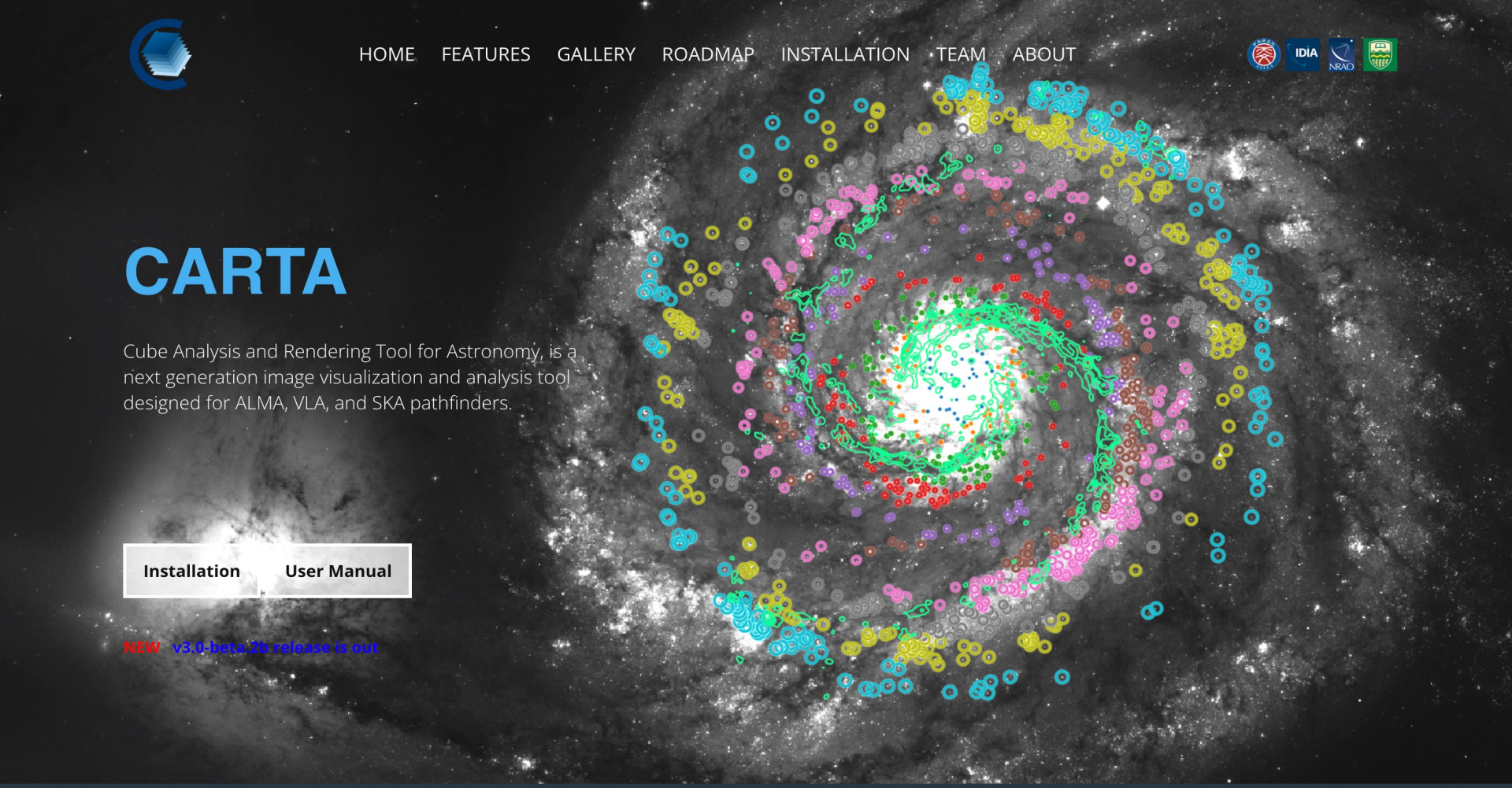


CARTA

Juergen Ott

CARTA
Cube Analysis and Rendering Tool for Astronomy

Project: ASIAA, IDIA, NRAO, U Alberta

Webpage: https://cartavis.org; Github: https://github.com/CARTAvis

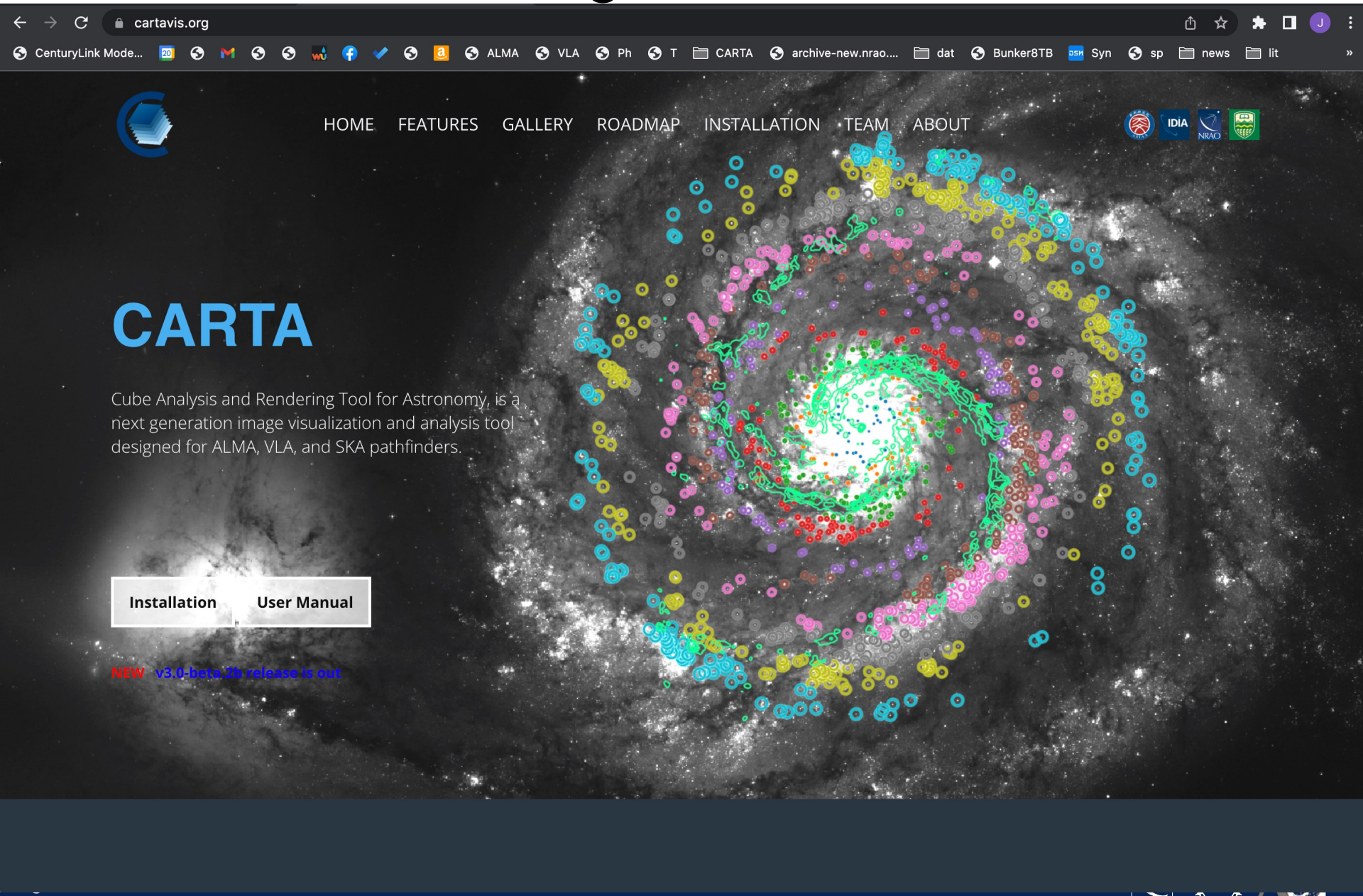
Current release version 4.1

Image viewer for multiple image (cube) formats

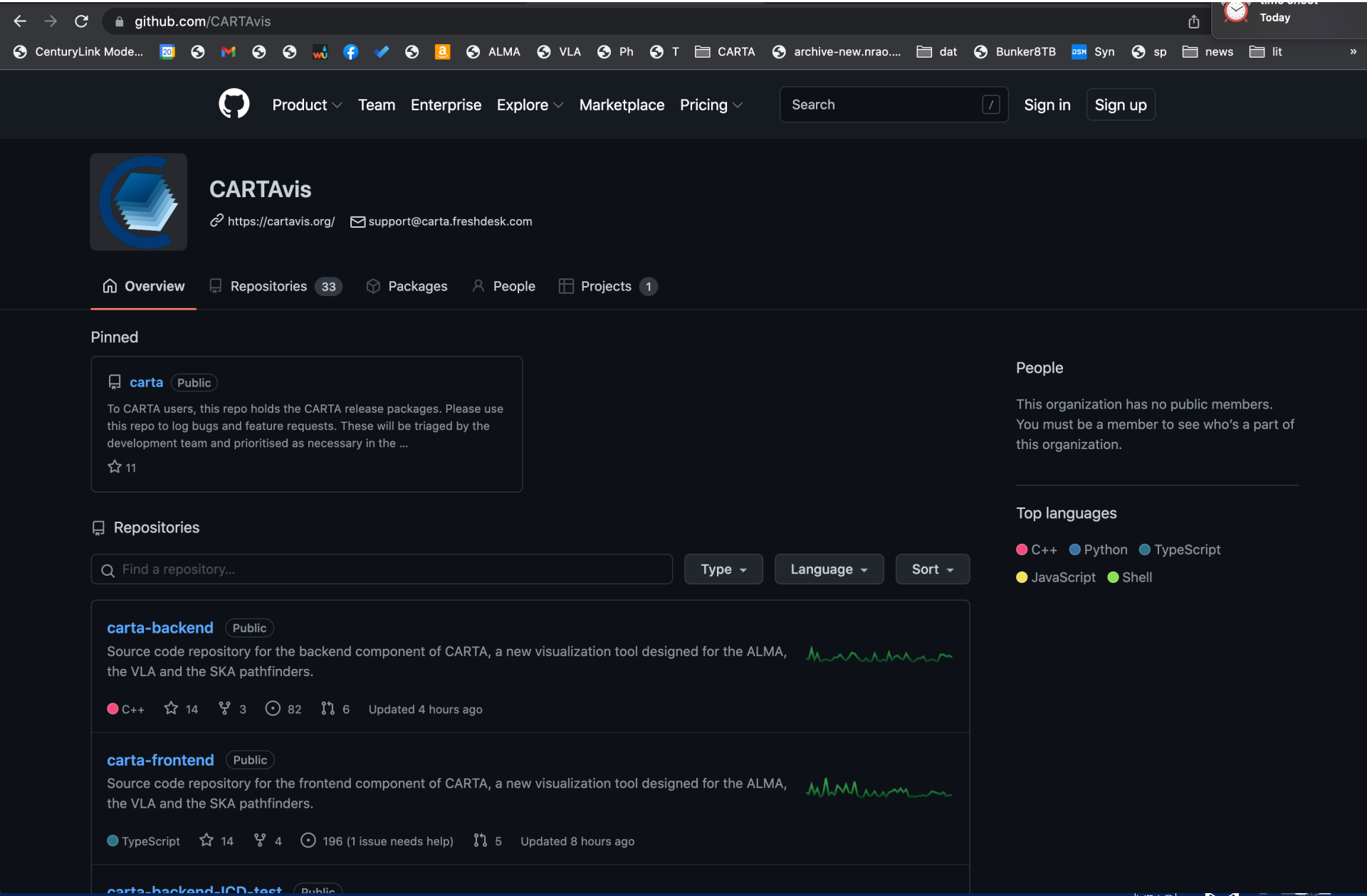
- high performance
- versatile
- analysis tool
- collaborative tool
- publication ready files
- focus is on radio astronomy data but other data will be displayed as well (fits)

- Replaces the CASA viewer (except visibilities)
- serves as archive interface for SKA (precursors), ALMA, NRAO SRDP
- Server – client architecture allows for remote image viewing
- Interactive and scriptable interfaces (python; development in progress)

CARTA on cartavis.org



CARTA on github.com/CARTAvis



CARTA

- The focus is on performance for large datasets
  - Memory efficient image loading (1TB cubes in seconds)
  - Parallelization and GPU-accelerated rendering
  - Progressive and responsive update of spectral profile
  - Tiled image rendering

- Works on CASA, fits, gzipped fits, MIRIAD, HDF5 image (cube) formats

- Image analysis tasks frequently (but not always) use CASA code to ensure consistency

- In remote version (recommended) it is run as a server, and connected to by one or multiple frontends in a browser; the server can but does not have to be at a remote site

- A stand-alone version launches electron (which is a standalone browser replacement)

- OS: MacOS, Ubuntu, RHEL

CARTA Features

Viewing:

- Image rendering with (global) min/max clipping, scaling functions and color maps
- Image panning, zooming, etc.
- Multi-panel (3beta)
- Hardcopy
- Image/region saving
- Image blinking
- Image WCS matching spatially and spectrally
- Support of projections
- Contours with different generators, colors, color maps
- Catalog overlays
- Setting of rest frequency
- Complex image support
- pV image support
- FT image support
- Vector overlays

CARTA Features

Tools/Analysis:

- Regions: rotating box, ellipses, polygons (line, point, polyline)
- X, Y and Z profiles
- Spectral profiles can convert spectral axis labels (velocity, frequency, wavelength)
- Histogram
- Image/Region Statistics
- Image fitting
- Stokes analysis widget
- Moment generator
- Position Velocity Plots (interactive and saving)
- Spectral line labelling
- Spectral smoothing
- Distance measuring tool
- Intensity conversion
- Server authentication
- Inserting rest frequencies of lines

CARTA Features

Other:

- Server-client infrastructure for remote image access
- Tiled rendering for performance
- Docking and Preferred layouts and layout saving
- Workspaces
- Saving subsections of images
- Basic python scripting is under active development

CARTA – Start

MacOX installed stand-alone:

carta (or click the icon in the Applications folder).

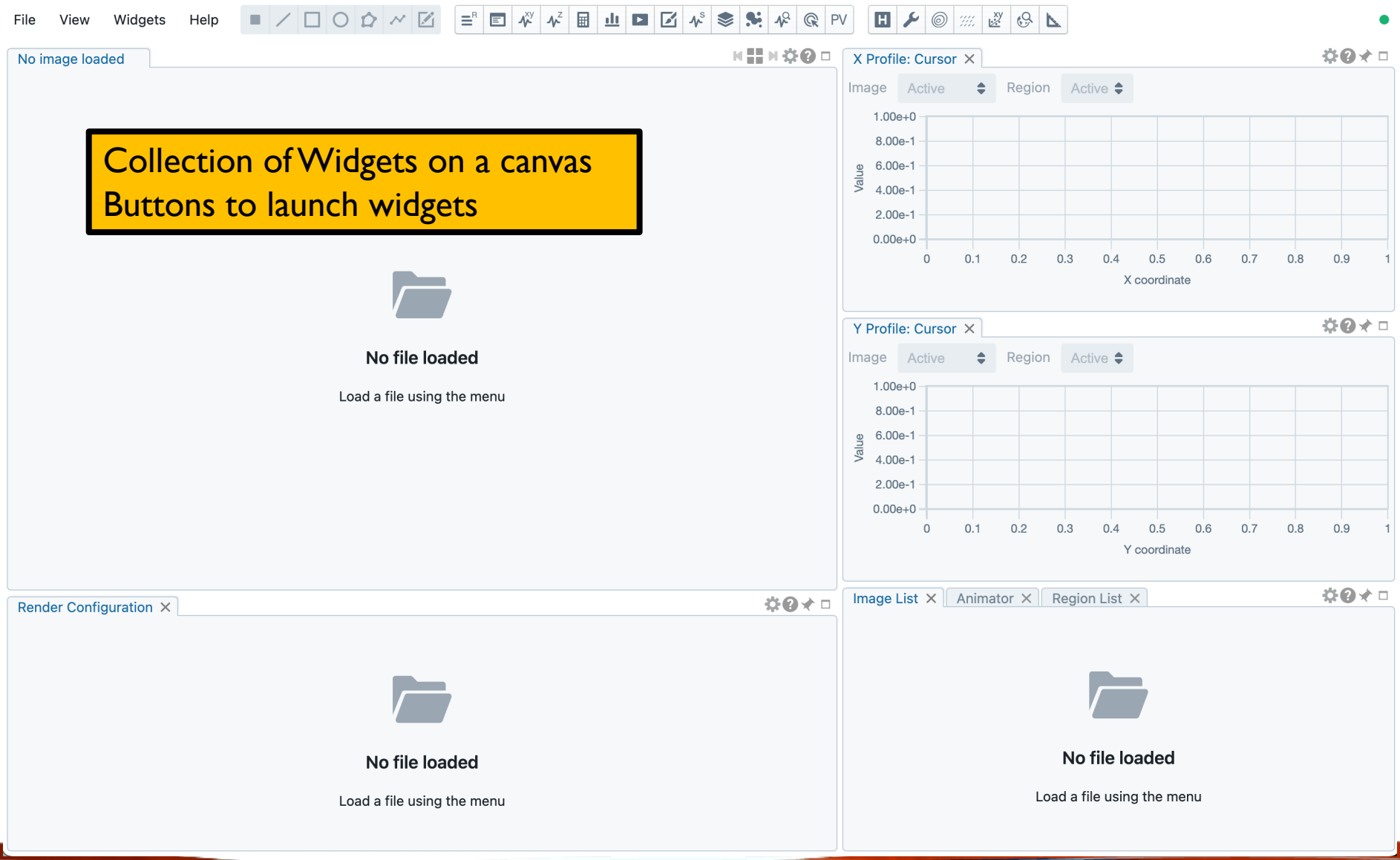
Linux or remote:

jott@rocky carta> carta --no_browser
[2024-05-14 17:01:33.373Z] [CARTA] [info] Writing to the log file: /users/jott/.carta-beta/log/carta.log
[2024-05-14 17:01:33.378Z] [CARTA] [info] /tmp/.mount_cartadHINdA/bin/carta_backend: Version 4.1.0
[2024-05-14 17:01:33.391Z] [CARTA] [info] Serving CARTA frontend from /tmp/.mount_cartadHINdA/share/carta/frontend
[2024-05-14 17:01:33.391Z] [CARTA] [info] Listening on port 3002 with top level folder /, starting folder /lustre/aoc/projects/vlass/jott/gridder/casa-versions. The number of OpenMP worker threads will be handled automatically.
[2024-05-14 17:01:33.391Z] [CARTA] [info] CARTA is accessible at http://146.88.1.42:3002/?token=de1fd985-4c43-40a5-a859-106dcbe08ecb

→ **Copy and past this URL in your local browser**

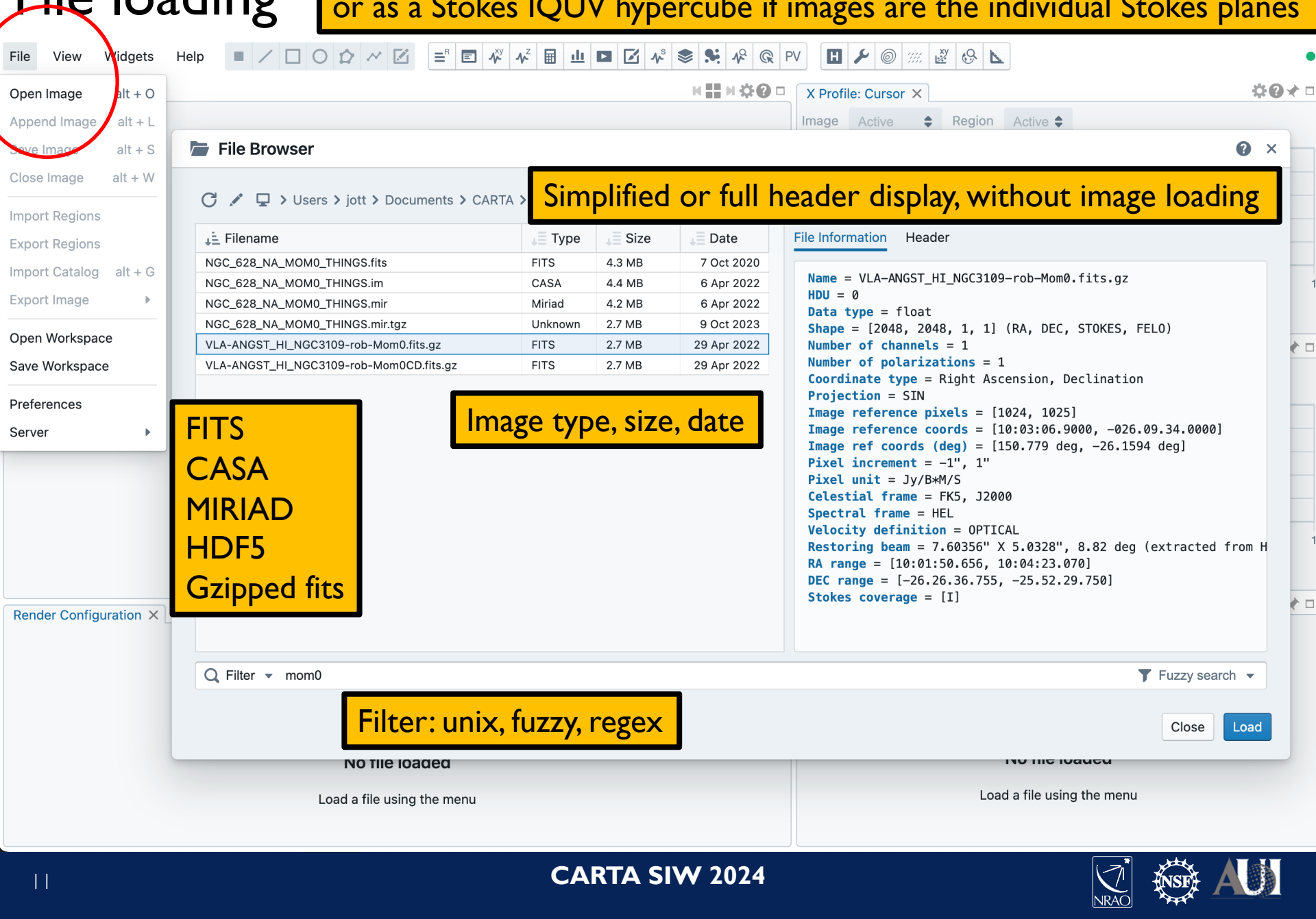
(For NRAO, see https://info.nrao.edu/computing/guide/cluster-processing/software)

