ALMA Imaging

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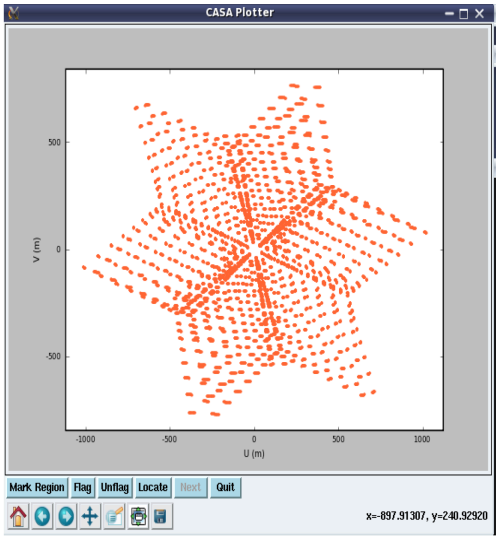
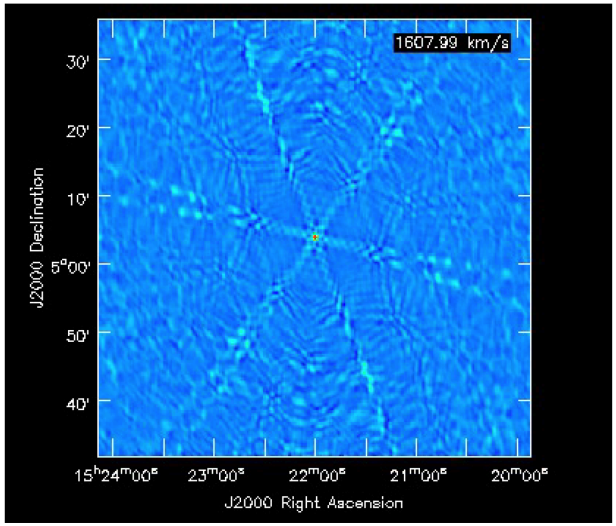
Allegro

What do we do with the calibrated visibilities?

$$FT^{-1}$$

$$V_{obs}(u,v) \rightarrow I_{dirty\_model}(x,y)$$





CLEAN: Replace the dirty psf by a 'cleaned' psf without sidelobes

$$I_{dirty\_model}(x,y) \rightarrow I_{clean\_model}(x,y) \sim I_{true}(x,y)$$

Data Inspection

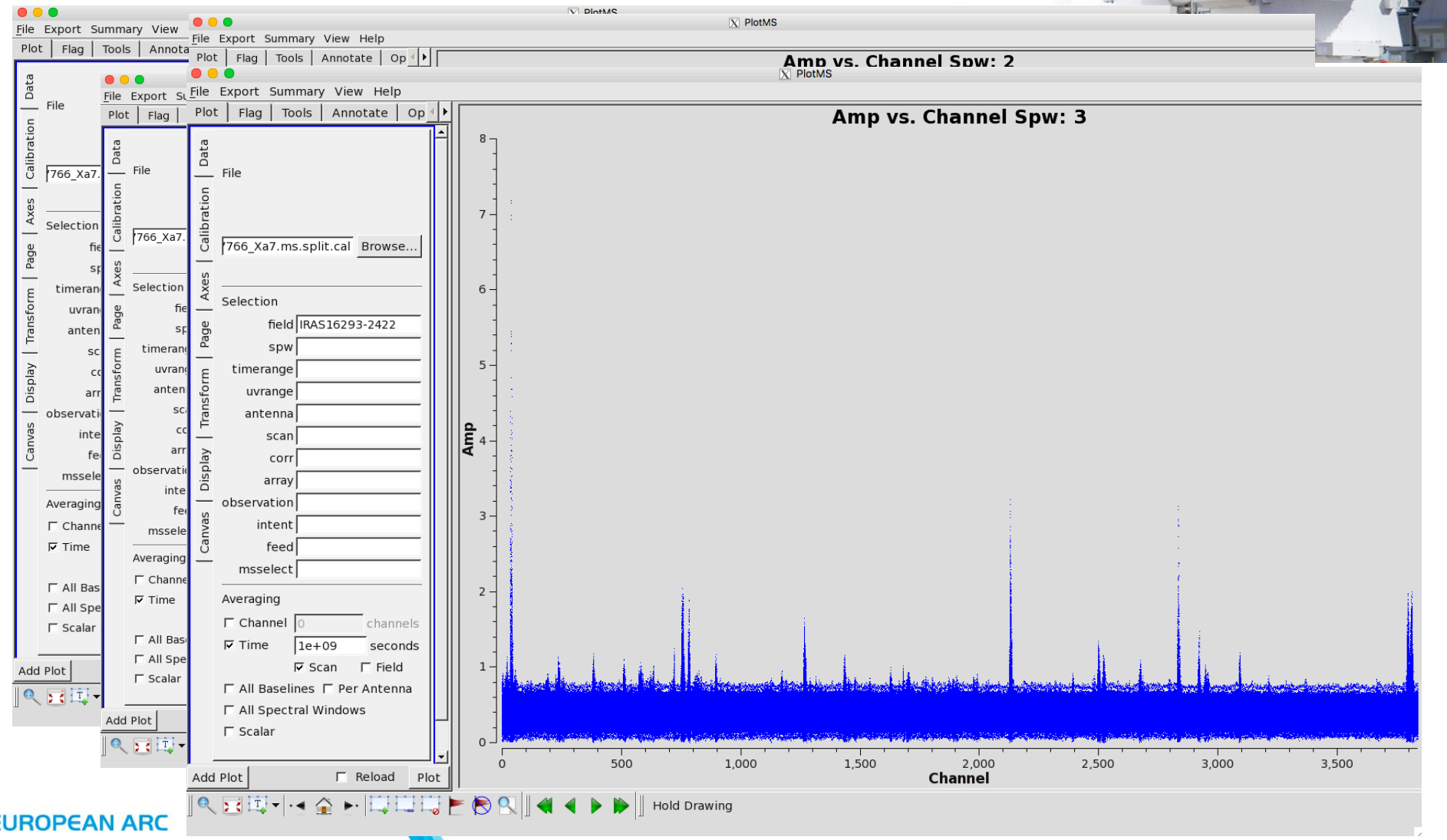
- Input: calibrated ms
  - data=calibrated.ms
- Listobs
  - listobs(data, listfile='calibrated.listobs')
- Plotms
  - plotms(vis=data, spw='', xaxis='frequency',
    yaxis='amp', avgtime='1e8', avgscan=T,
    iteraxis='spw', xselfscale=T)

