ALMA Imaging

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If multiple measurement sets are available for a target, it may be appropriate 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.

When imaging one or more spectral lines, it may be appropriate to use contsub to subtract the continuum in the visibility data first.

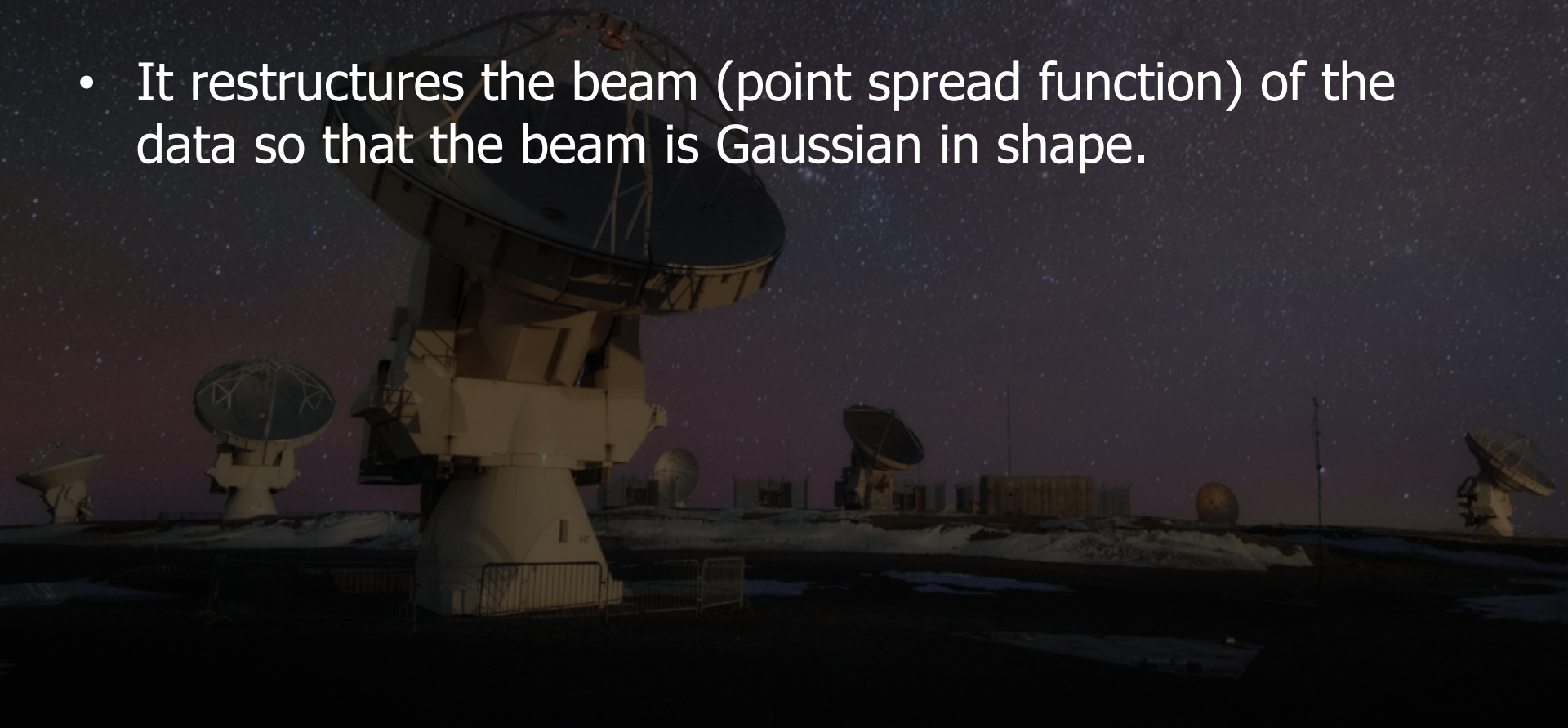
A typical approach to doing this is as follows:

- Create an image cube of the data without continuum subtraction.
- Identify the channels with continuum emission.
- Subtract the continuum with contsub.
- Image the continuum-subtracted data.

The continuum channels were identified in advance for this demonstration.

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.



The example script was created using the official script generator. Only very minor alterations have been made

The various options for tclean can be divided into roughly four groups:

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

Input/Output Information

`vis`	Input filename
`imagename`	Output filename

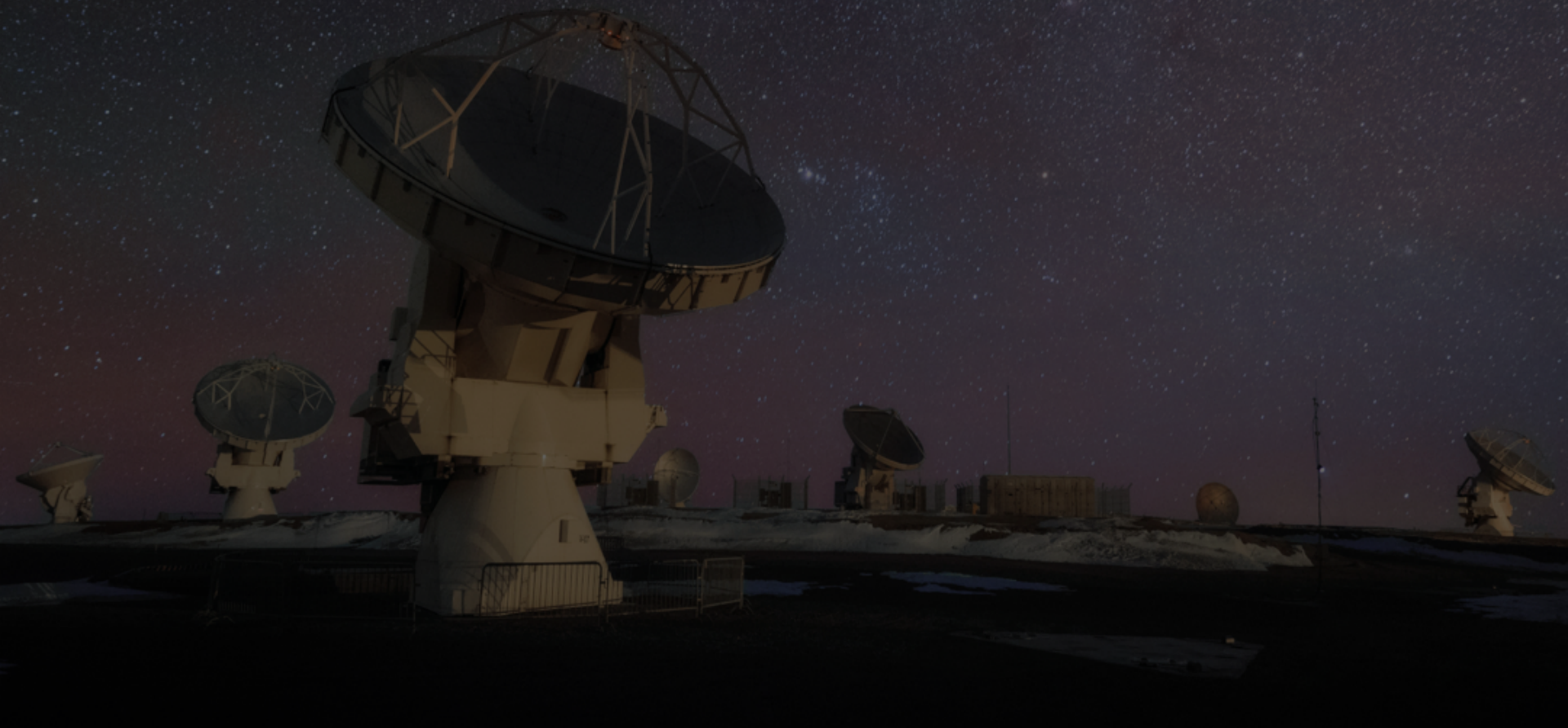


Image plane settings

`field`	Fields to be imaged
`stokes`	Stokes parameter to be imaged
`imsize`	Image size in pixels
`cell`	Pixel scale
`gridder`	Projection method
`pbcor`	Setting to apply PB correction
`phasecenter`	Centre position of image (not used in the example script)

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
`outframe`	Velocity frame
`restfreq`	Rest frequency of reference line (optional)
`specmode`	Spectral imaging mode
`nterms`	Number of Taylor coefficients in spectral slope (only when mtmfs is used for specmode)
`start`	Staring point of spectral cube (not used in the example script)
`nchan`	Number of spectral cube channels
`width`	Width of spectral cube channels

Important points on spectral dimension settings

- The `outframe` should be set just to avoid confusion. The recommended value is "LSRK".
- 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.
- The `specmode` should be set to "mtmfs" or "mfs" for continuum images and "cube" for spectral cube.
- The `start`, `nchan`, and `width` options should be set for spectral cubes but not for continuum images. Omitting `start` and setting `nchan` to -1 will image the entire spectral window.

