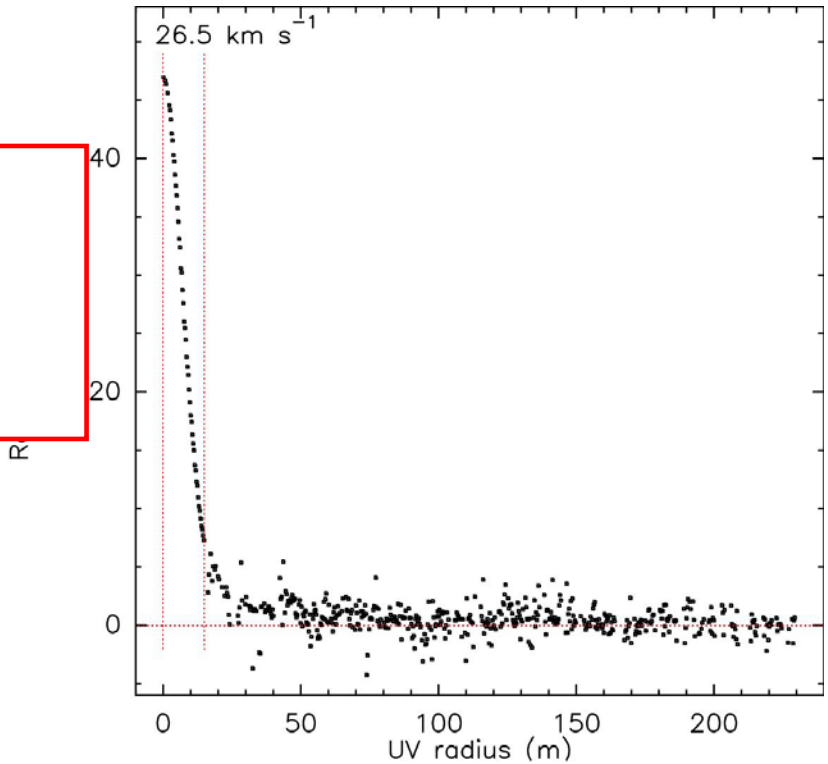
Scans identified and removed from the hpb !!

(if doubts, ask your Local Contact)