Data Inspection: Listobs

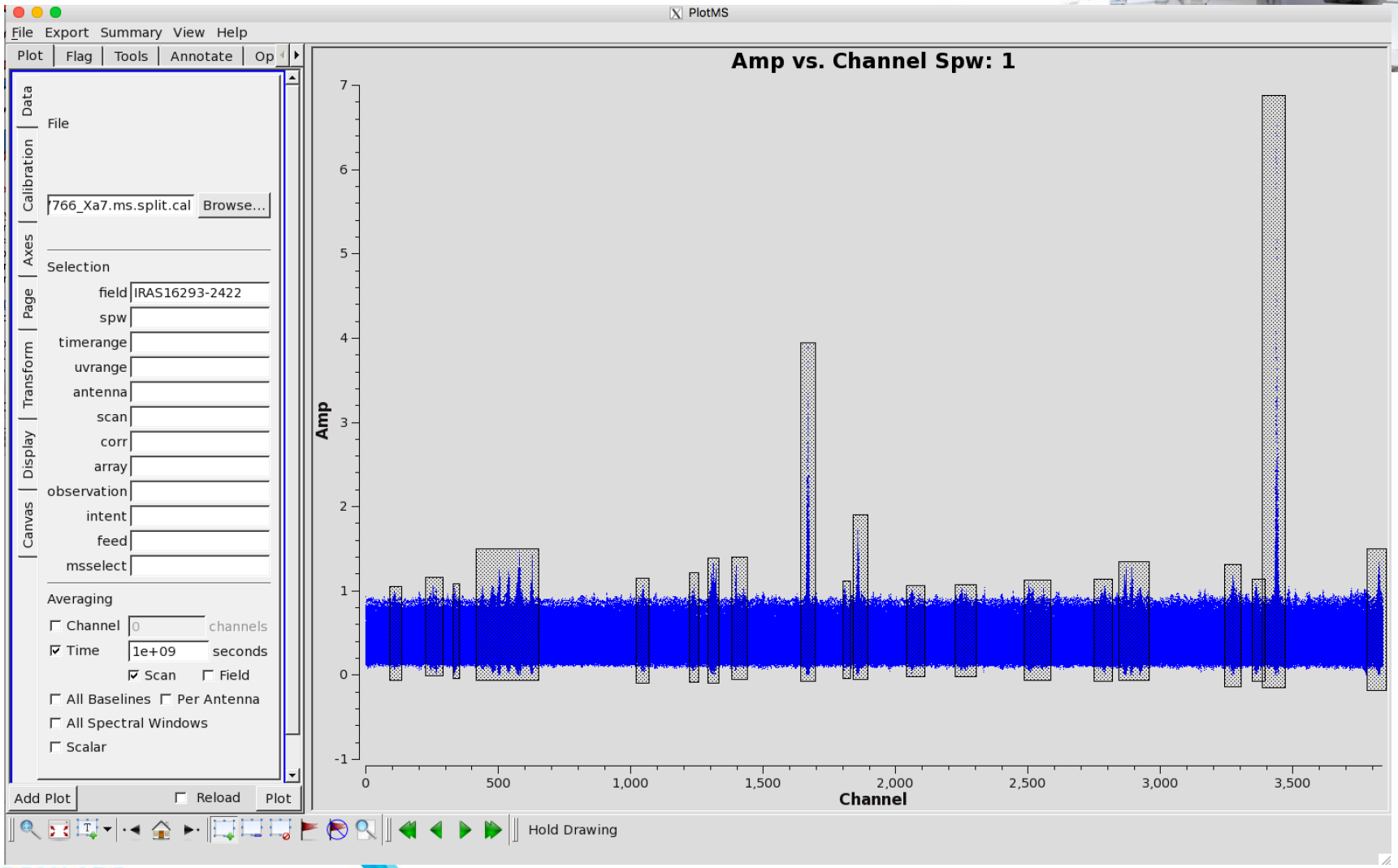
```
================================================================================
           MeasurementSet Name:  /lustre/allegro/data/projects/BAXM80vX/analysis/ycontreras/20XX.1.0XXXX.S/sg_ouss_id/group_ouss_id/member_ouss_id/calibrated/uid___A002_X867766_Xa7.ms.split.cal      MS Version 2
================================================================================
   Observer: satoko     Project: uid://A002/X8666bf/Xc
Observation: ALMA
Data records: 816960       Total elapsed time = 5192.88 seconds
   Observed from   11-Jul-2014/04:01:40.1   to   11-Jul-2014/05:28:13.0 (UTC)

   ObservationID = 0         ArrayID = 0
  Date        Timerange (UTC)          Scan  FldId FieldName             nRows     SpwIds   Average Interval(s)    ScanIntent
  11-Jul-2014/04:01:40.1 - 04:06:56.8     4      0 J1700-2610              55200  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_BANDPASS#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              04:07:35.6 - 04:10:13.4     6      1 J1517-243               27600  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_AMPLI#ON_SOURCE,CALIBRATE_FLUX#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              04:10:31.3 - 04:11:01.6     7      2 J1625-2527               5520  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_PHASE#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              04:11:36.5 - 04:17:56.8     9      3 IRAS16293-2422          66240  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [OBSERVE_TARGET#ON_SOURCE]
              04:18:10.1 - 04:18:40.4    10      2 J1625-2527               5520  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_PHASE#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              04:18:56.3 - 04:25:16.6    11      3 IRAS16293-2422          66240  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [OBSERVE_TARGET#ON_SOURCE]
              04:25:33.0 - 04:26:03.3    12      2 J1625-2527               5520  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_PHASE#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              04:26:37.0 - 04:32:57.2    14      3 IRAS16293-2422          66240  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [OBSERVE_TARGET#ON_SOURCE]
              04:33:17.5 - 04:33:47.8    15      2 J1625-2527               5520  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_PHASE#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              04:34:03.9 - 04:40:24.2    16      3 IRAS16293-2422          66240  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [OBSERVE_TARGET#ON_SOURCE]
              04:40:37.2 - 04:41:07.5    17      2 J1625-2527               5520  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_PHASE#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              04:41:46.9 - 04:48:07.2    19      3 IRAS16293-2422          66240  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [OBSERVE_TARGET#ON_SOURCE]
              04:48:20.3 - 04:48:50.5    20      2 J1625-2527               5520  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_PHASE#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              04:49:06.5 - 04:55:26.7    21      3 IRAS16293-2422          66240  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [OBSERVE_TARGET#ON_SOURCE]
              04:55:40.0 - 04:56:10.3    22      2 J1625-2527               5520  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_PHASE#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              04:56:45.0 - 05:03:05.3    24      3 IRAS16293-2422          66240  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [OBSERVE_TARGET#ON_SOURCE]
              05:03:25.3 - 05:03:55.6    25      2 J1625-2527               5520  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_PHASE#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              05:04:12.9 - 05:10:33.2    26      3 IRAS16293-2422          66240  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [OBSERVE_TARGET#ON_SOURCE]
              05:10:46.4 - 05:11:16.6    27      2 J1625-2527               5520  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_PHASE#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              05:11:57.0 - 05:18:17.2    29      3 IRAS16293-2422          66240  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [OBSERVE_TARGET#ON_SOURCE]
              05:18:30.8 - 05:19:01.0    30      2 J1625-2527               5520  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_PHASE#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              05:19:17.2 - 05:25:37.4    31      3 IRAS16293-2422          66240  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [OBSERVE_TARGET#ON_SOURCE]
              05:25:50.7 - 05:26:20.9    32      2 J1625-2527               5520  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_PHASE#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
              05:26:57.3 - 05:27:27.5    34      3 IRAS16293-2422          66240  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [OBSERVE_TARGET#ON_SOURCE]
              05:27:42.8 - 05:28:13.0    35      2 J1625-2527               5520  [0,1,2,3]  [6.05, 6.05, 6.05, 6.05] [CALIBRATE_PHASE#ON_SOURCE,CALIBRATE_WVR#ON_SOURCE]
          (nRows = Total number of rows per scan)
Fields: 4
  ID   Code Name                RA               Decl           Epoch   SrcId      nRows
  0    none J1700-2610          17:00:53.154060 -26.10.51.72530 J2000   0          55200
  1    none J1517-243           15:17:41.813132 -24.22.19.47608 J2000   1          27600
  2    none J1625-2527          16:25:46.891640 -25.27.38.32690 J2000   2          66240
  3    none IRAS16293-2422      16:32:22.735600 -24.28.32.50000 J2000   3         667920
Spectral Windows:  (4 unique spectral windows and 1 unique polarization setups)
  SpwID  Name                           #Chans   Frame   Ch0(MHz)  ChanWid(kHz)  TotBW(kHz) CtrFreq(MHz) BBC Num  Corrs
  0      ALMA_RB_04#BB_1#SW-01#FULL_RES   3840   TOPO  156833.170       122.070    468750.0 157067.4843        1  XX  YY
  1      ALMA_RB_04#BB_2#SW-01#FULL_RES   3840   TOPO  157286.899       488.281   1875000.0 158224.1547        2  XX  YY
  2      ALMA_RB_04#BB_3#SW-01#FULL_RES   3840   TOPO  147236.910       -61.035    234375.0 147119.7531        3  XX  YY
  3      ALMA_RB_04#BB_4#SW-01#FULL_RES   3840   TOPO  146981.861      -488.281   1875000.0 146044.6047        4  XX  YY
Sources: 16
  ID   Name               SpwId RestFreq(MHz)  SysVel(km/s)
  0    J1700-2610         0     157052.295     0
  0    J1700-2610         1     158230         0
  0    J1700-2610         2     147103.902     0
  0    J1700-2610         3     146050         0
  1    J1517-243          0     157052.295     0
  1    J1517-243          1     158230         0
  1    J1517-243          2     147103.902     0
  1    J1517-243          3     146050         0
  2    J1625-2527         0     157052.295     0
  2    J1625-2527         1     158230         0
  2    J1625-2527         2     147103.902     0
  2    J1625-2527         3     146050         0
  3    IRAS16293-2422     0     157052.295     3
  3    IRAS16293-2422     1     158230         3
  3    IRAS16293-2422     2     147103.902     3
  3    IRAS16293-2422     3     146050         3
```