Deconvolution options

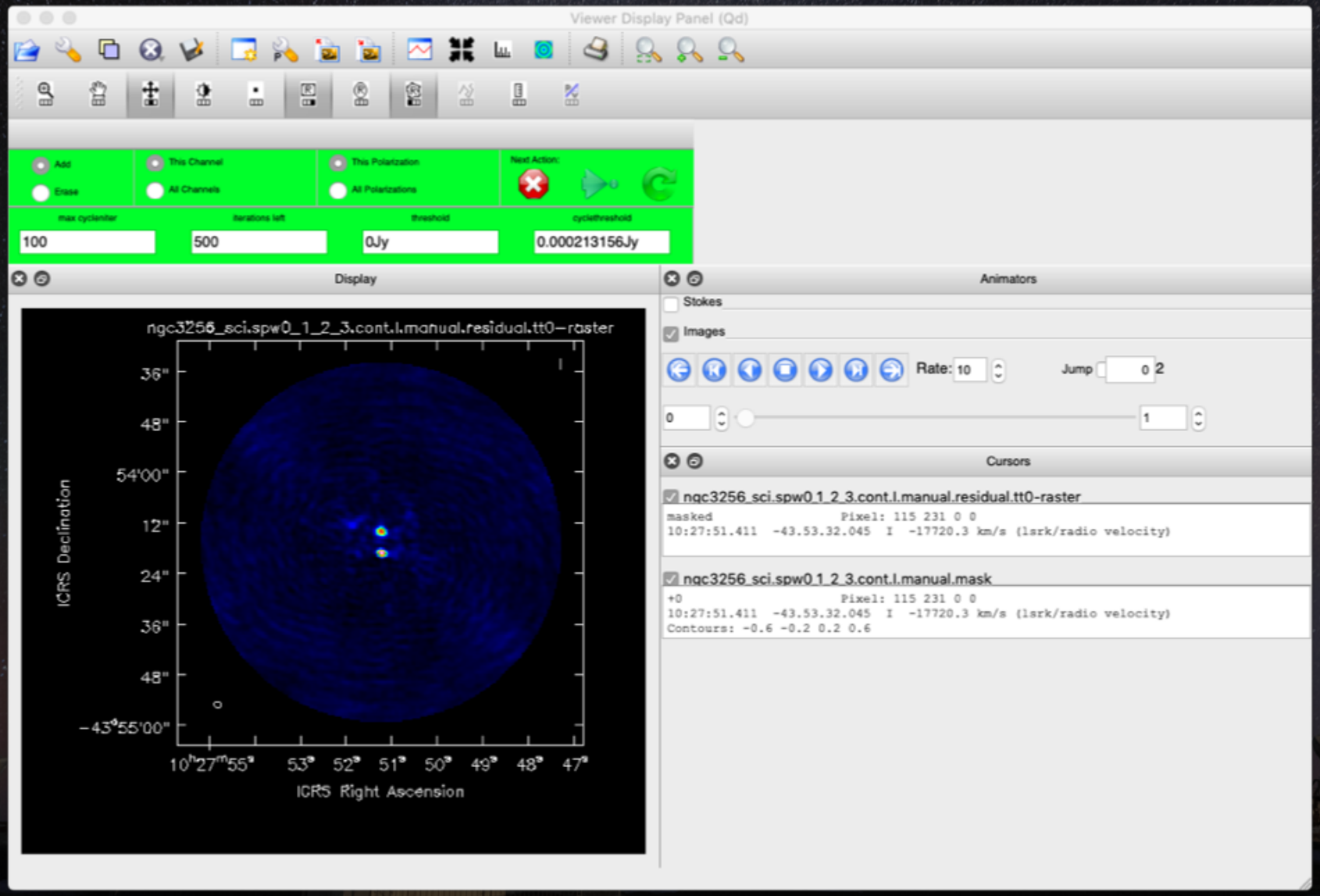
`deconvolver`	Cleaning algorithm
`niter`	Maximum number of iterations
`weighting`	Cleaning weights
`robust`	Adjustment factor for Briggs weighting
`mask`	Mask for identifying known sources
`threshold`	Stopping threshold
`interactive`	Interactive mode setting

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 frequently used in ALMA 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 (Qd)
Add
Erase
This Channel
All Channels
This Polarization
All Polarizations
Next Action:
max cycleniter
iterations left
threshold
cyclethreshold
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Display
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ICRS Declination
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ICRS Right Ascension
Animators
Stokes
Images
Rate: 10
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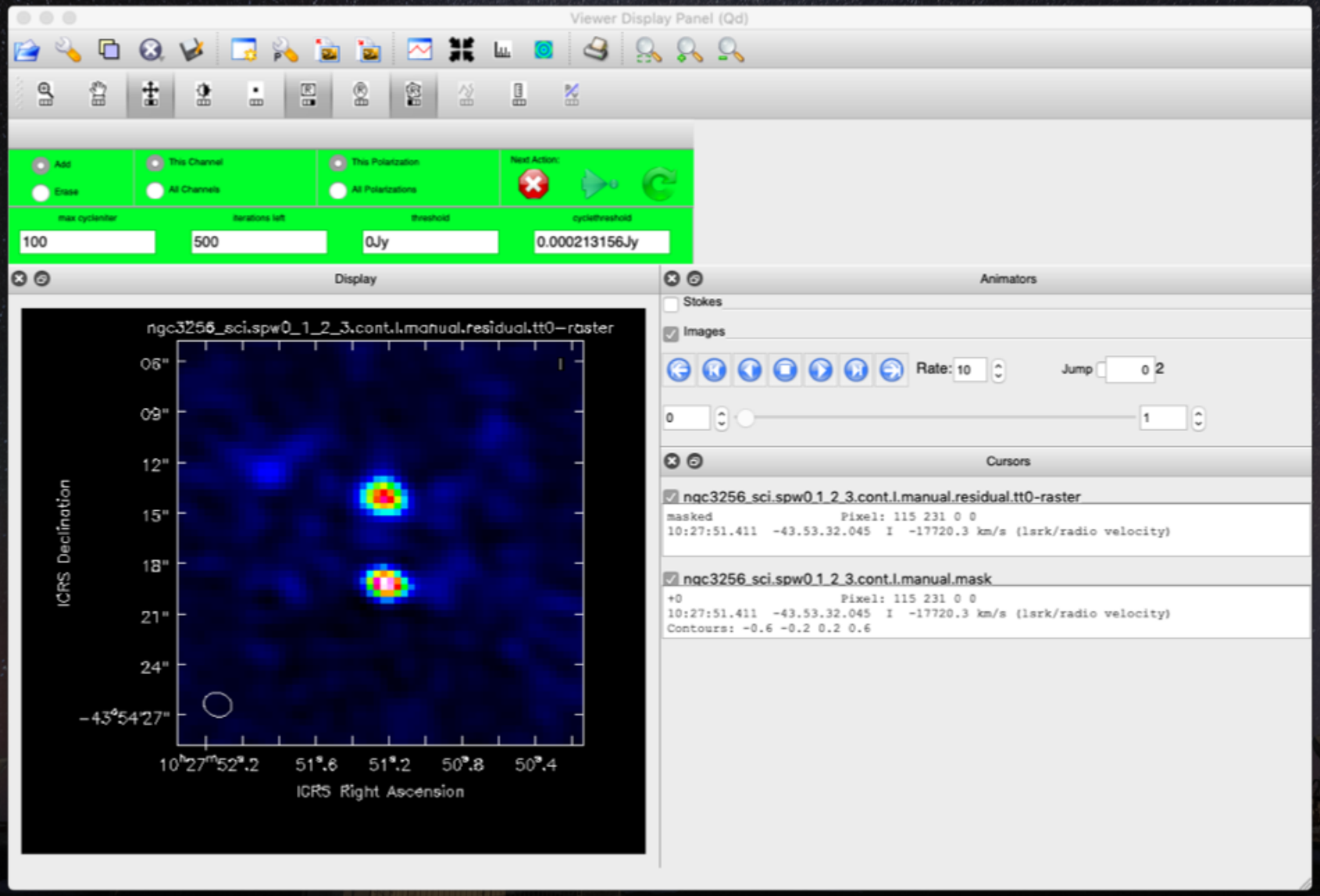
Cursors
ngc3256_sci.spw0_1_2_3.cont.I.manual.residual.tt0-raster
masked Pixel: 115 231 0 0
10:27:51.411 -43.53.32.045 I -17720.3 km/s (lsrk/radio velocity)
ngc3256_sci.spw0_1_2_3.cont.I.manual.mask
+0 Pixel: 115 231 0 0
10:27:51.411 -43.53.32.045 I -17720.3 km/s (lsrk/radio velocity)
Contours: -0.6 -0.2 0.2 0.6