(2) Passing directly from hpb → mapping

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

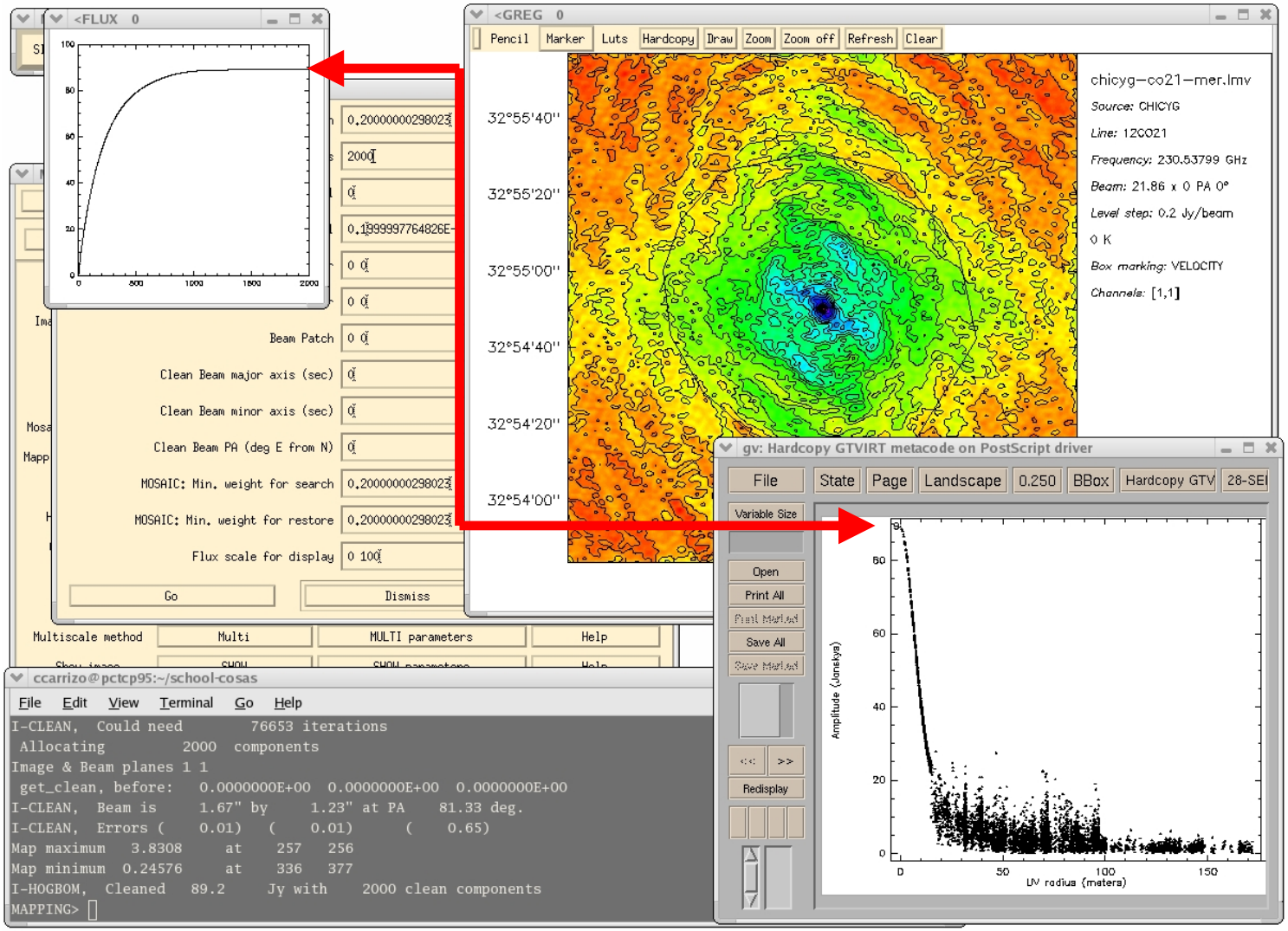




+ Short-spacing data

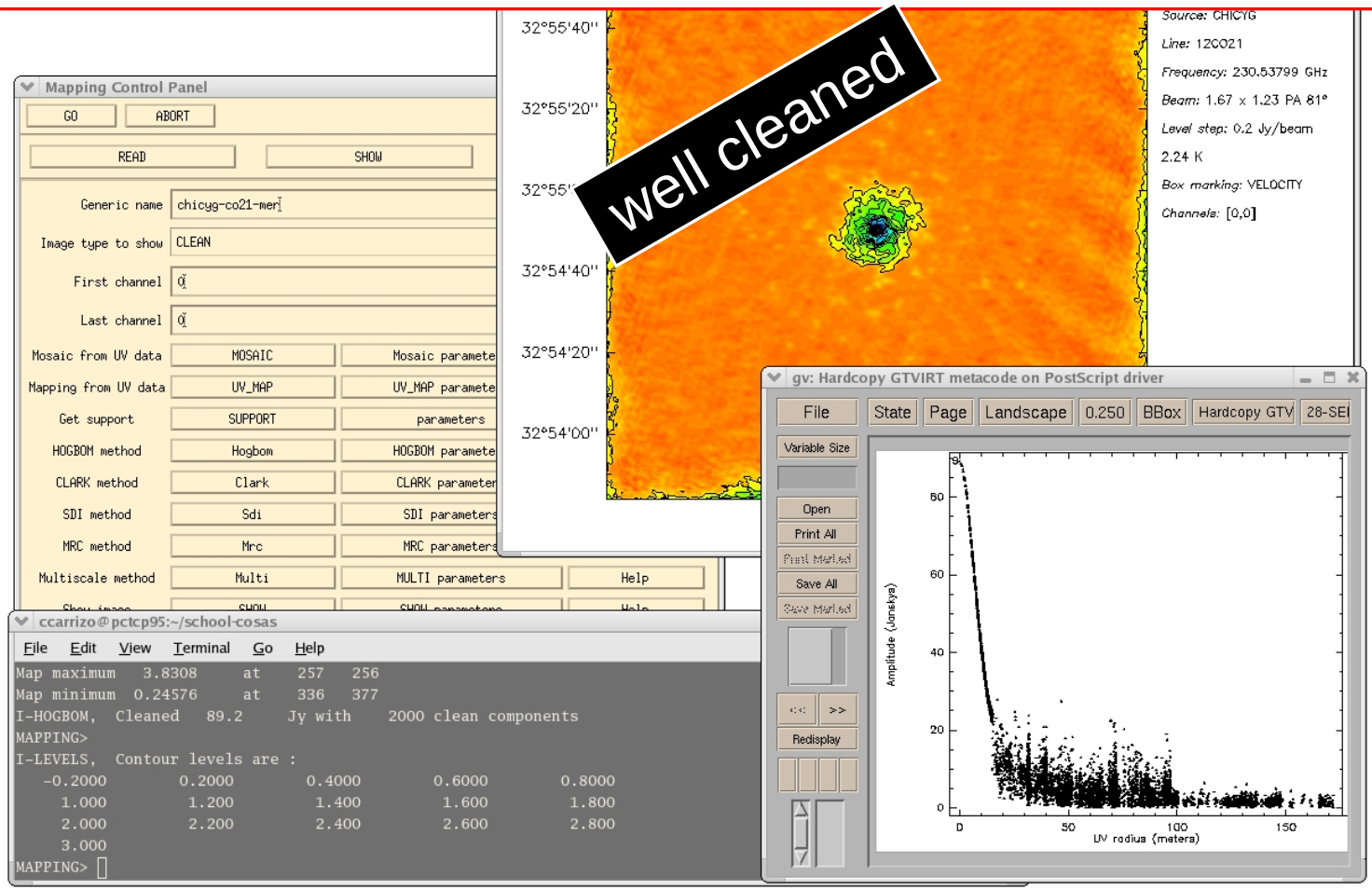
(3) Passing directly from hpb → mapping

Good practice: When cleaning (extended sources)…



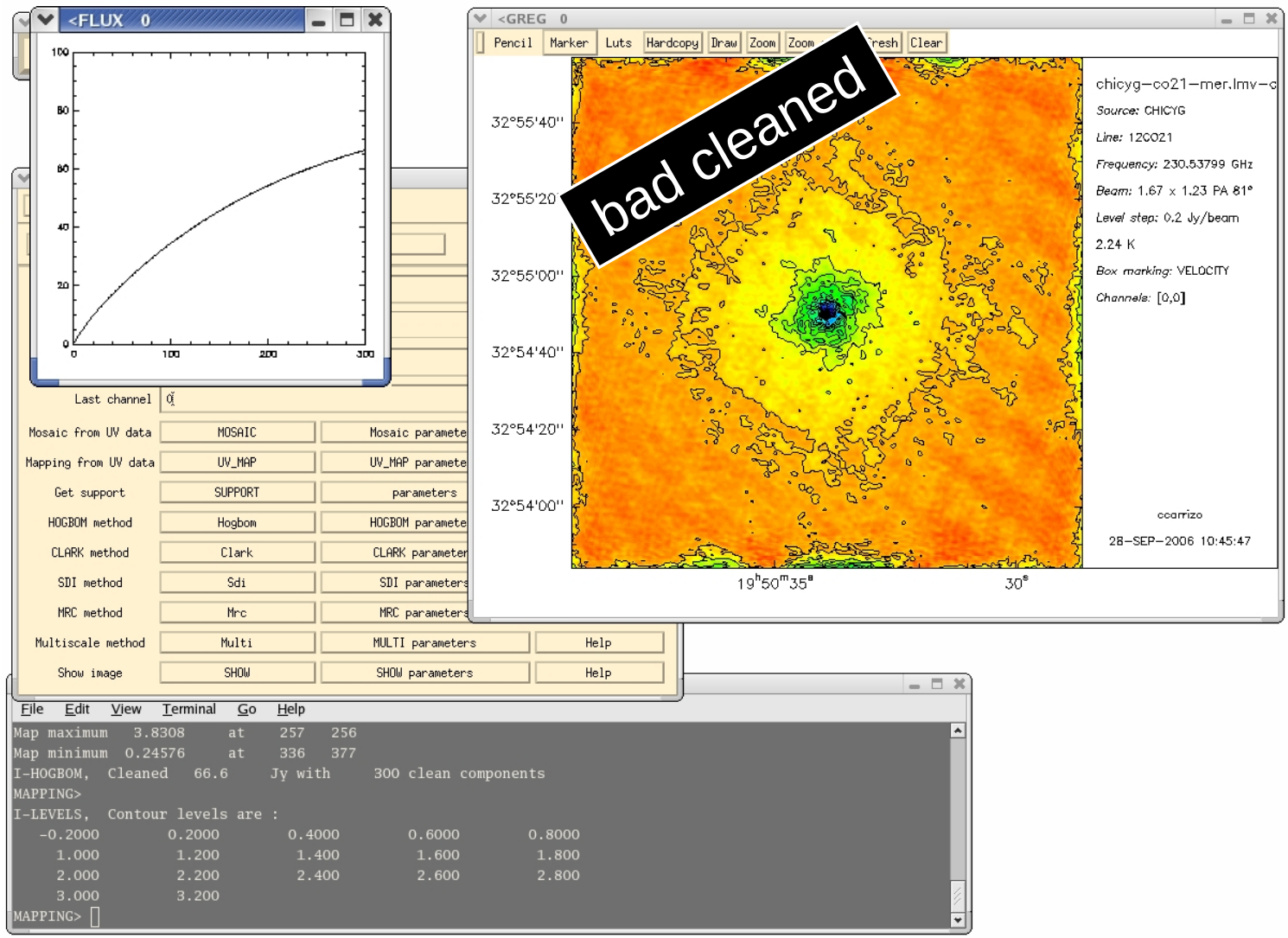
(3) Passing directly from hpb → mapping

When cleaning (specially extended sources or with supports) verify that the flux in the image plane coincides with that at the zero-spacing



(3) Passing directly from hpb → mapping

If not, it may happen…



We all agree now:

An inspection of the data in the *uv*-plane saves time

Data analysis in the *uv*-plane

procedures and tasks

```
MAPPING>  go uvall
MAPPING>  input uvall
```

```
MAPPING>  run uv_compress
MAPPING>  help uv_compress
```