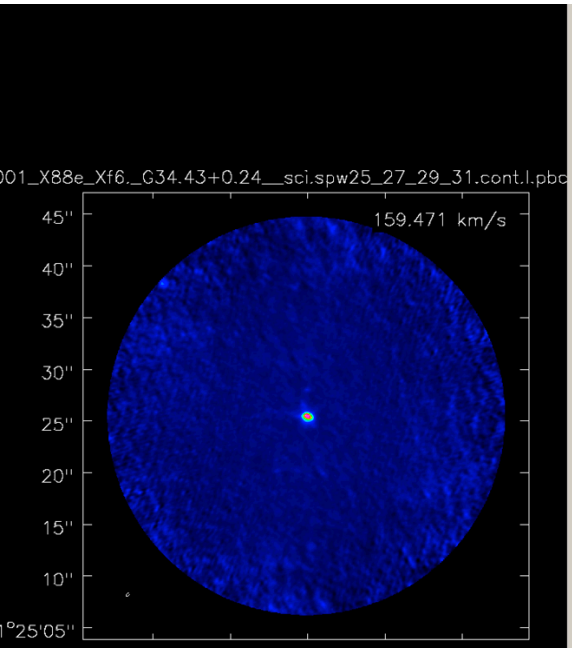
Data Inspection: plotms

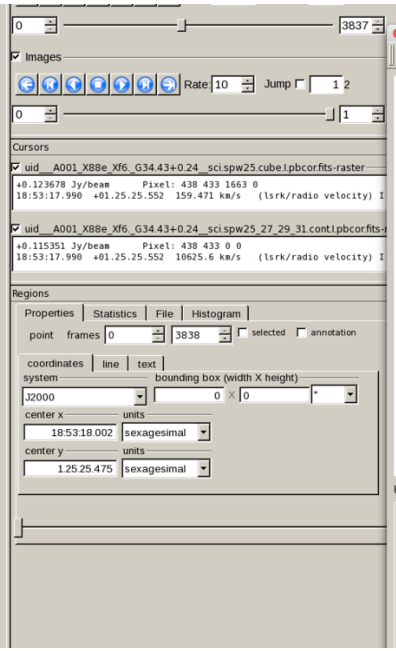


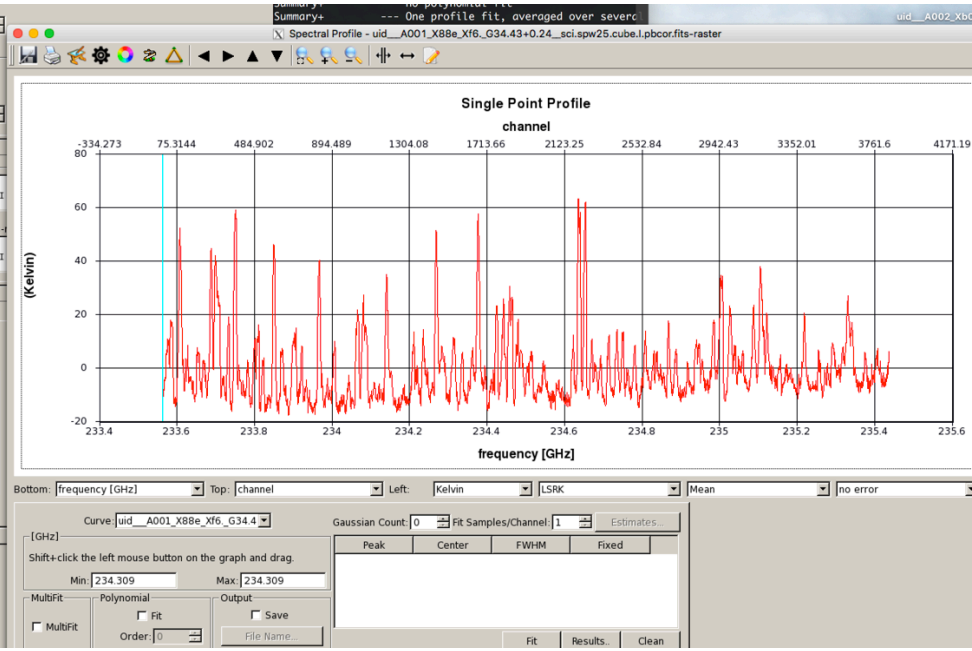
Data Inspection: Identifying Line-Free channels



Data Inspection: Identifying Line-Free channels







Solution:
- STATCONT
- BE VERY PATIENT
- FORGET ABOUT THE CONTINUUM

ScriptForImaging.py

Since last cycle is not part of the delivered data

If you have it…This script does not always provides science quality imaging, but it a good start for the data imaging.