Viewer Display Panel (Qd)
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All Channels
This Polarization
All Polarizations
Next Action:
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iterations left
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ICRS Right Ascension
Animators
Stokes
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Rate: 10
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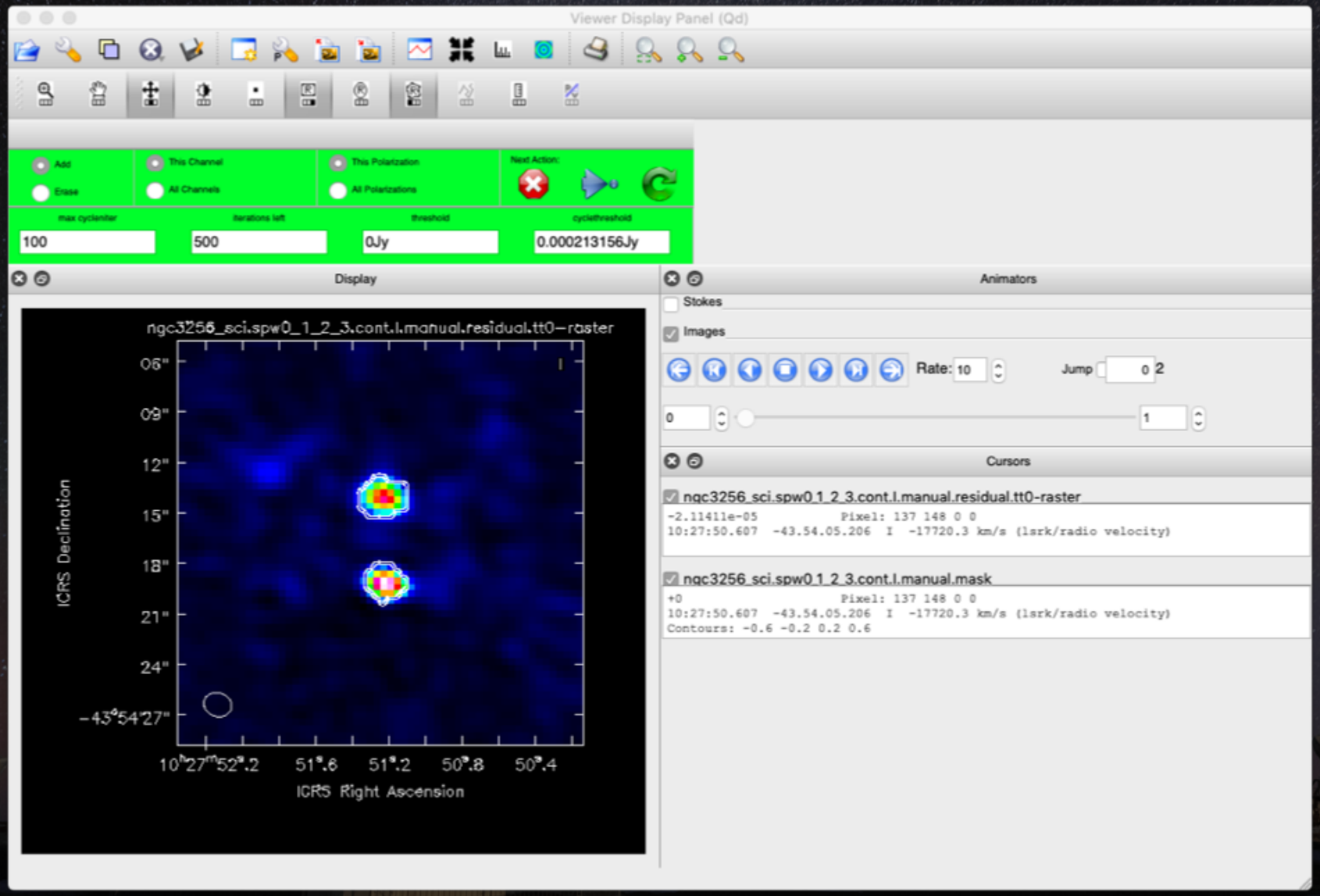
Pixel: 115 231 0 0
10:27:51.411 -43.53.32.045 I -17720.3 km/s (lsrk/radio velocity)
Contours: -0.6 -0.2 0.2 0.6


Viewer Display Panel (Qd)
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Next Action:
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iterations left
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ICRS Right Ascension
Animators
Stokes
Images
Rate: 10
Jump
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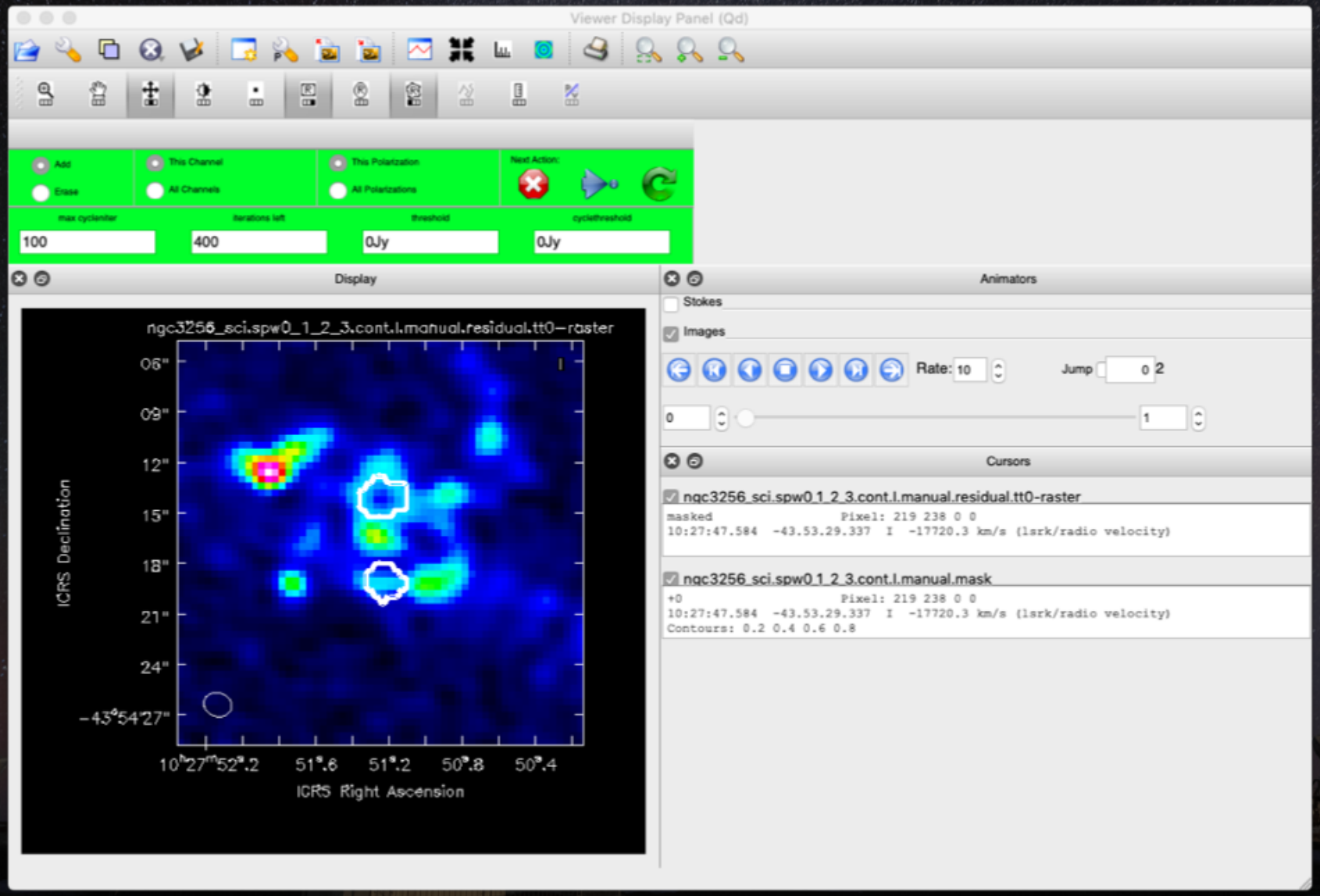
ngc3256_sci.spw0_1_2_3.cont.I.manual.residual.tt0-raster
-2.11411e-05 Pixel: 137 148 0 0
10:27:50.607 -43.54.05.206 I -17720.3 km/s (lsrk/radio velocity)
ngc3256_sci.spw0_1_2_3.cont.I.manual.mask
+0 Pixel: 137 148 0 0
10:27:50.607 -43.54.05.206 I -17720.3 km/s (lsrk/radio velocity)
Contours: -0.6 -0.2 0.2 0.6