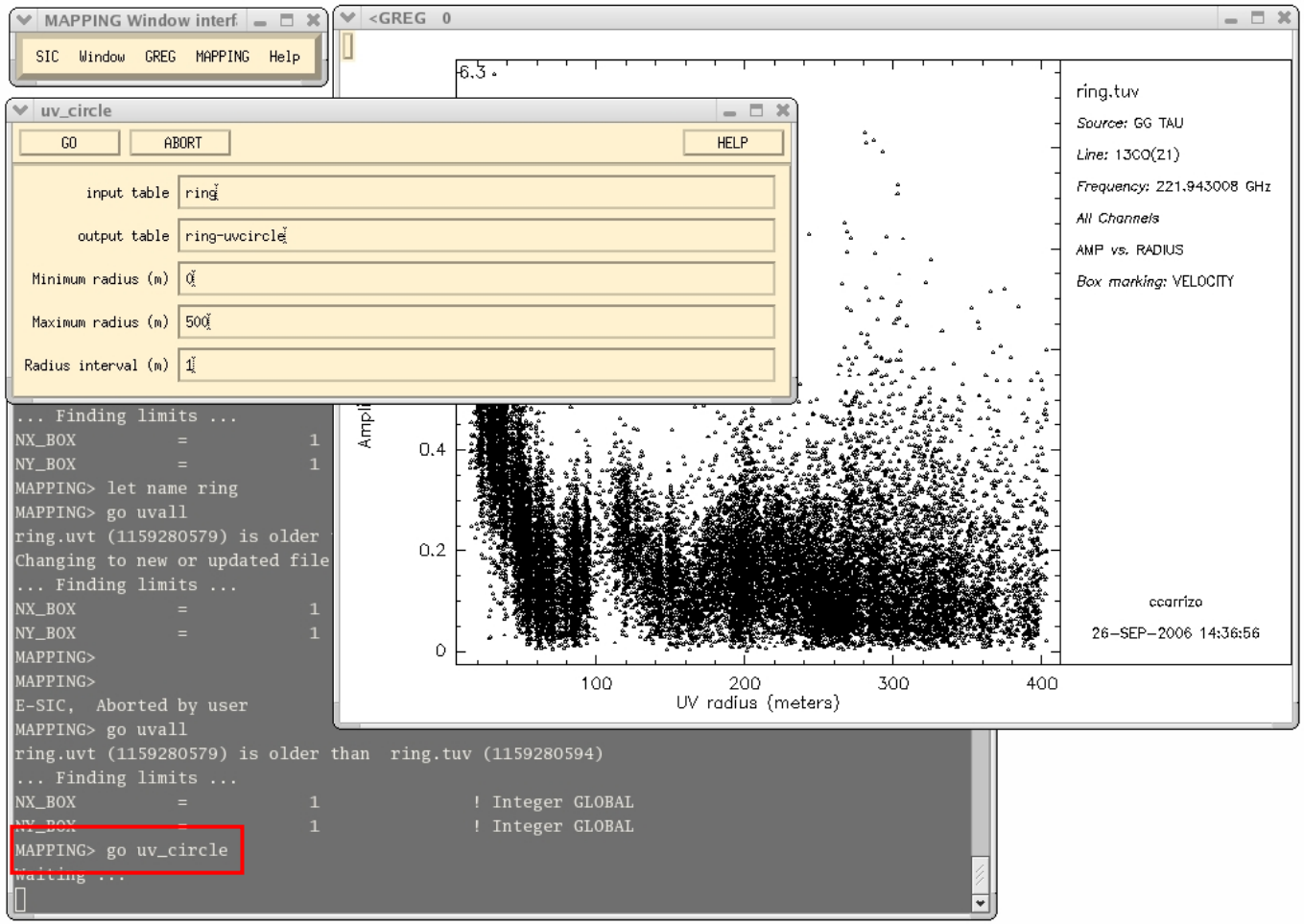
Data analysis in the *uv*-plane

MAPPING> run …

MAPPING> help …

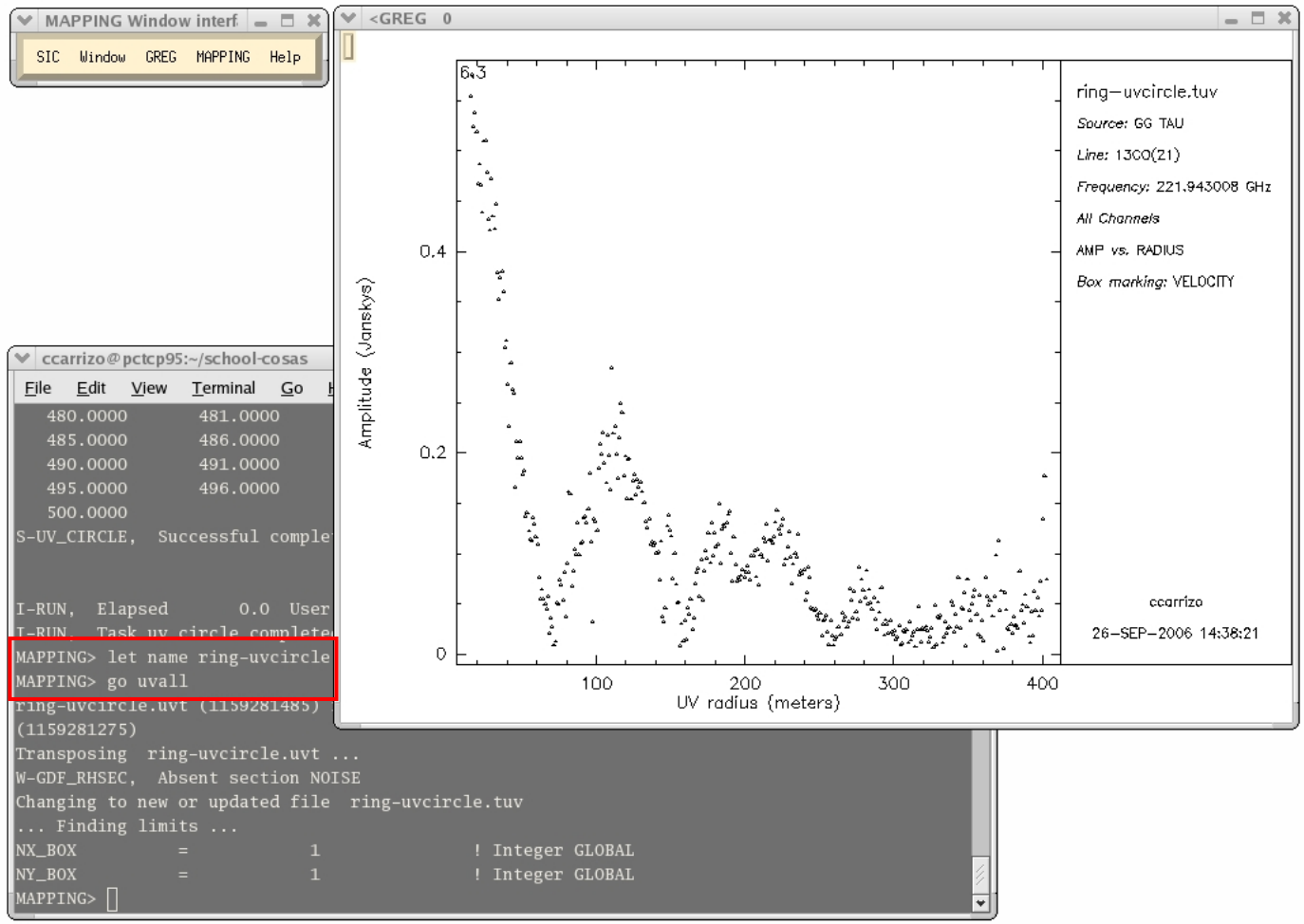
uv_applyphase	uv_dft	uv_merge	uv_solve
uv_ascal	uv_extract	uv_mflag	uv_sort
uv_atm	uv_fidelity	uv_model	uv_splitfield
uv_average	uv_fit-s	uv_mult	uv_stat
uv_cal	uv_flag	uv_noise	uv_substract
uv_ccmodel	uv_fmodel	uv_observe	uv_table
uv_cct	uv_gain	uv_pointing	uv_timeaverage
uv_center	uv_hanning	uv_selfcal	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



