Data Processing: Imaging

If multiple measurement sets are available for a target, it is necessary to concatenate the data before imaging the data. (This is not the case for the example.)

Concatenation can be performed with the following command:

```
concat(vis=['uid1.ms,uid2.ms‘],concatvis=‘calibrated.ms’)
```

Any old calibrated.ms files should be deleted before running this command.

Interferometry data are converted into images using a process called cleaning. This serves two purposes:

- It converts the visibility (phase and amplitude data) into signal on the sky plane.
- It restructures the beam (point spread function) of the data so that the beam is Gaussian in shape.

Cleaning is done using either the old clean command or the new tclean command. The example tclean command for the continuum imaging looks like the following:

```
tclean(
  vis='uid___A002_Xb4264b_X946.ms.split.cal', #Input filename
  imagename='NGC3169.continuum',             #Output filename
  field='2',                                 #Fields to be imaged
  gridder='standard',                        #Projection method
  phasecenter=2,                             #Centre position of image
  imsize=[500, 500],                         #Image size in pixels
  cell='0.1arcsec',                          #Pixel scale  pbcor=True,
  pblimit=0.0,                               #PB gain level at which to cut
                                             #  off normalization
  spw='0,1,2,3:0~1200;2500~3839',            #Spectral windows to image
  specmode='mfs',                            #Imaging mode (continuum)
  outframe='lsrk',                           #Velocity frame of image
  deconvolver='hogbom',                      #Cleaning algorithm
  nterms=1,                                  #Number of Taylor coefficients
                                             #  in spectral slope
  chanchunks=-1,                             #Chunking for gridding
channels
  niter=100,                                 #Maximum number of iterations
  threshold='0.1mJy',                        #Stopping threshold
  weighting='natural',                       #Cleaning weights
  interactive=F                              #Interactive mode setting
  )
```

The various options for tclean in this example have been reorganized into rough groups:

- Input/output information
- Image plane settings
- Spectral dimension settings
- Deconvolution options

Input/Output Information

`vis`	Input filename
`imagename`	Output filename

Image plane settings

`field`	Fields to be imaged
`gridder`	Projection method (tclean only)
`phasecenter`	Centre position of image
`imsize`	Image size in pixels
`cell`	Pixel scale
`pbcor`	Setting to apply PB correction
`pblimit`	PB gain level at which to cut off normalization (tclean only)

Important points on image plane settings

- The `gridder` should be set to “standard” for single pointings and “mosaic” for multiple pointings.
- The `phasecenter` can be specified either by a field number or by coordinates (which may be necessary when working with multiple pointings).
- The `cell` value should be at least 2× (and preferable 3-4×) the size of the beam.
- It is recommended to apply the primary beam (PB) correction.

Spectral dimension settings

`spw`	Spectral windows to image
`specmode`	Spectral imaging mode (`mode` in clean)
`start`	Staring point of spectral cube
`nchan`	Number of spectral cube channels
`width`	Width of spectral cube channels
`outframe`	Velocity frame
`restfreq`	Rest frequency of reference line (optional)

Important points on spectral dimension settings

- The `specmode` should be set to "mfs" for continuum images and "cube" for spectral cube. The older clean command had multiple options instead of "cube", such as "frequency", "velocity", and "channel".
- The `start`, `nchan`, and `width` options should be set for spectral cubes but not for continuum images.
- The `outframe` should be set just to avoid confusion. Currently, tclean only supports "lsrk", but for clean, "lsrk" is recommended for galactic objects and "bary" for extragalactic objects.

Important points on spectral dimension settings

- The `restfreq` is optional. The CASA software will be able to perform some additional meaningful unit conversions between frequency and velocity if this is given.

Deconvolution options

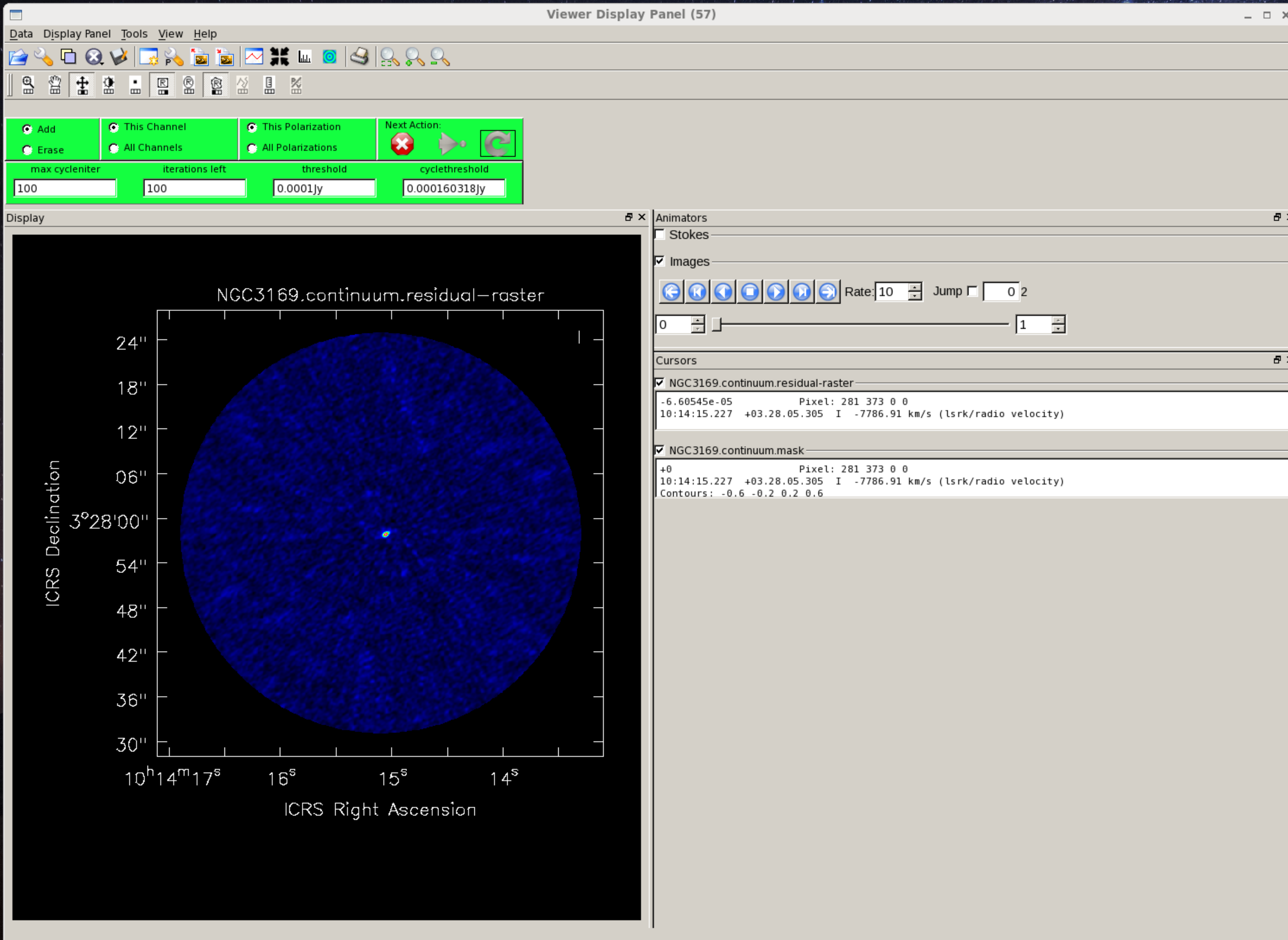
`deconvolver`	Cleaning algorithm (`imagermode` in clean)
`nterms`	Number of Taylor coefficients in spectral slope (tclean only)
`chanchunks`	Chunking for gridding channels (tclean only)
`niter`	Maximum number of iterations
`threshold`	Stopping threshold
`weighting`	Cleaning weights
`interactive`	Interactive mode setting