Viewer Display Panel (Qd)
Add
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This Channel
All Channels
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All Polarizations
Next Action:
max cycleniter
iterations left
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ICRS Right Ascension
Animators
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Images
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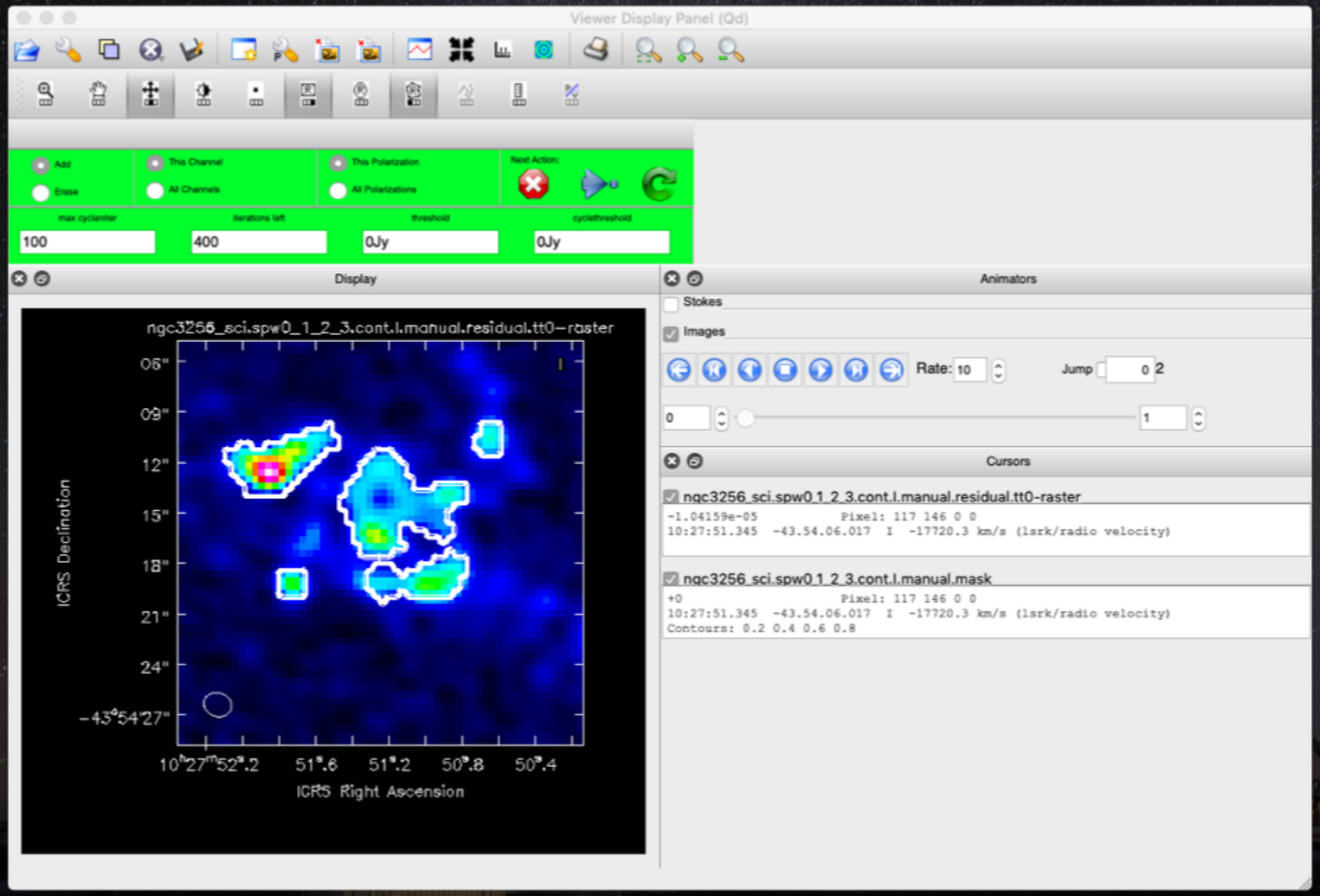
ngc3256_sci.spw0_1_2_3.cont.I.manual.residual.tt0-raster
masked
Pixel: 219 238 0 0
10:27:47.584 -43.53.29.337 I -17720.3 km/s (lsrk/radio velocity)
ngc3256_sci.spw0_1_2_3.cont.I.manual.mask
+0
Pixel: 219 238 0 0
10:27:47.584 -43.53.29.337 I -17720.3 km/s (lsrk/radio velocity)
Contours: 0.2 0.4 0.6 0.8


Viewer Display Panel (Qd)
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All Channels
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Next Action:
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ICRS Right Ascension
Animators
Stokes
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Rate: 10
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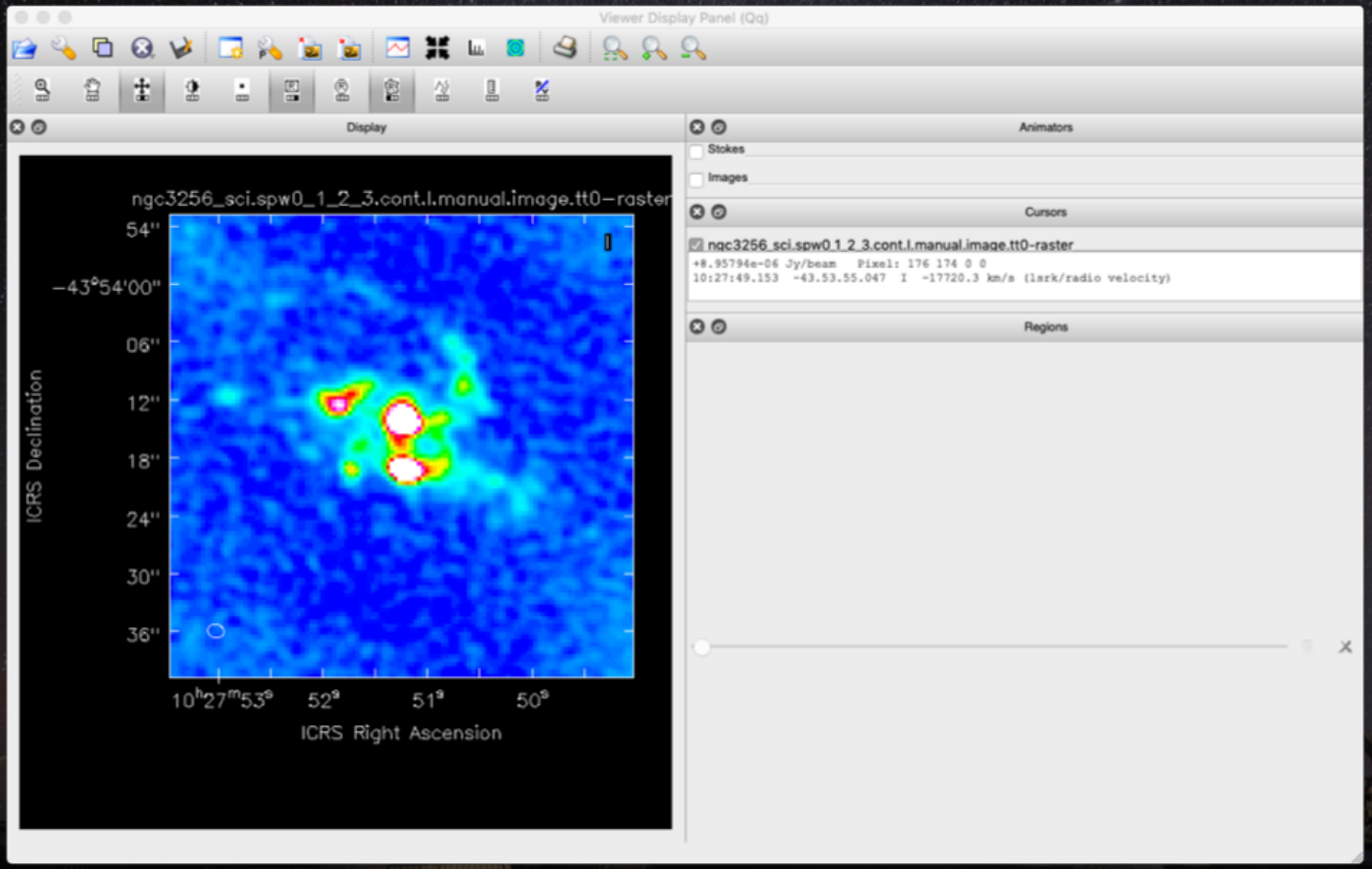
ngc3256_sci.spw0_1_2_3.cont.I.manual.residual.tt0-raster
-1.04159e-05 Pixel: 117 146 0 0
10:27:51.345 -43.54.06.017 I -17720.3 km/s (lsrk/radio velocity)
ngc3256_sci.spw0_1_2_3.cont.I.manual.mask
+0 Pixel: 117 146 0 0
10:27:51.345 -43.54.06.017 I -17720.3 km/s (lsrk/radio velocity)
Contours: 0.2 0.4 0.6 0.8