First Screen



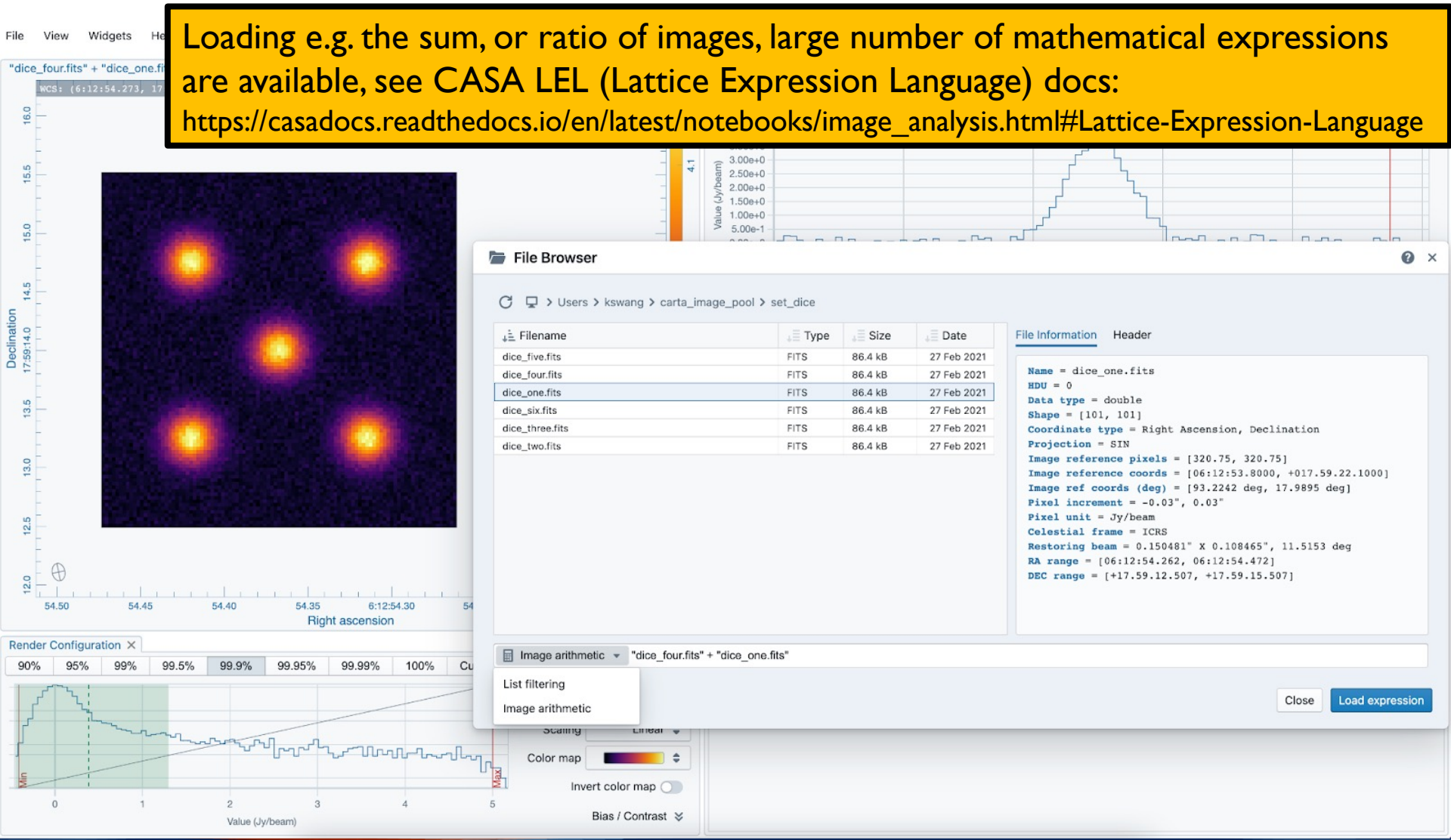
File loading

Selecting multiple images can be applied as stack of images
or as a Stokes IQUV hypercube if images are the individual Stokes planes

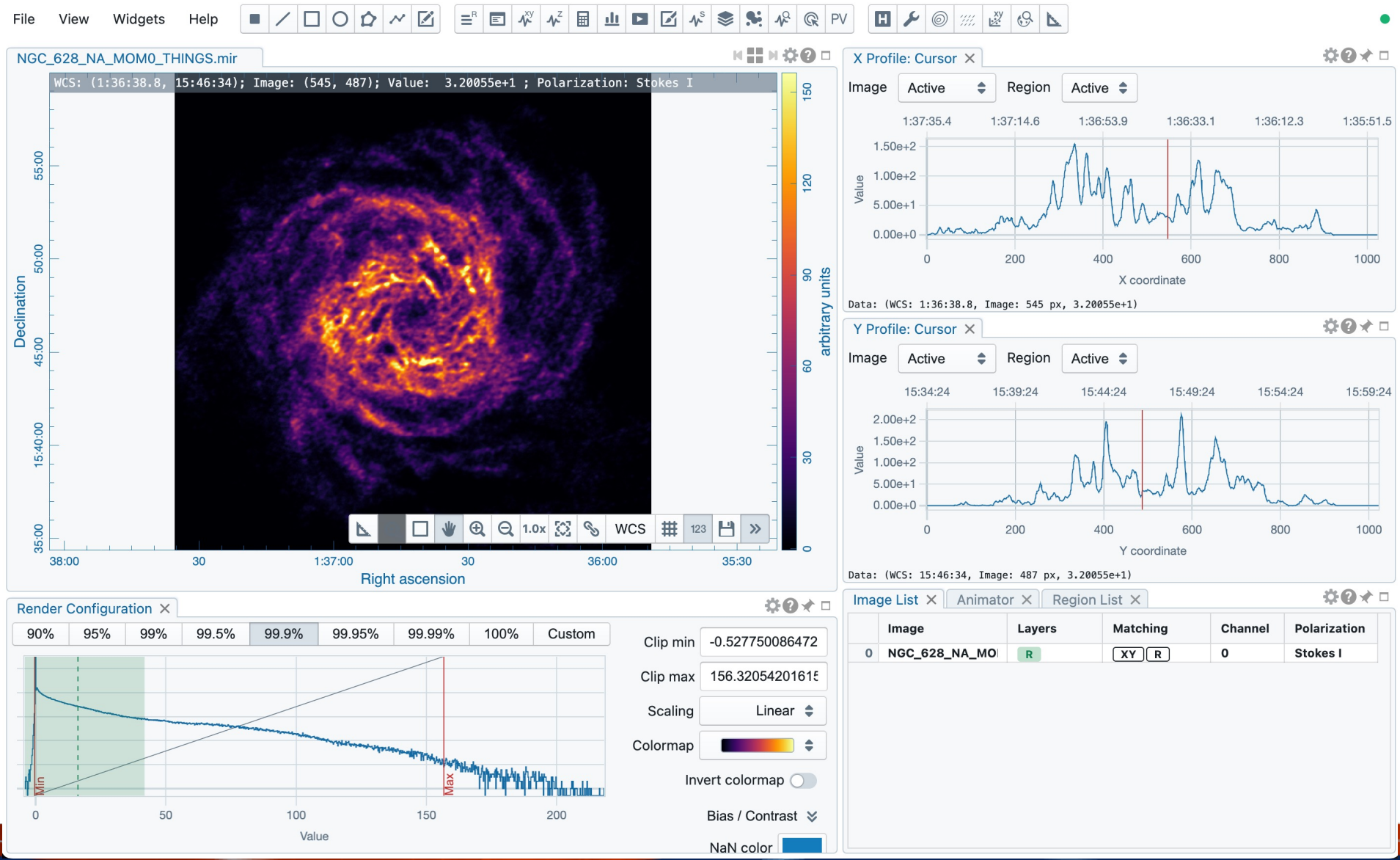


LEL image loading (mathematical expressions)

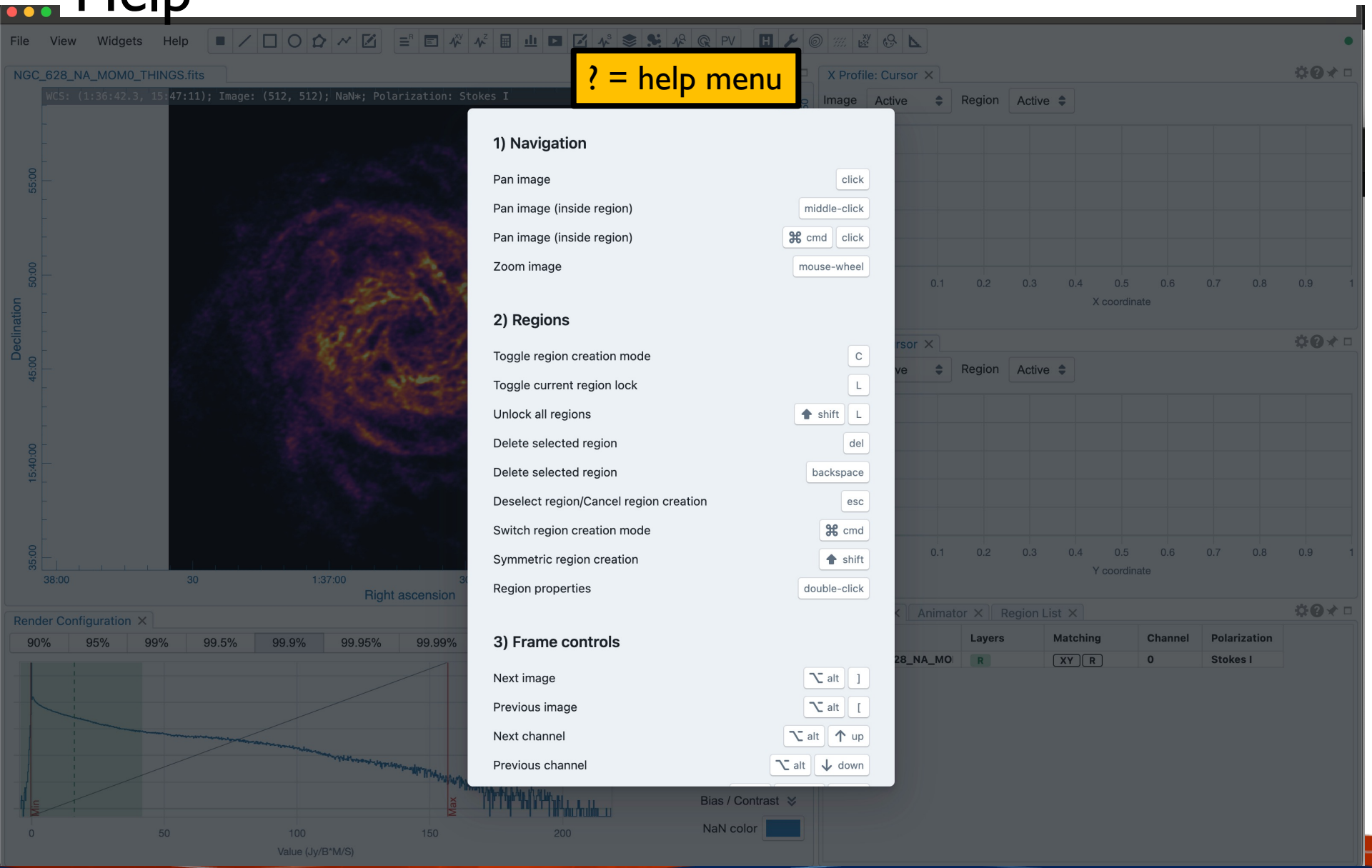
Loading e.g. the sum, or ratio of images, large number of mathematical expressions are available, see CASA LEL (Lattice Expression Language) docs:
https://casadocs.readthedocs.io/en/latest/notebooks/image_analysis.html#Lattice-Expression-Language



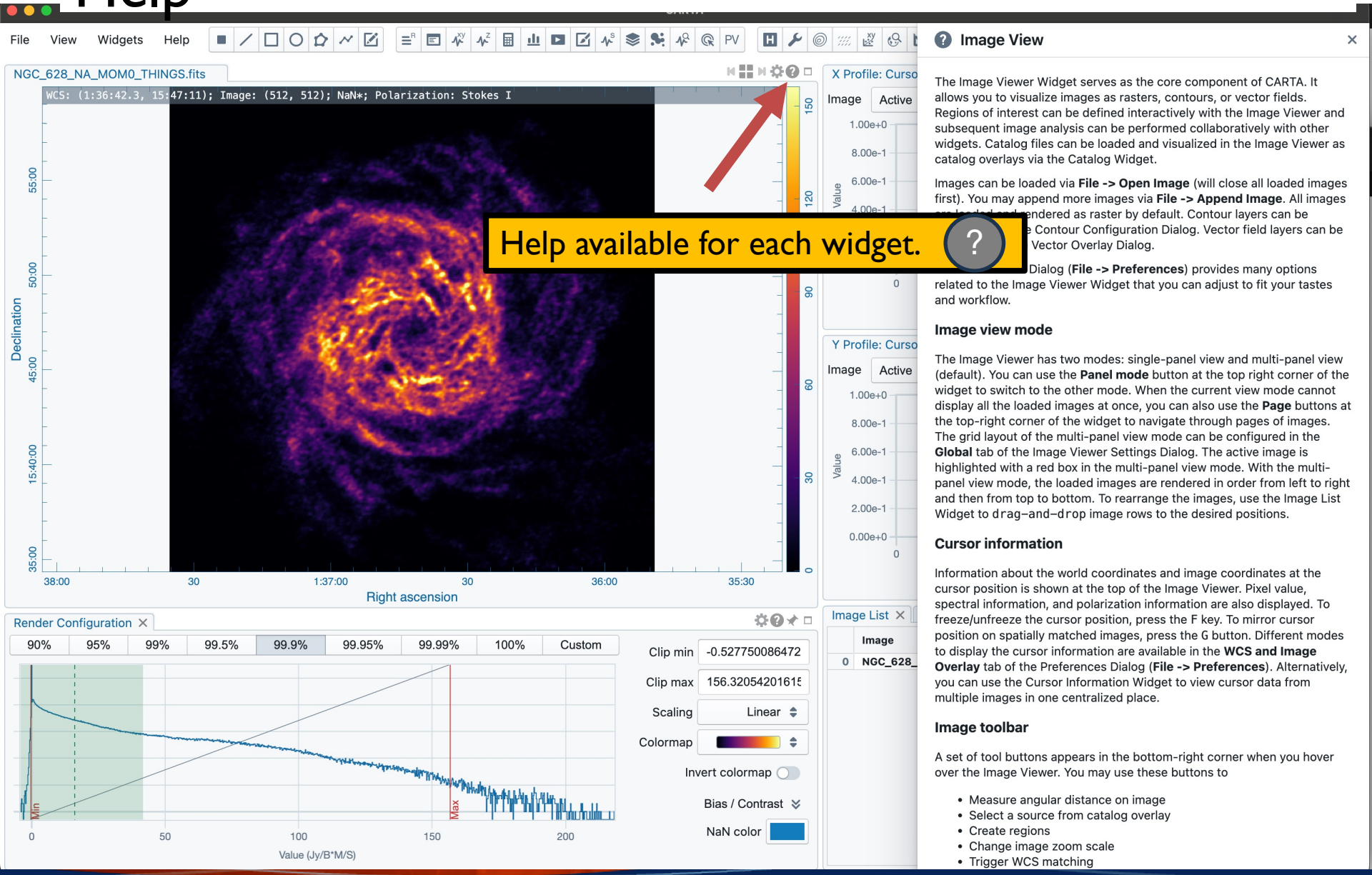
First Look


File
View
Widgets
Help
NGC_628_NA_MOM0_THINGS.mir
WCS: (1:36:38.8, 15:46:34); Image: (545, 487); Value: 3.20055e+1 ; Polarization: Stokes I
Declination
Right ascension
arbitrary units
X Profile: Cursor
Image
Active
Region
Active
Value
X coordinate
Data: (WCS: 1:36:38.8, Image: 545 px, 3.20055e+1)
Y Profile: Cursor
Y coordinate
Data: (WCS: 15:46:34, Image: 487 px, 3.20055e+1)
Render Configuration
90%
95%
99%
99.5%
99.9%
99.95%
99.99%
100%
Custom
Clip min
-0.527750086472
Clip max
156.3205420161
Scaling
Linear
Colormap
Invert colormap
Bias / Contrast
NaN color
Min
Max
Image List
Animator
Region List
Image
Layers
Matching
Channel
Polarization
NGC_628_NA_MO
XY
R
Stokes I

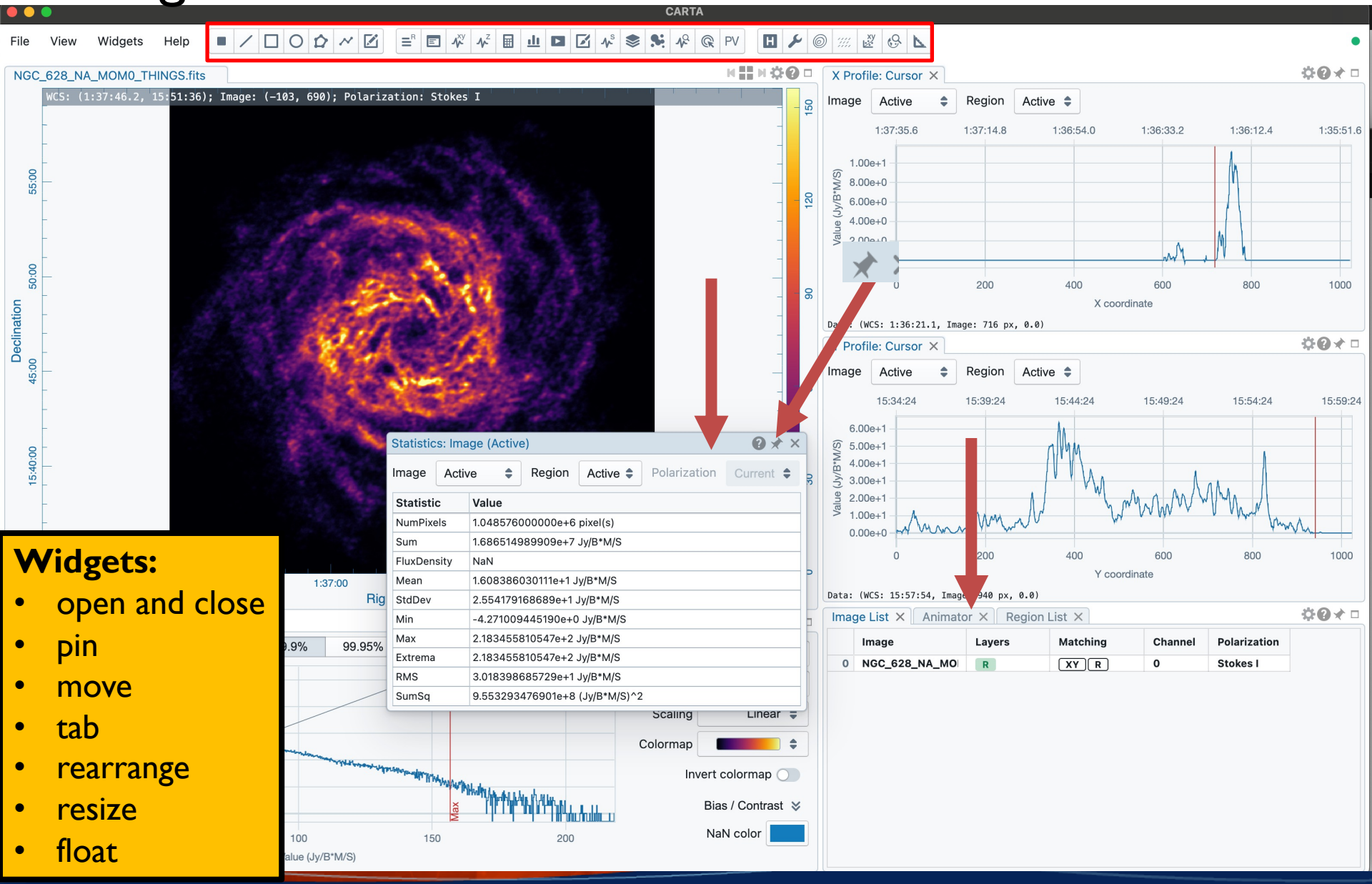
Help


? = help menu
1) Navigation
Pan image
click
Pan image (inside region)
middle-click
Pan image (inside region)
cmd
click
Zoom image
mouse-wheel
2) Regions
Toggle region creation mode
C
Toggle current region lock
L
Unlock all regions
shift
L
Delete selected region
del
Delete selected region
backspace
Deselect region/Cancel region creation
esc
Switch region creation mode
cmd
Symmetric region creation
shift
Region properties
double-click
3) Frame controls
Next image
alt
]
Previous image
alt
[
Next channel
alt
up
Previous channel
alt
down
File
View
Widgets
Help
NGC_628_NA_MOM0_THINGS.fits
X Profile: Cursor
Image
Active
Region
Active
Declination
Right ascension
X coordinate
Y coordinate
Render Configuration
90%
95%
99%
99.5%
99.9%
99.95%
99.99%
Value (Jy/B*M/S)
Min
Max
Bias / Contrast
NaN color
Animator
Region List
Layers
Matching
Channel
Polarization
Stokes I

Help


File
View
Widgets
Help
NGC_628_NA_MOM0_THINGS.fits
WCS: (1:36:42.3, 15:47:11); Image: (512, 512); NaN*; Polarization: Stokes I
Declination
Right ascension
Help available for each widget.
Image View
The Image Viewer Widget serves as the core component of CARTA. It allows you to visualize images as rasters, contours, or vector fields. Regions of interest can be defined interactively with the Image Viewer and subsequent image analysis can be performed collaboratively with other widgets. Catalog files can be loaded and visualized in the Image Viewer as catalog overlays via the Catalog Widget.
Image view mode
Cursor information
Image toolbar
Render Configuration
Clip min
Clip max
Scaling
Colormap
Invert colormap
Bias / Contrast
NaN color
Image List

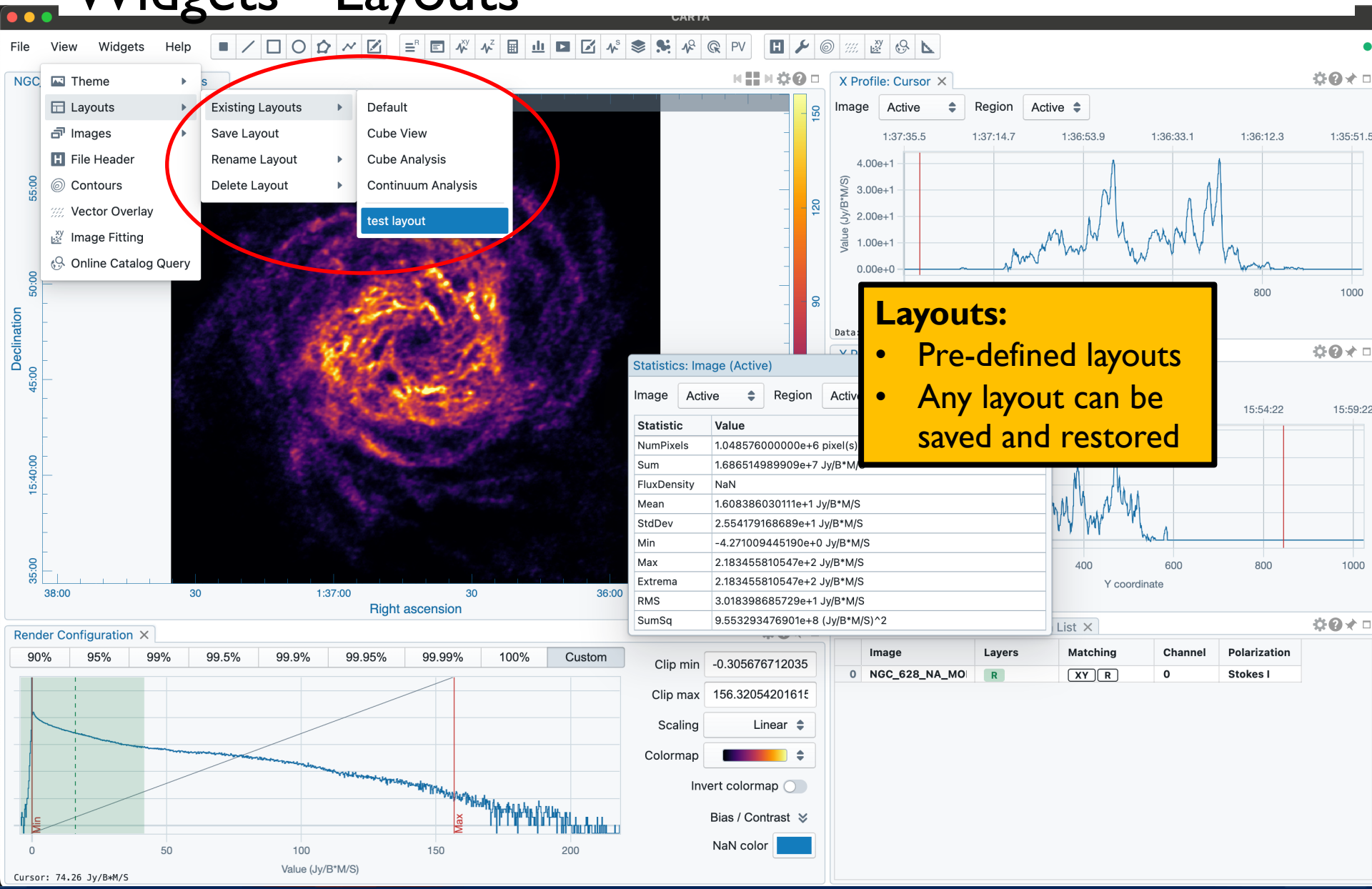
Widgets



Widgets:

- open and close
- pin
- move
- tab
- rearrange
- resize
- float

Widgets - Layouts



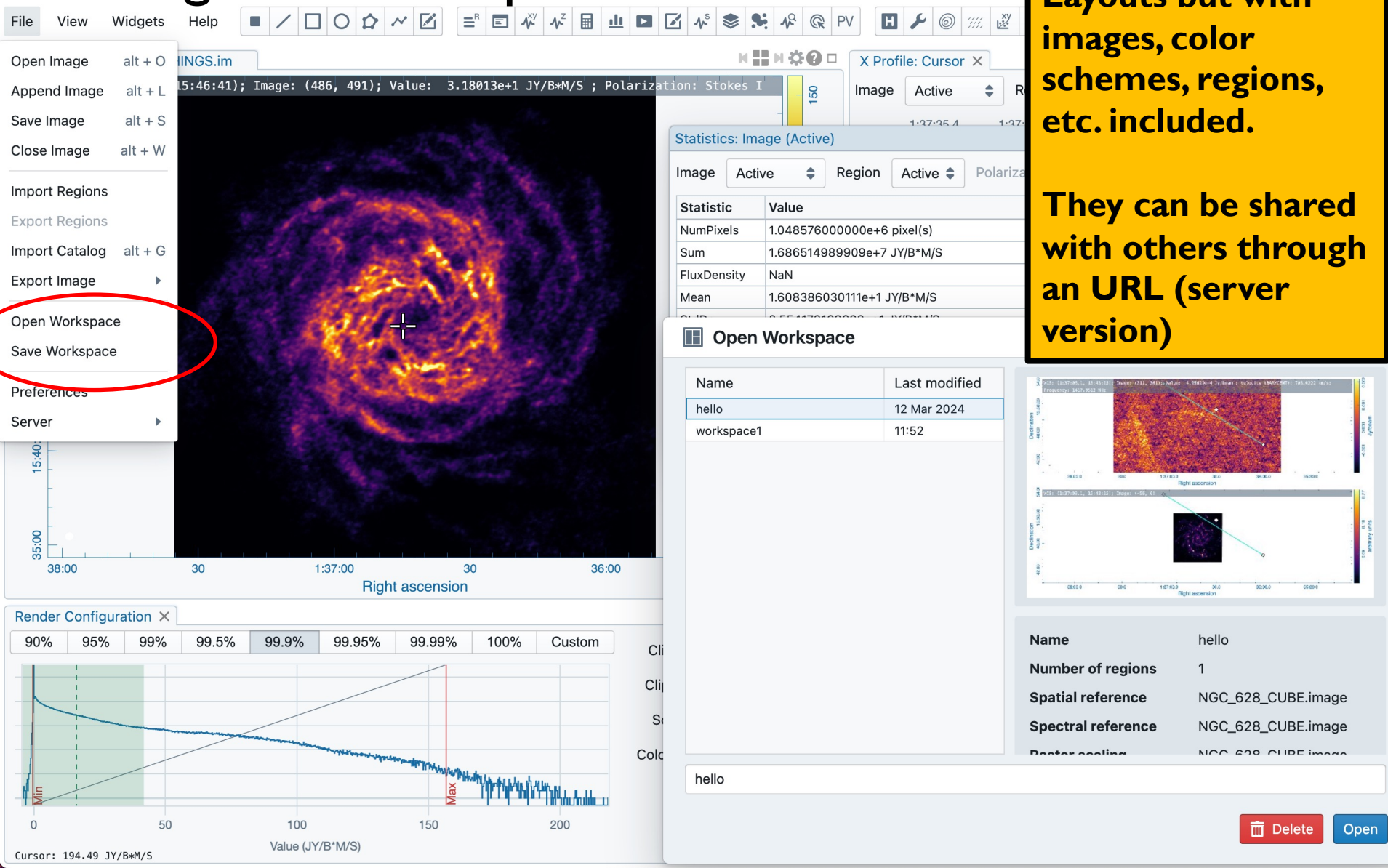
Layouts:

- Pre-defined layouts
- Any layout can be saved and restored

Widgets - Workspaces

Workspaces: Layouts but with images, color schemes, regions, etc. included.

They can be shared with others through an URL (server version)



Widgets

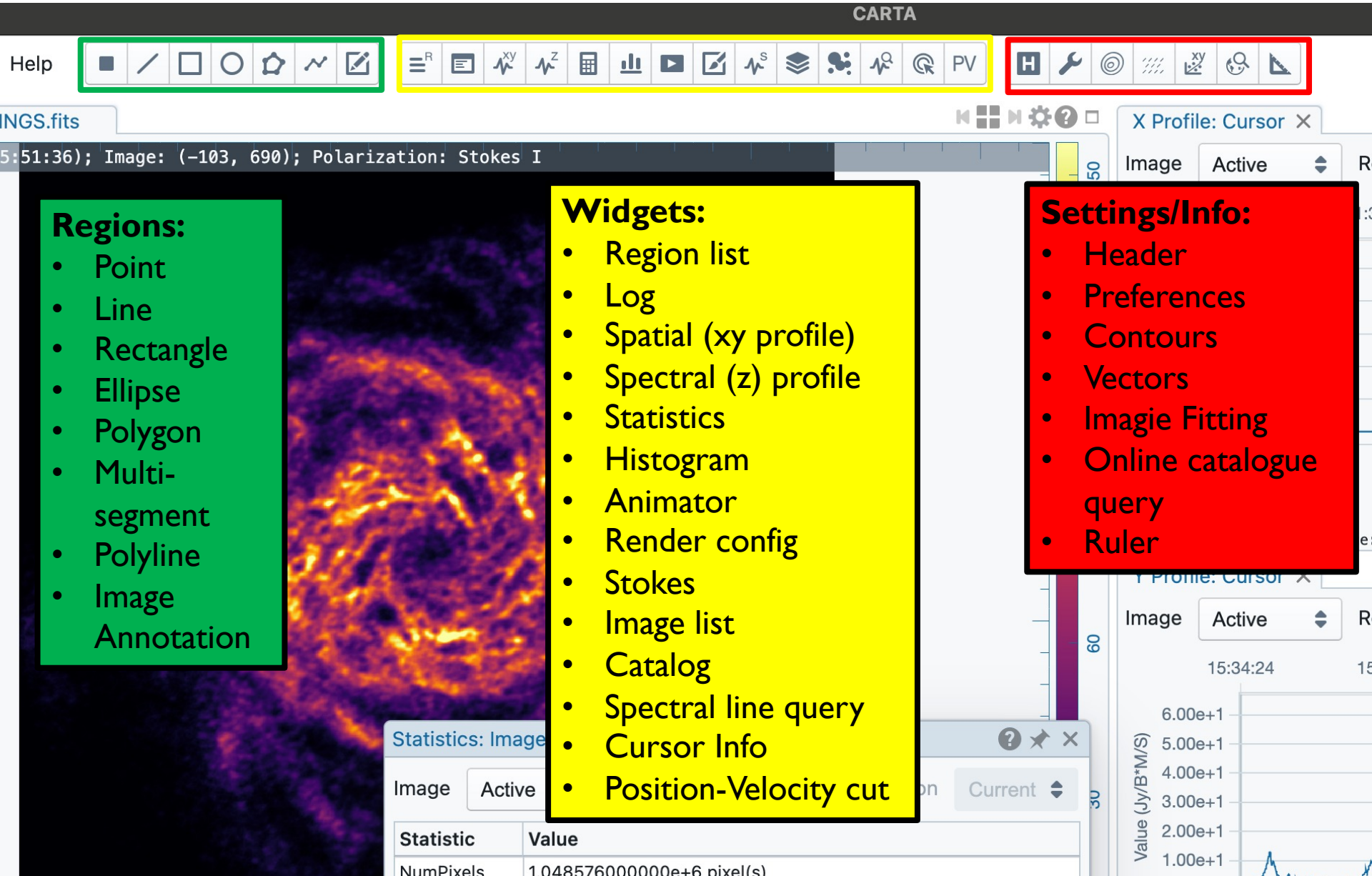
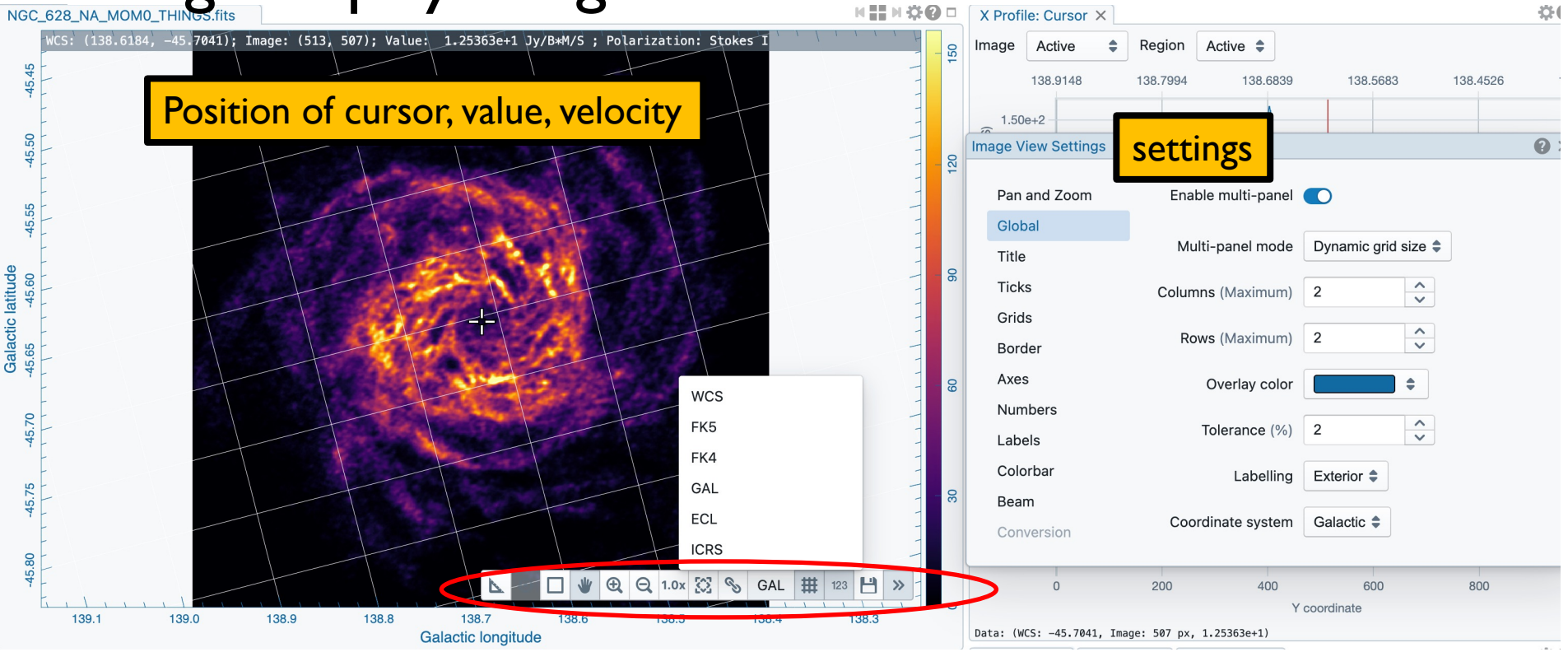

CARTA
Help
PV
INGS.fits
5:51:36); Image: (-103, 690); Polarization: Stokes I
X Profile: Cursor
Image
Active
Regions:
• Point
• Line
• Rectangle
• Ellipse
• Polygon
• Multi-segment
• Polyline
• Image Annotation
Widgets:
• Region list
• Log
• Spatial (xy profile)
• Spectral (z) profile
• Statistics
• Histogram
• Animator
• Render config
• Stokes
• Image list
• Catalog
• Spectral line query
• Cursor Info
• Position-Velocity cut
Settings/Info:
• Header
• Preferences
• Contours
• Vectors
• Imagie Fitting
• Online catalogue query
• Ruler
Statistics: Image
Image
Active
Current
Statistic
Value
NumPixels
1.048576000000e+6 pixel(s)
15:34:24
6.00e+1
5.00e+1
4.00e+1
3.00e+1
2.00e+1
1.00e+1
Value (Jy/B*M/S)

Image display widget



- distance tool
- catalog source selection
- Regions
- Pan
- Zoom in
- Zoom out

- Zoom to 1x
- Zoom to fit
- WCS matching
- Overlay coordinate
- Grid
- Labels
- Export