Important points on deconvolution options

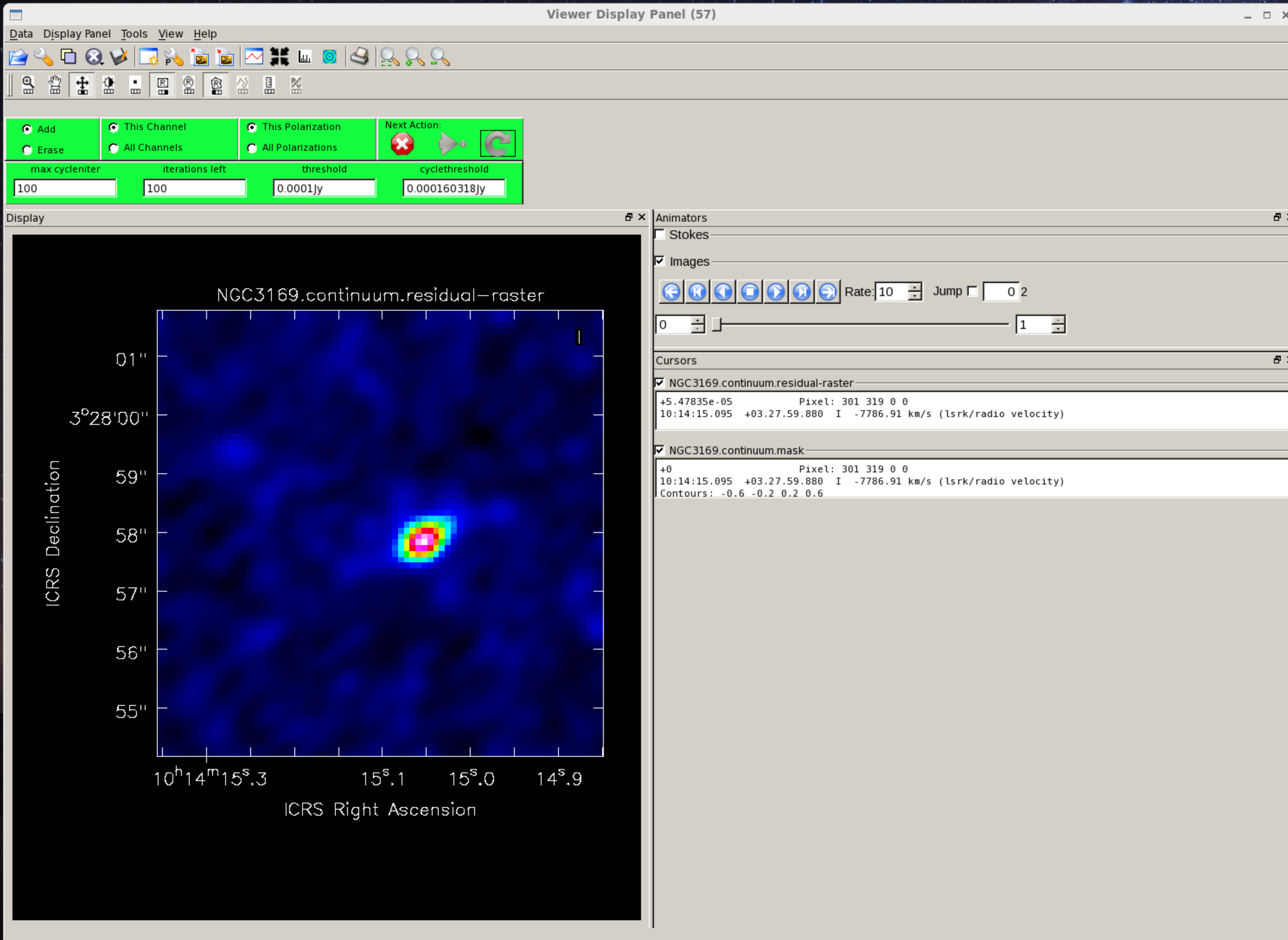
- The `weighting` is very important. Three standard options are used in radio interferometry.
  - Natural weighting is based on not altering the weights of data points in the uv plane. This results in images with more large-scale structure
  - Uniform weighting is based on altering the weights to account for the lack of data on long baselines in the uv plane (thus making the uv plane appear "uniform"). This results in images with more small-scale structure, but ALMA image with uniform weights tend to look too noisy.
  - Briggs weighting allows for adjusting between these two extremes. The `robust` parameter can be used to adjust between these extremes, with "2" equivalent to natural and "-2" equivalent to uniform. A `robust` value of "0.5" is used in most ALMA QA2 imaging.

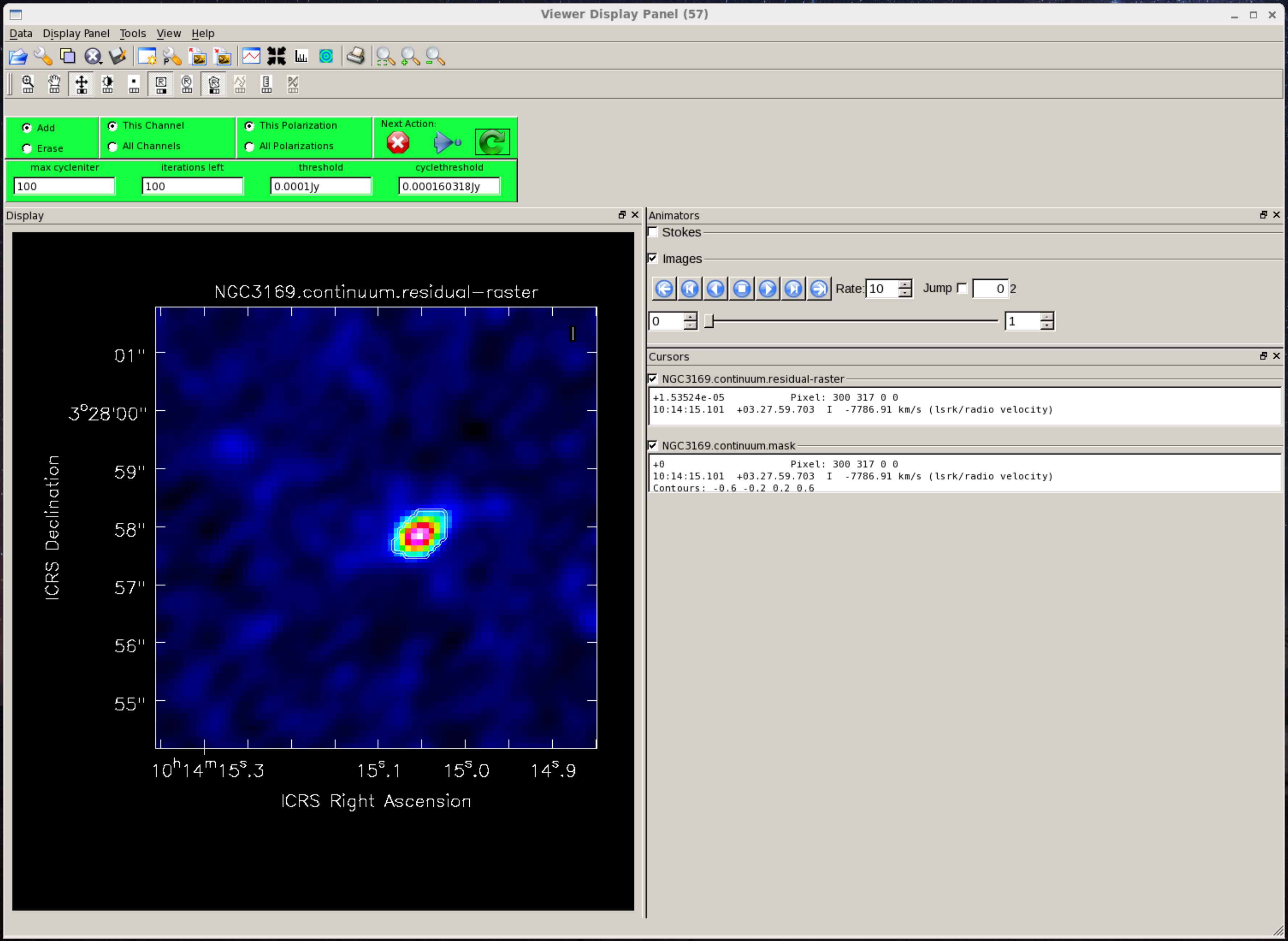
Cleaning is an iterative process in which the following is done in each iteration:

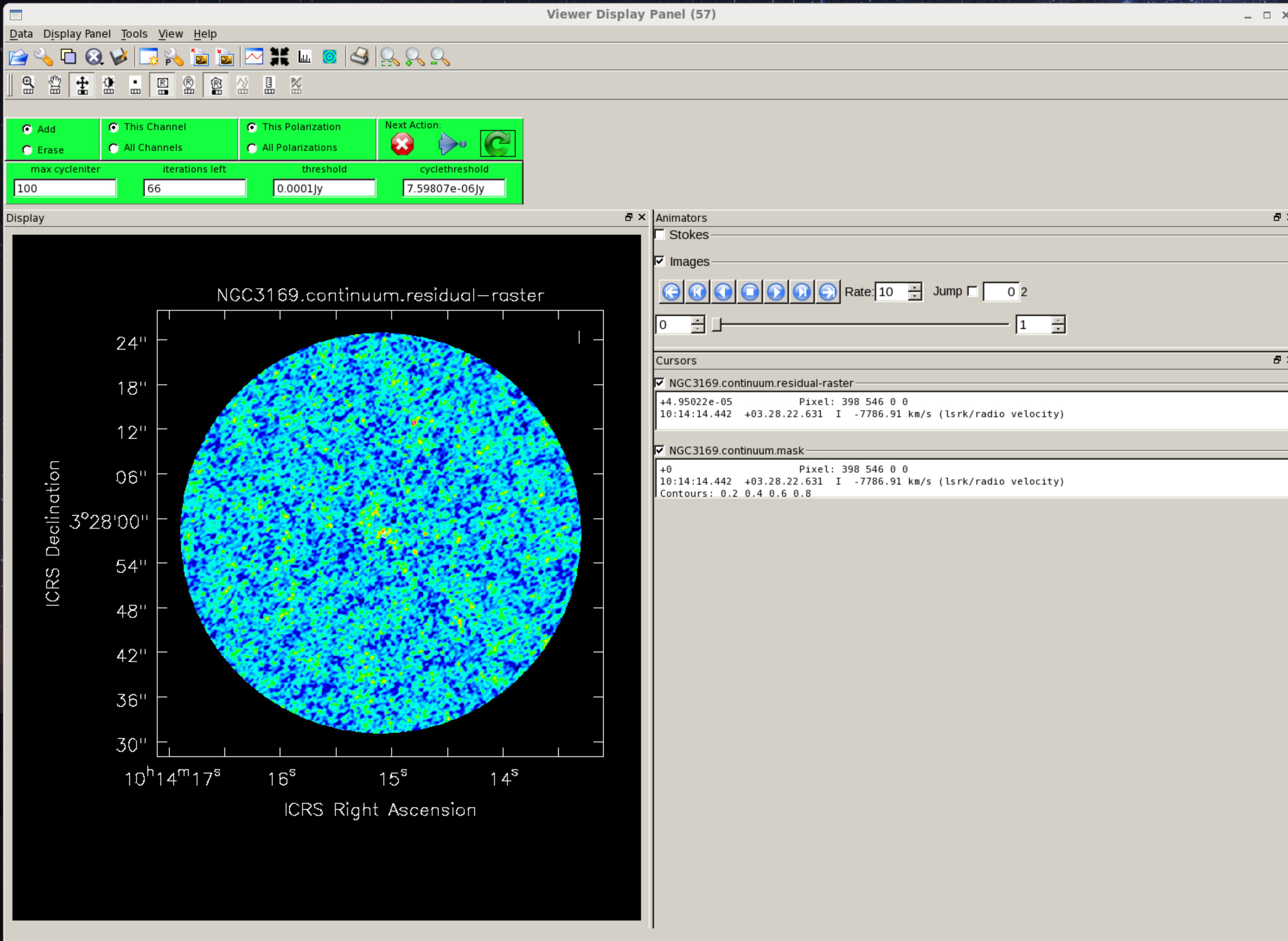
- An image is displayed.
- Either the user or the program identifies sources and masks them.
- Using the identified sources, the algorithm models and removes them from the image, producing a residual image that is used at the beginning of the cycle.