Viewer Display Panel (Qq)
Display
Animators
Stokes
Images
Cursors
ngc3256_sci.spw0_1_2_3.cont.I.manual.image.tt0-raster
+8.95794e-06 Jy/beam Pixel: 176 174 0 0
10:27:49.153 -43.53.55.047 I -17720.3 km/s (lsrk/radio velocity)
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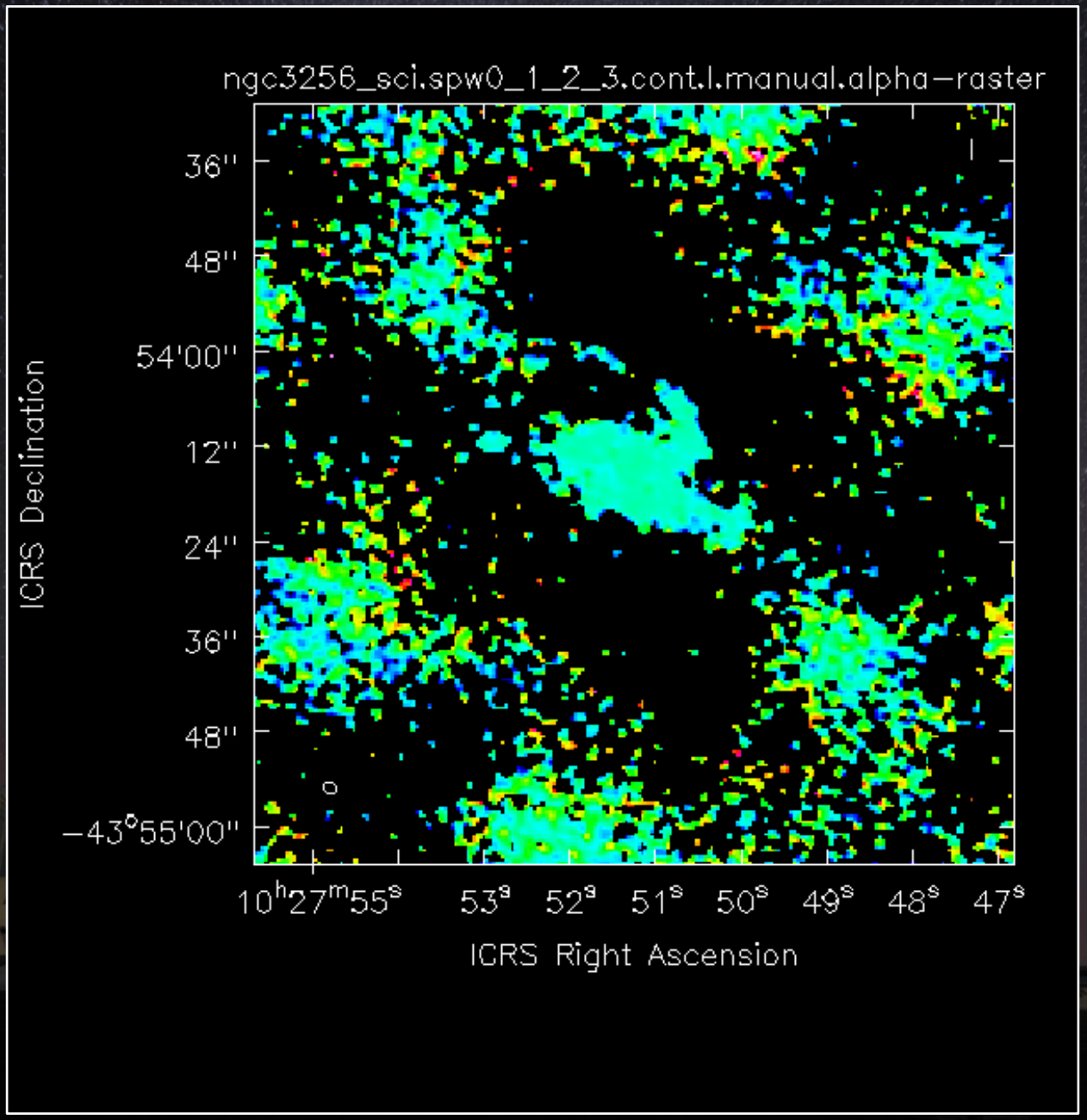
Multiple files are created after cleaning:

• 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
• sumwt	Values indicating the sum of the weights per image plane
• weight	Sum of primary beams for mosaic mapping (not created by the example script)

Using mtmfs creates separate images for the separate Taylor components of the image (labelled 0, 1, etc.).

The component labelled tt0 corresponds to the flux at the image's reference frequency.

The mtmfs option will also lead to the creation of an image labelled alpha, which indicates the spectral