Image display widget - multipanel

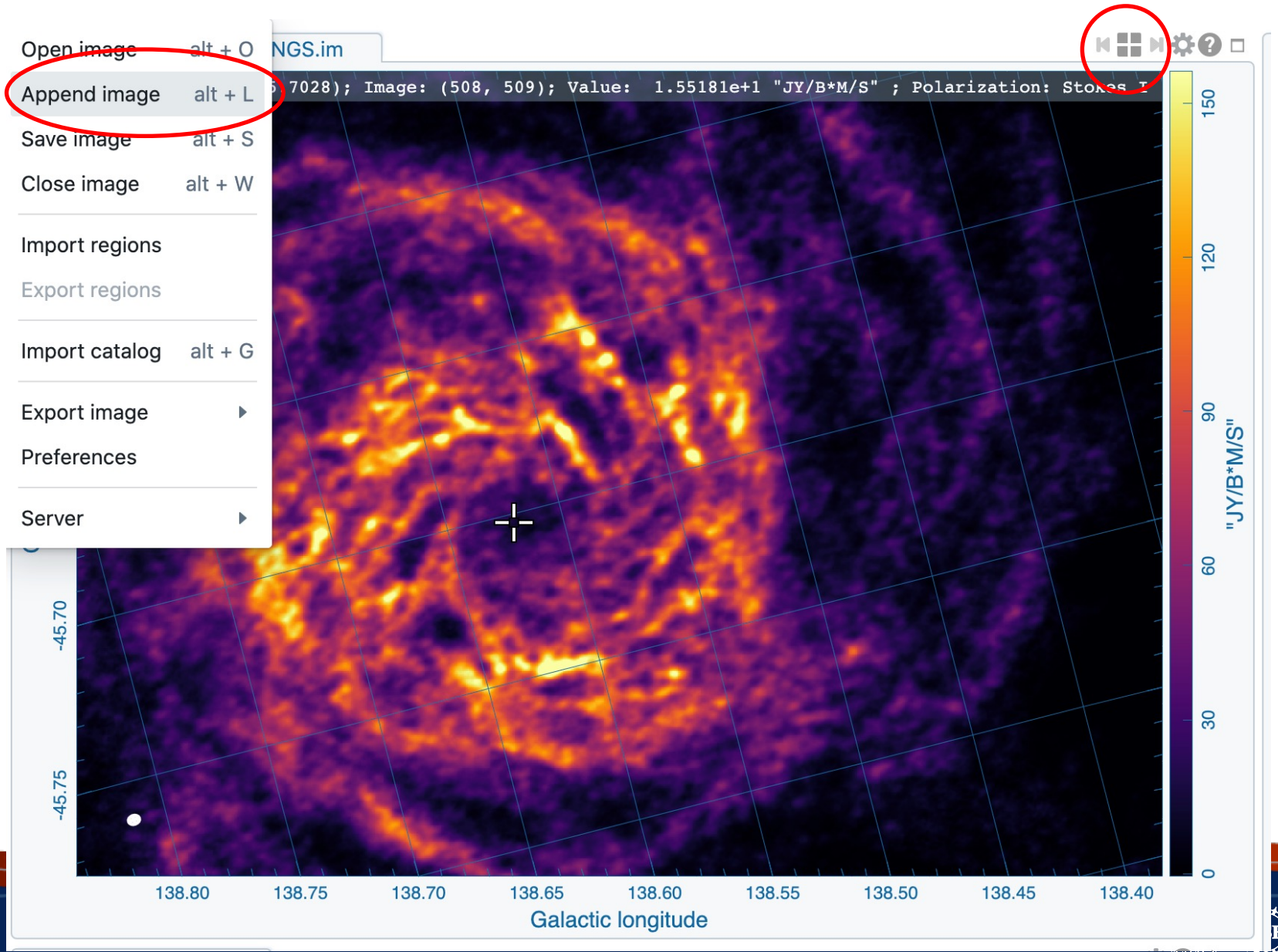


Image display widget - multipanel

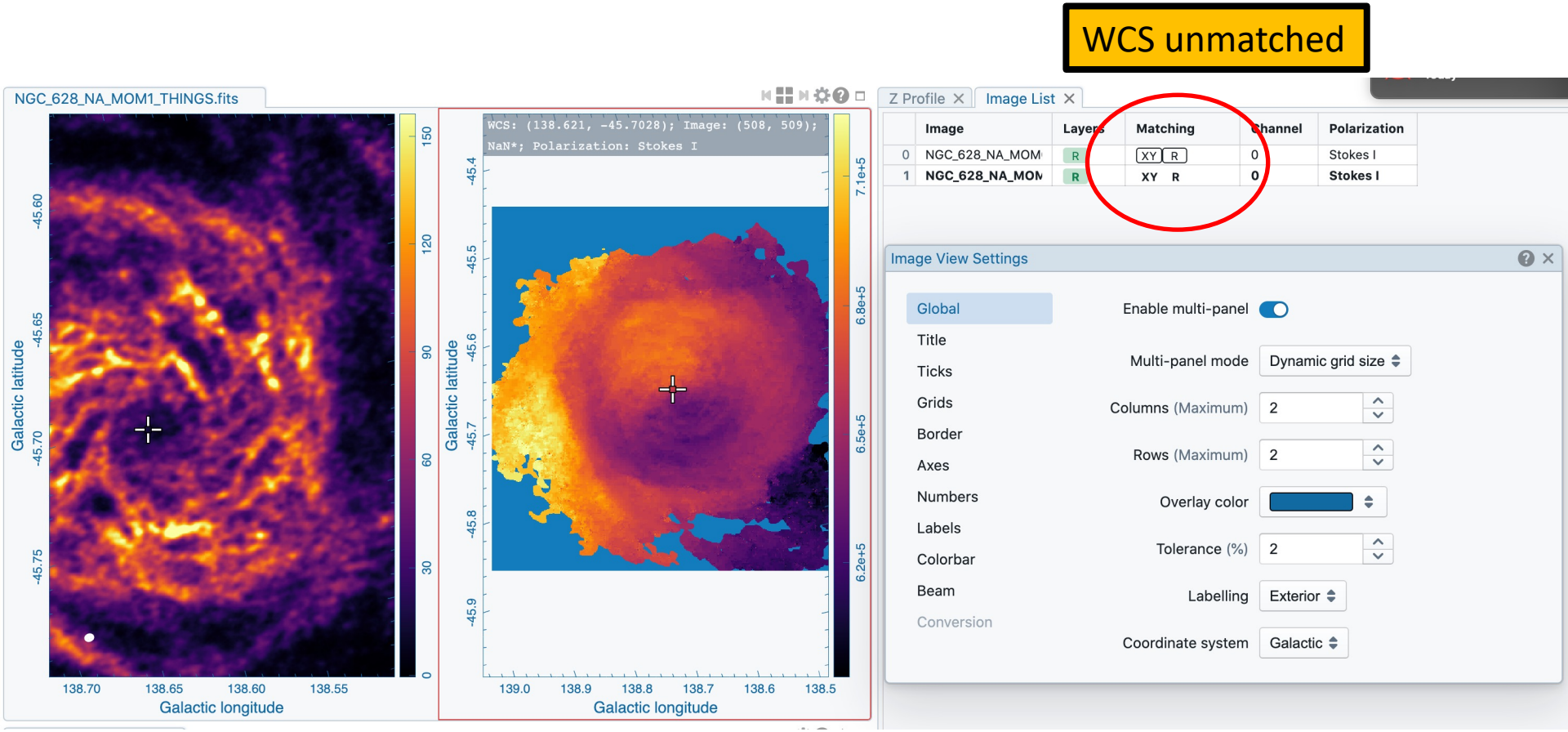


Image display widget - multipanel

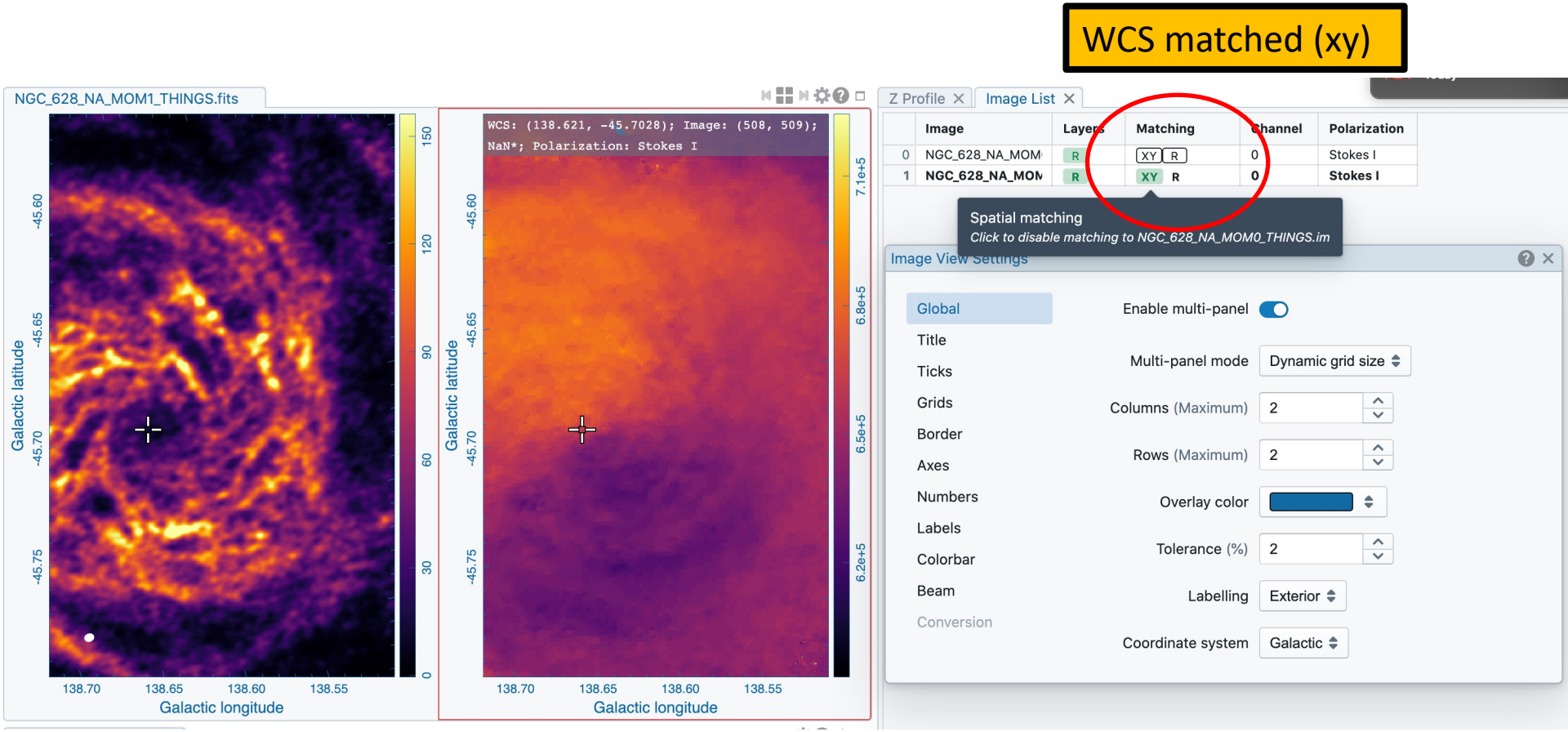
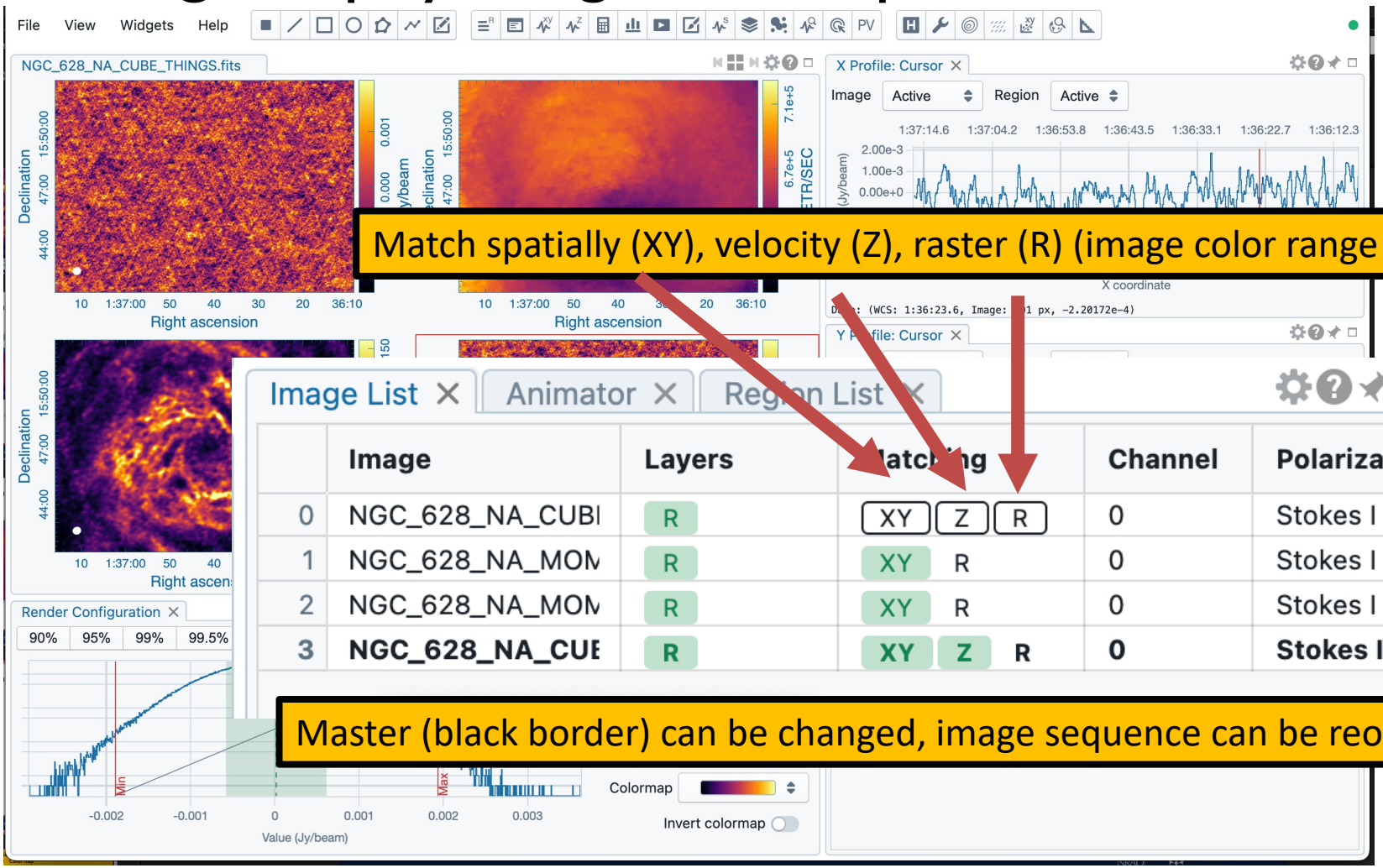
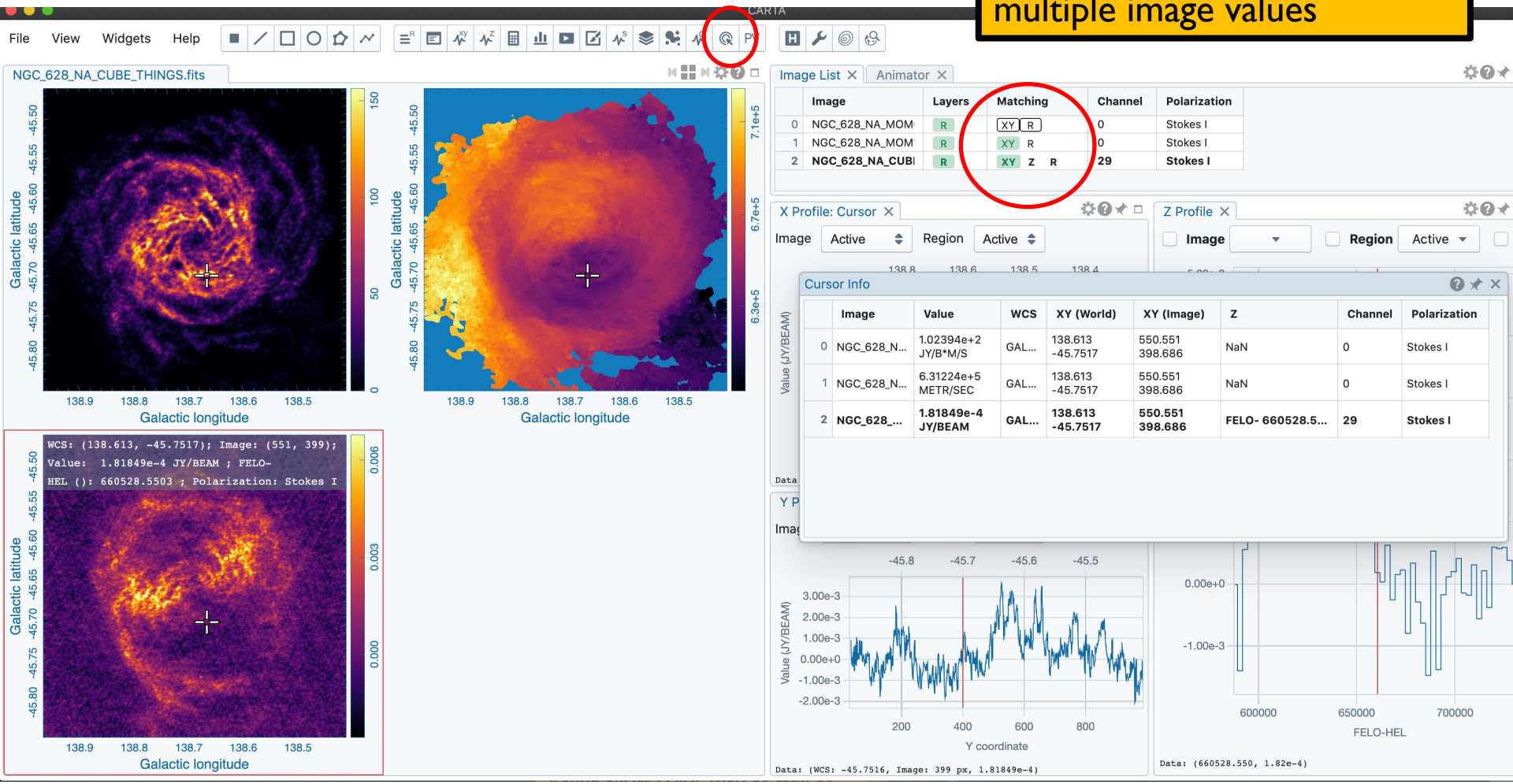


Image display widget - multipanel

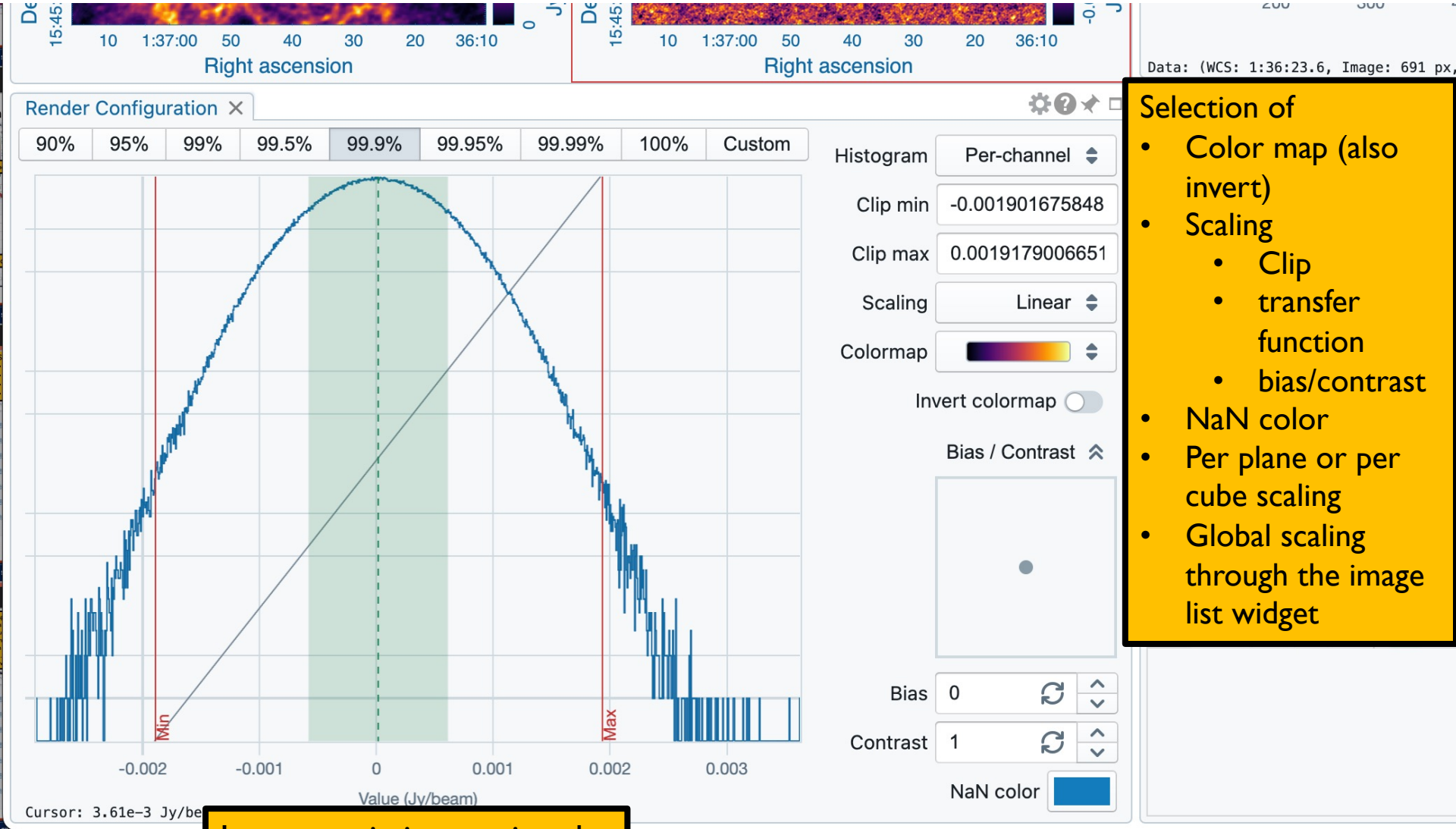


Cursor Widget

Match WCS first to see multiple image values



Rendering



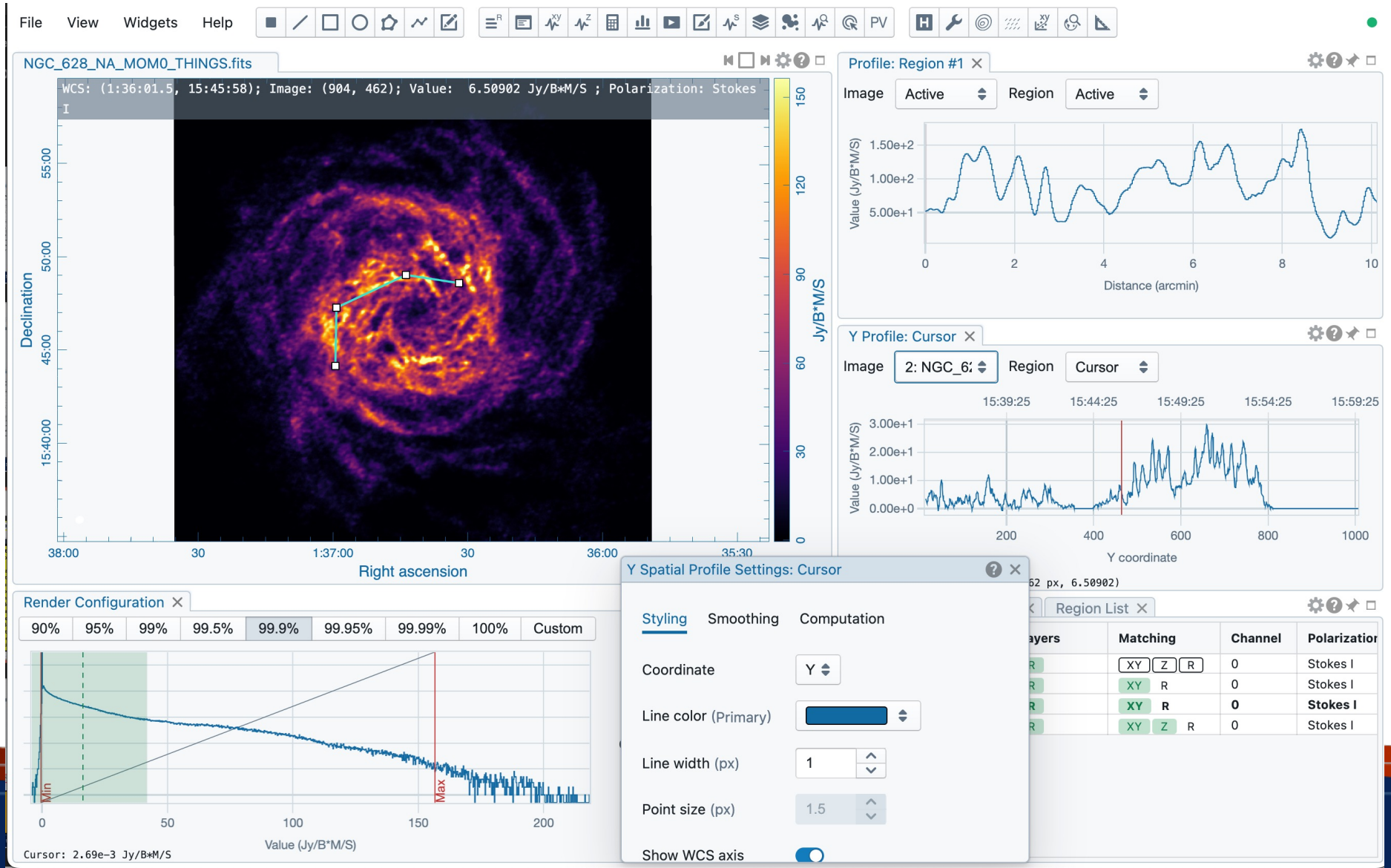
Selection of

- Color map (also invert)
- Scaling
  - Clip
  - transfer function
  - bias/contrast
- NaN color
- Per plane or per cube scaling
- Global scaling through the image list widget

Image statistics, setting the cuts manually or by percentage or by values

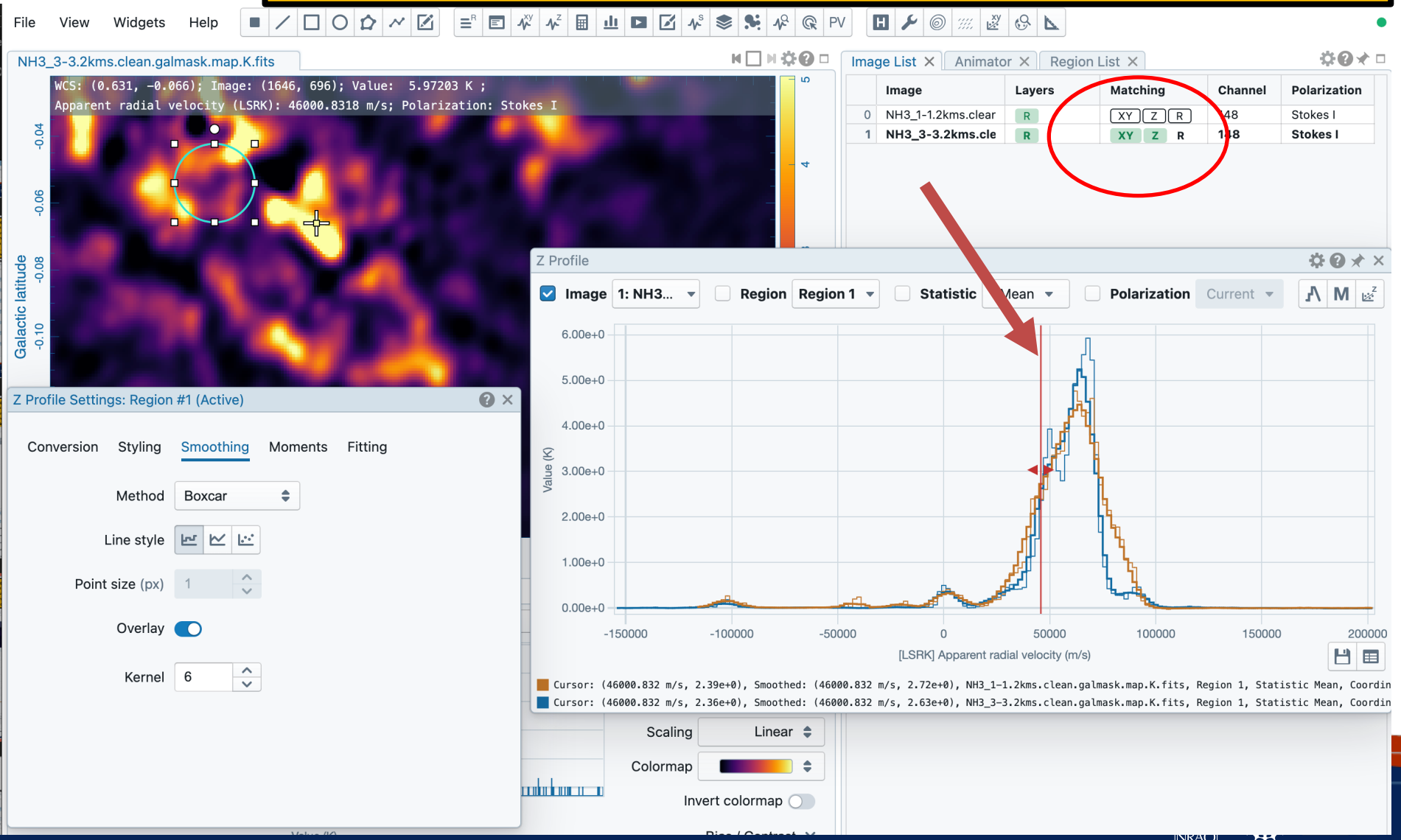
Profiles

- Spatial/Spectral profile: Line shape can be changed (color, steps/connect/points), spectral smoothing; data can be saved as ascii (or png)
- Marker is the position of the cursor/animator (freeze with 'f')
- Selection of region and image in each widget
- Spatial: cut along a segmented line or simply x and y