- Continuum imaging
- UV Continuum subtraction
- Line Imaging
- PB correction
- Export to fits files

ScriptForImaging.py

CLEAN

– Normal clean used widely on other interferometer data analysis packages

TCLEAN

– CASA own clean algorithm, it is faster and it is more robust than CLEAN for ALMA data

Use TCLEAN and version >5.4

ScriptForImaging.py

Example of continuum

```
import re

if re.search('^4.7.0', casadef.casa_version) == None:
    sys.exit('ERROR: PLEASE USE THE SAME VERSION OF CASA THAT YOU USED FOR GENERATING THE SCRIPT: 4.7.0')

print "# Running clean."

visdata='uid___A002_X867766_Xa7.ms.split.cal'
fieldname='3'
phasecenter=3
cellsize='0.15arcsec'
imagesize=[640, 640]

spwcont='1:0~89;131~224;288~328;350~415;649~1019;1065~1221;1253~1290;1324~1380;1431~1650;1698~1790;1880~2020;2100~2200;2300~2450;2550~2750;2950~3250;3300~3350;
    3380~3420;3520~3800'


tclean(vis = visdata,
       imagename = 'IRAS.continuum',
       field = fieldname,
       spw = spwcont,
       specmode = 'mfs',
       deconvolver='hogbom',
       nterms=1,
       chanchunks=-1,
       gridder = 'mosaic',
       interactive = F,
       imsize = imagesize,
       cell = cellsize,
       phasecenter = phasecenter,
       weighting = 'briggs',
       robust = 0.5,
       pbcor=True,
       outframe='LSRK',
       niter=100)

```

ScriptForImaging.py

- UV Continuum subtraction

```
###Continuum subtraction for Line Imaging
fitspw = '0:0~200;300~350;500~800;1250~1600,1800~2100;2500~2700,2900~3200'
linespw = '0' # line spectral windows. You can subtract the continuum from multiple spectral line windows at once.

uvcontsub(vis=visdata,
          spw=linespw, # spw to do continuum subtraction on
          fitspw=fitspw, # select spws to fit continuum. exclude regions with strong lines.
          combine='spw',
          solint='int',
          fitorder=1,
          want_cont=False) # This value should not be changed.

```

want_cont=False

ScriptForImaging.py

```
##############################################
# Image line emission [REPEAT AS NECESSARY]

linevis = visdata + '.contsub'

##############################################
# Image CH3OH line emission

sourcename ='IRAS16293' # name of source
linename = 'Methanol' # name of transition (see science goals in OT for name)
lineimagename = sourcename+'_'+linename+'_image' # name of line image

restfreq='157.17902GHz' # Typically the rest frequency of the line of
                        # interest. If the source has a significant
                        # redshift (z>0.2), use the observed sky
                        # frequency (nu_rest/(1+z)) instead of the
                        # rest frequency of the
                        # line.

#start='-90km/s' # start velocity. See science goals for appropriate value.
#width='0.1km/s' # velocity width. See science goals.
#nchan = 1800  # number of channels. See science goals for appropriate value.
spwline='0' # uncomment and replace with appropriate spw if necessary.

tclean(vis=linevis,
       imagename=lineimagename,
       field=fieldname,
       spw=spwline,
       specmode='cube',
       deconvolver='hogbom',
       nterms=1,
       chanchunks=-1,
       phasecenter=phasecenter,
       #start=start,
       #width=width,
       #nchan=nchan,
       outframe='LSRK',
       veltype='radio',
       restfreq=restfreq,
       niter=100,
       #threshold=threshold,
       interactive=False,
       imsize = imagesize,
       cell = cellsize,
       weighting='briggs',
       robust=0.5,
       pbcor=True,
       gridder='mosaic')
```

ScriptForImaging.py

- PB Correction, and conversion to fits.

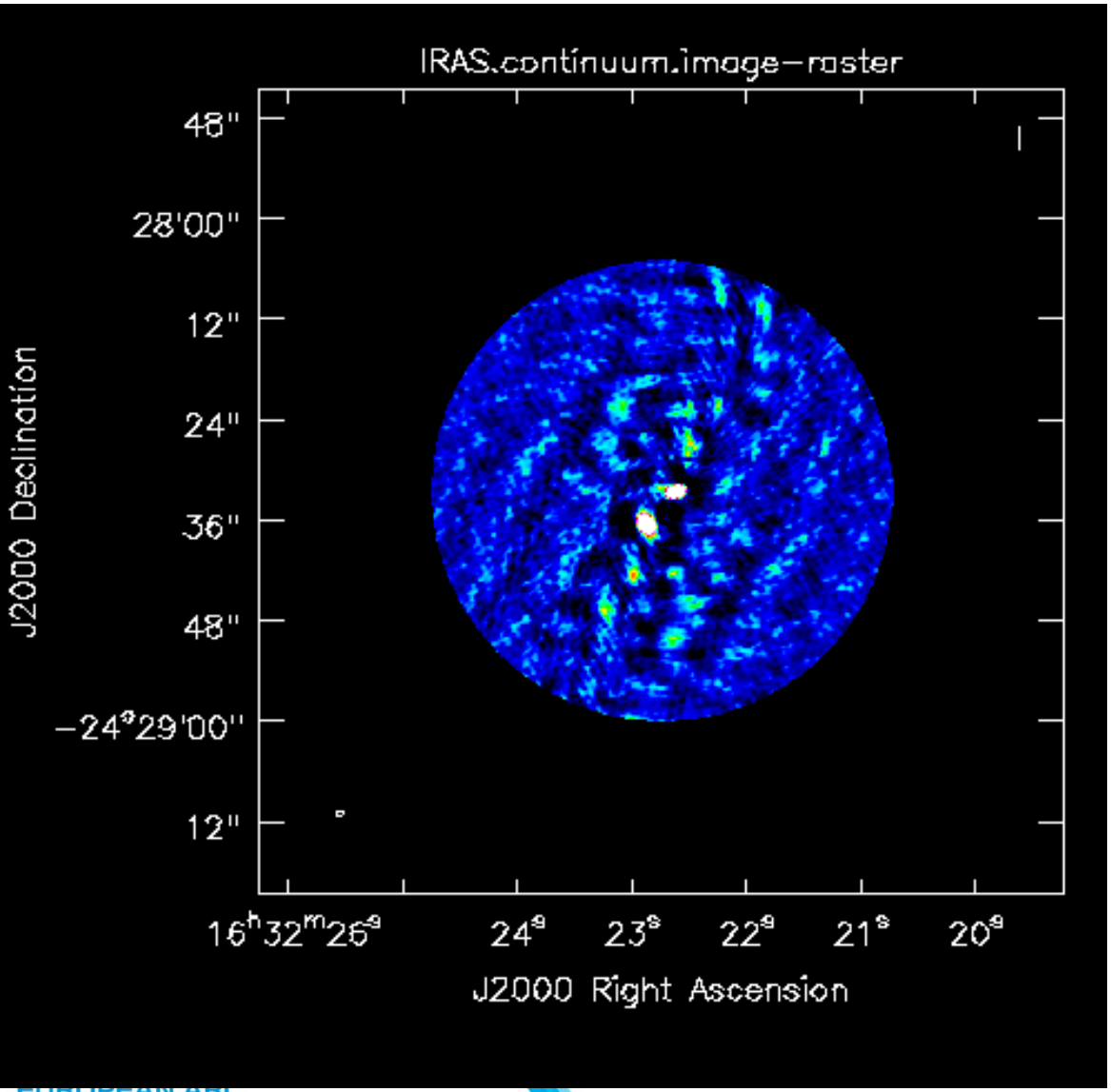
```
##Make pb correction, export fits.
for myimagebase in ['IRAS.continuum',lineimage]:
    print myimagebase
    # export the corrected image and the PB image
    exportfits(imagename=myimagebase+'.image.pbcor', fitsimage=myimagebase+'.image.pbcor.fits'
    exportfits(imagename=myimagebase+'.pb', fitsimage=myimagebase+'.flux.fits')
```