ngc3256_sci.spw0_1_2_3.cont.I.manual.alpha−raster
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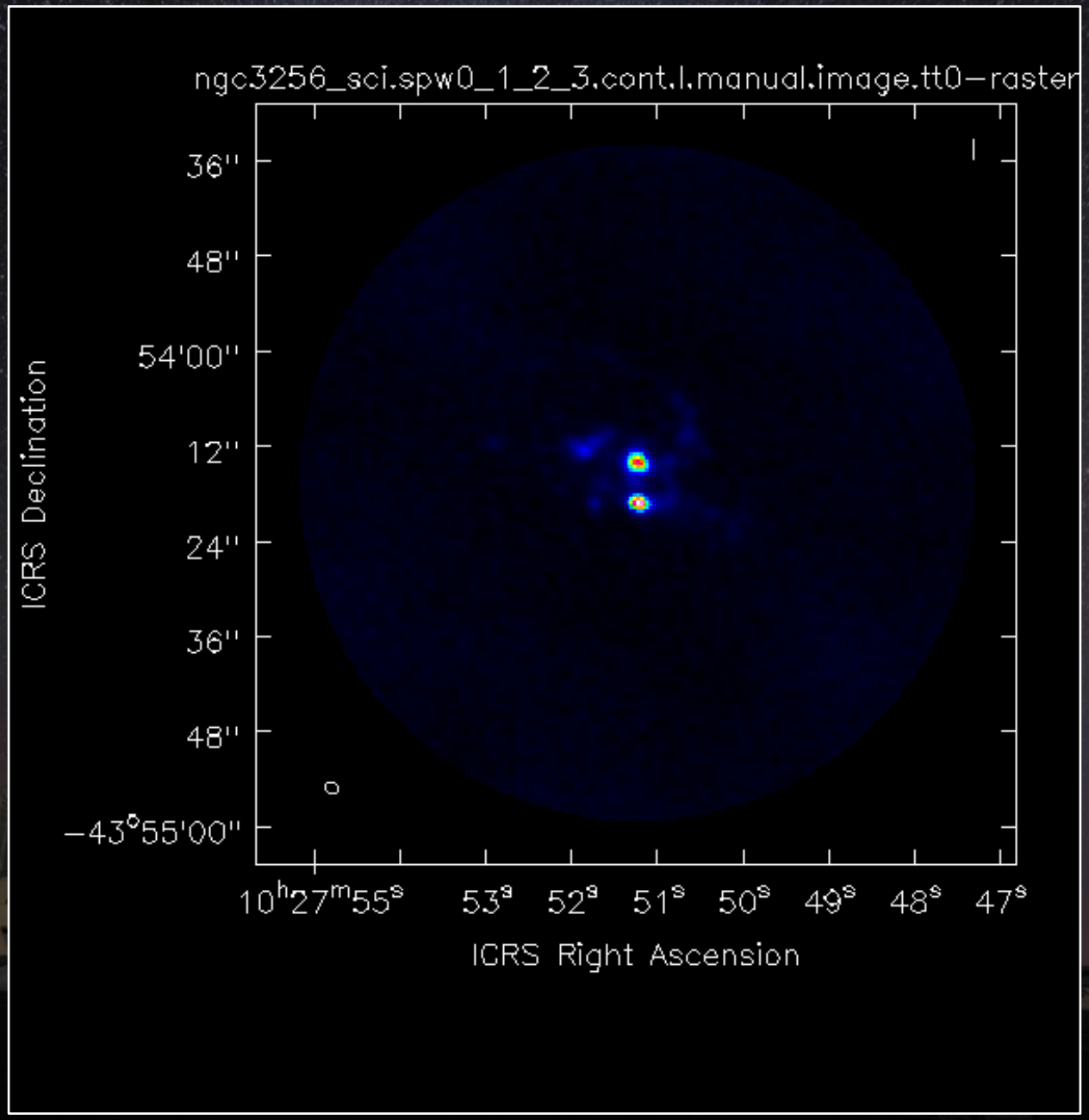
ngc3256_sci.spw0_1_2_3.cont.I.manual.image.tt0-raster
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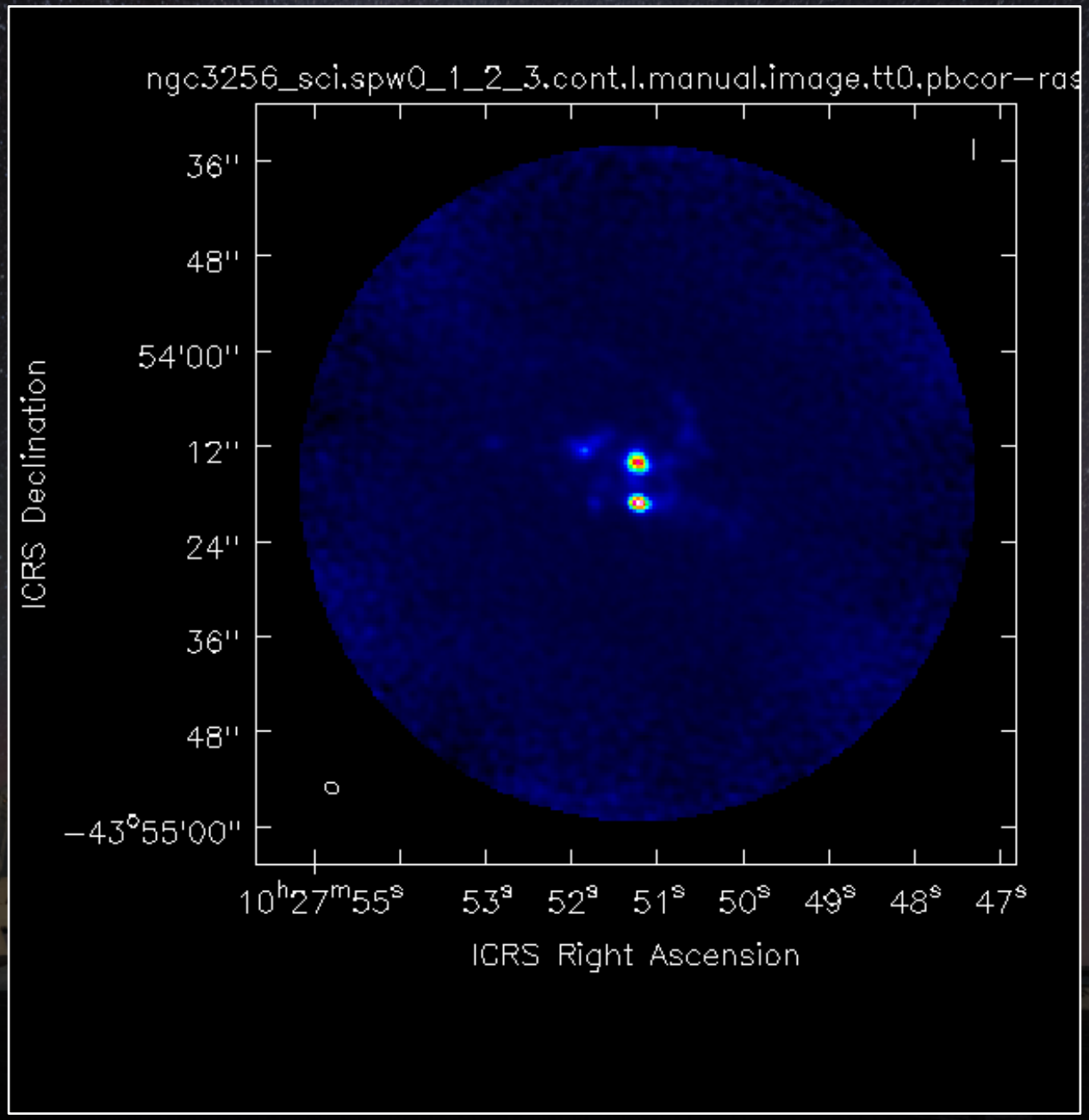
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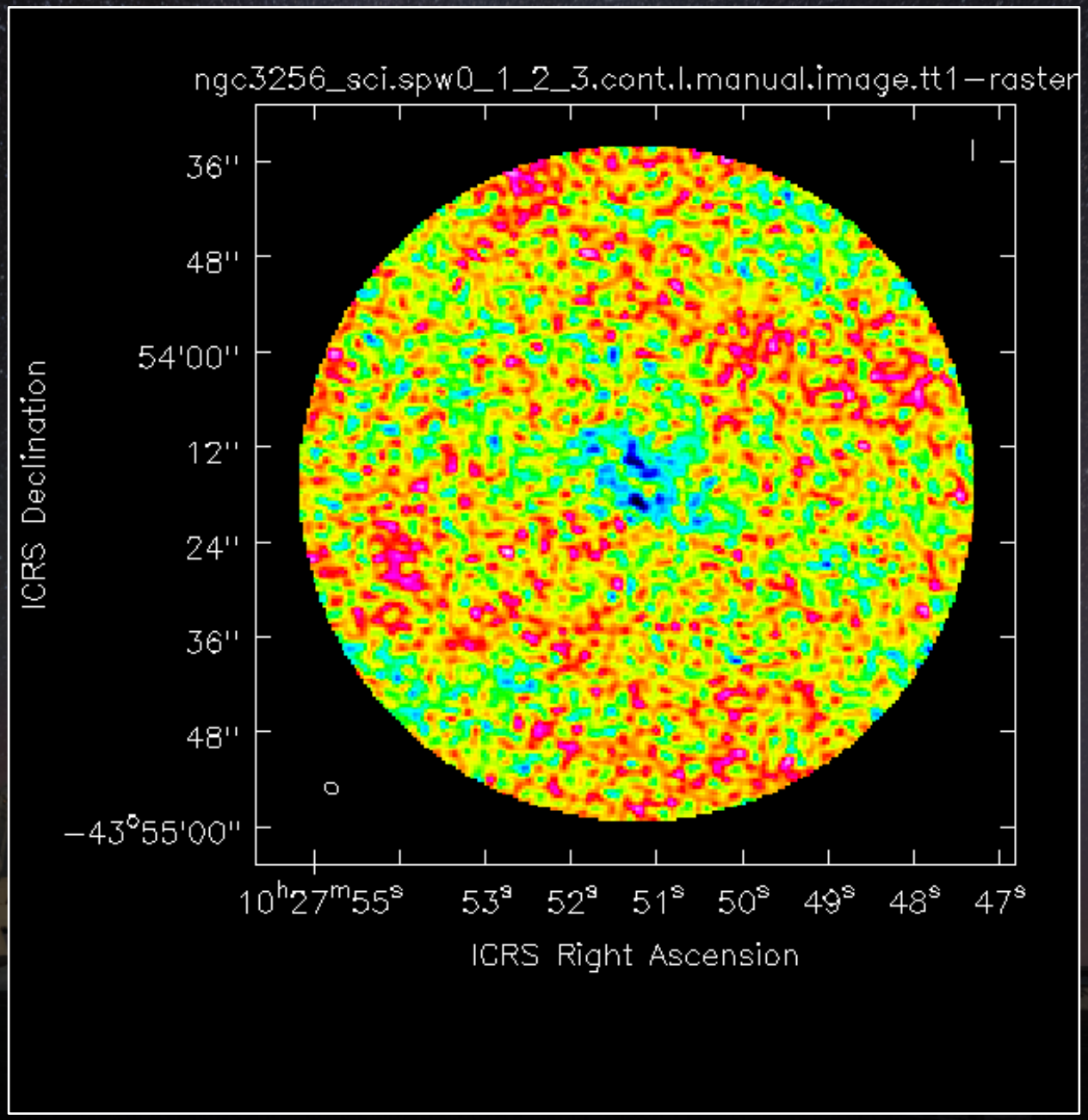