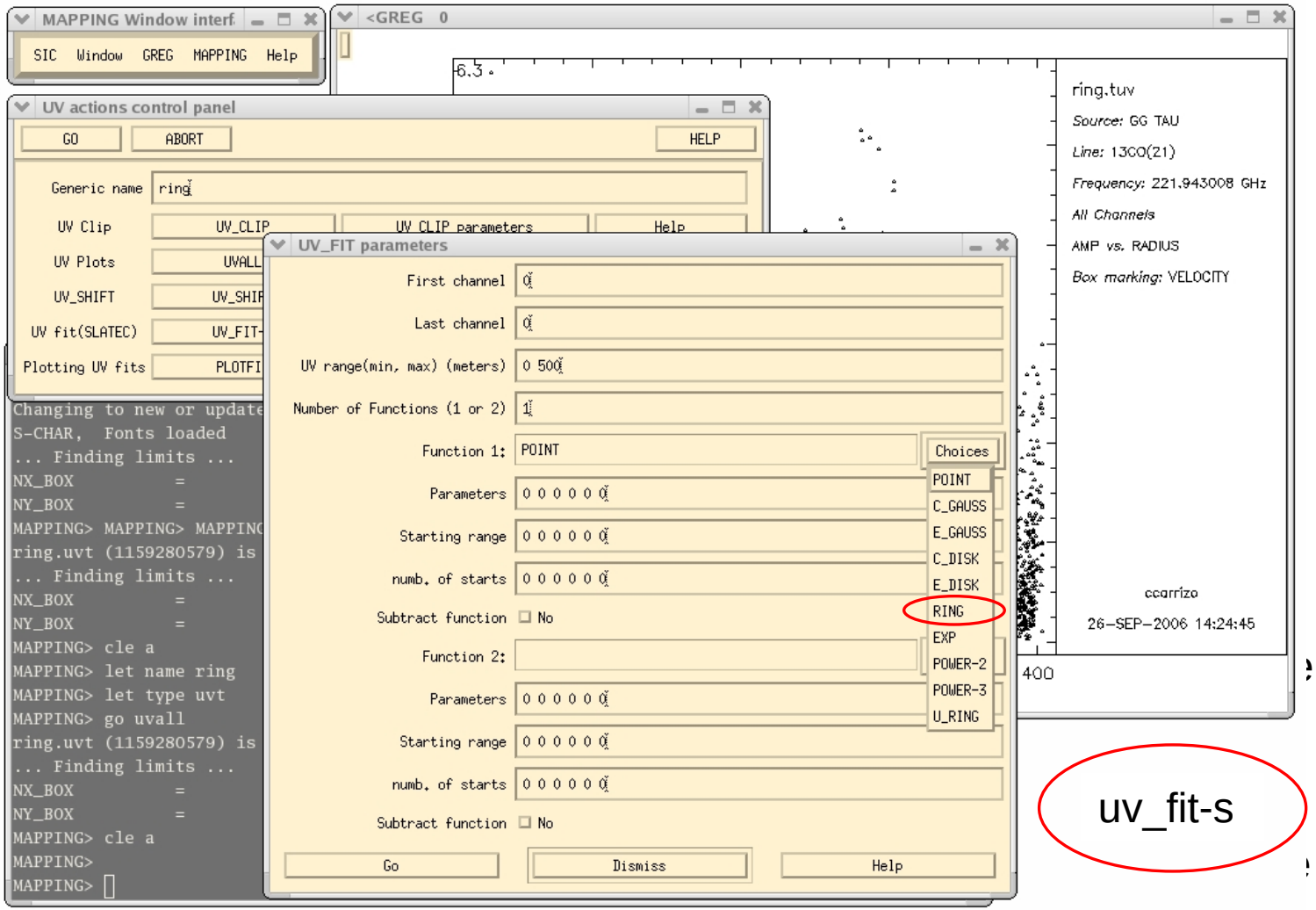
uv_applyphase
uv_ascal
uv_atm
uv_average
uv_cal
uv_ccmodel
uv_cct
uv_center
uv_circle
uv_clip
uv_compress
uv_cuts
uv_map
uv_mcal
uv_single
uv_sinusphase
uv_zero

Data analysis in the *uv*-plane



uv_applyphase
uv_ascal
uv_atm
uv_average
uv_cal
uv_ccmodel
uv_cct
uv_center
uv_circle
uv_clip
uv_compress
uv_cuts
uv_map
uv_mcal
uv_single
uv_sinusphase
uv_zero