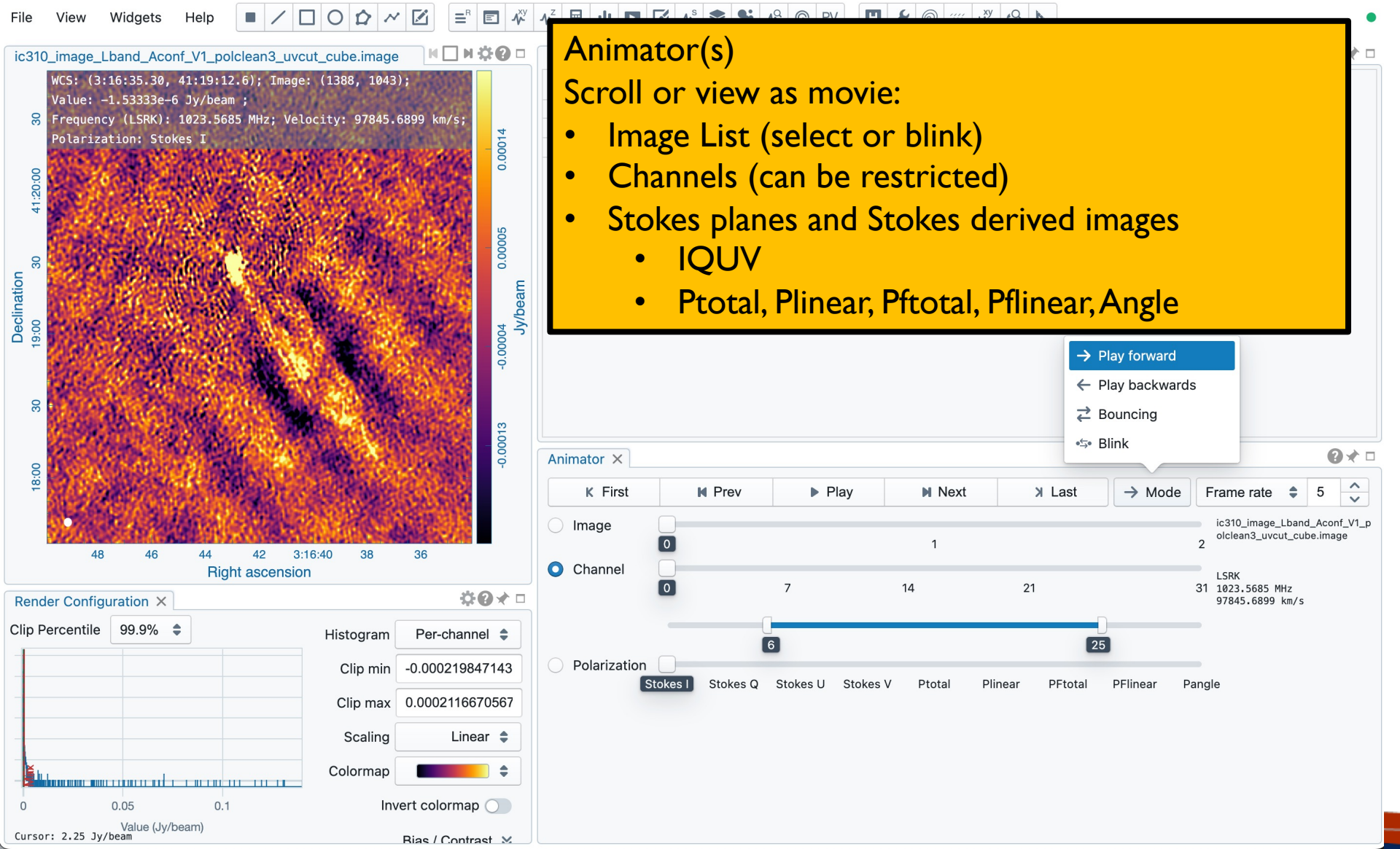


Profiles

- Spatial/Spectral profile: Line shape can be changed (color, steps/connect/points), spectral smoothing; data can be saved as ascii (or png)
- Marker is the position of the cursor/animator (freeze with 'f')
- Selection of region and image in each widget
- Spectral: Multiple line overlay / changing of units

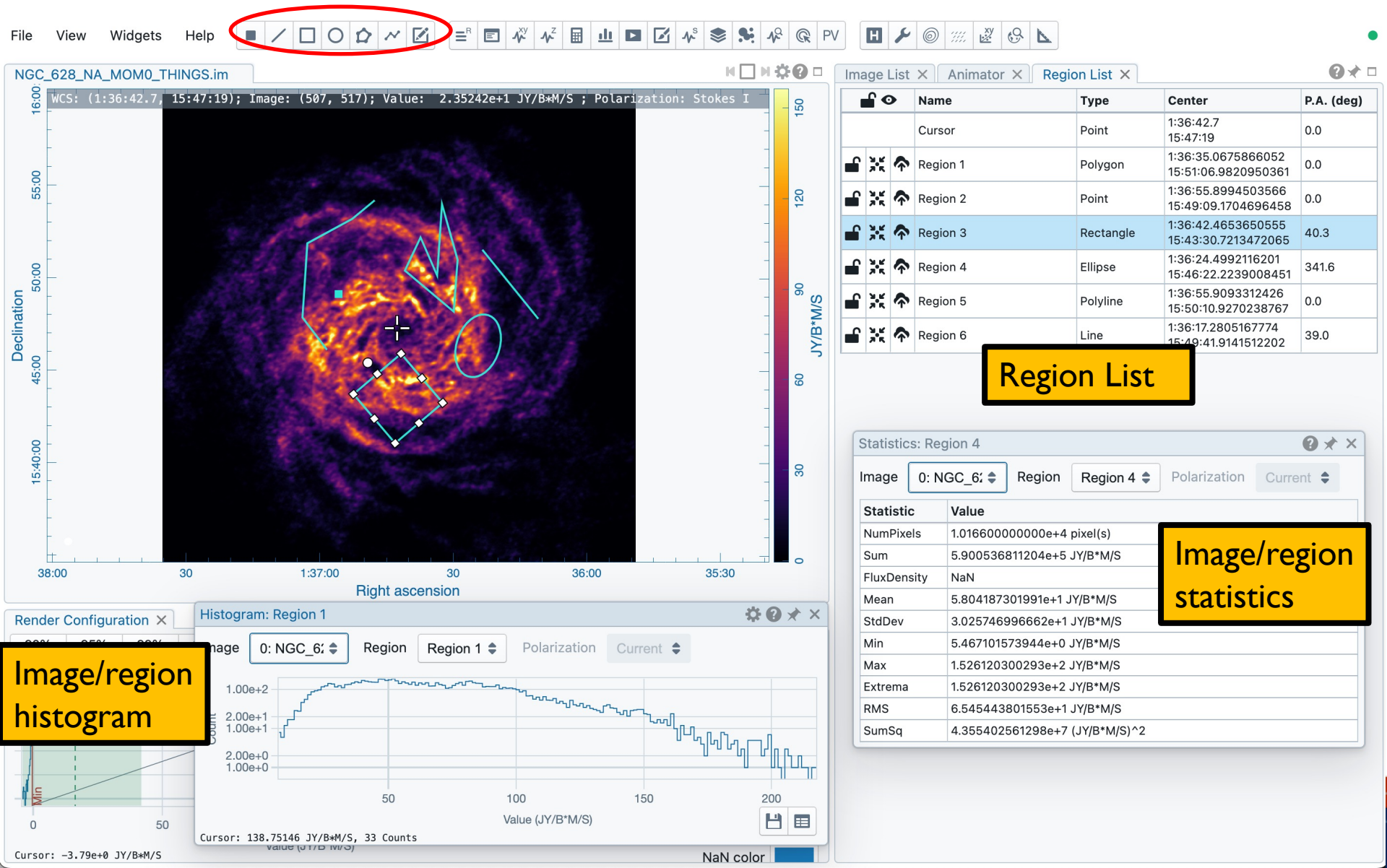


Animator


File
View
Widgets
Help
ic310_image_Lband_Aconf_V1_polclean3_uvcut_cube.image
WCS: (3:16:35.30, 41:19:12.6); Image: (1388, 1043);
Value: -1.53333e-6 Jy/beam ;
Frequency (LSRK): 1023.5685 MHz; Velocity: 97845.6899 km/s;
Polarization: Stokes I
Declination
Right ascension
Jy/beam
Animator(s)
Scroll or view as movie:
• Image List (select or blink)
• Channels (can be restricted)
• Stokes planes and Stokes derived images
• IQUV
• Ptotal, Plinear, Pftotal, Pflinear, Angle
Play forward
Play backwards
Bouncing
Blink
Animator
First
Prev
Play
Next
Last
Mode
Frame rate
Image
Channel
Polarization
Stokes I
Stokes Q
Stokes U
Stokes V
Ptotal
Plinear
PFtotal
PFlinear
Pangle
Render Configuration
Clip Percentile
99.9%
Histogram
Per-channel
Clip min
-0.000219847143
Clip max
0.0002116670567
Scaling
Linear
Colormap
Invert colormap
Value (Jy/beam)
Cursor: 2.25 Jy/beam

Regions

Regions can be created, deleted, rotated, modified, moved.
Analysis can be done on selected regions
Save regions as CRTF of ds9



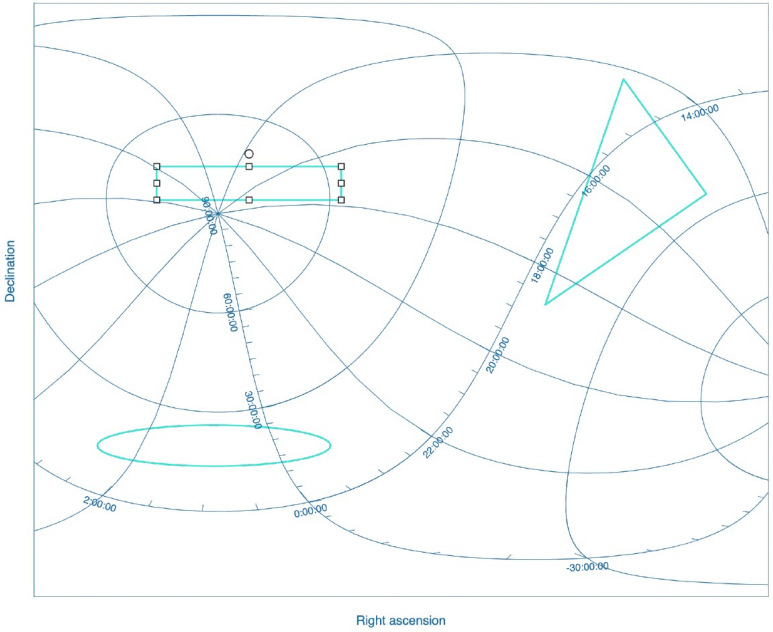
CARTA

Projection handling:

To avoid regridding, WCS matching shifts and rotates the image to the master image
This produces a small error for large fields, only visible in blinking
But images are projected correctly when overlaid as contours

Spectral matching: Nearest interpolation

Regions: They project correctly when moving across the sky in different coordinate systems



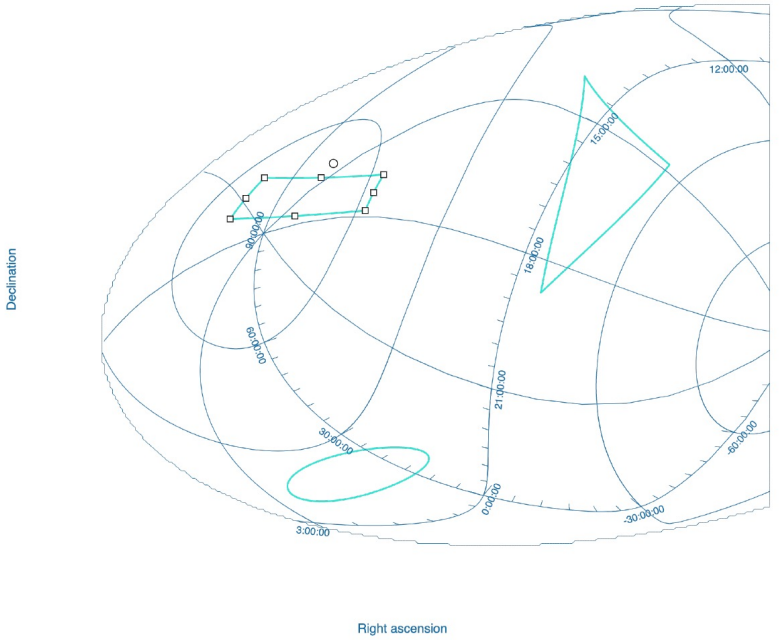
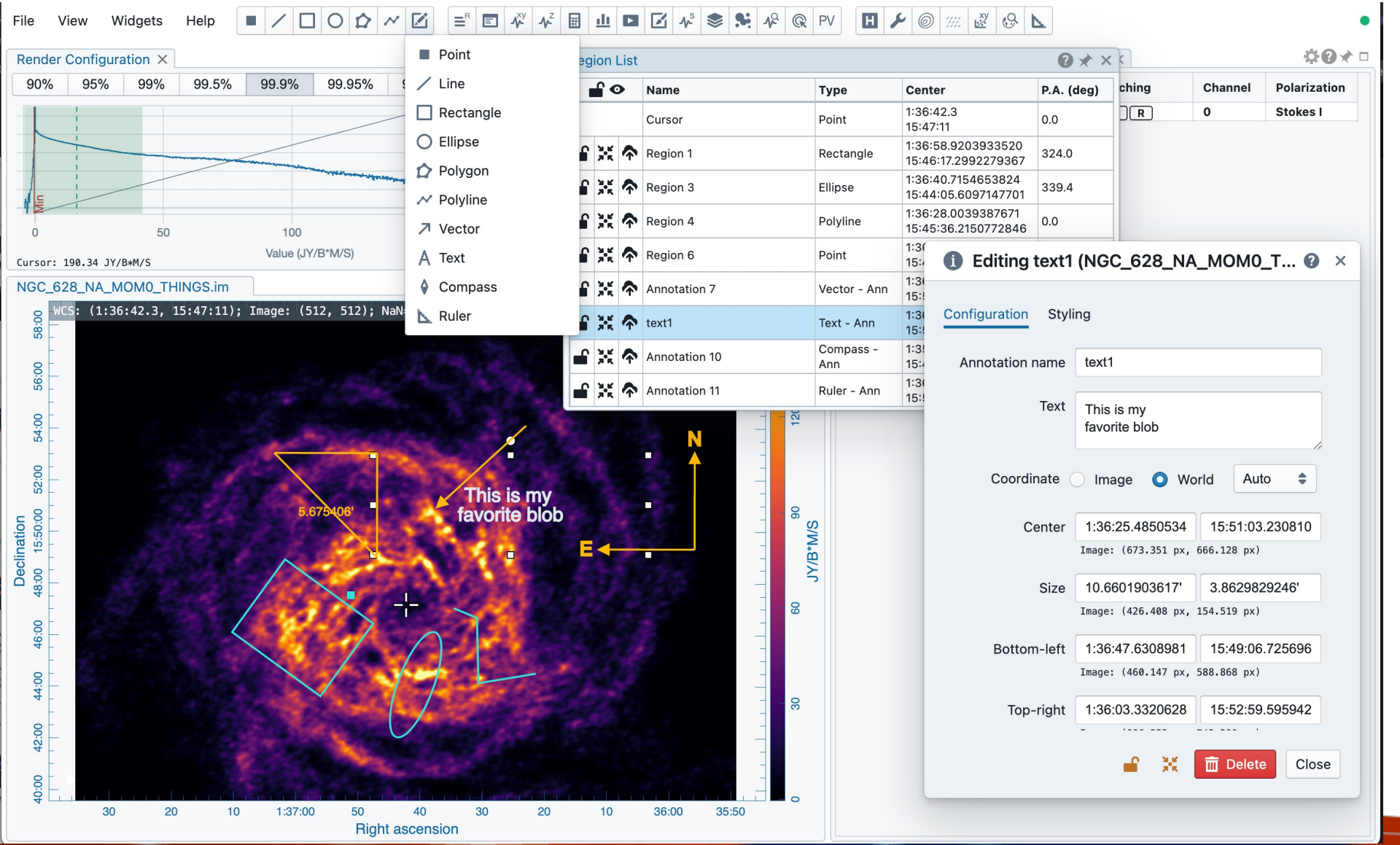
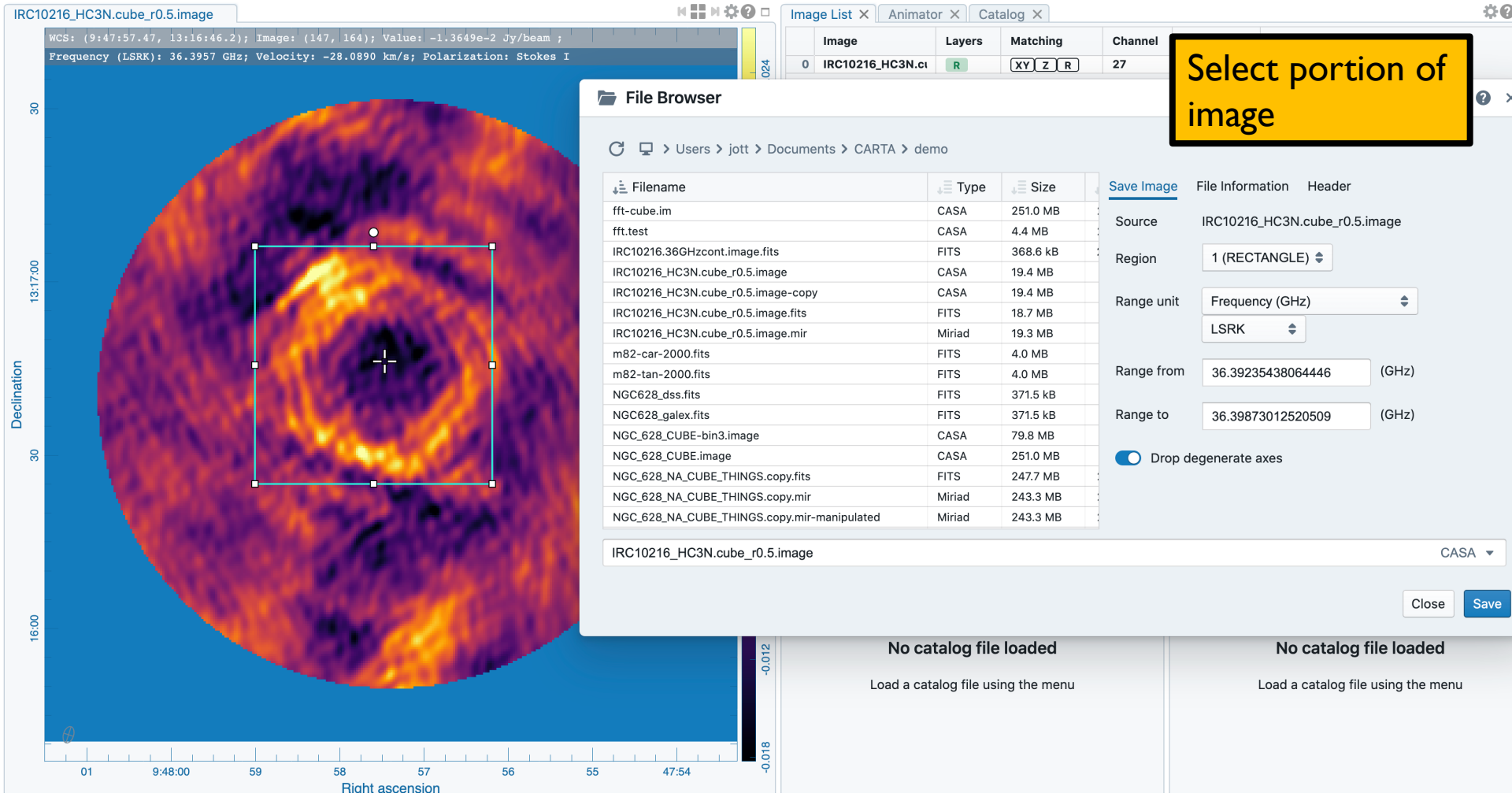


Image annotation

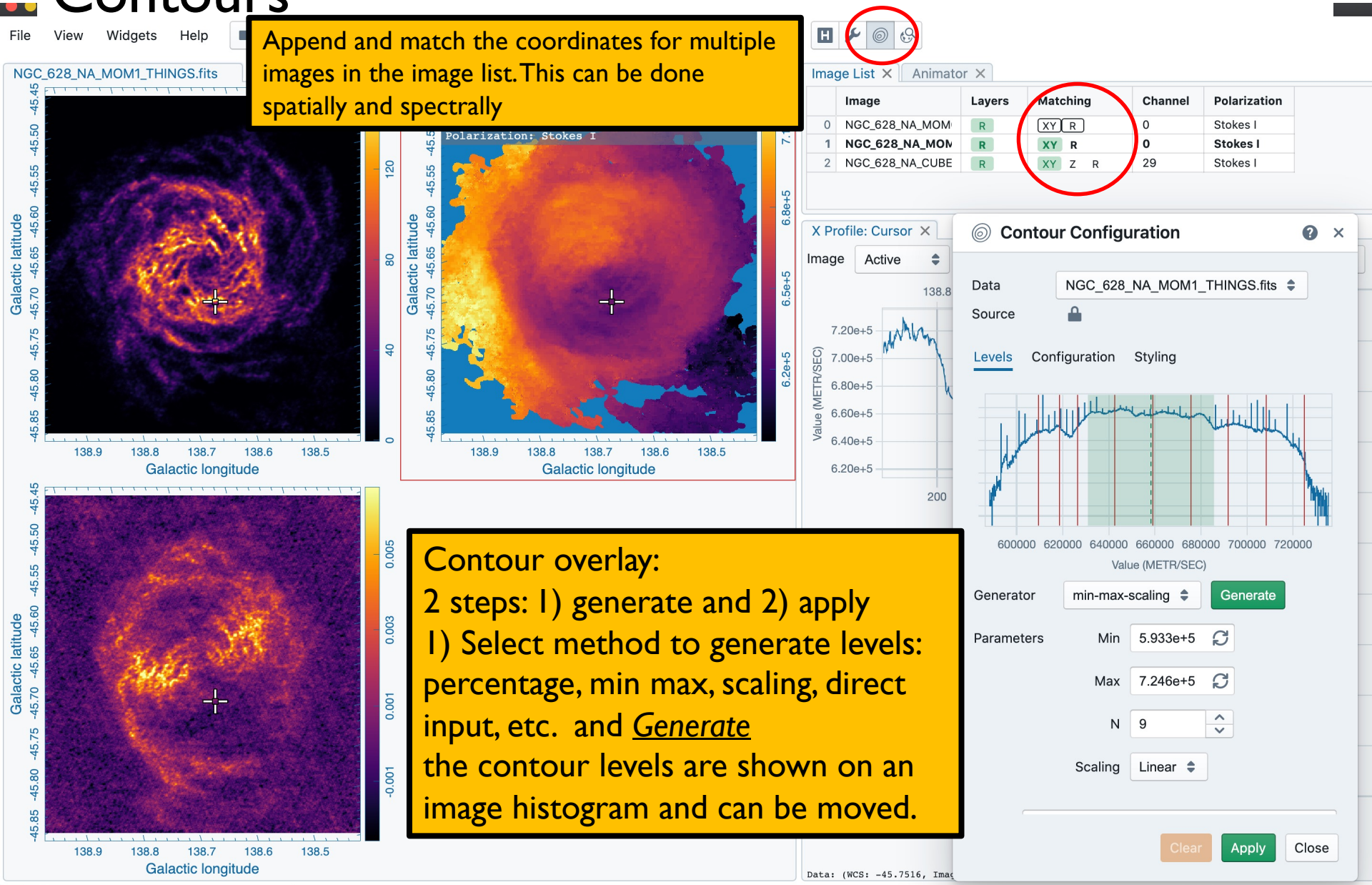
Annotations appear in region list
Save as CRTF annotation in regions file