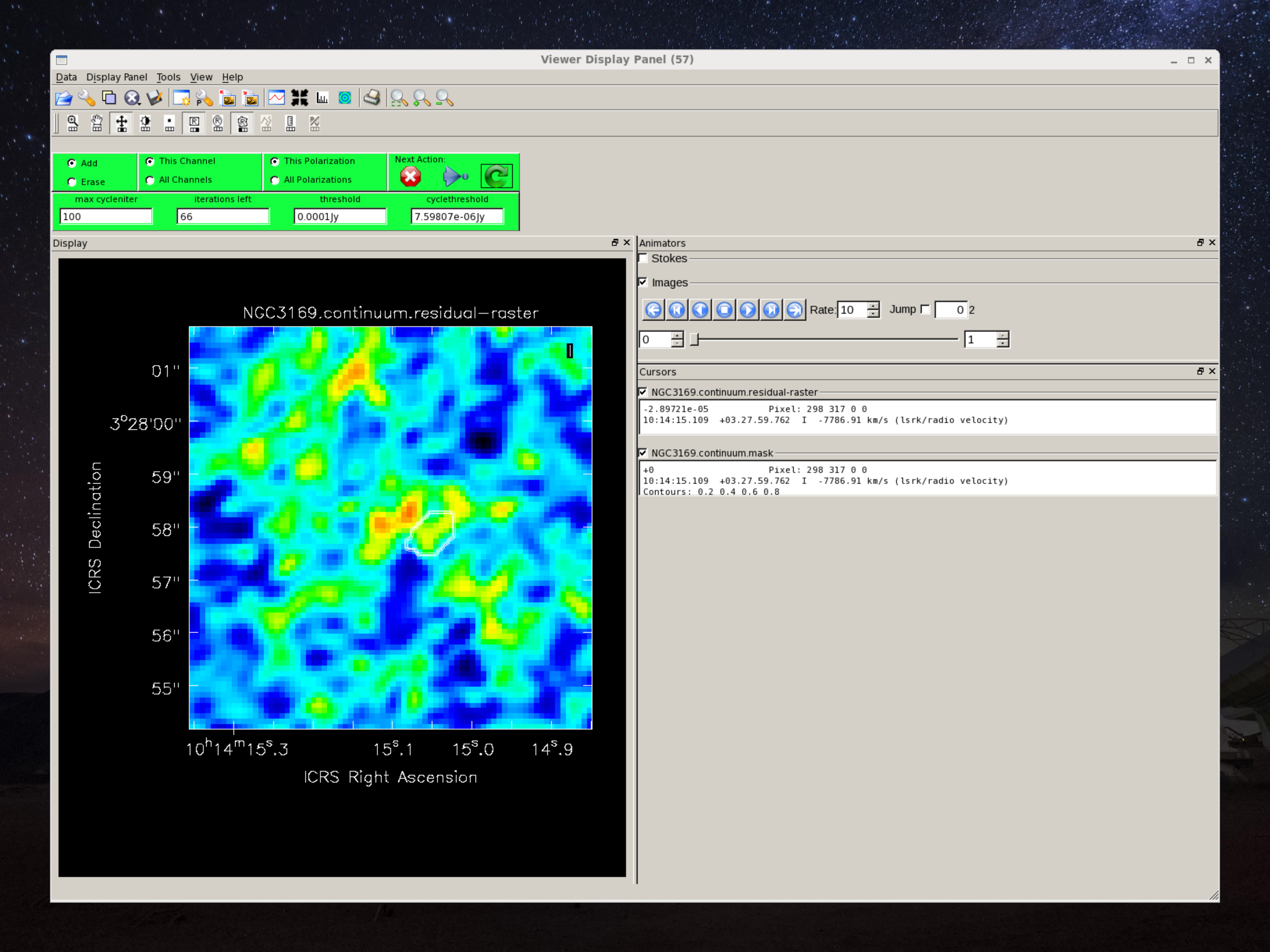
Viewer Display Panel (57)
Data
Display Panel
Tools
View
Help
Add
Erase
This Channel
All Channels
This Polarization
All Polarizations
Next Action:
max cycleniter
iterations left
threshold
cyclethreshold
100
100
0.0001Jy
0.000160318Jy
Display
NGC3169.continuum.residual–raster
24"
18"
12"
06"
3°28'00"
54"
48"
42"
36"
30"
ICRS Declination
10h14m17s
16s
15s
14s
ICRS Right Ascension
Animators
Stokes
Images
Rate: 10
Jump
0 2
0
1
Cursors
NGC3169.continuum.residual-raster
-6.60545e-05 Pixel: 281 373 0 0
10:14:15.227 +03.28.05.305 I -7786.91 km/s (lsrk/radio velocity)
NGC3169.continuum.mask
+0 Pixel: 281 373 0 0
10:14:15.227 +03.28.05.305 I -7786.91 km/s (lsrk/radio velocity)
Contours: -0.6 -0.2 0.2 0.6


Viewer Display Panel (57)
Data Display Panel Tools View Help
Add
Erase
This Channel
All Channels
This Polarization
All Polarizations
Next Action:
max cycleniter
100
iterations left
100
threshold
0.0001Jy
cyclethreshold
0.000160318Jy
Display
NGC3169.continuum.residual−raster
01''
3°28'00''
59''
58''
57''
56''
55''
ICRS Declination
10h14m15s.3
15s.1
15s.0
14s.9
ICRS Right Ascension
Animators
Stokes
Images
Rate: 10
Jump
0 2
0
1
Cursors
NGC3169.continuum.residual-raster
+5.47835e-05 Pixel: 301 319 0 0
10:14:15.095 +03.27.59.880 I -7786.91 km/s (lsrk/radio velocity)
NGC3169.continuum.mask
+0 Pixel: 301 319 0 0
10:14:15.095 +03.27.59.880 I -7786.91 km/s (lsrk/radio velocity)
Contours: -0.6 -0.2 0.2 0.6


Viewer Display Panel (57)
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
0.0001Jy
0.000160318Jy
Display
NGC3169.continuum.residual-raster
01"
3°28'00"
59"
58"
57"
56"
55"
ICRS Declination
10h14m15s.3
15s.1
15s.0
14s.9
ICRS Right Ascension
Animators
Stokes
Images
Rate: 10
Jump
0 2
0
1
Cursors
NGC3169.continuum.residual-raster
+1.53524e-05 Pixel: 300 317 0 0
10:14:15.101 +03.27.59.703 I -7786.91 km/s (lsrk/radio velocity)
NGC3169.continuum.mask
+0 Pixel: 300 317 0 0
10:14:15.101 +03.27.59.703 I -7786.91 km/s (lsrk/radio velocity)
Contours: -0.6 -0.2 0.2 0.6