If you use clean, ALWAYS put “pbcor=False”.
For tclean you have to use “pbcor=True”

Continuum

```
clean(vis=msfile,
      imagename='continuum',
      field=thetarget,
      phasecenter=thephasecenter,
      spw=spwcont,
      mode='mfs',
      nterms=1,
      weighting='briggs',
      robust=0.5,
      threshold='2mJy',
      pbcor=False,
      imsize=[128,128],
      cell=['0.1arcsec'],
      psfmode='clark'
      imagermode='mosaic'
      interactive=True)
```

```
tclean(vis=ms1,
      imagename='continuum',
      field=thetarget,
      phasecenter=thephasecenter,
      spw=spwcont,
      specmode='mfs',
      nterms=1,
      weighting='briggs',
      robust=0.5,
      threshold='2mJy',
      pbcor=True,
      imsize=themosaicimsize,
      cell=thecellsize,
      deconvolver='hogbom',
      chanchunks=-1,
      gridder='mosaic',
      interactive=True)
```


IRAS.continuum.image-raster
48"
28'00"
12"
24"
36"
48"
−24°29'00"
12"
J2000 Declination
16h32m26s
24s
23s
22s
21s
20s
J2000 Right Ascension

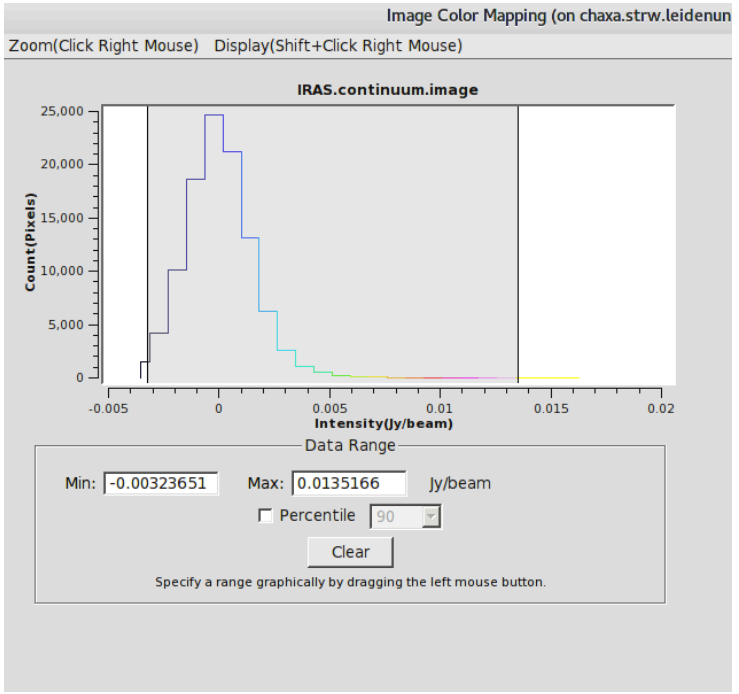


Image Color Mapping (on chaxa.strw.leidenun
Zoom(Click Right Mouse) Display(Shift+Click Right Mouse)
IRAS.continuum.image
25,000
20,000
15,000
10,000
5,000
0
Count(Pixels)
-0.005
0
0.005
0.01
0.015
0.02
Intensity(Jy/beam)
Data Range
Min: -0.00323651
Max: 0.0135166
Jy/beam
Percentile
90
Clear
Specify a range graphically by dragging the left mouse button.

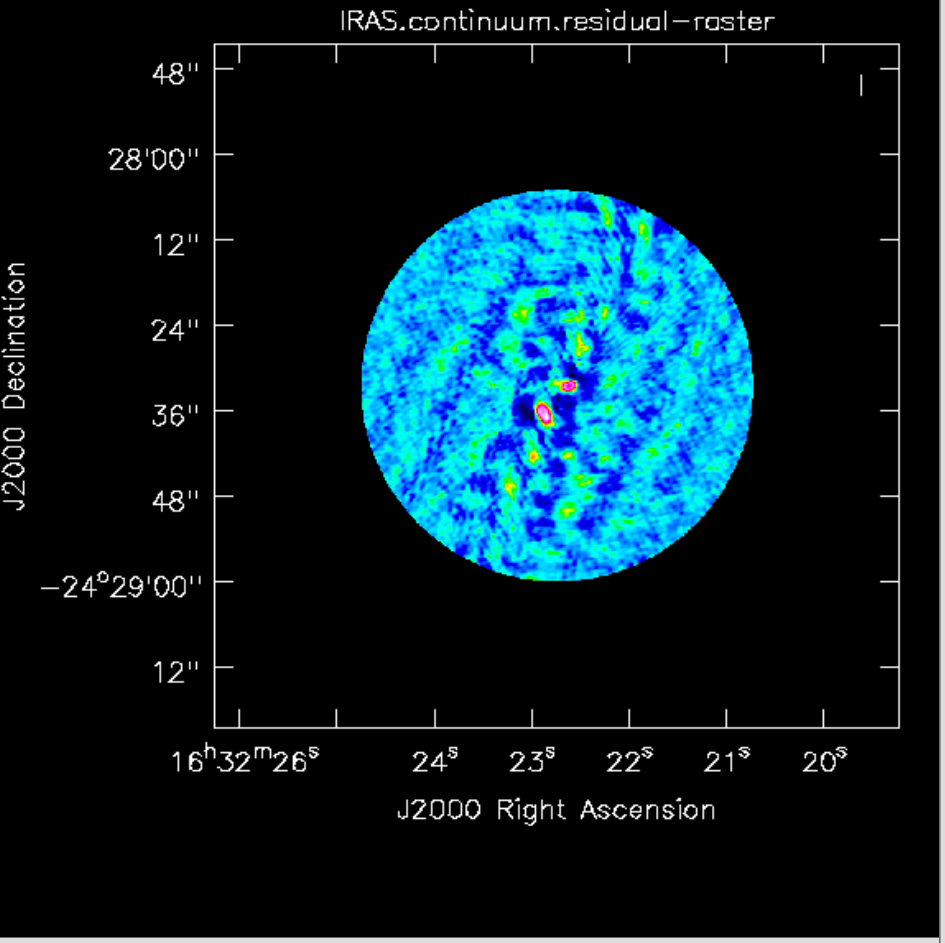
Viewer Display Panel (q2) (on chaxa.strw.leidenuniv.nl)