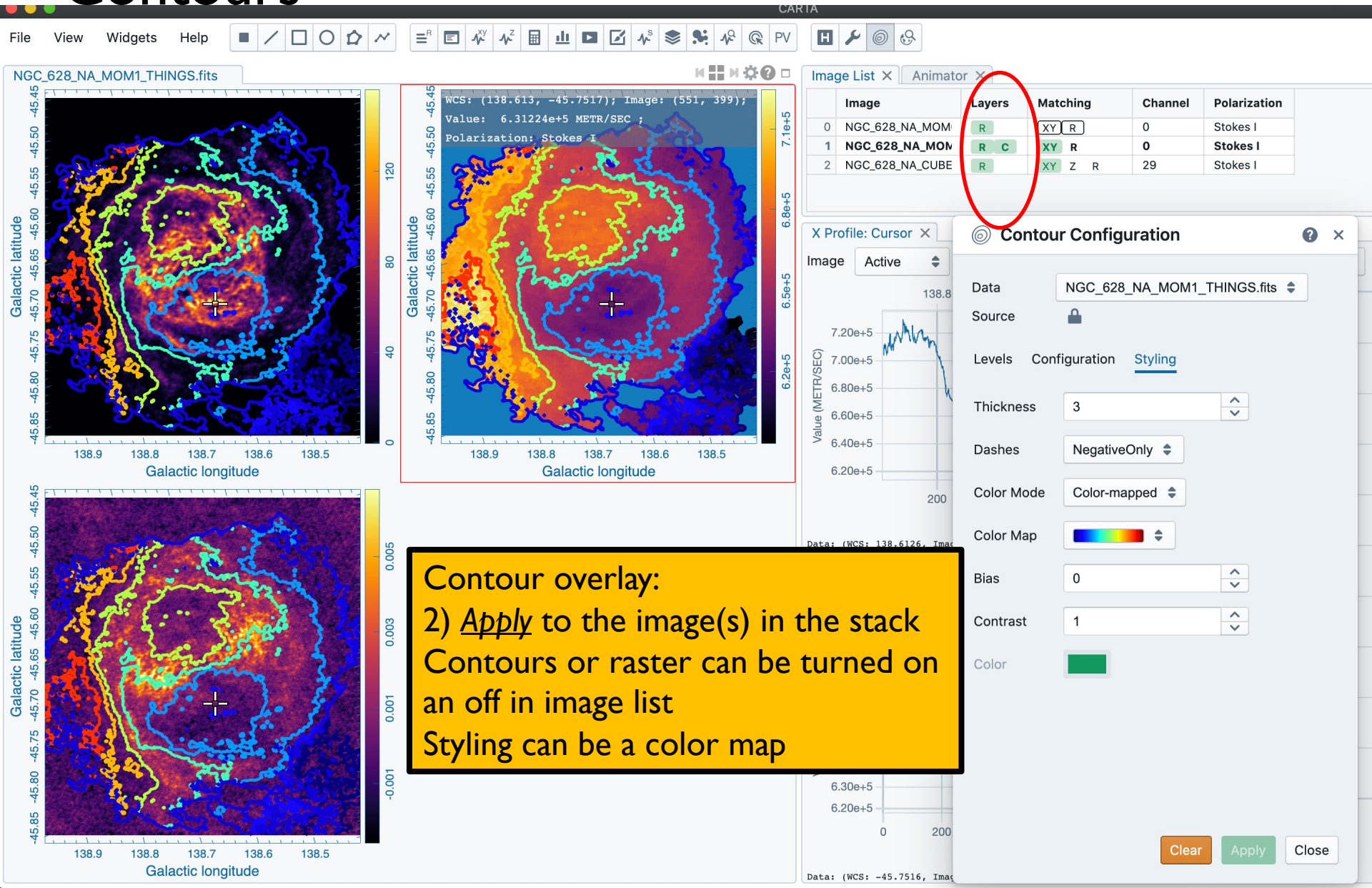
Saving subimages



Contours


File
View
Widgets
Help
Append and match the coordinates for multiple images in the image list. This can be done spatially and spectrally
NGC_628_NA_MOM1_THINGS.fits
Polarization: Stokes I
Galactic latitude
Galactic longitude
Image List
Animator
Image
Layers
Matching
Channel
Polarization
0 NGC_628_NA_MOM R XY R 0 Stokes I
1 NGC_628_NA_MOM R XY R 0 Stokes I
2 NGC_628_NA_CUBE R XY Z R 29 Stokes I
X Profile: Cursor
Image Active
Value (METR/SEC)
Contour Configuration
Data NGC_628_NA_MOM1_THINGS.fits
Source
Levels
Configuration
Styling
Value (METR/SEC)
Generator min-max-scaling Generate
Parameters
Min 5.933e+5
Max 7.246e+5
N 9
Scaling Linear
Clear
Apply
Close
Contour overlay:
2 steps: 1) generate and 2) apply
1) Select method to generate levels: percentage, min max, scaling, direct input, etc. and Generate
the contour levels are shown on an image histogram and can be moved.

Contours



Contour overlay:

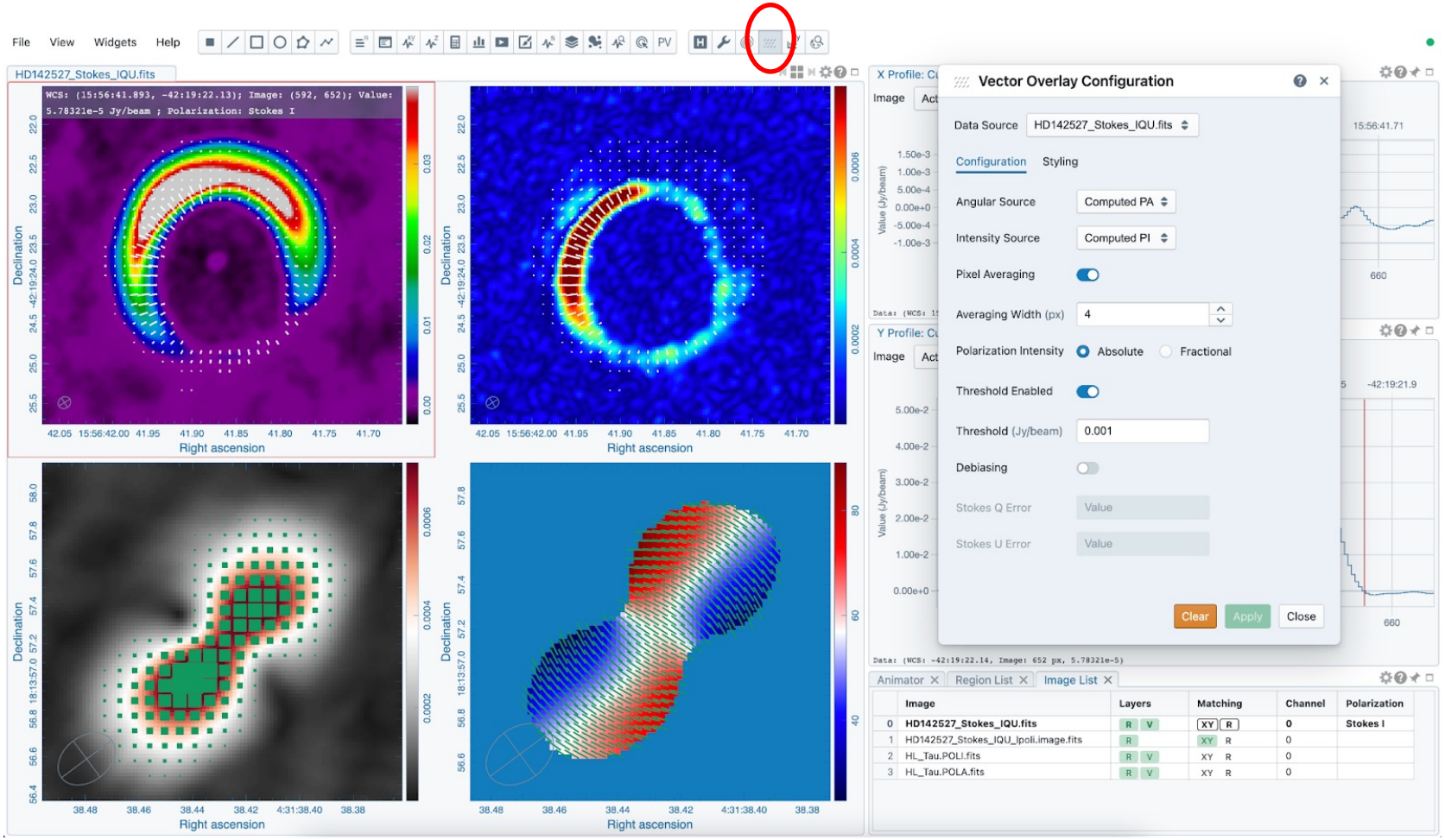
2) *Apply* to the image(s) in the stack

Contours or raster can be turned on an off in image list

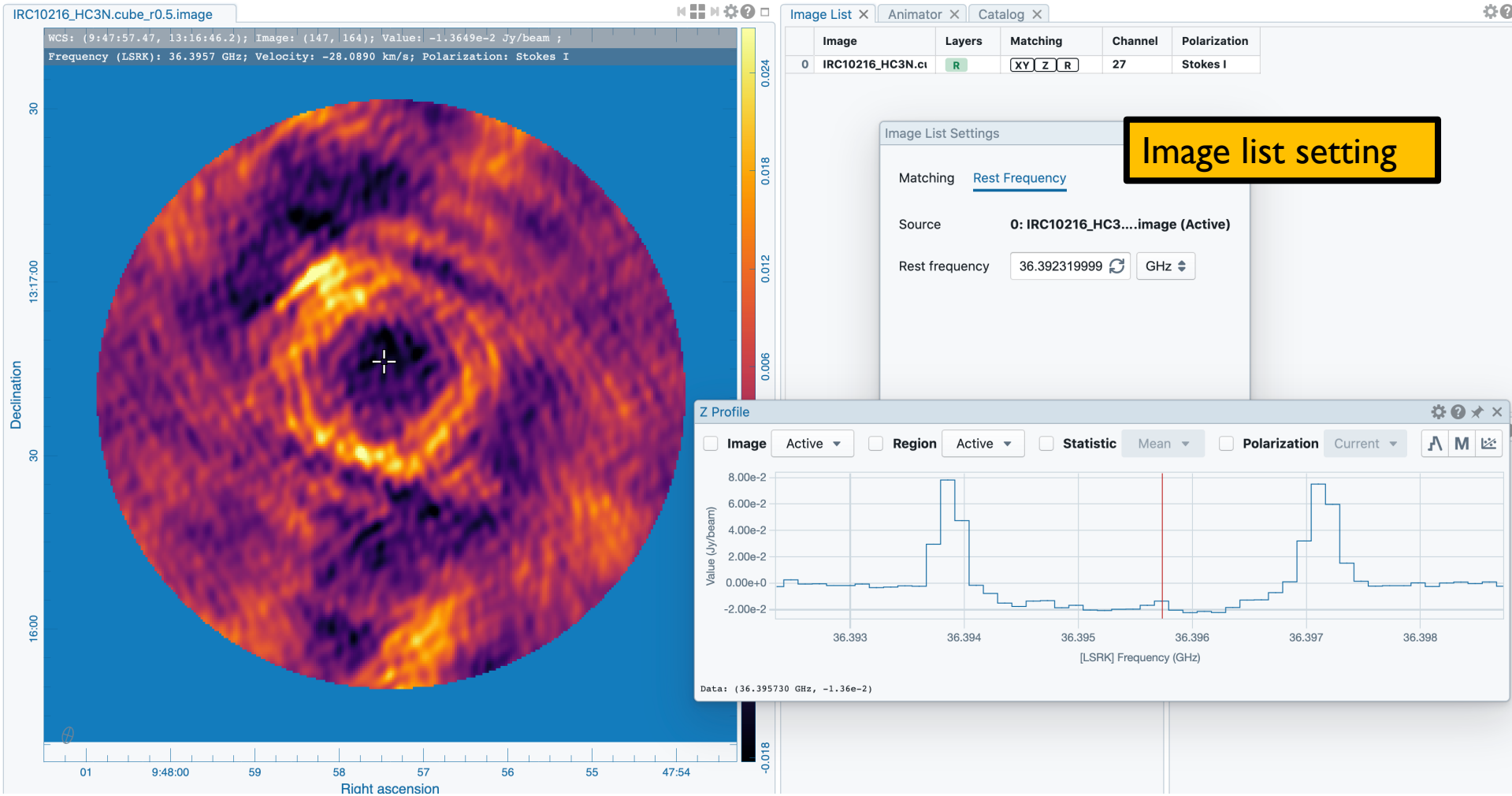
Styling can be a color map

Vector field rendering

Define images for a) intensity and b) angle

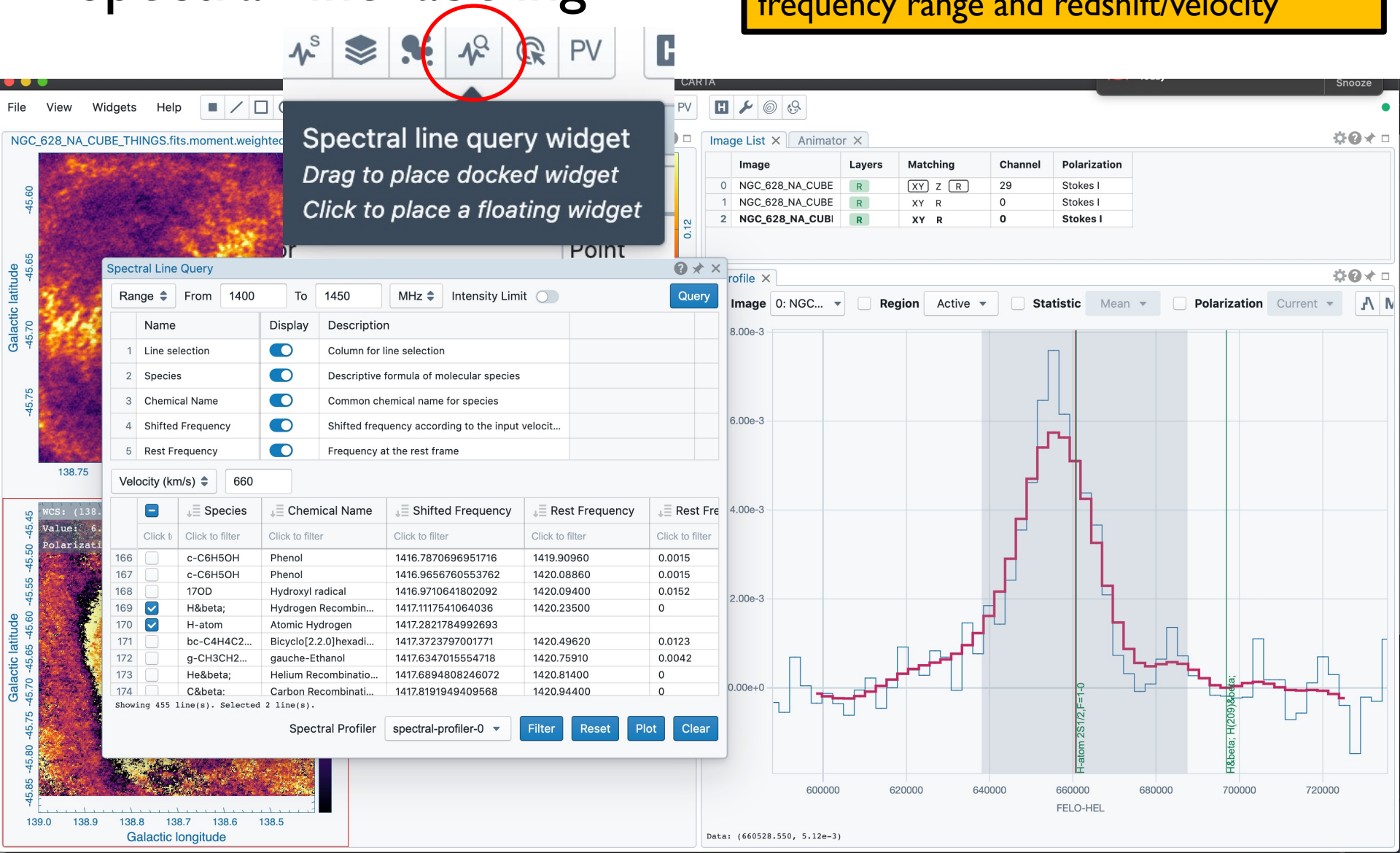


Set new rest frequency



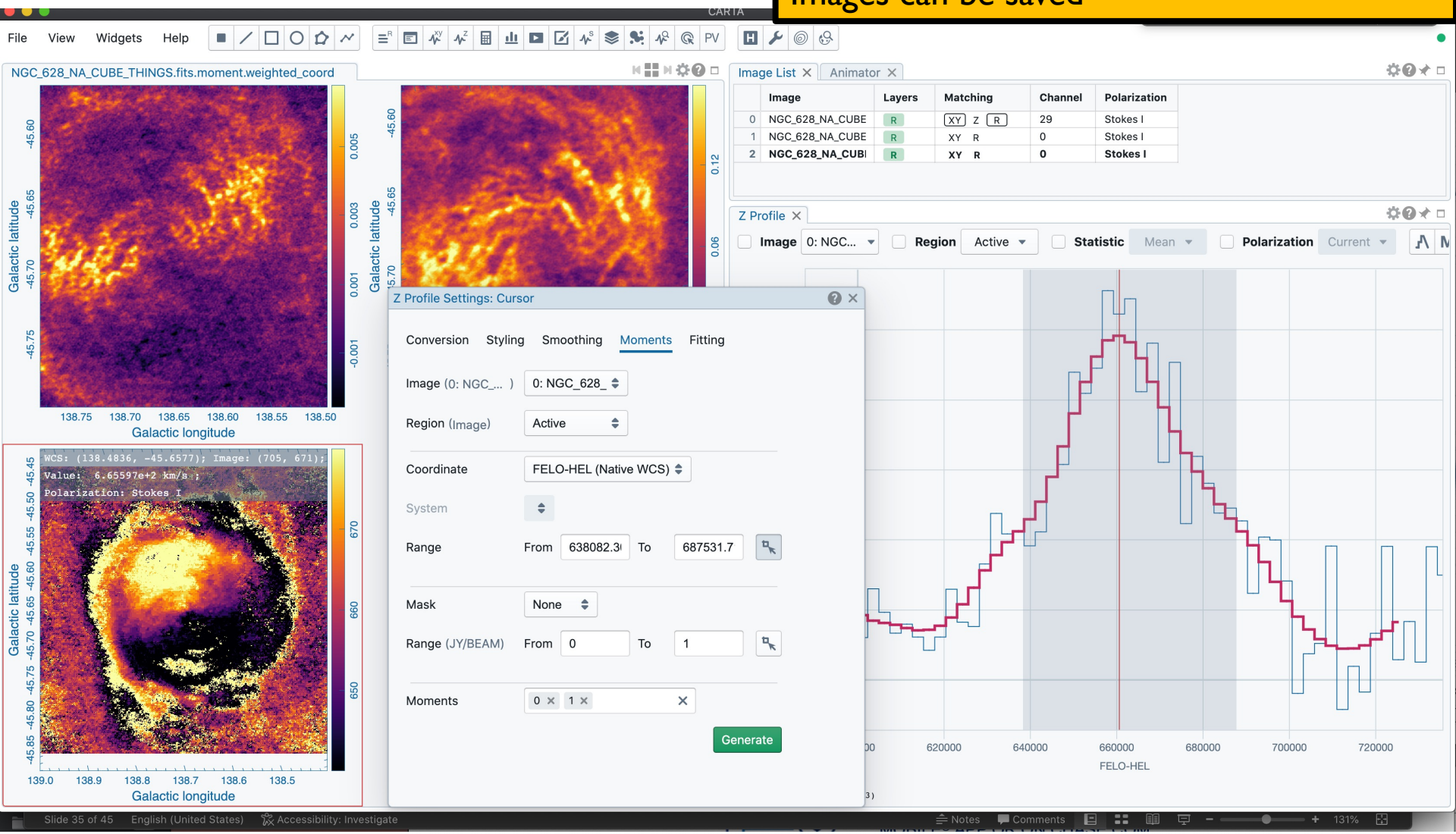
Spectral line labeling

Based on splatalogue, select line strength, frequency range and redshift/velocity



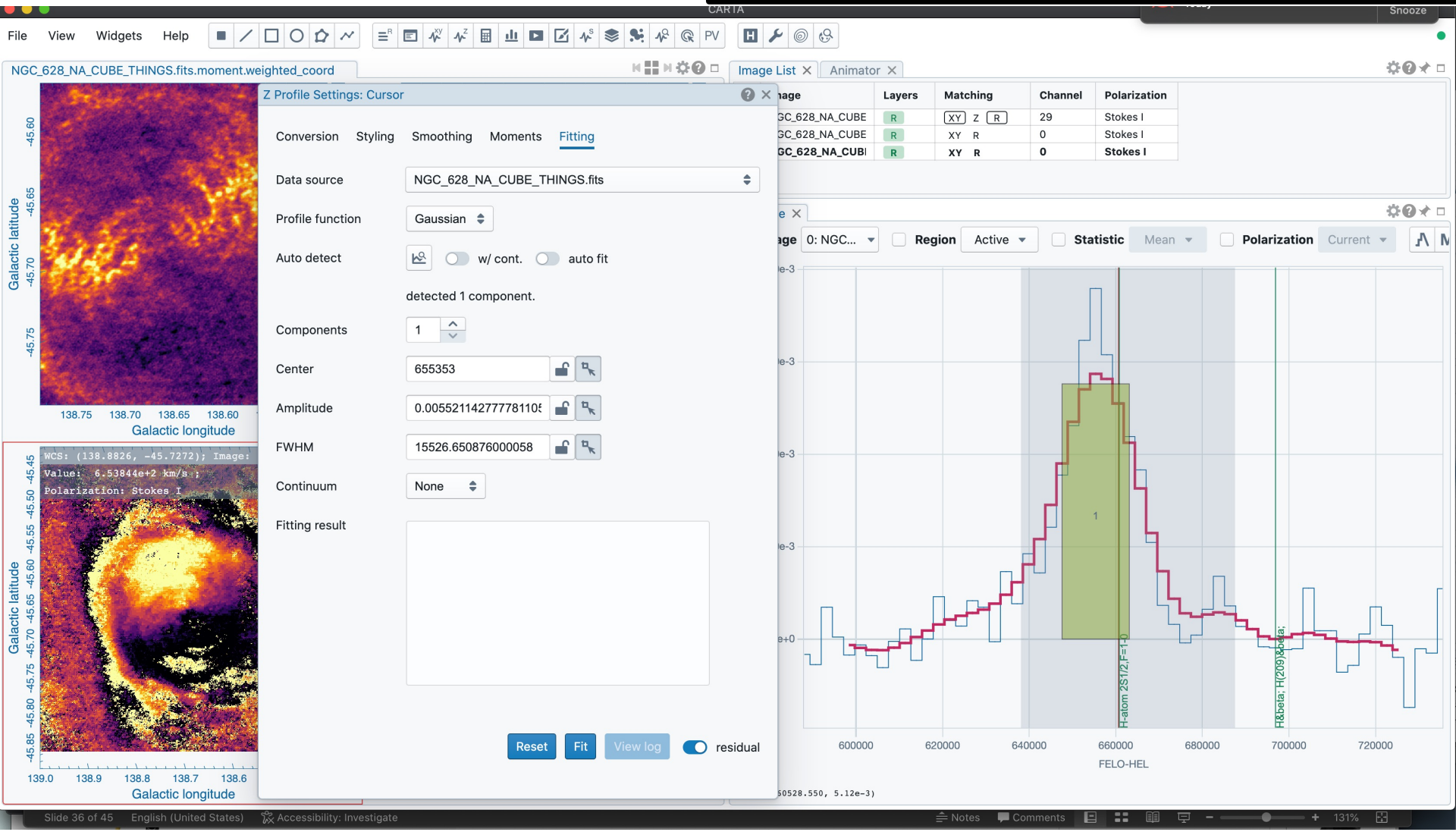
Moment maps

Spectral selection can be done interactively, including clip (uses CASA's immoments). Images can be saved