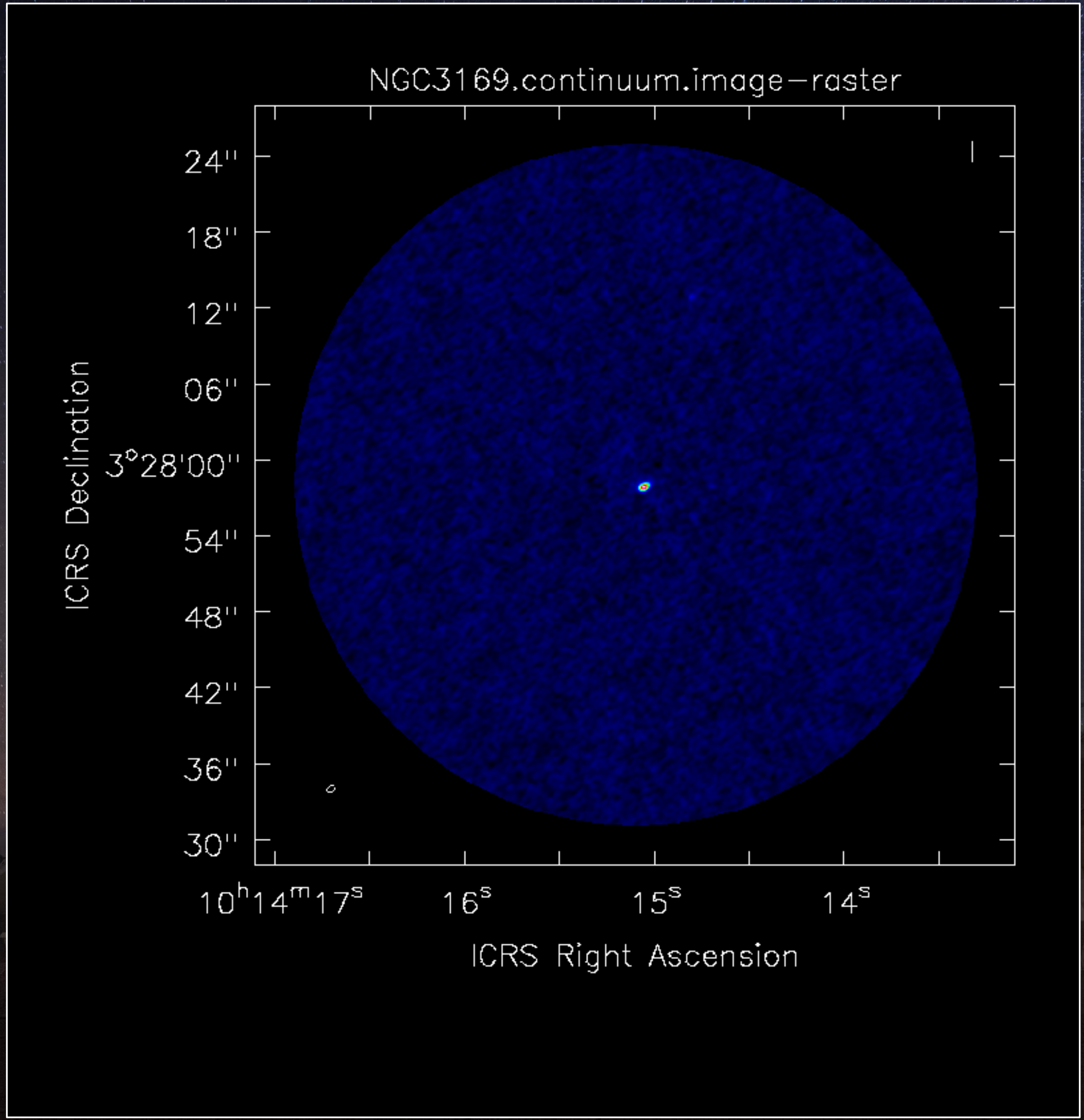


Viewer Display Panel (57)
Data Display Panel Tools View Help
Add
Erase
This Channel
All Channels
This Polarization
All Polarizations
Next Action:
max cycleniter
100
iterations left
66
threshold
0.0001Jy
cyclethreshold
7.59807e-06Jy
Display
NGC3169.continuum.residual−raster
24"
18"
12"
06"
3°28'00"
54"
48"
42"
36"
30"
ICRS Declination
10h14m17s
16s
15s
14s
ICRS Right Ascension
Animators
Stokes
Images
Rate: 10
Jump
0 2
0
1
Cursors
NGC3169.continuum.residual-raster
+4.95022e-05 Pixel: 398 546 0 0
10:14:14.442 +03.28.22.631 I -7786.91 km/s (lsrk/radio velocity)
NGC3169.continuum.mask
+0 Pixel: 398 546 0 0
10:14:14.442 +03.28.22.631 I -7786.91 km/s (lsrk/radio velocity)
Contours: 0.2 0.4 0.6 0.8

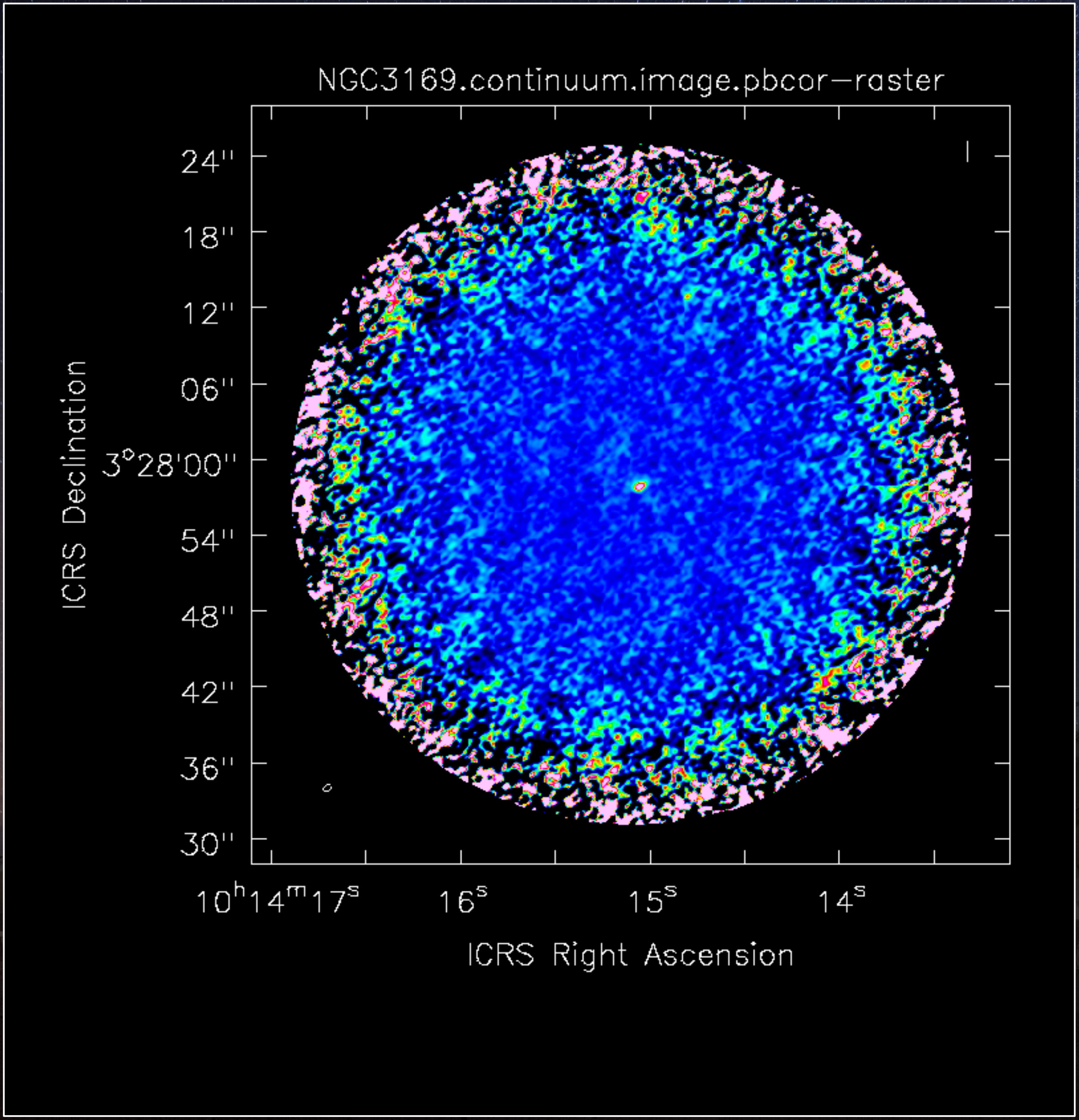

Viewer Display Panel (57)
Data Display Panel Tools View Help
Add
Erase
This Channel
All Channels
This Polarization
All Polarizations
Next Action:
max cycleniter
100
iterations left
66
threshold
0.0001Jy
cyclethreshold
7.59807e-06Jy
Display
NGC3169.continuum.residual-raster
01"
3°28'00"
59"
58"
57"
56"
55"
ICRS Declination
10h14m15s.3
15s.1
15s.0
14s.9
ICRS Right Ascension
Animators
Stokes
Images
Rate: 10
Jump
0 2
0
1
Cursors
NGC3169.continuum.residual-raster
-2.89721e-05 Pixel: 298 317 0 0
10:14:15.109 +03.27.59.762 I -7786.91 km/s (lsrk/radio velocity)
NGC3169.continuum.mask
+0 Pixel: 298 317 0 0
10:14:15.109 +03.27.59.762 I -7786.91 km/s (lsrk/radio velocity)
Contours: 0.2 0.4 0.6 0.8