Data analysis in the *uv*-plane



uv_fit-s

uv_compress uv_map uv_single uv_zero

uv_cuts uv_mcal uv_sinusphase

Data analysis in the *uv*-plane

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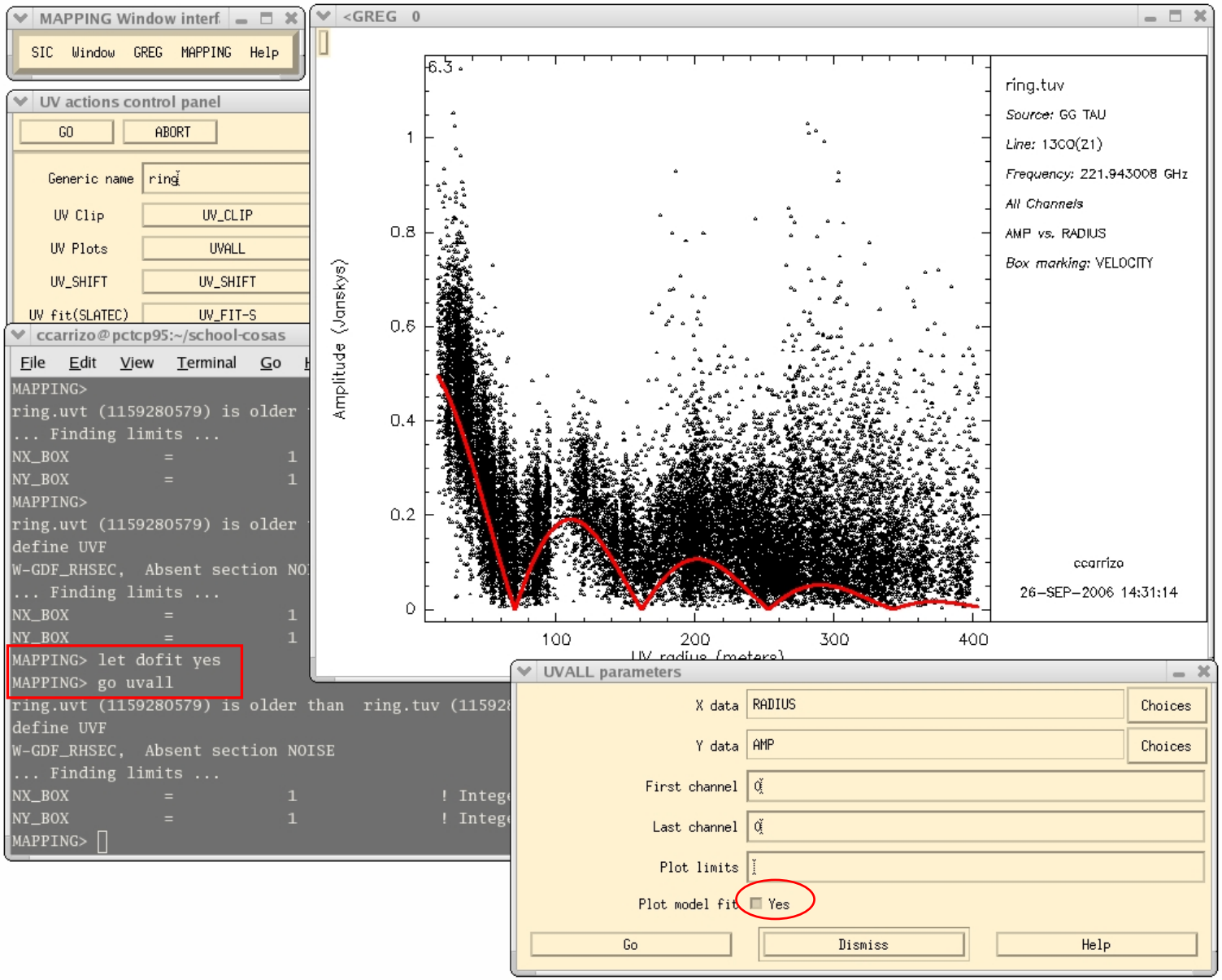
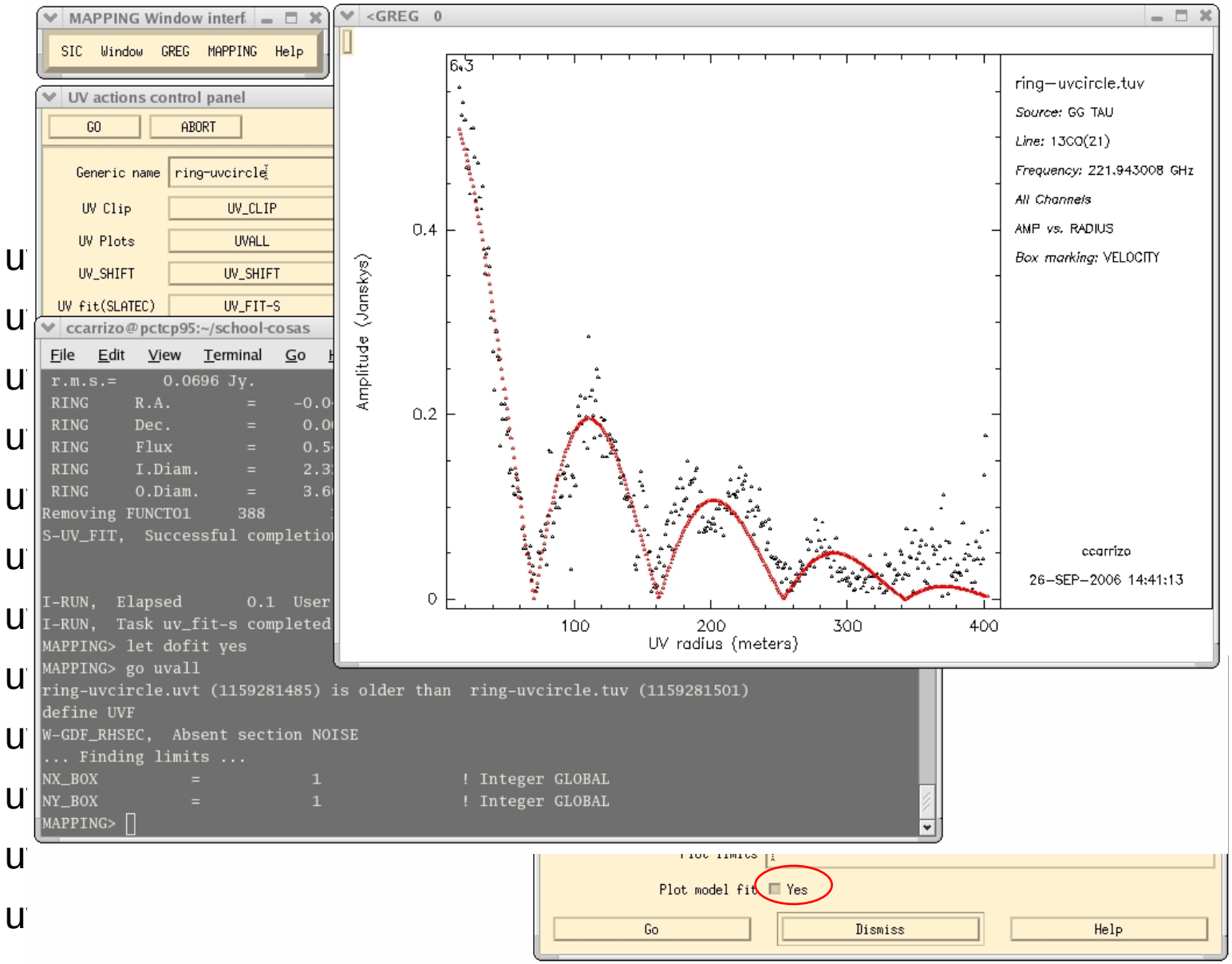
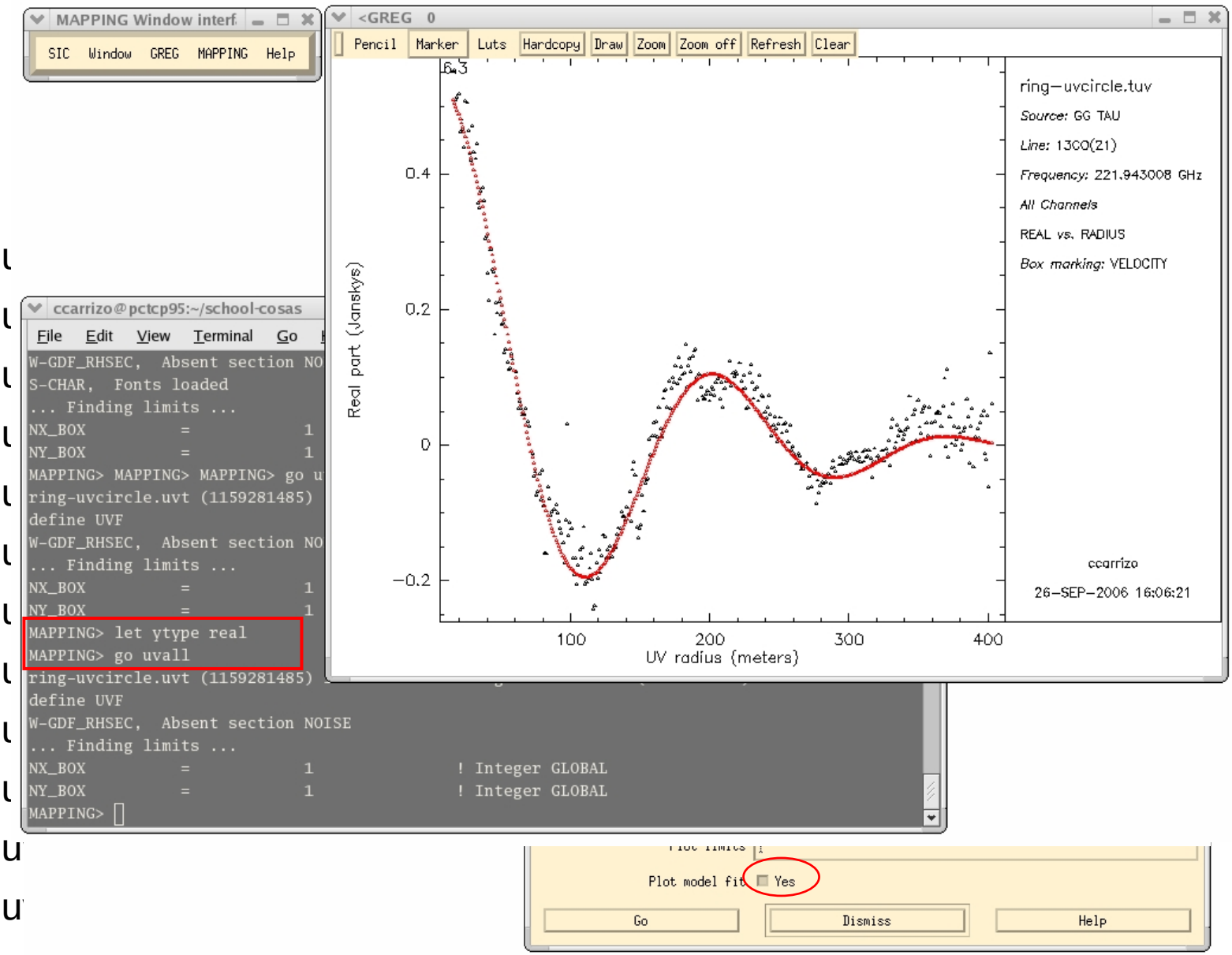