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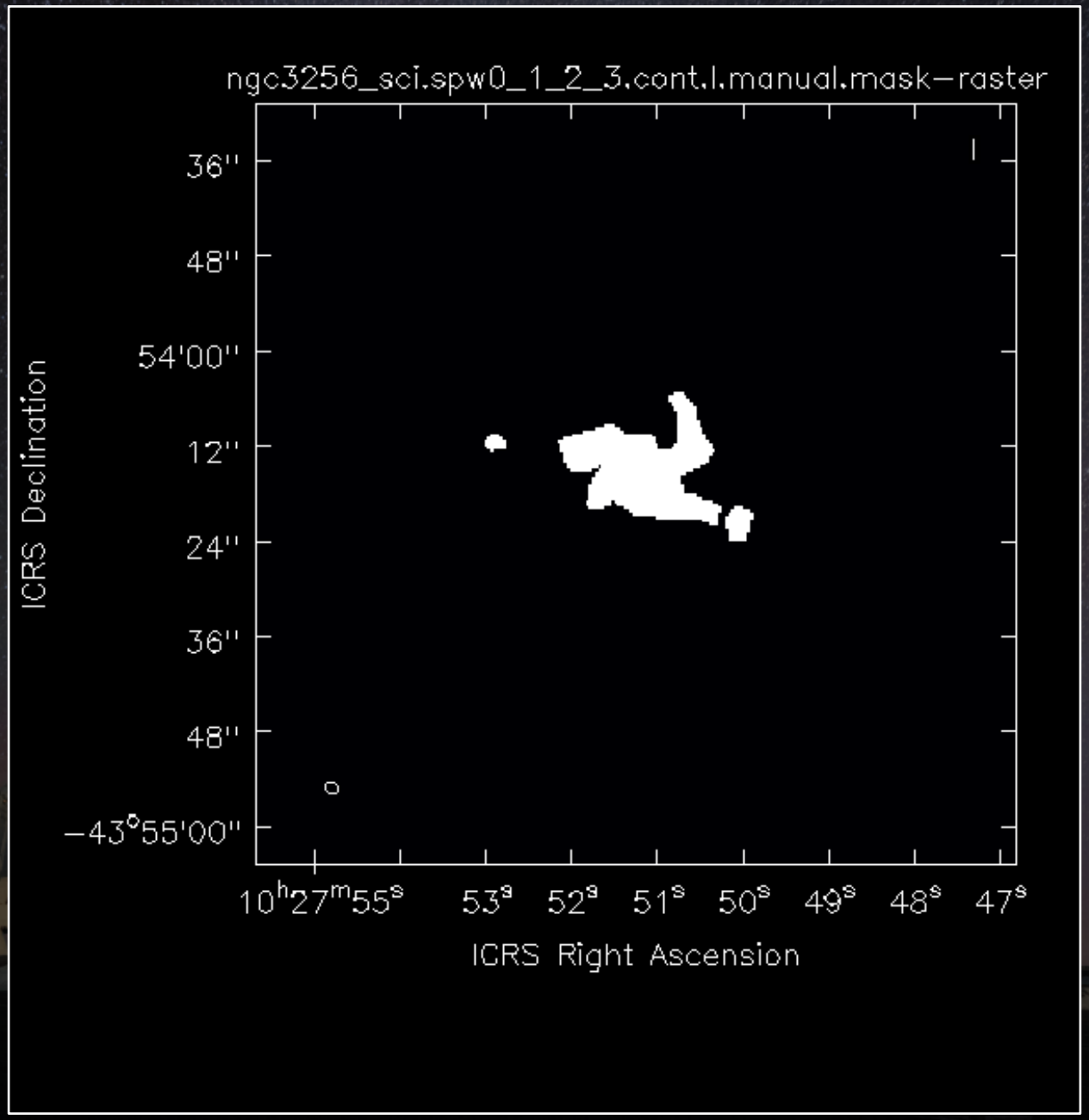
ngc3256_sci.spw0_1_2_3.cont.I.manual.mask−raster
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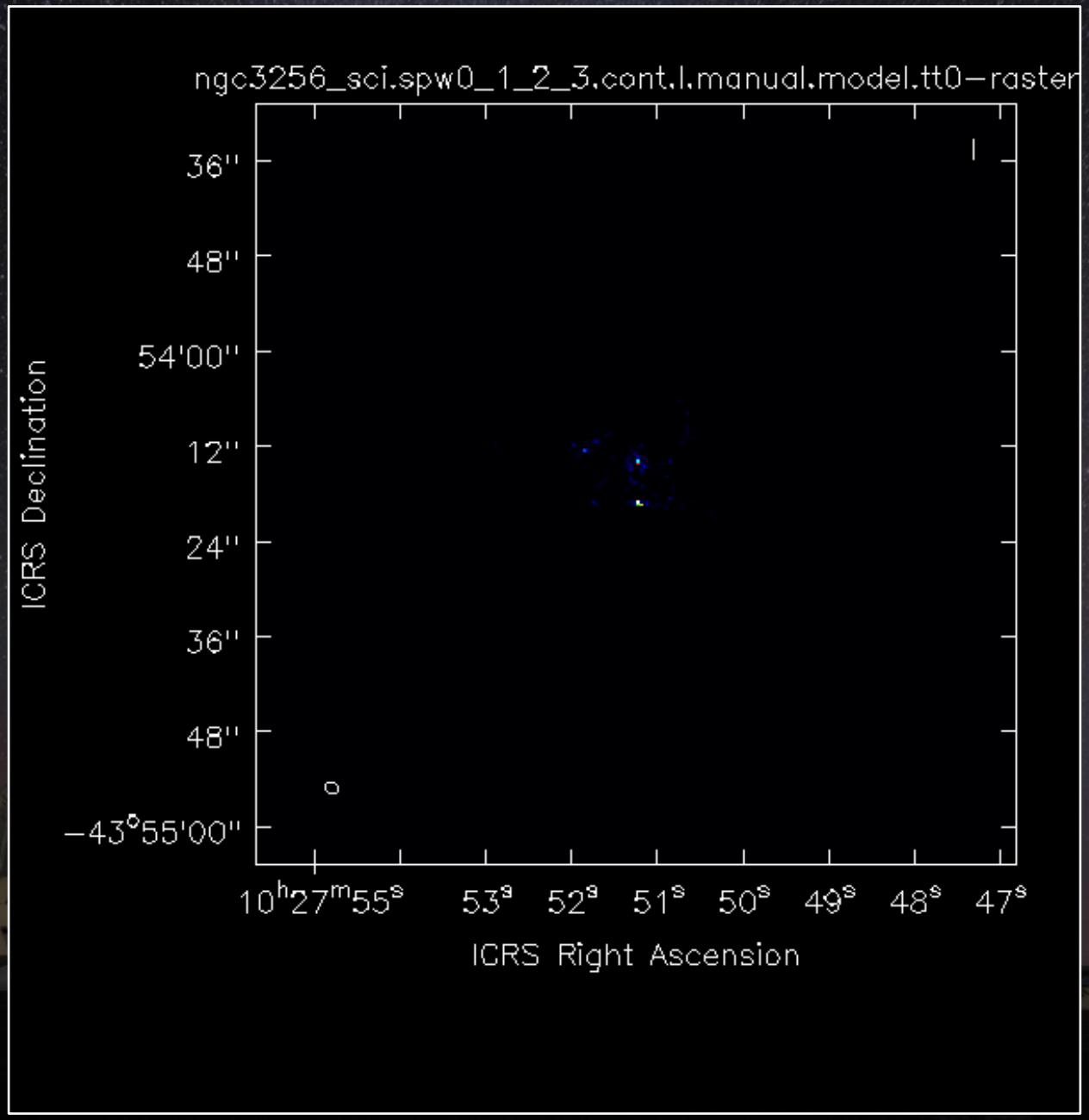
ngc3256_sci.spw0_1_2_3.cont.I.manual.model.tt0-raster
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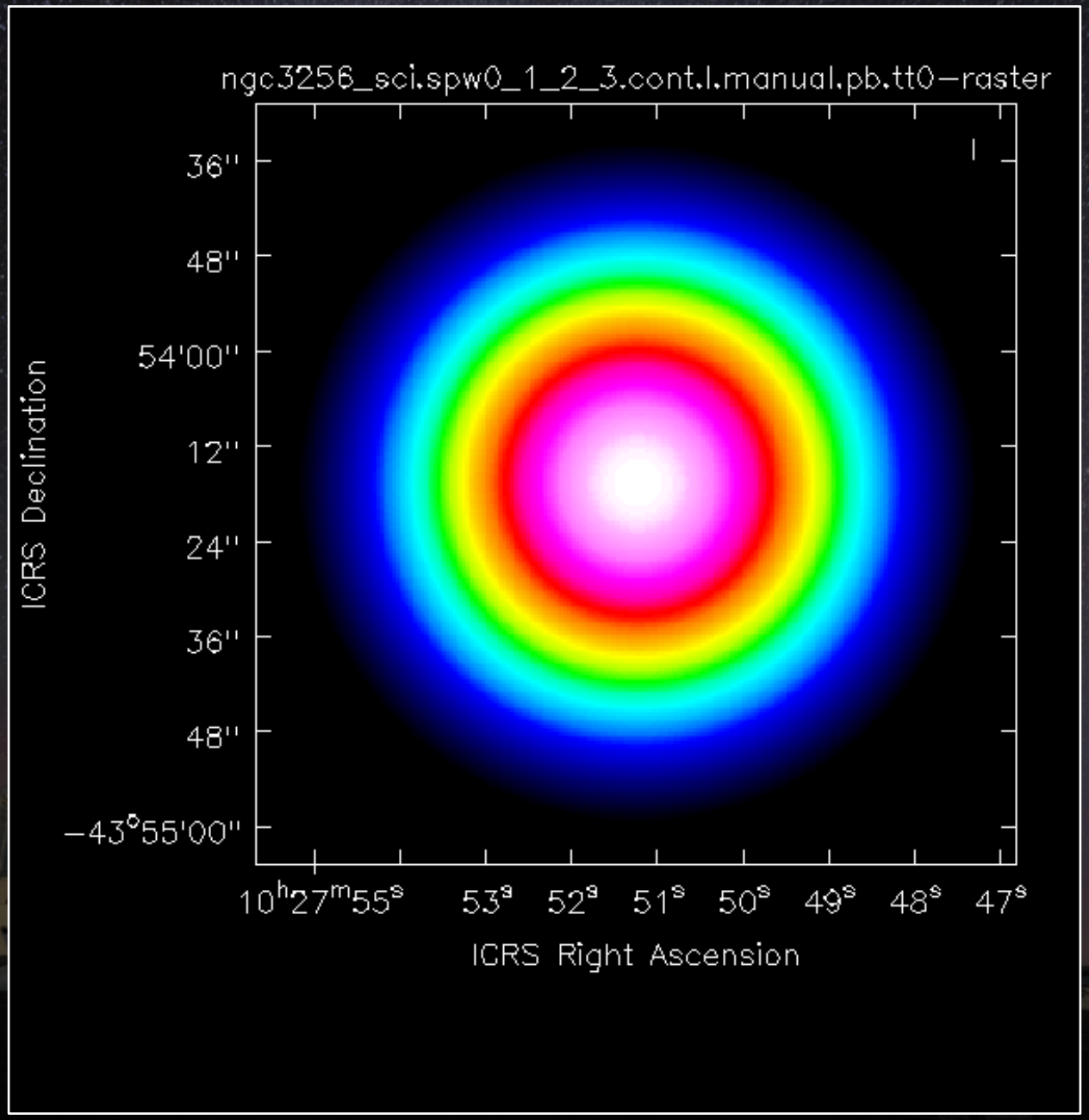
ngc3256_sci.spw0_1_2_3.cont.I.manual.pb.tt0-raster