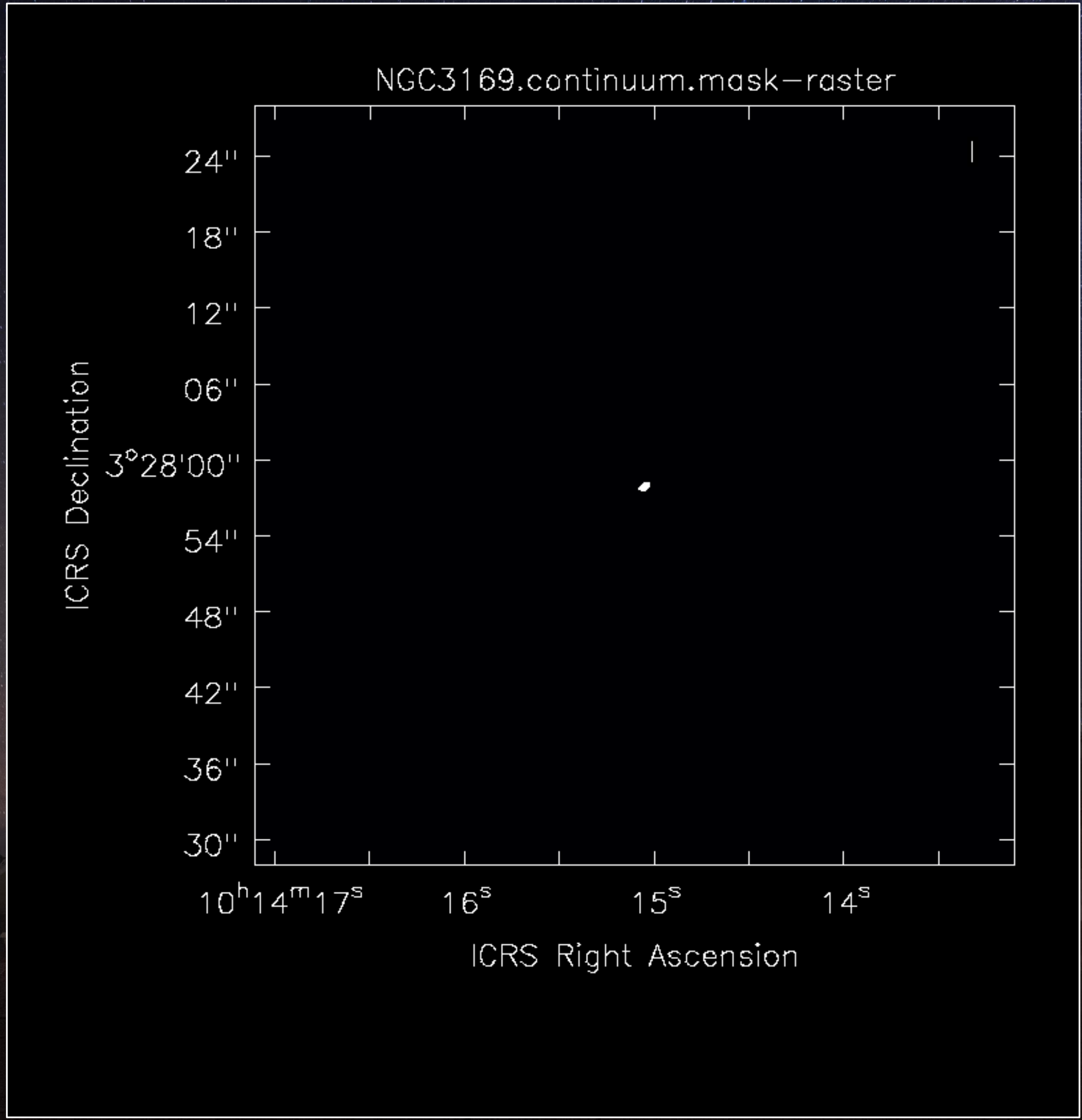
Multiple files are created after cleaning:

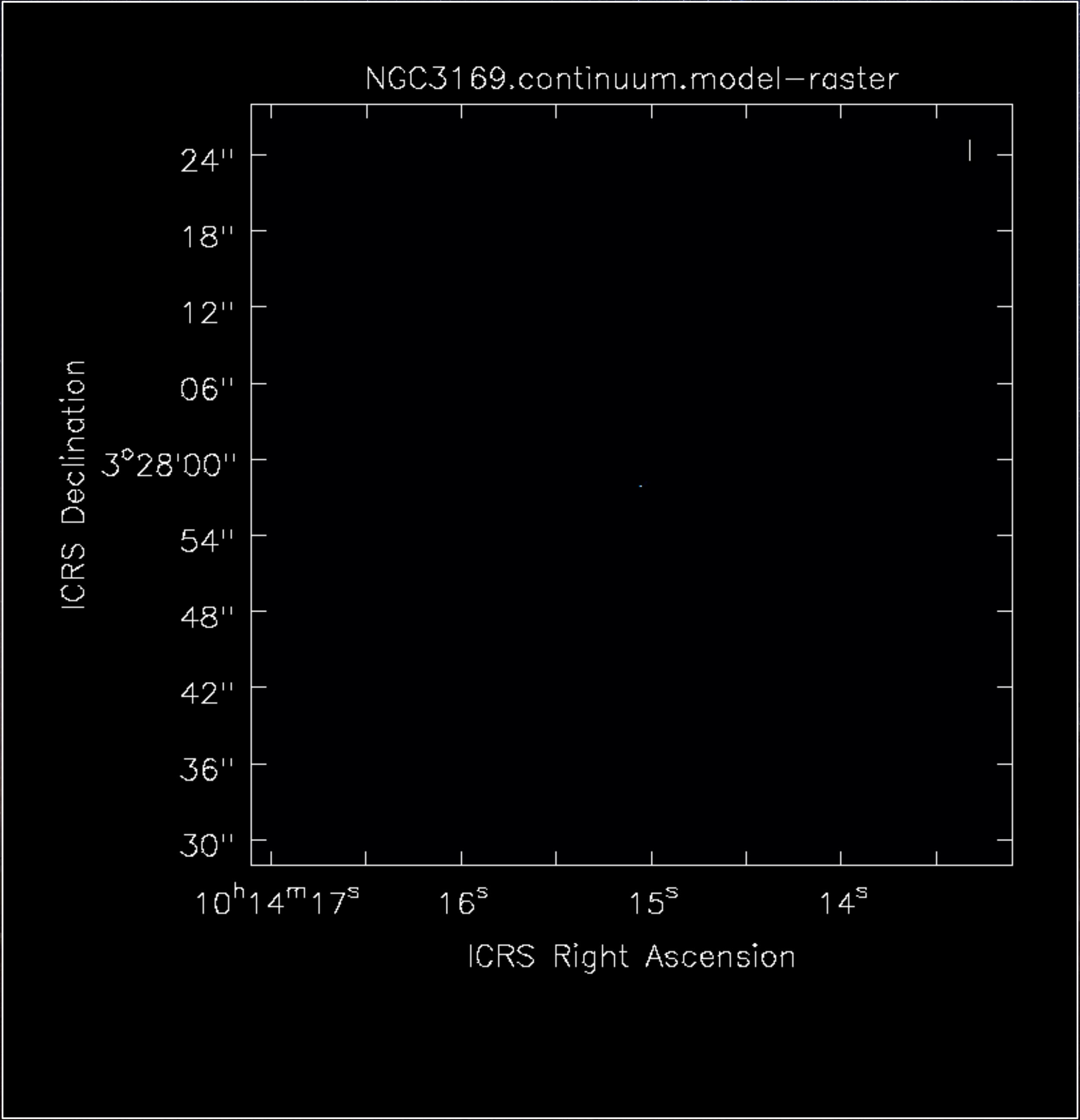
- image — Science image
- image.pbcor — Science image with a PB correction
- mask — Image mask created while cleaning
- model — Model of the emission used for deconvolution
- pb — Primary beam (area where the telescope was sensitive)
- psf — Beam before cleaning
- residual — Residuals after the final iteration of cleaning