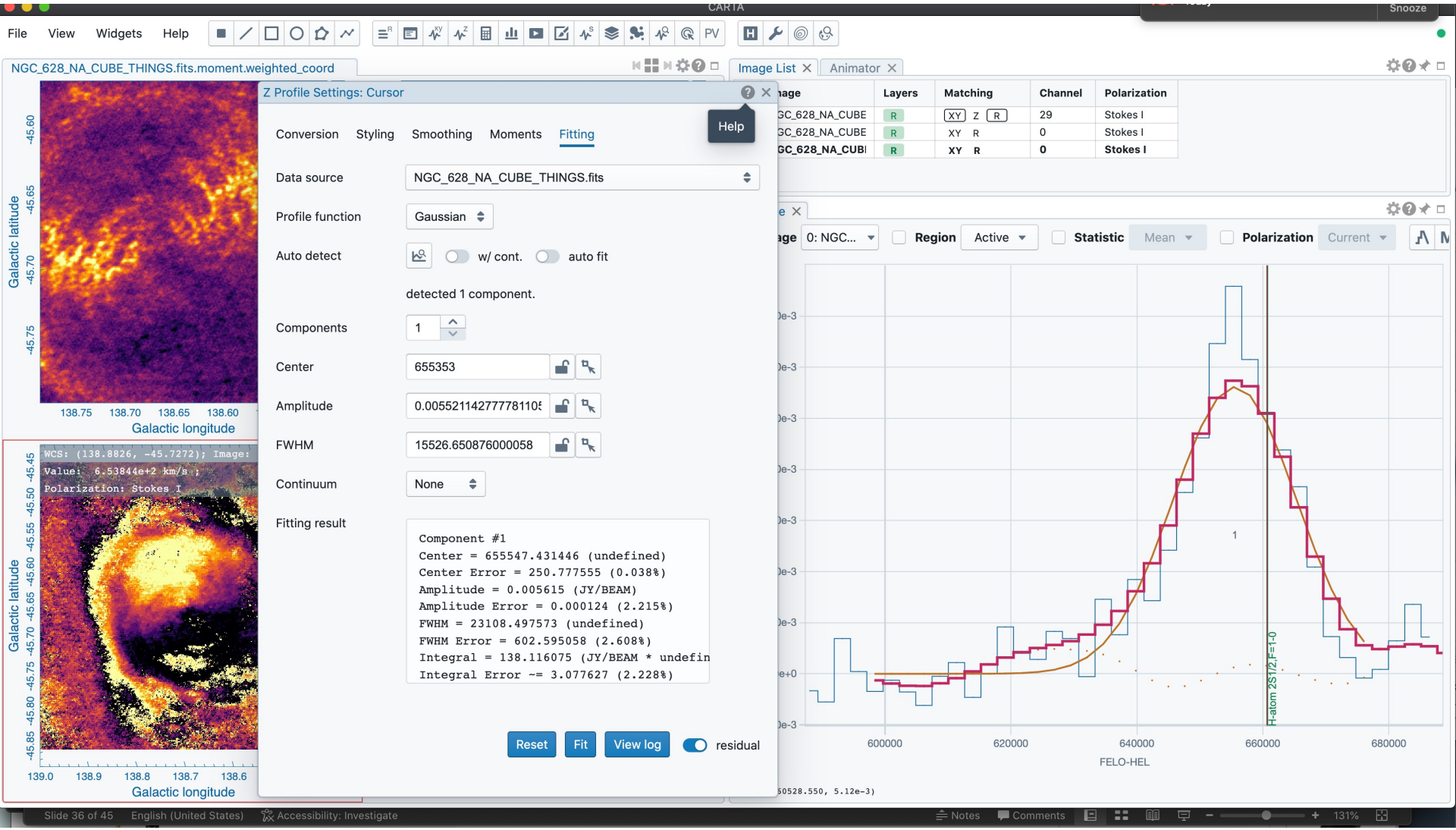
Spectral Line Fitting

Autodetection of line (can also be set manually.
Options: Gaussians, Lorenzians



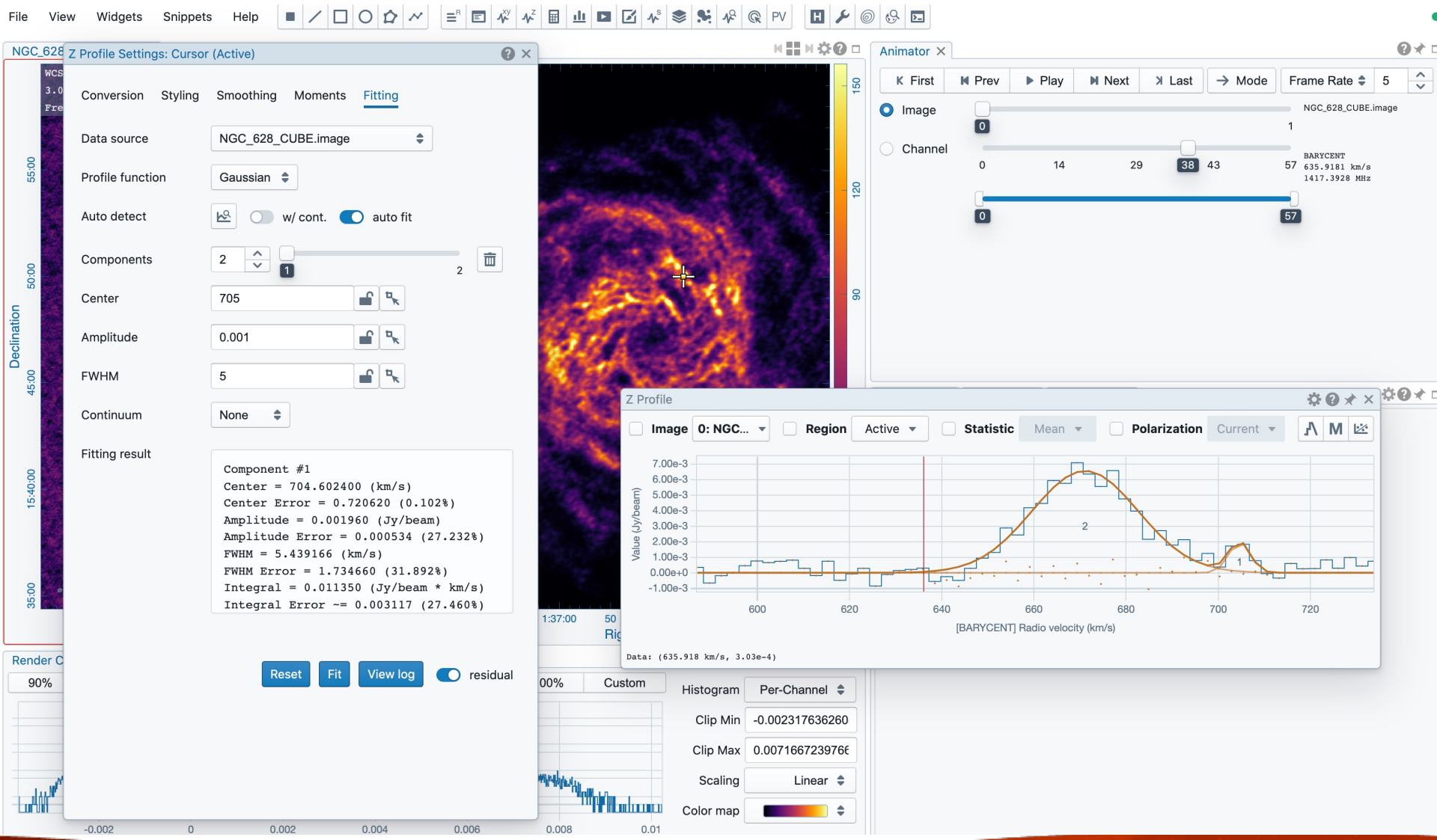
Spectral Line Fitting

Fit results can be copied/pasted/saved/displayed



Multiple Gaussians

Spectral Line Fitting



Position-Velocity

Interactive display, slice can be rotated, moved, stretched, displayed on other matched images.
Save as a an pV image file (will appear in stack and can be exported)

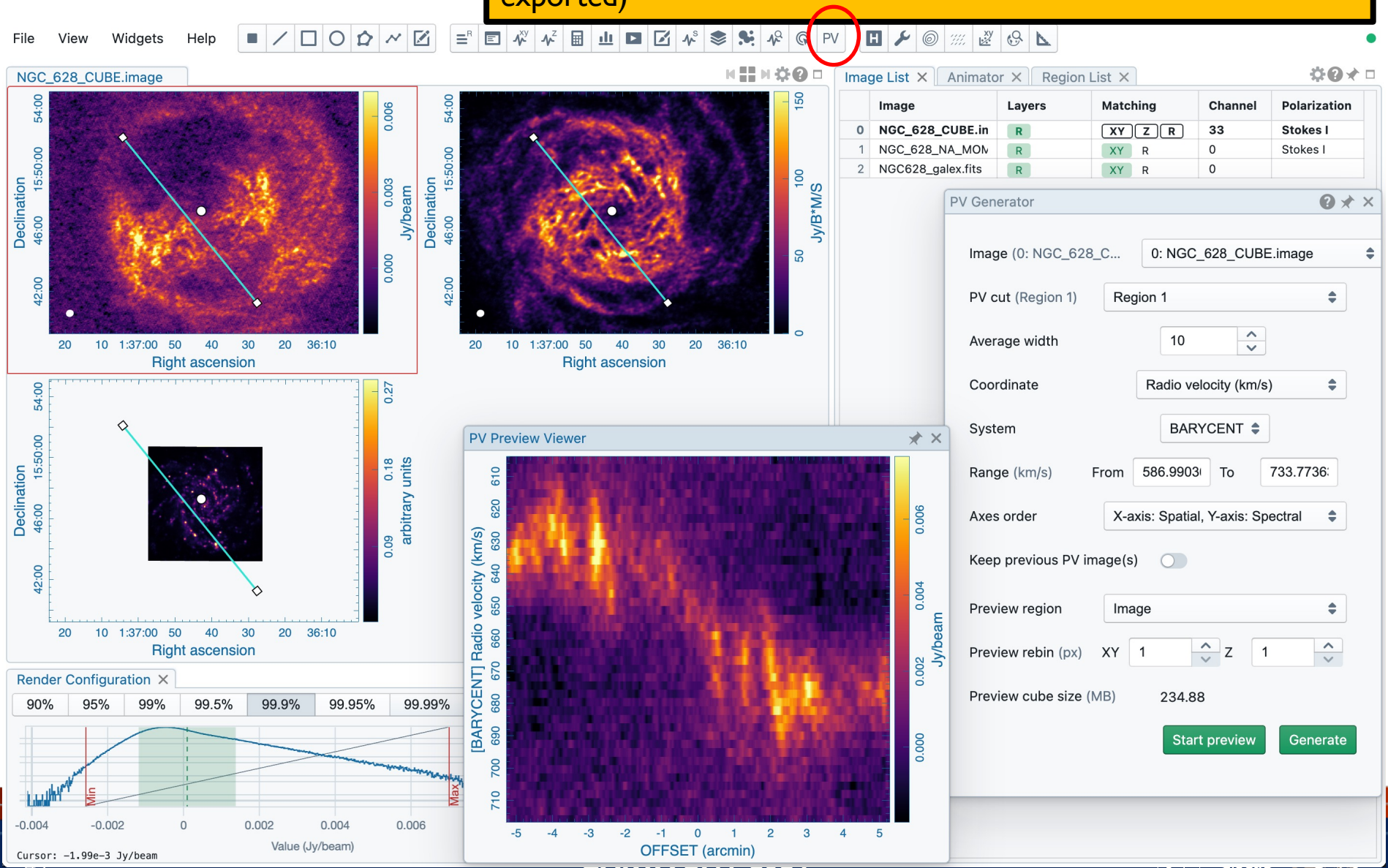
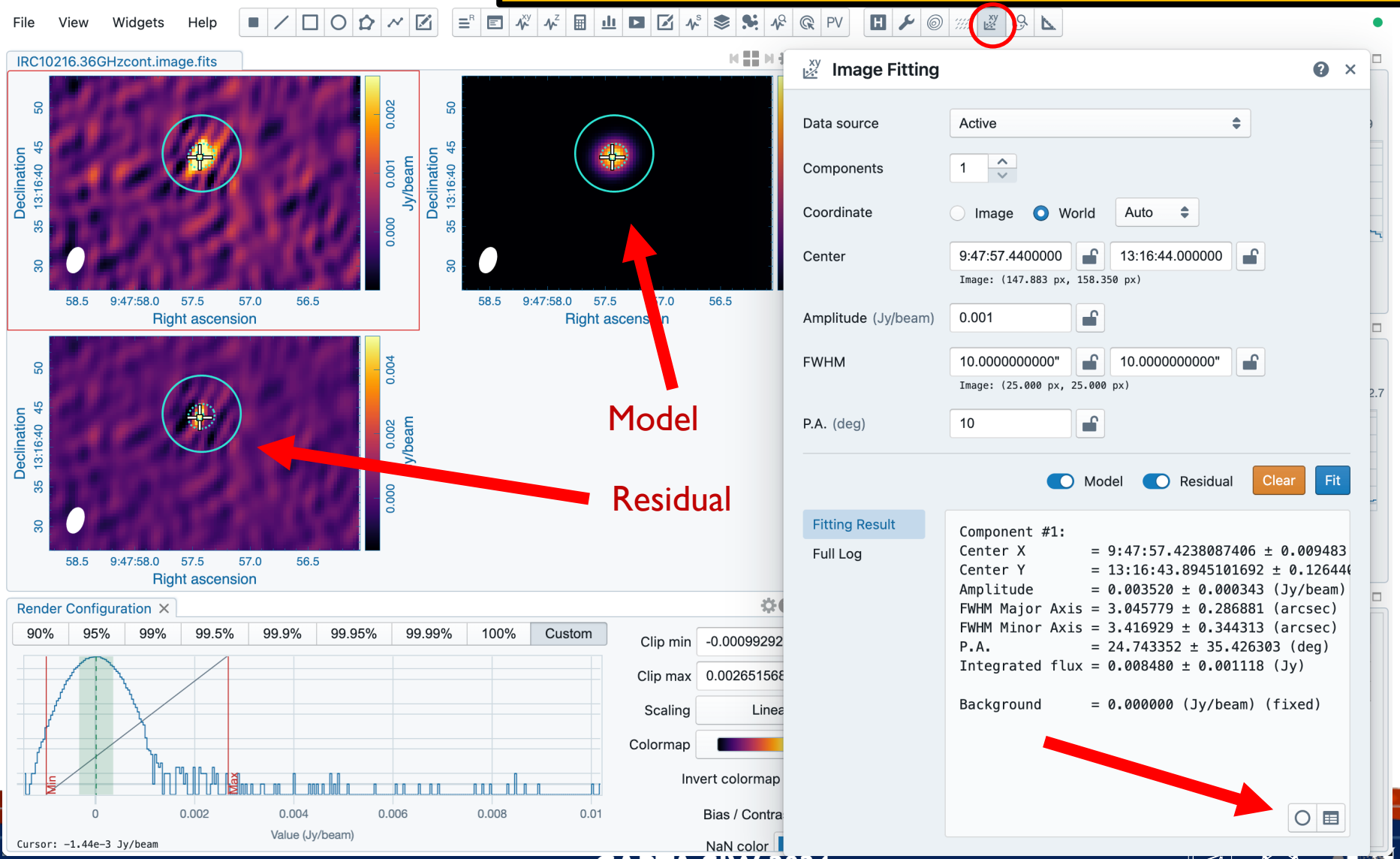


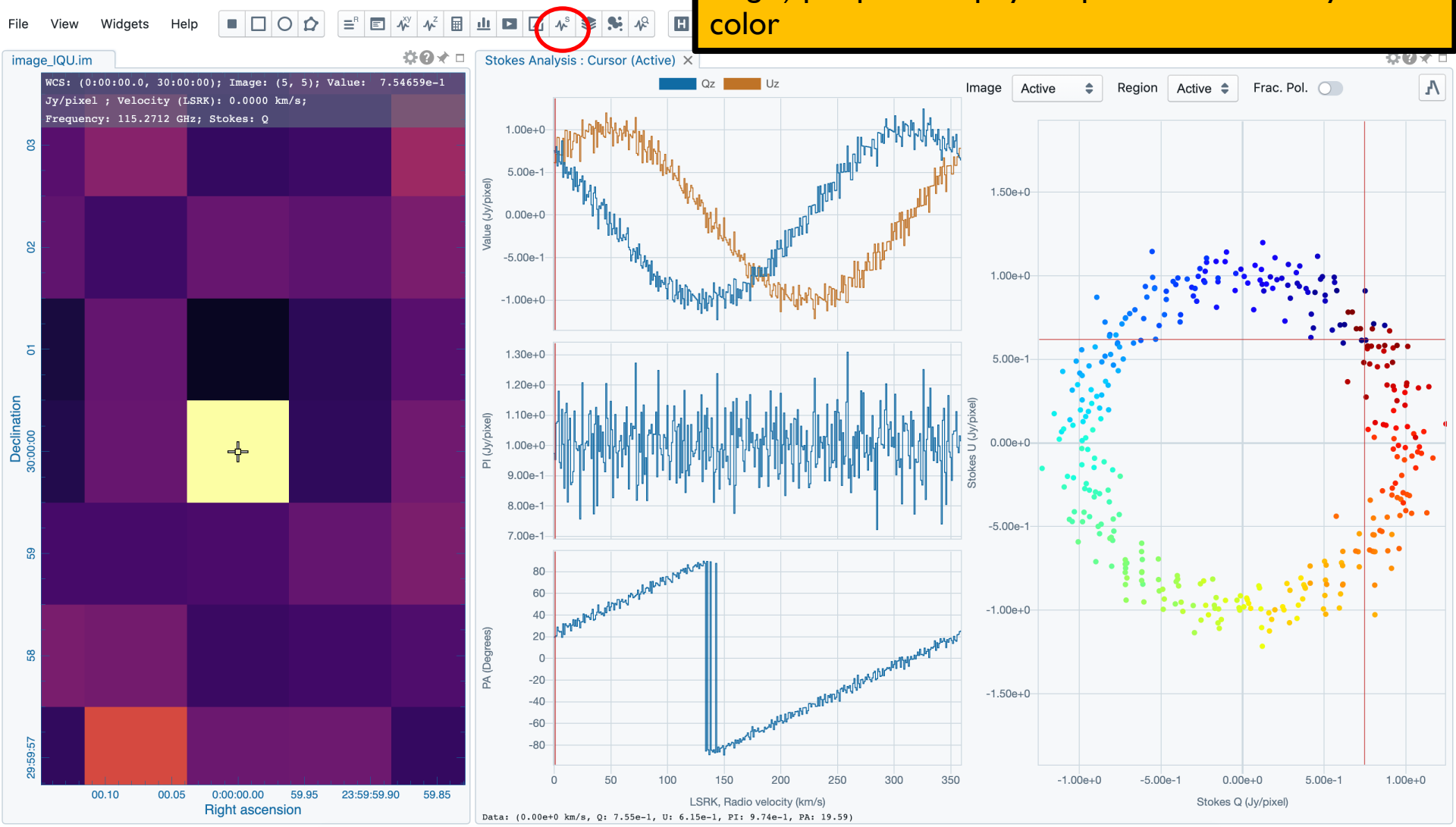
Image Fitting

Specify #components and initial starting values for the fit.
Each value can be specified as fixed or variable.
Display of Model and Residual, plus region made from fit results
Copy/paste or save fit results and regions.



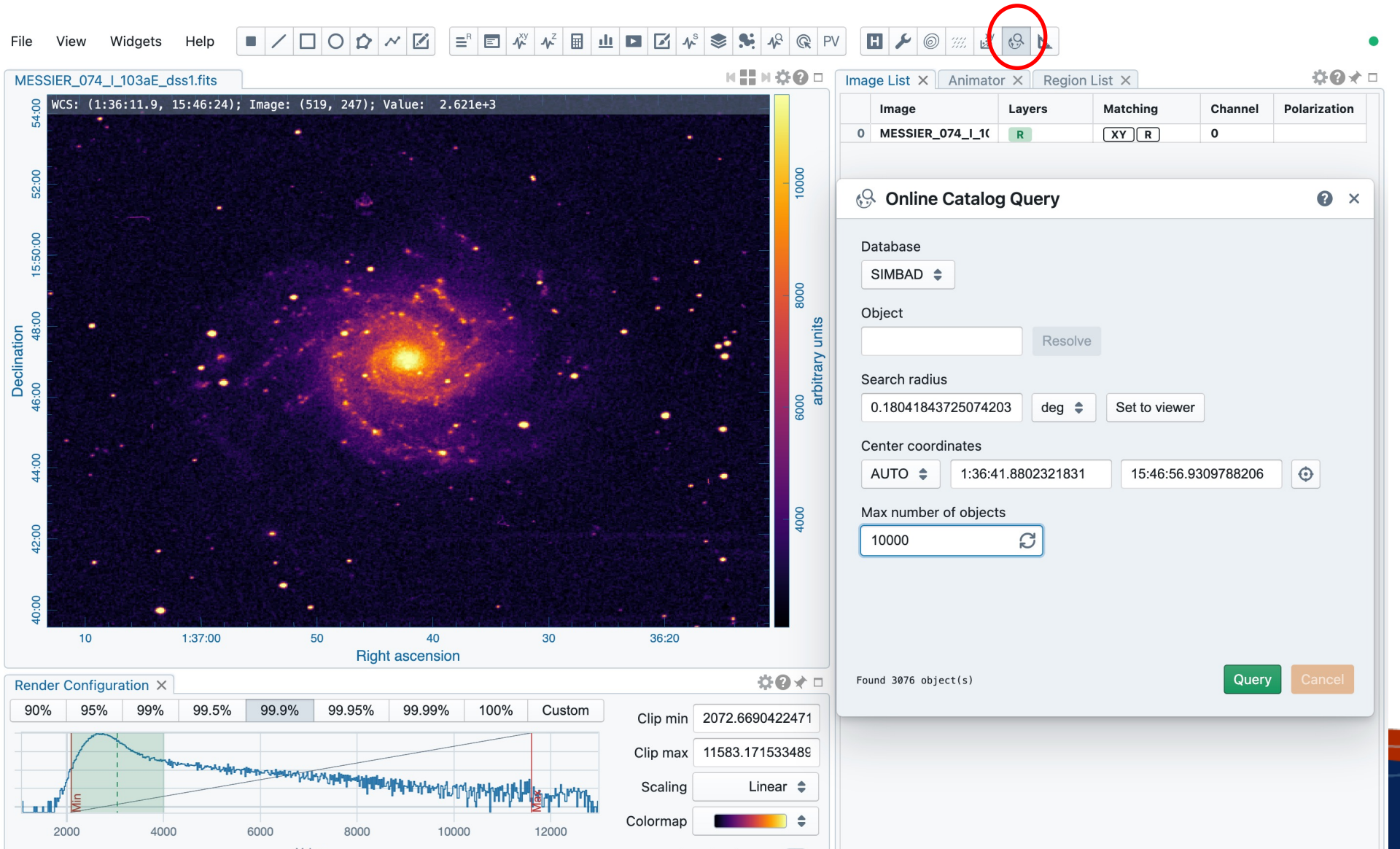
Stokes Analysis Widget

Stokes cubes (or hypercubes):
Calculate Polarization properties (Polarized Intensity, Angle) per plane; display as spectrum or velocity in color