Data Display Panel Tools View Help

Add / Erase | This Channel / All Channels | This Polarization / All Polarizations | Next Action:

max cycleniter	iterations left	threshold	cyclethreshold
100	100	0Jy	0.00227476Jy

Display



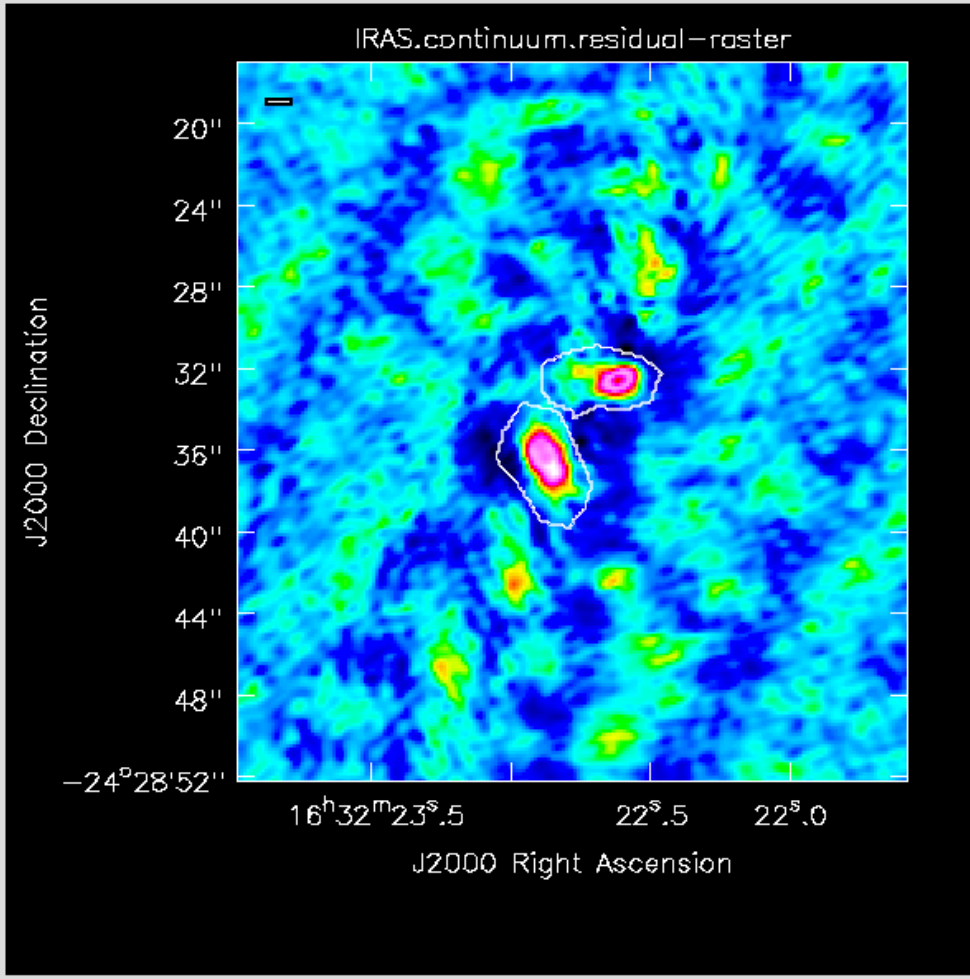
Viewer Display Panel (q2) (on chaxa.strw.leidenuniv.nl)

Data Display Panel Tools View Help

Add / Erase | This Channel / All Channels | This Polarization / All Polarizations | Next Action:

max cycleniter	iterations left	threshold	cyclethreshold
100	100	0Jy	0.00227476Jy

Display



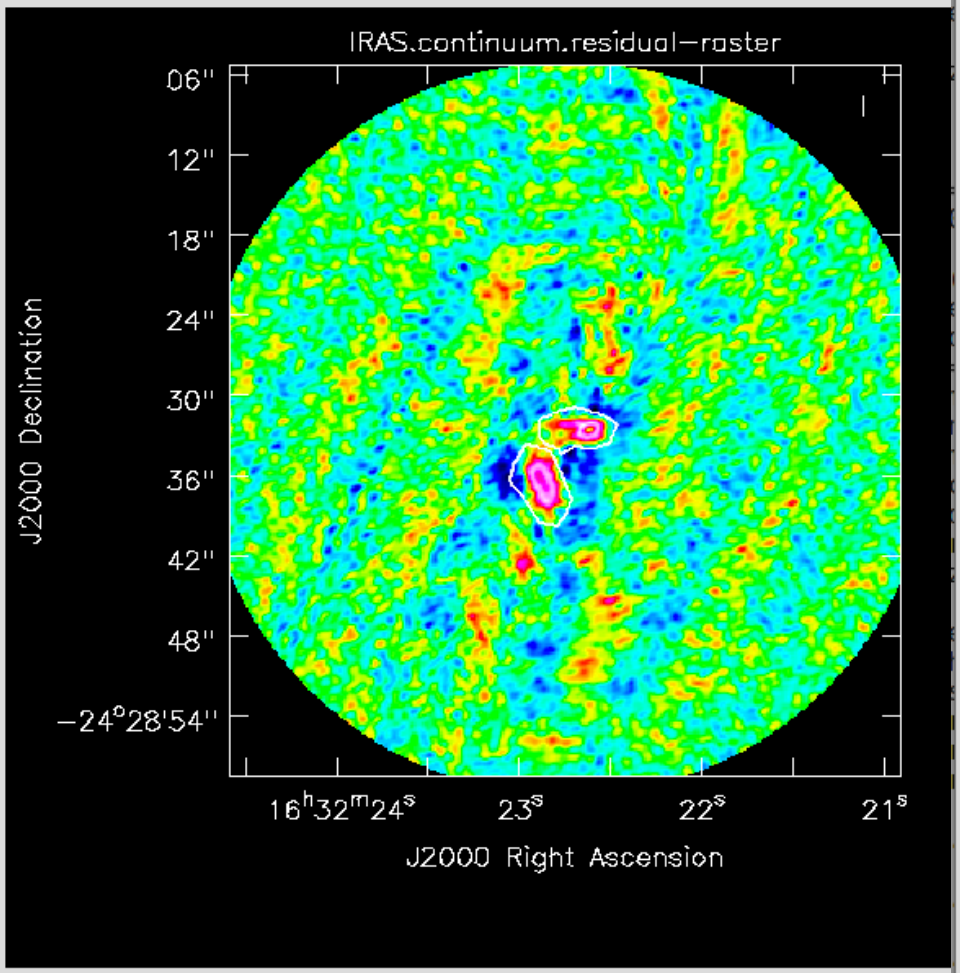
Viewer Display Panel (q2) (on chaxa.strw.leidenuniv.nl)