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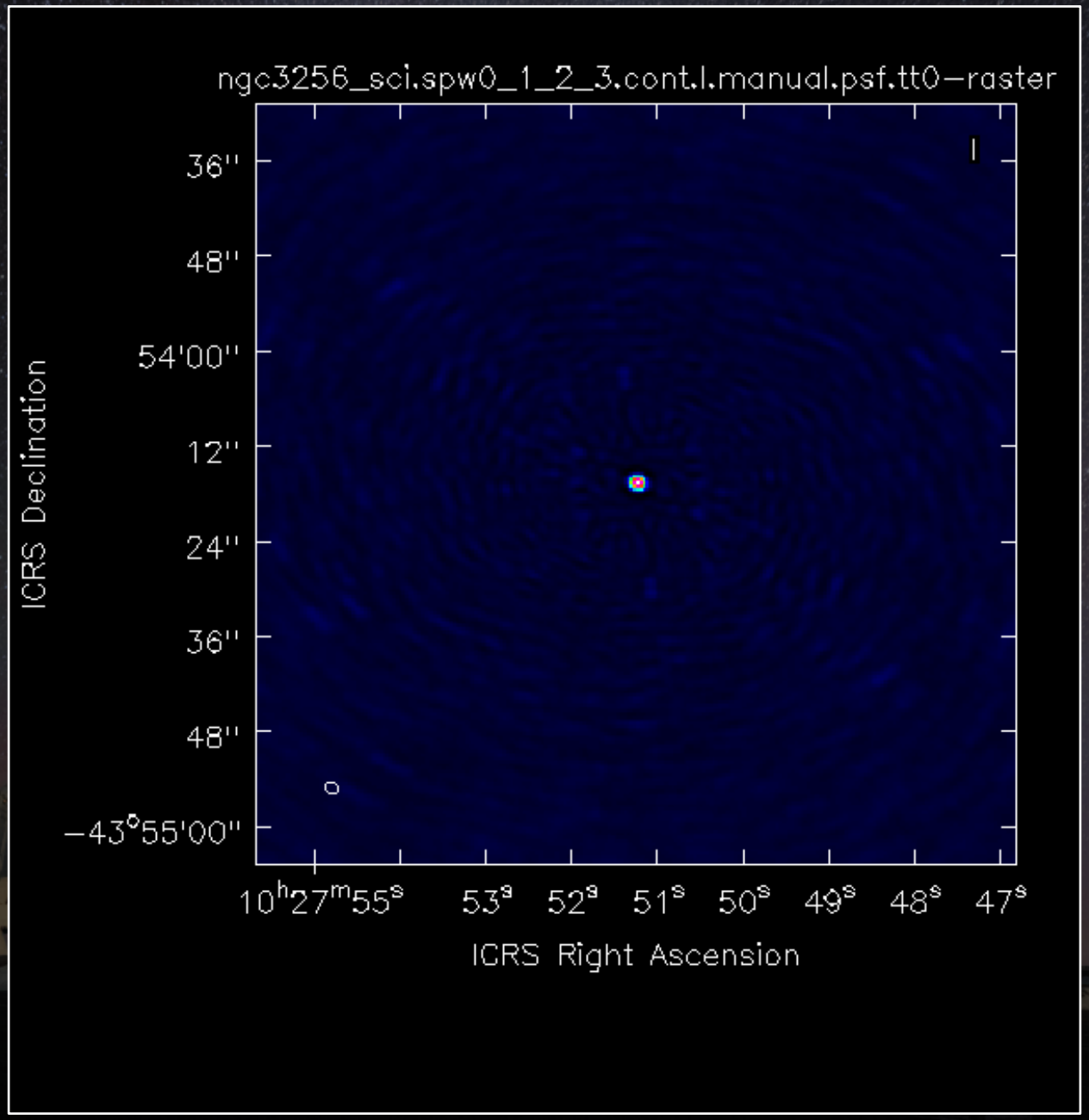
ngc3256_sci.spw0_1_2_3.cont.I.manual.psf.tt0−raster
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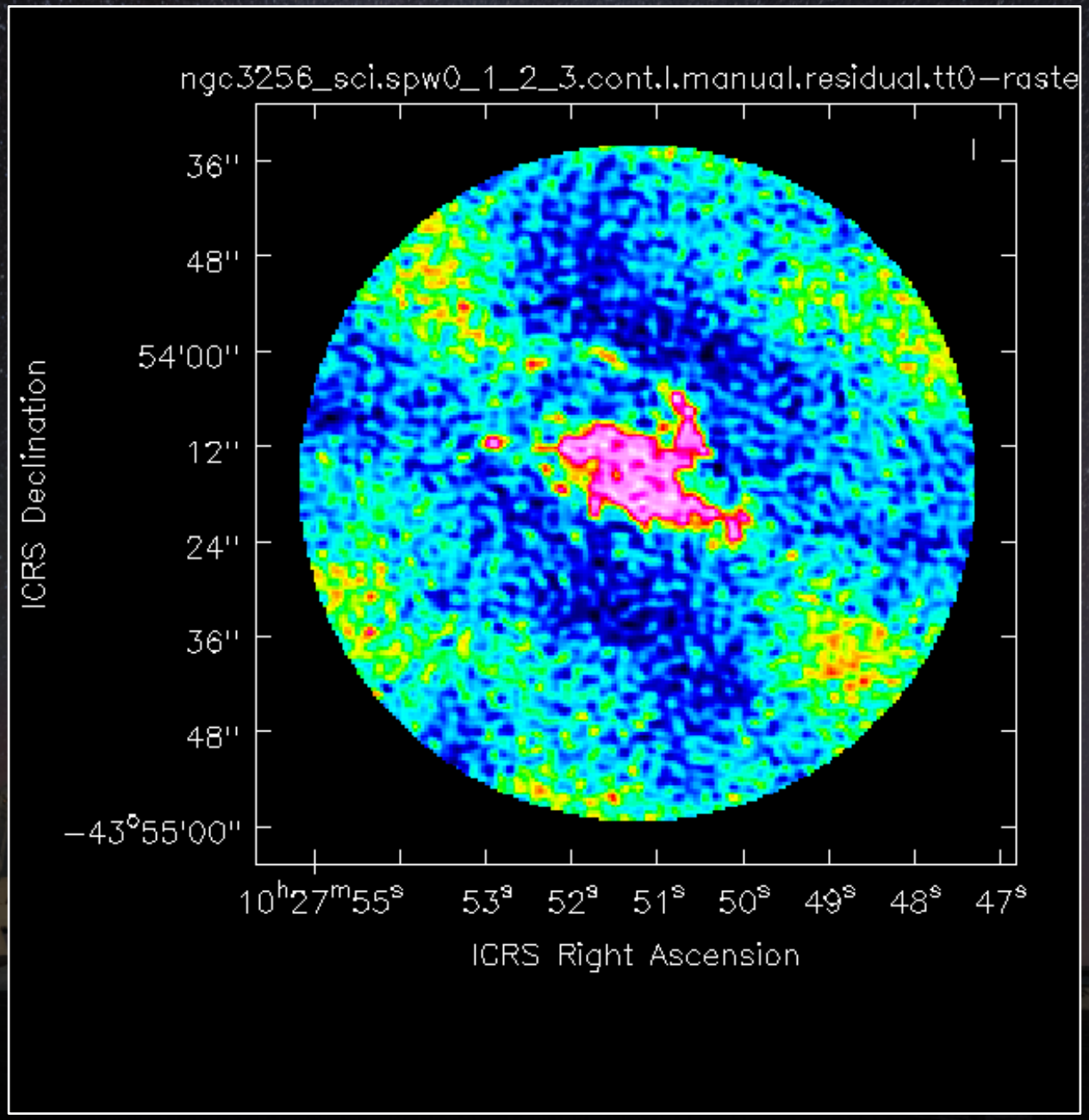
ngc3256_sci.spw0_1_2_3.cont.I.manual.residual.tt0-raste
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Imaging tips

- 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.