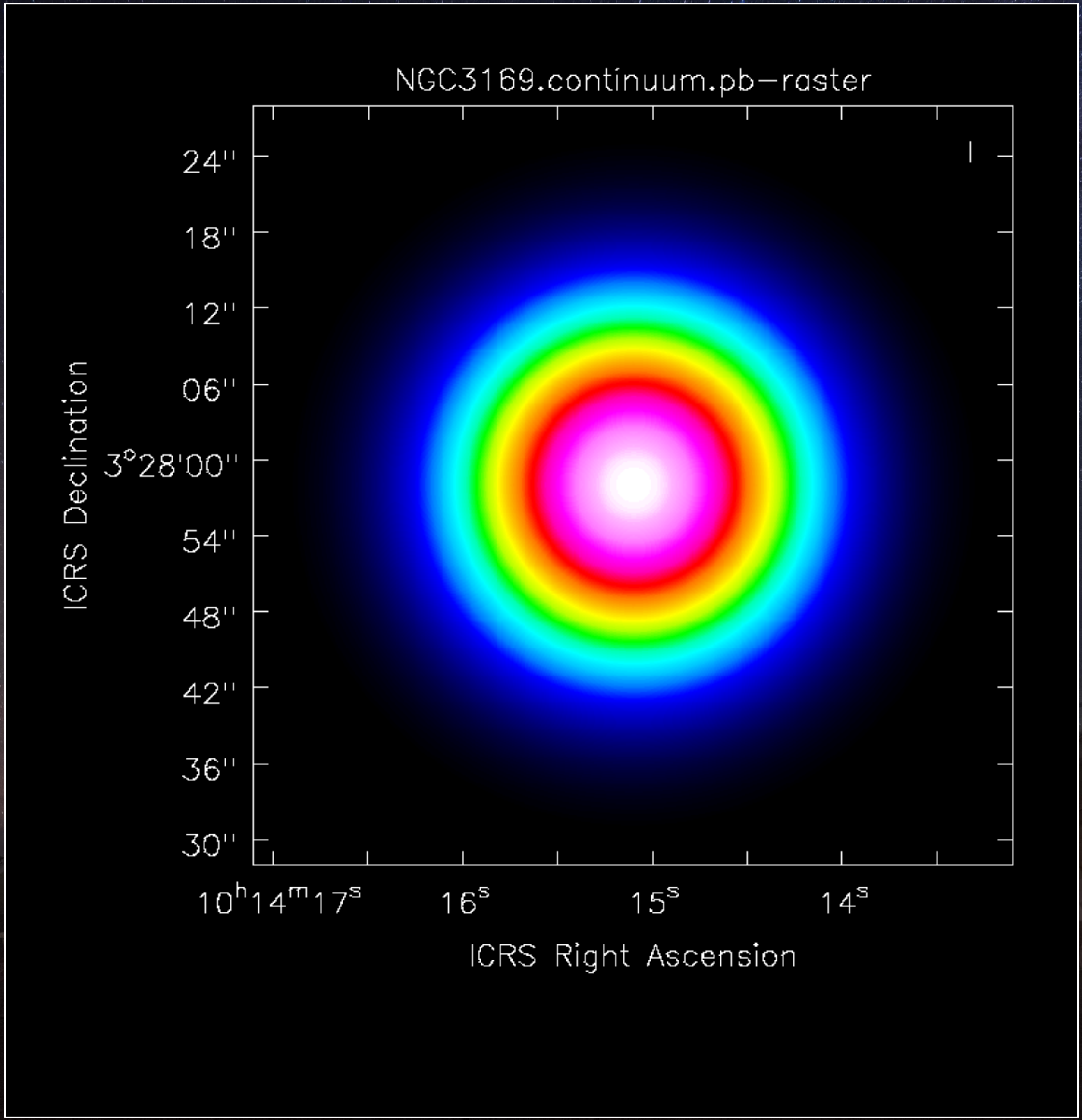


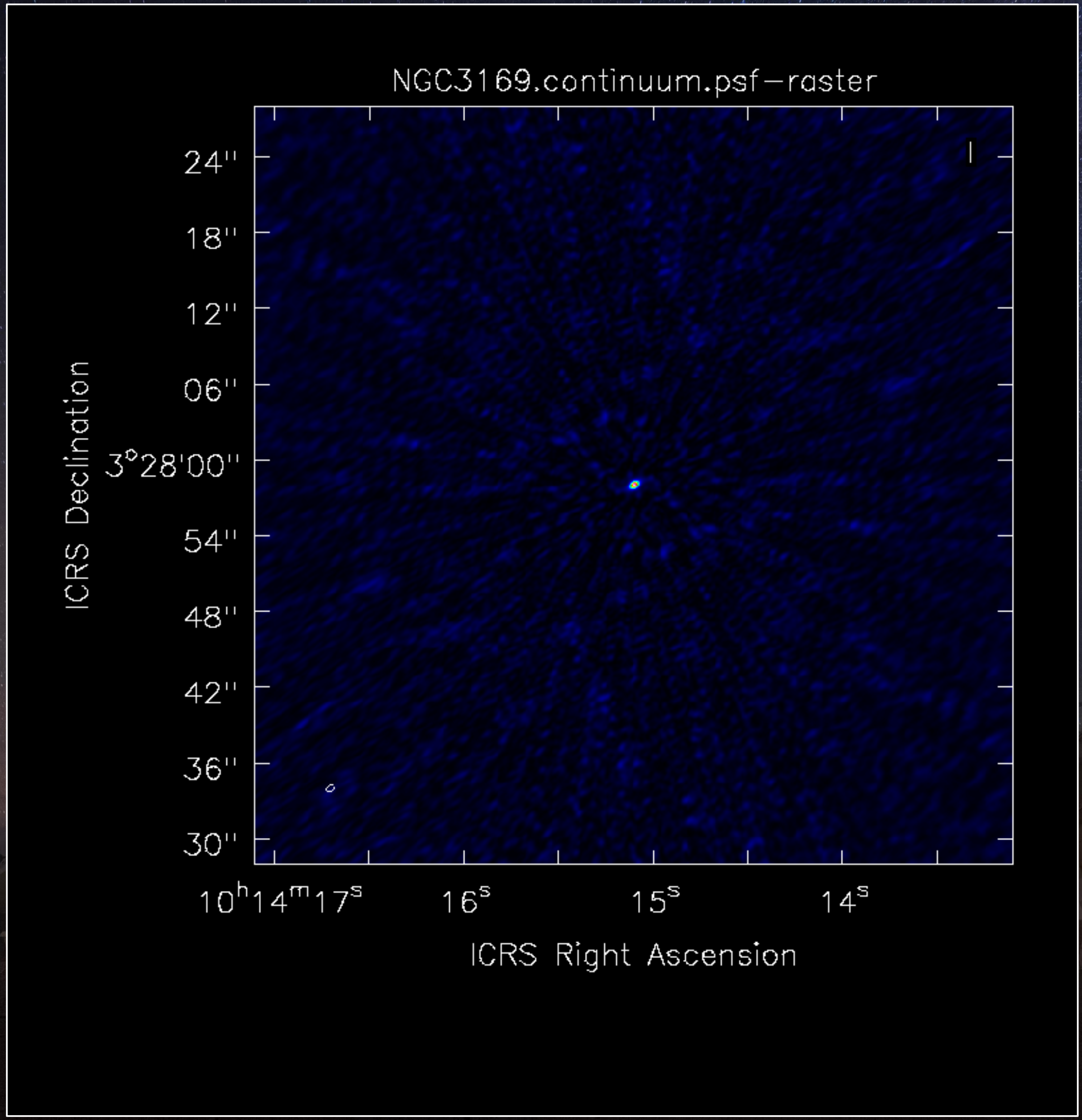
NGC3169.continuum.image-raster
ICRS Declination
24''
18''
12''
06''
3°28'00''
54''
48''
42''
36''
30''
10h14m17s
16s
15s
14s
ICRS Right Ascension