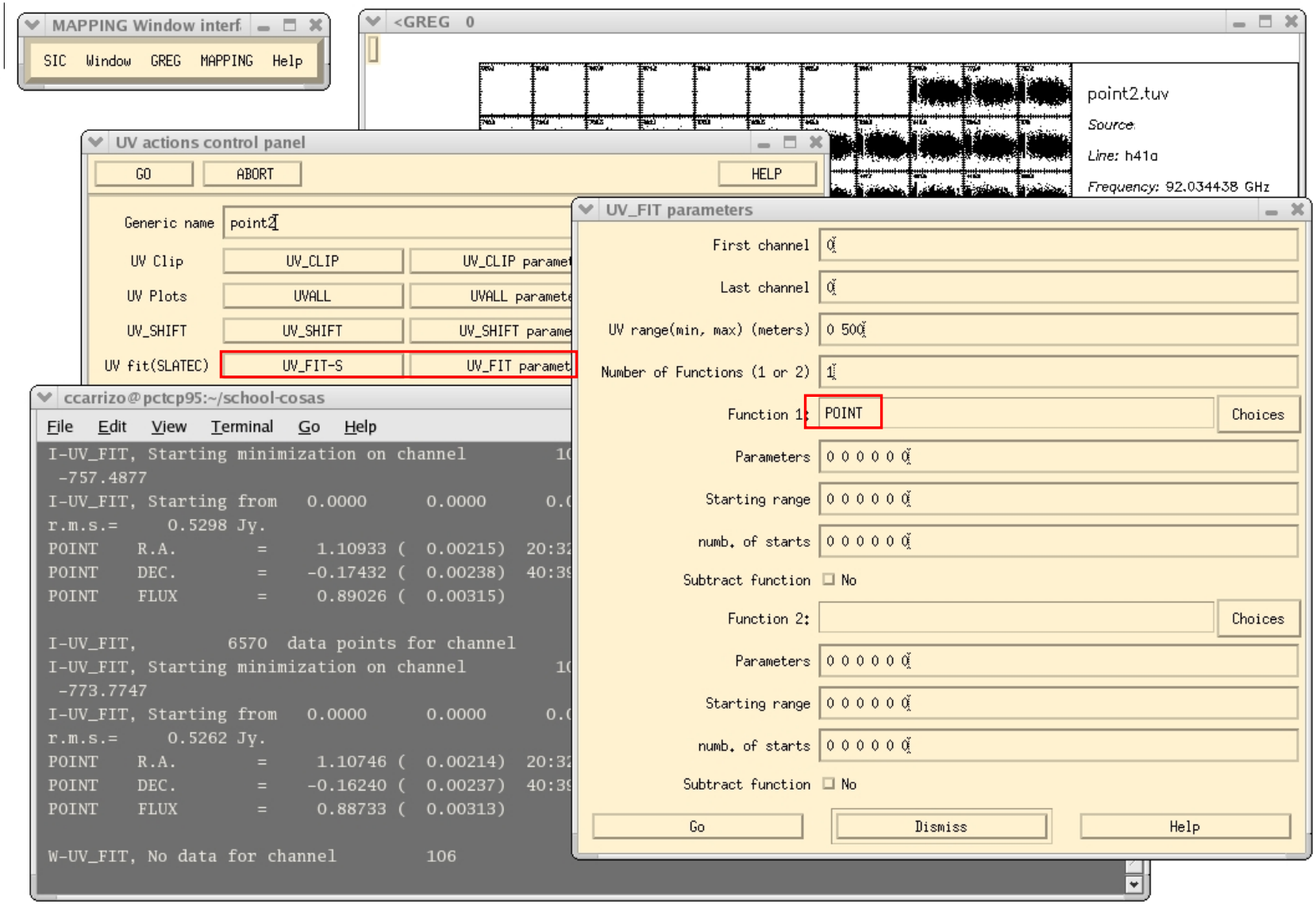
Data analysis in the *uv*-plane



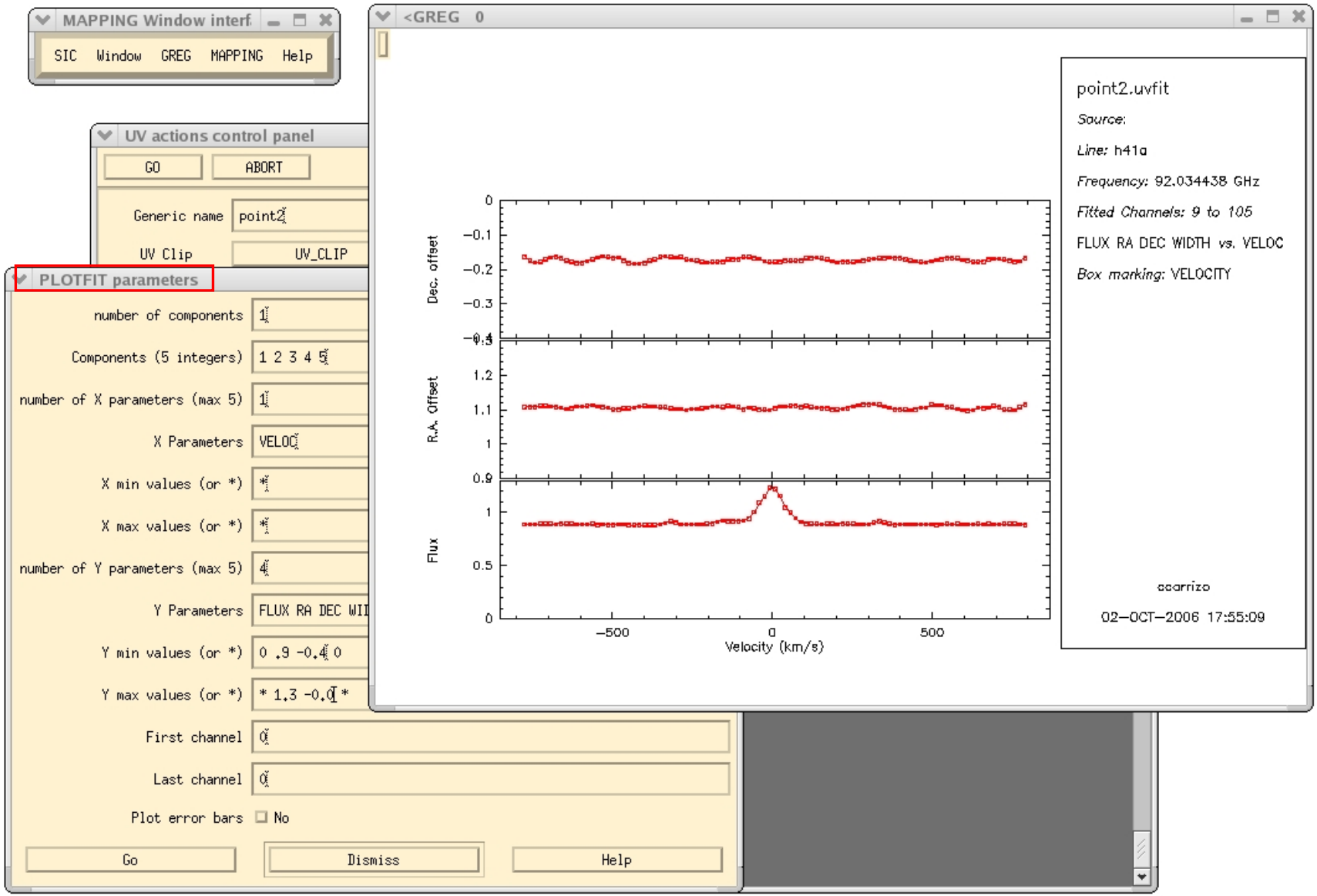
Data analysis in the *uv*-plane



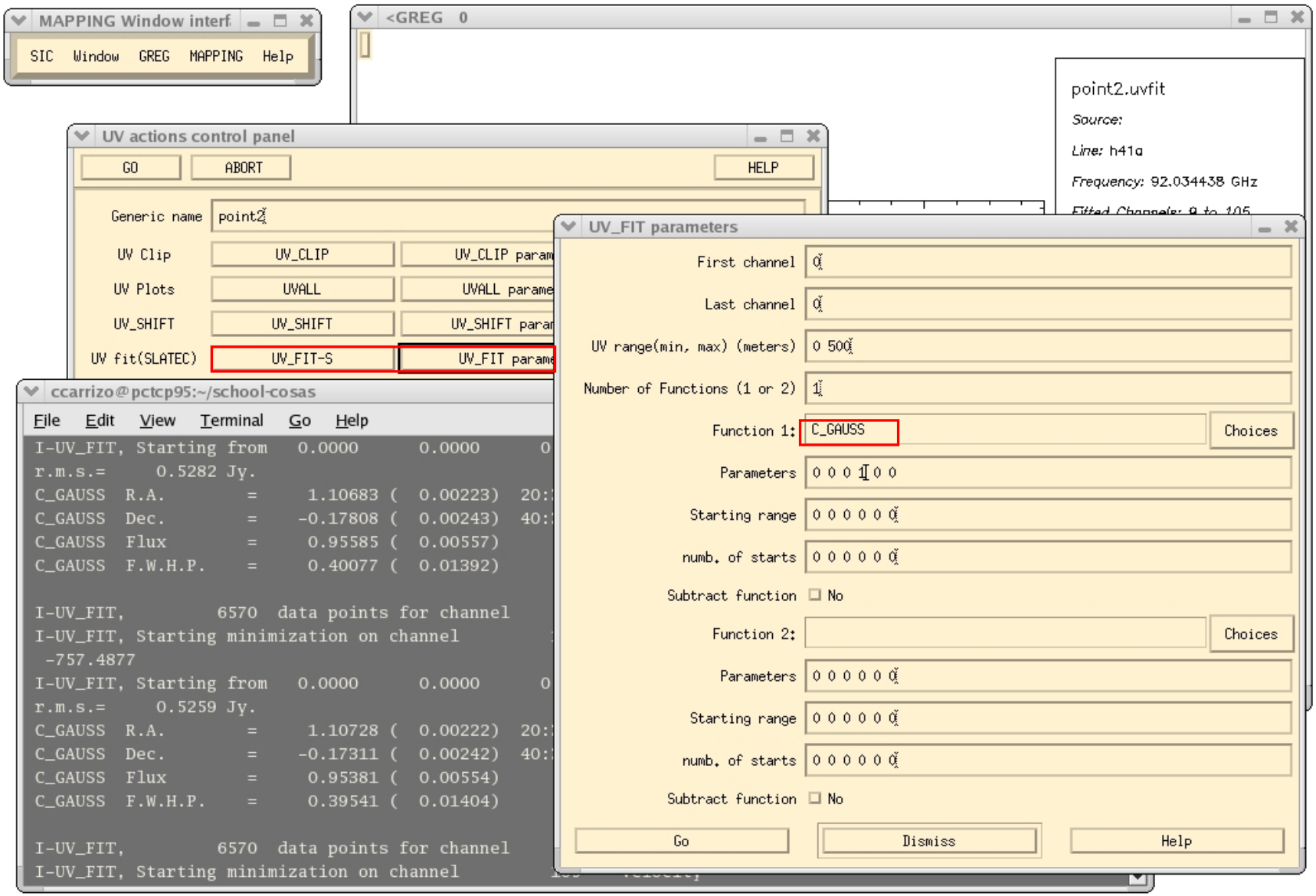
Data analysis in the *uv*-plane



Data analysis in the *uv*-plane