Data Display Panel Tools View Help

Add Erase | This Channel All Channels | This Polarization All Polarizations | Next Action:

max cycleniter	iterations left	threshold	cyclethreshold
100	0	0Jy	0.00103942Jy

Display



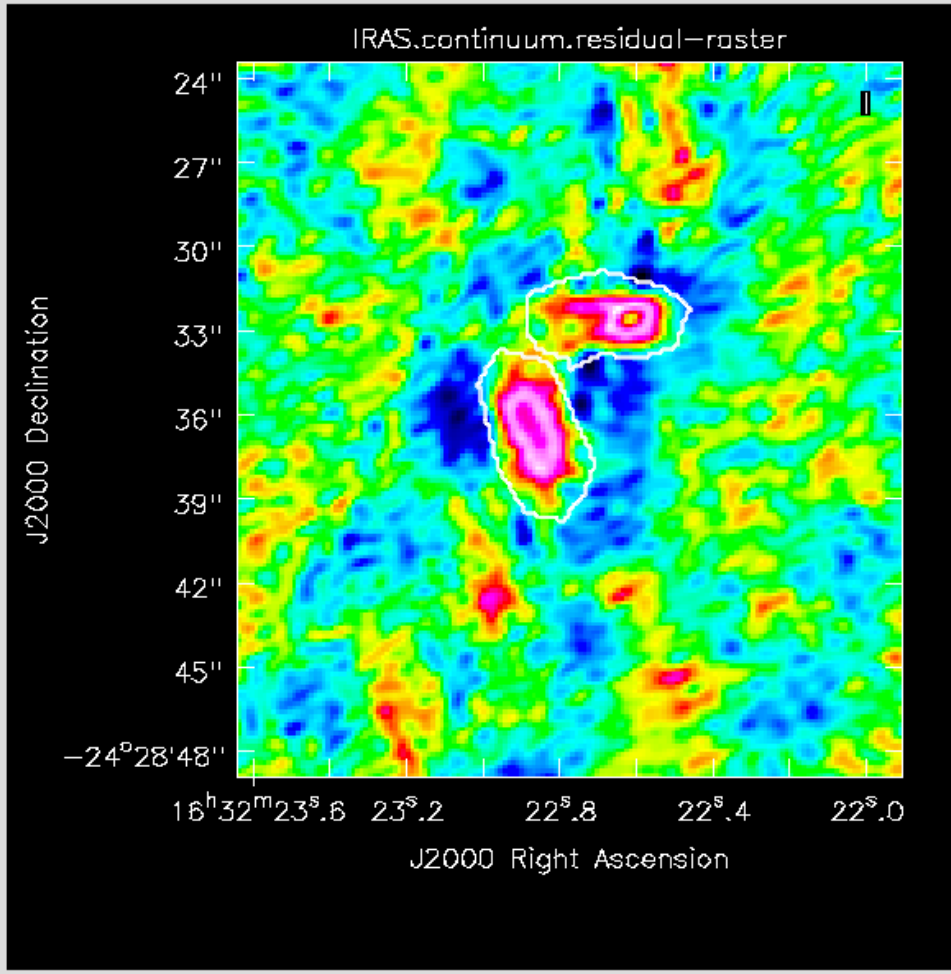
Viewer Display Panel (q2) (on chaxa.strw.leidenuniv.nl)

Data Display Panel Tools View Help

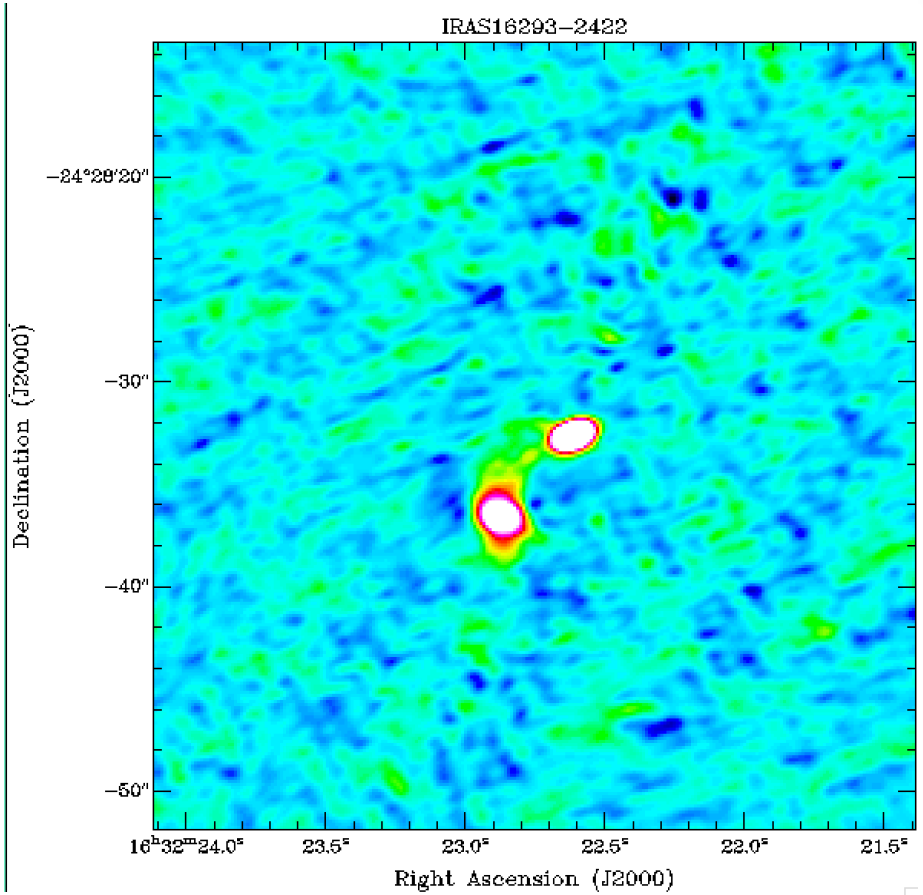
Add Erase | This Channel All Channels | This Polarization All Polarizations | Next Action:

max cycleniter	iterations left	threshold	cyclethreshold
100	0	0Jy	0.00103942Jy

Display



Cleaning…



To really get rid of the artefact seen here we need to self-calibrate the image

Lines

```
clean( vis=ms1,
    imagename=thetarget+_C18O',
    field=thetarget,
    spw="2",
    mode="velocity",
    width="0.096km/s",
    start=-9.6km/s,
    nchan=200,
    outframe=theoutframe,
    veltype="radio",
   niter=1000,
   threshold="14mJy",
   psfmode="clark",
   imagermode="mosaic",
   interactive=True,
   imsize=themosaicimsize,
   cell=thecellsize,
  phasecenter=thephasecenter,
   restfreq="219.56035GHz", # C18O 2-1
   weighting="briggs",
   robust=0.5 )
```

```
tclean( vis=ms1,
      imagename=thetarget+_C18O-tclean,
      field=thetarget,
      spw=[ 2 ],
      specmode=cube,
      width=0.096km/s,
      start=-9.6km/s,
      nchan=200,
      outframe=LSRK,
      niter=1000,
      threshold=14mJy,
      deconvolver=hogbom,
      gridder=mosaic,
      pbcor=True,
      chanchunks=-1,
      interactive=True
      imsize=themosaicimsize,
      cell=thecellsize,
      phasecenter=thephasecenter,
      restfreq="219.56035GHz", # C18O
      weighting=briggs,
      robust=0.5 )
```

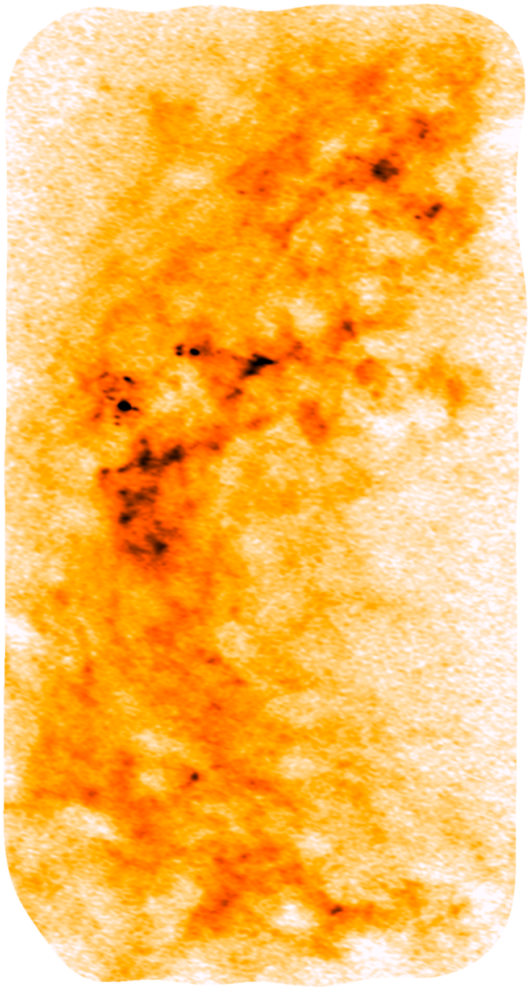
Weighting

- Natural:
  - Visibilities are weighted by the data weights, it will give the best signal-to-noise ratio and the worst angular resolution
- Uniform:
  - All cell have the same weigth
  - Makes the resolution finer, but this will increase the noise
- “briggs”:
  - Intermediate weighting, depending on the value of the robust. -2 more like the uniform, 2 more like natural
- Tapering:
  - Outer tapering only supported, which will reduce the weight of the longest baselines, thus increasing the sensitivity to the large-scale emission.
  - It will increase the noise

Creating Masks

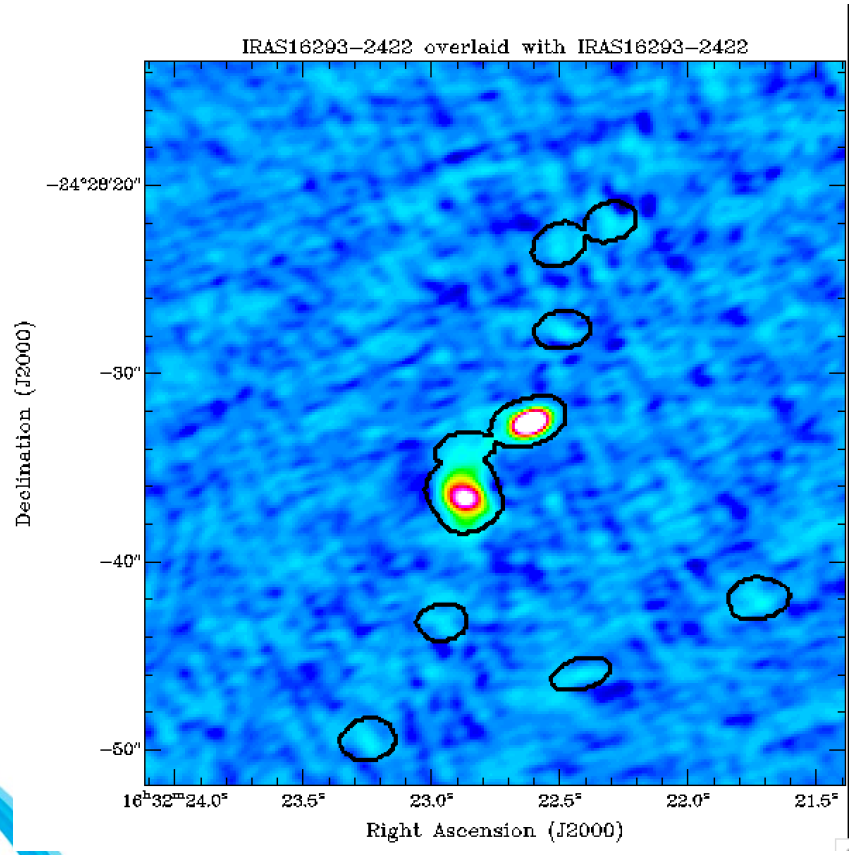
- MANUAL CLEANING
- MASKS BASED ON FLUX THRESHOLD
- TCLEAN: **AUTOMASK**

https://casaguides.nrao.edu/index.php/Automasking_Guide



Auto Masking

Useful for cleaning of line channels.
Explore well the parameters —-> easy to get wrong masks



Thing to consider

- The size of the image have to be at least twice the size of your primary beam
- To create the continuum do not flag the data, it is best to use the continuum channels as input into CLEAN (old scripts used to flag data instead)