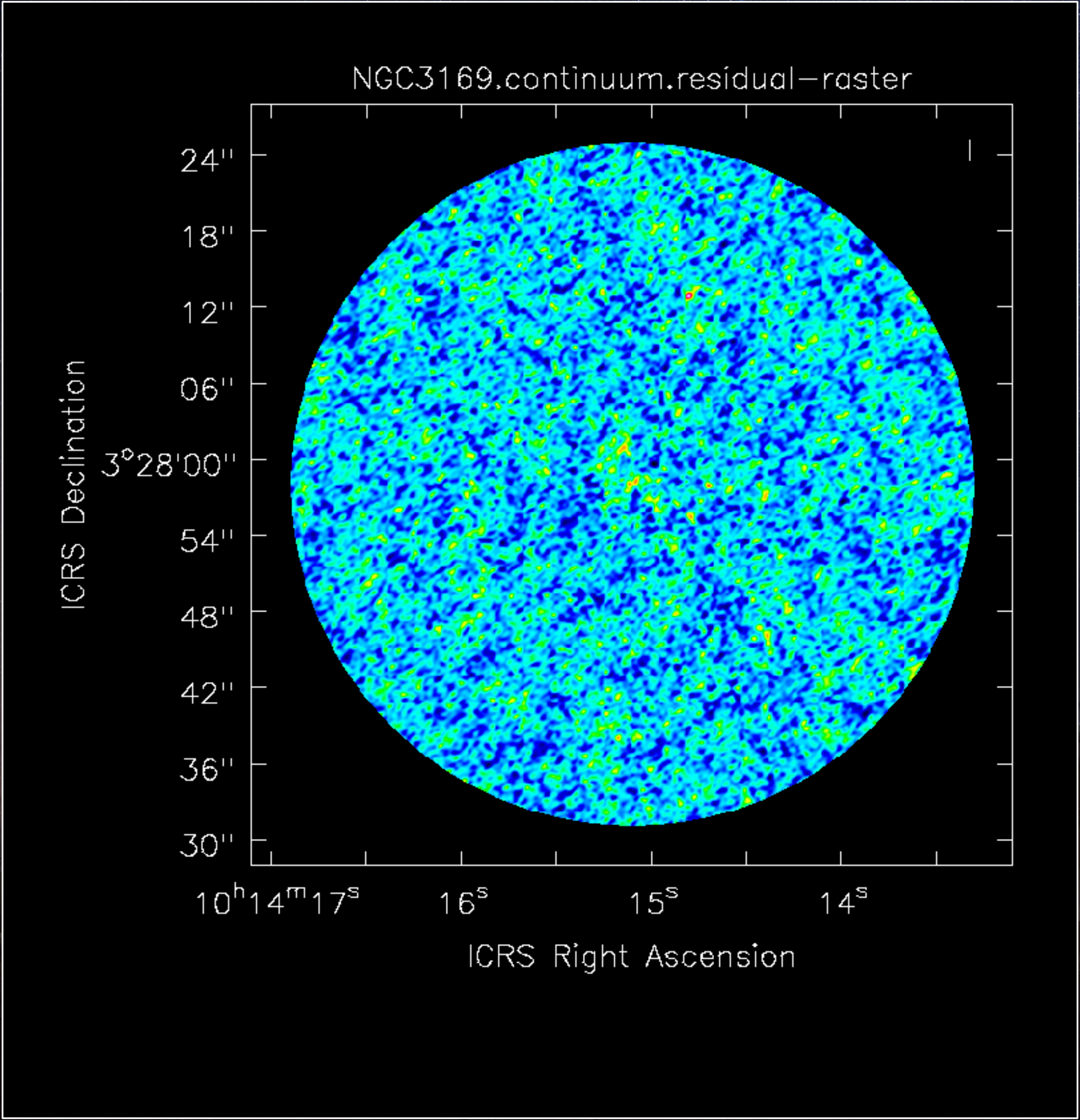

NGC3169.continuum.image.pbcor—raster
24''
18''
12''
06''
3°28'00''
54''
48''
42''
36''
30''
ICRS Declination
10h14m17s
16s
15s
14s
ICRS Right Ascension


NGC3169.continuum.mask−raster
24''
18''
12''
06''
3°28'00''
54''
48''
42''
36''
30''
ICRS Declination
10h14m17s
16s
15s
14s
ICRS Right Ascension


NGC3169.continuum.model-raster
ICRS Declination
24''
18''
12''
06''
3°28'00''
54''
48''
42''
36''
30''
10h14m17s
16s
15s
14s
ICRS Right Ascension


NGC3169.continuum.pb-raster
ICRS Declination
24''
18''
12''
06''
3°28'00''
54''
48''
42''
36''
30''
10h14m17s
16s
15s
14s
ICRS Right Ascension


NGC3169.continuum.psf−raster
ICRS Declination
24''
18''
12''
06''
3°28'00''
54''
48''
42''
36''
30''
10ʰ14ᵐ17ˢ
16ˢ
15ˢ
14ˢ
ICRS Right Ascension



NGC3169.continuum.residual−raster
24''
18''
12''
06''
3°28'00''
54''
48''
42''
36''
30''
ICRS Declination
10h14m17s
16s
15s
14s
ICRS Right Ascension

Imaging tips

- Try using different weights (natural or briggs with different robust values) to bring out emission on different spatial scales.
- Attempt changing the channel width to improve the S/N of line emission.
- To identify artefacts (such as ripples across the map), try producing images using only subsets of the data.
- To check the reliability of the flux densities, try one of the following:
  - Produce images using subsets of the data.
  - Image the calibration sources and check the flux densities using aU.planetFlux or aU.getALMAflux.