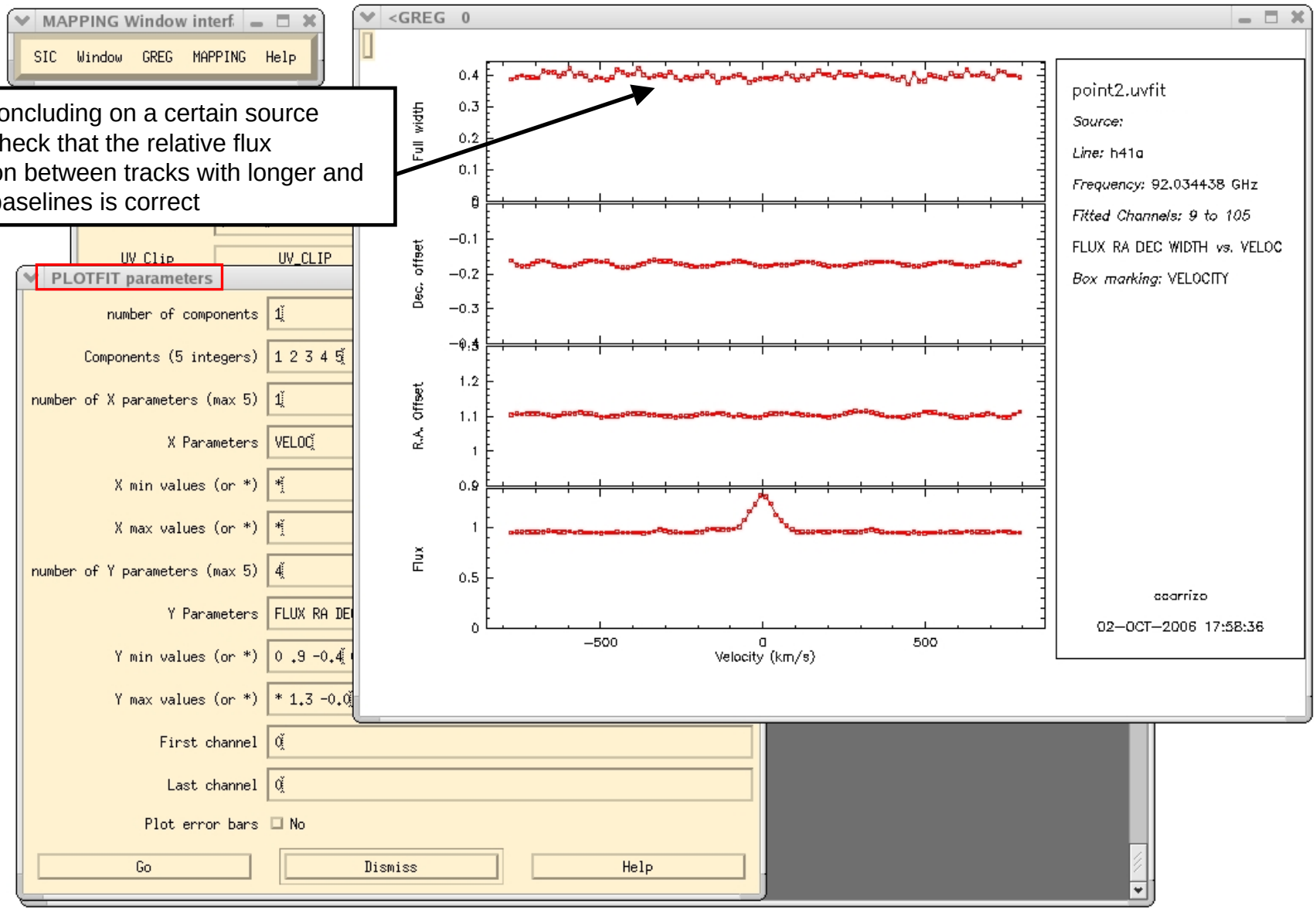


Data analysis in the *uv*-plane



Data analysis in the *uv*-plane

Before concluding on a certain source extent, check that the relative flux calibration between tracks with longer and shorter baselines is correct

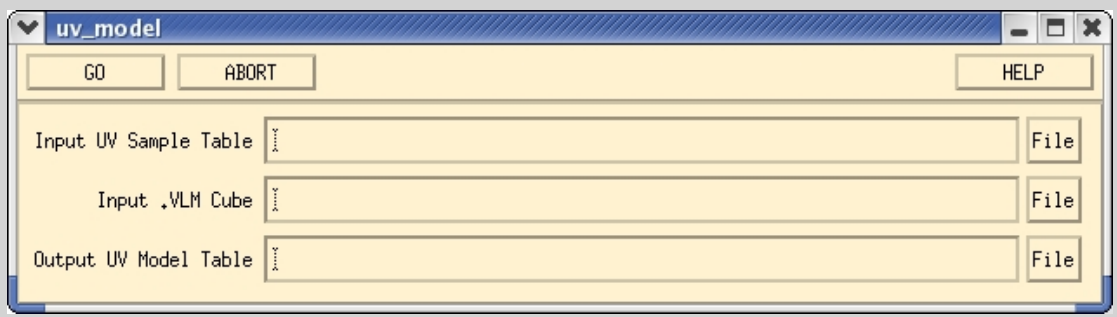


Data analysis in the *uv*-plane

MAPPING> run …

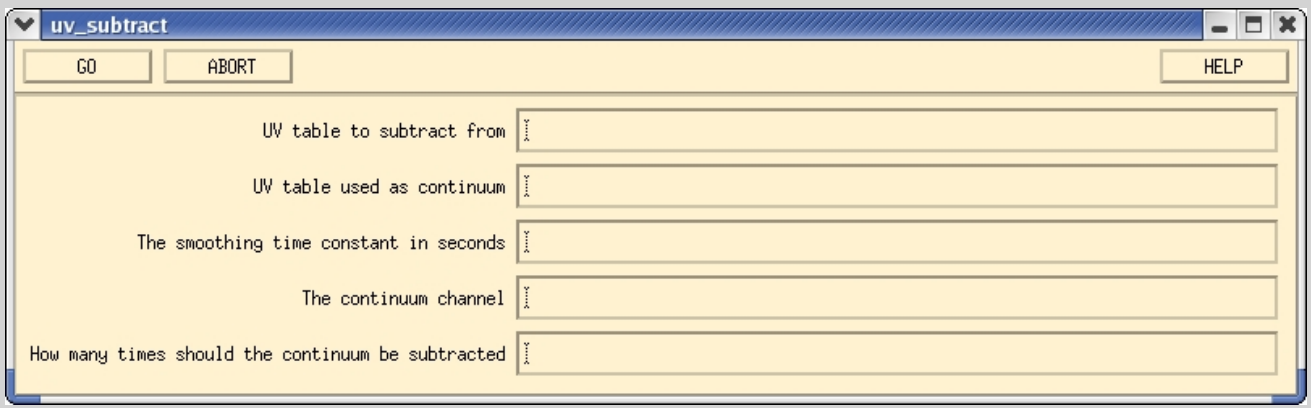
MAPPING> help …

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



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

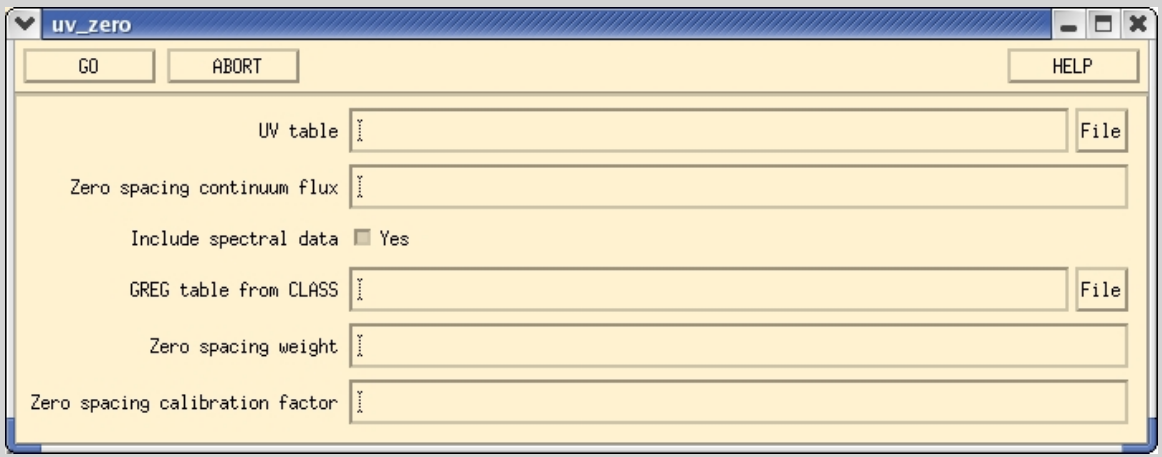
_solve
_sort
_splitfield
_stat

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> run …

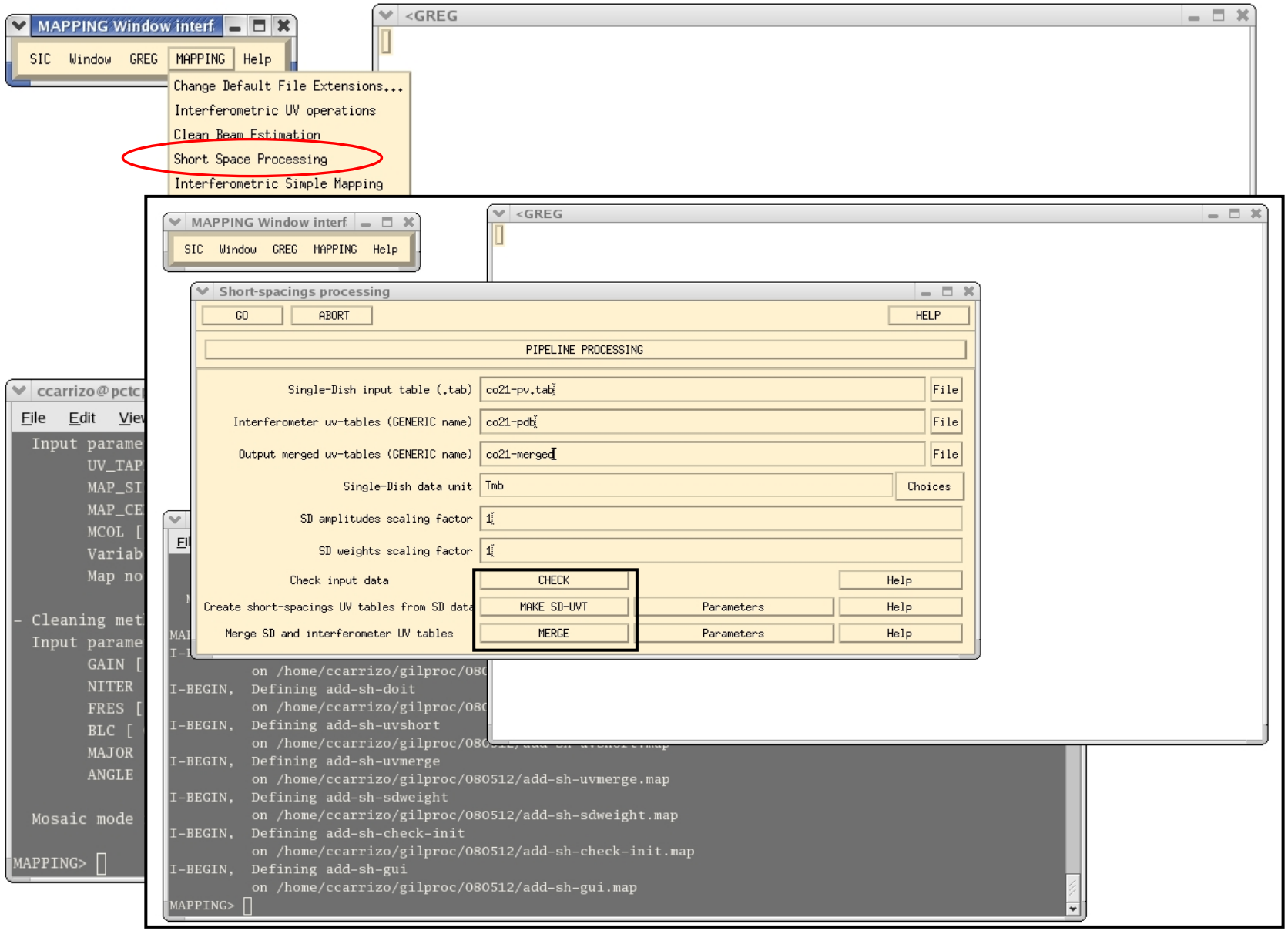
MAPPING> help …



To add a single-dish zero-spacing spectrum

_solve
_sort
_splitfield
_stat
_subtract
_table
_timeaverage
_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 tables are fully editable

uv table [visib dimension, # visibilities]

visib dimension = 7 + 3 x (# channels)

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 baseline

7 visib. characteristics

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

data at 1st channel

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

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

To conclude:

- Always an inspection of data in the *uv*-plane

- A more detailed analysis can be performed in the *uv*-plane: detection, modeling of simple structures, relative calibration to be checked, etc