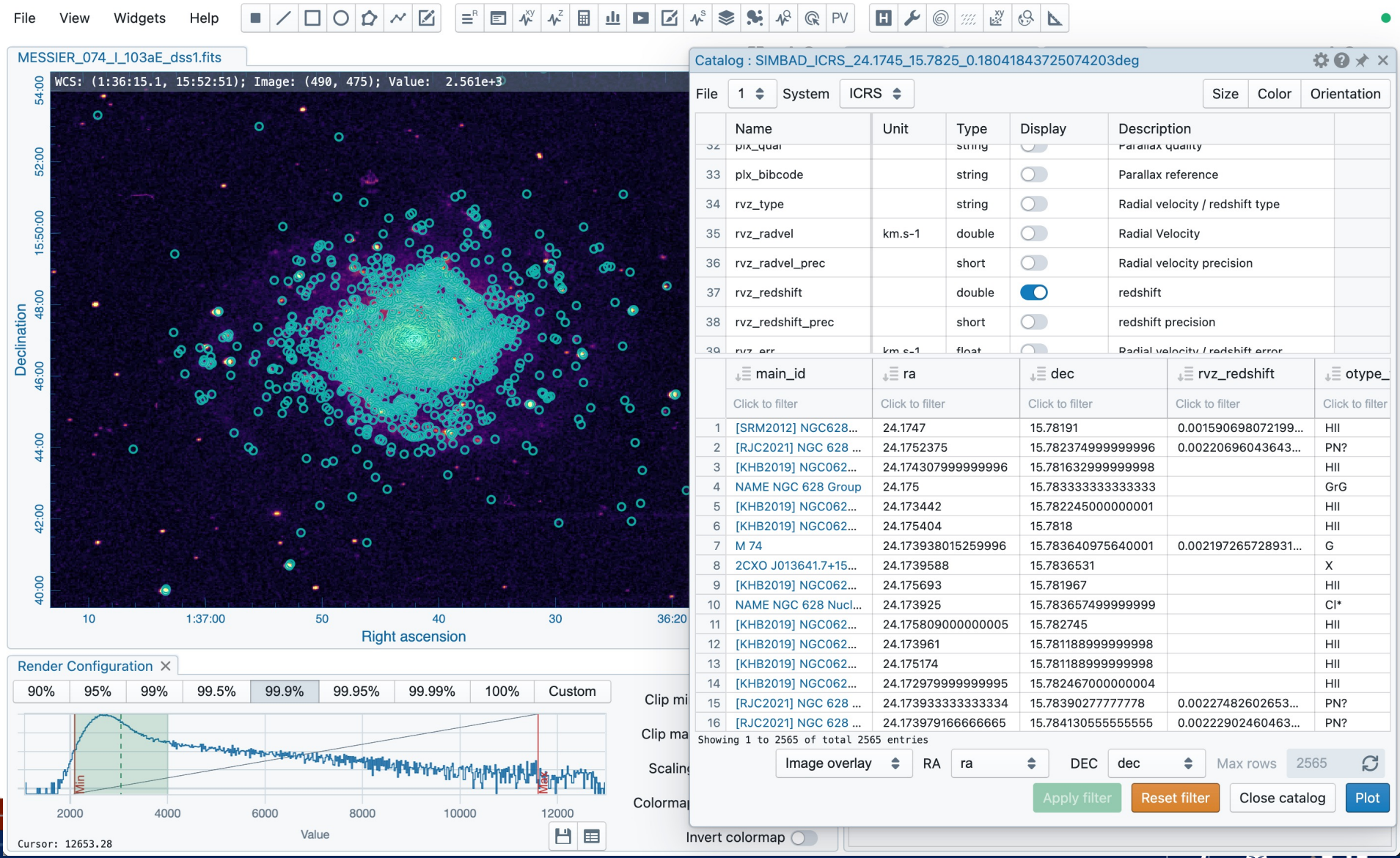
Catalog tool

Upload your own or search online, e.g. in Simbad for Catalogs



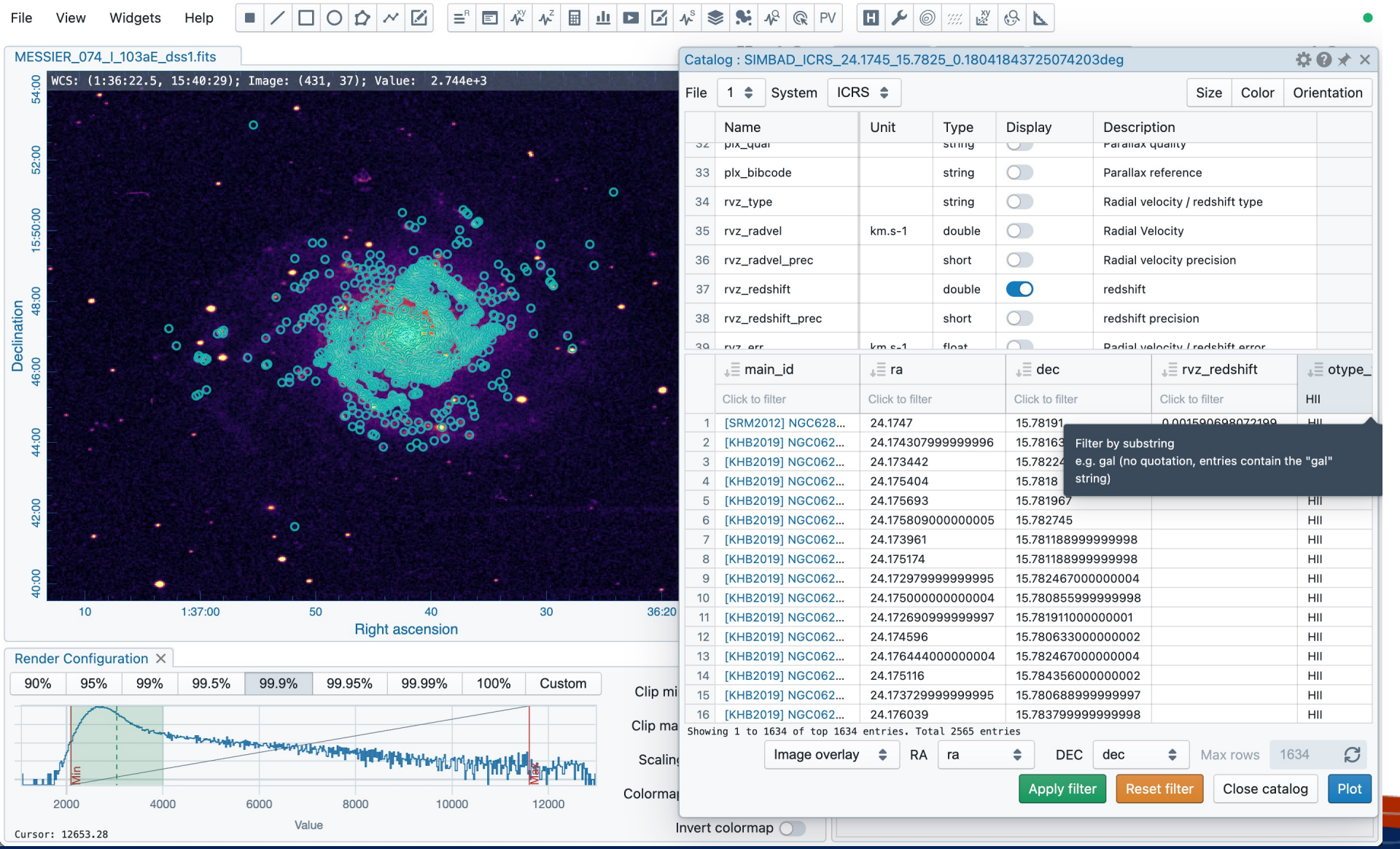
Catalog tool

The catalog result display can show or hide entries (similar to spectral line labelling tool



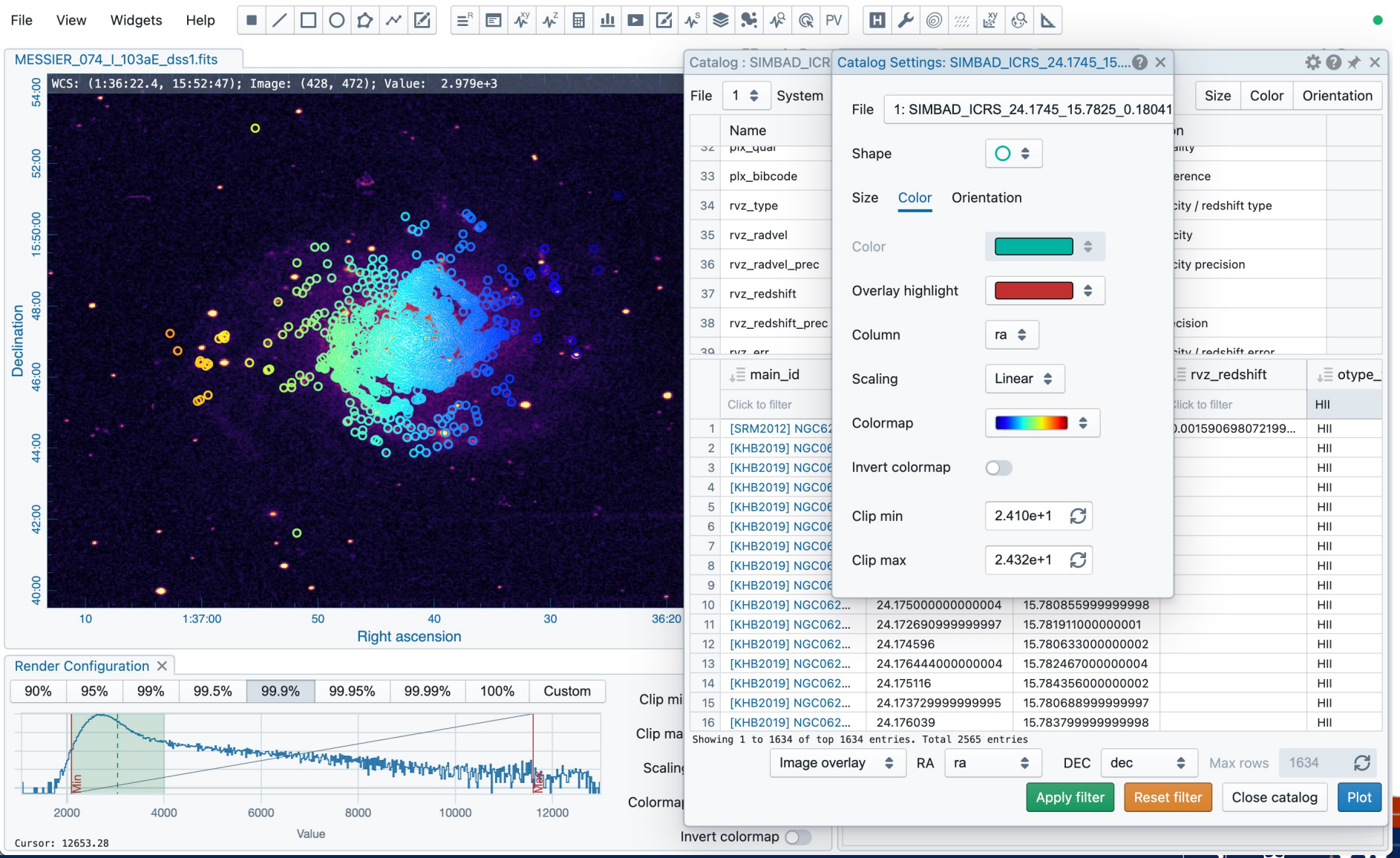
Catalog tool

Labels or ranges can be selected (e.g. "HII", "<24", "24…26", …)



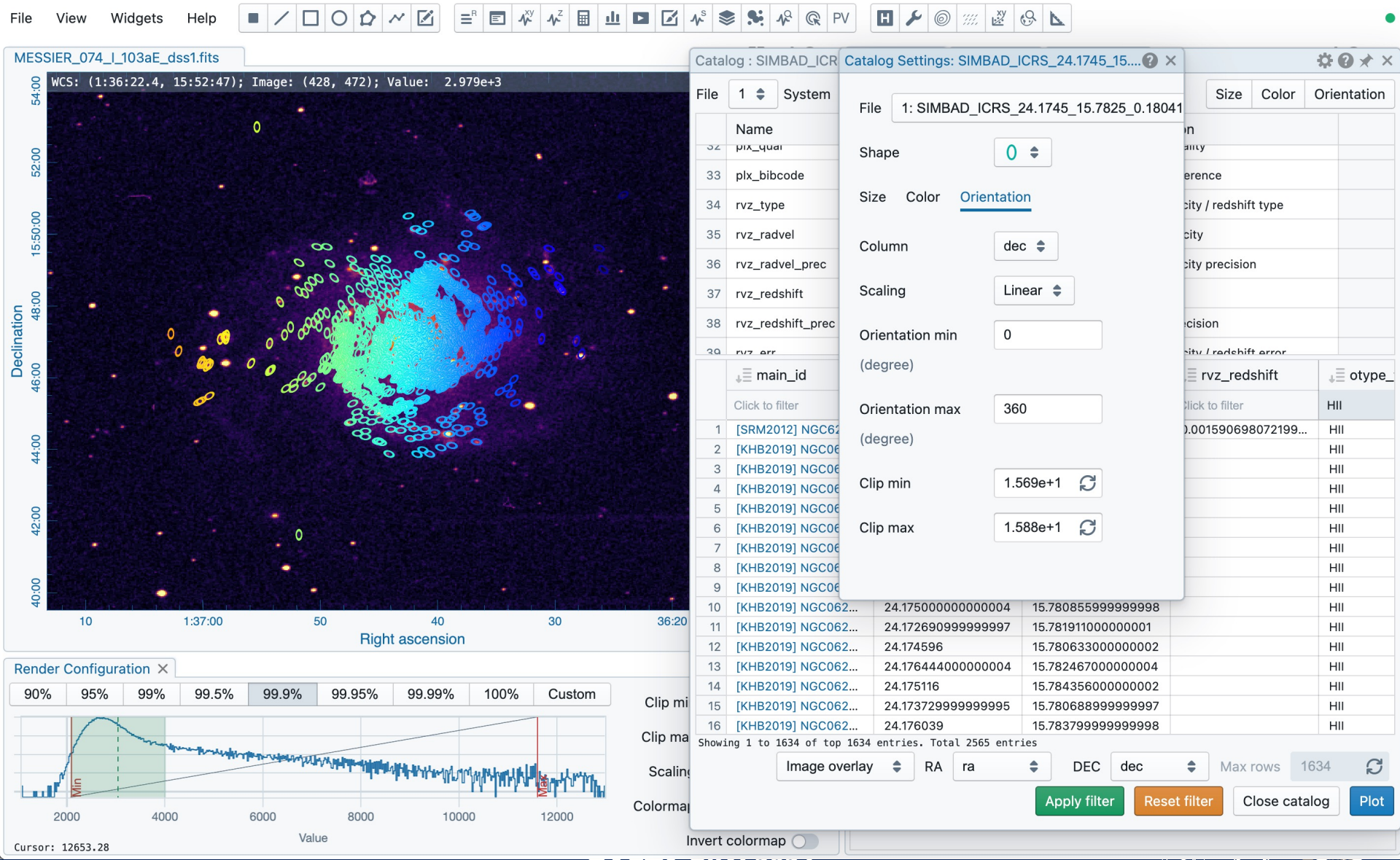
Catalog tool

Colorize your symbols by a catalog quantity



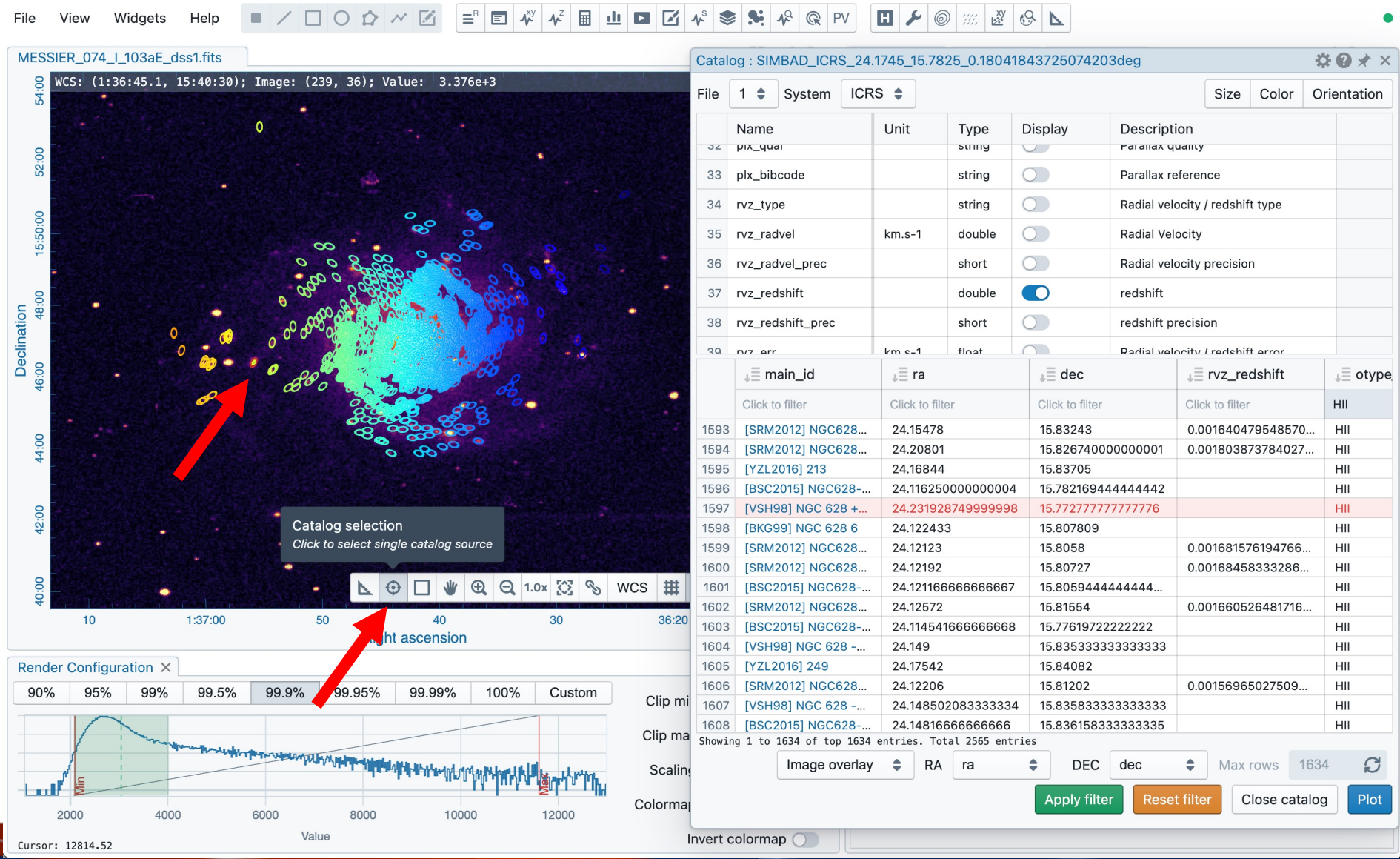
Catalog tool

Orientation of shapes can also be specified from a catalog entry



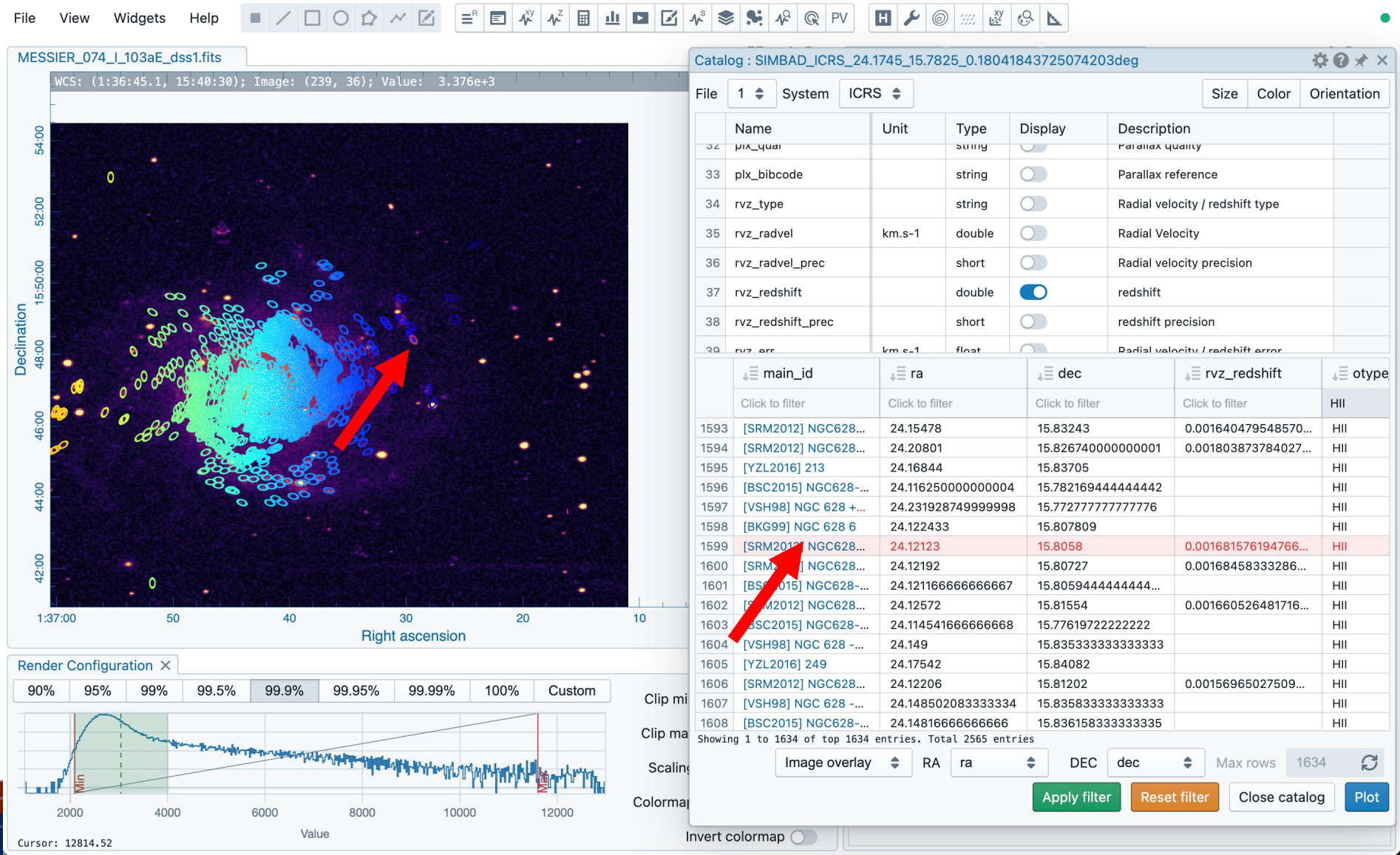
Catalog tool

Select symbol in image shows the corresponding entry in the catalog



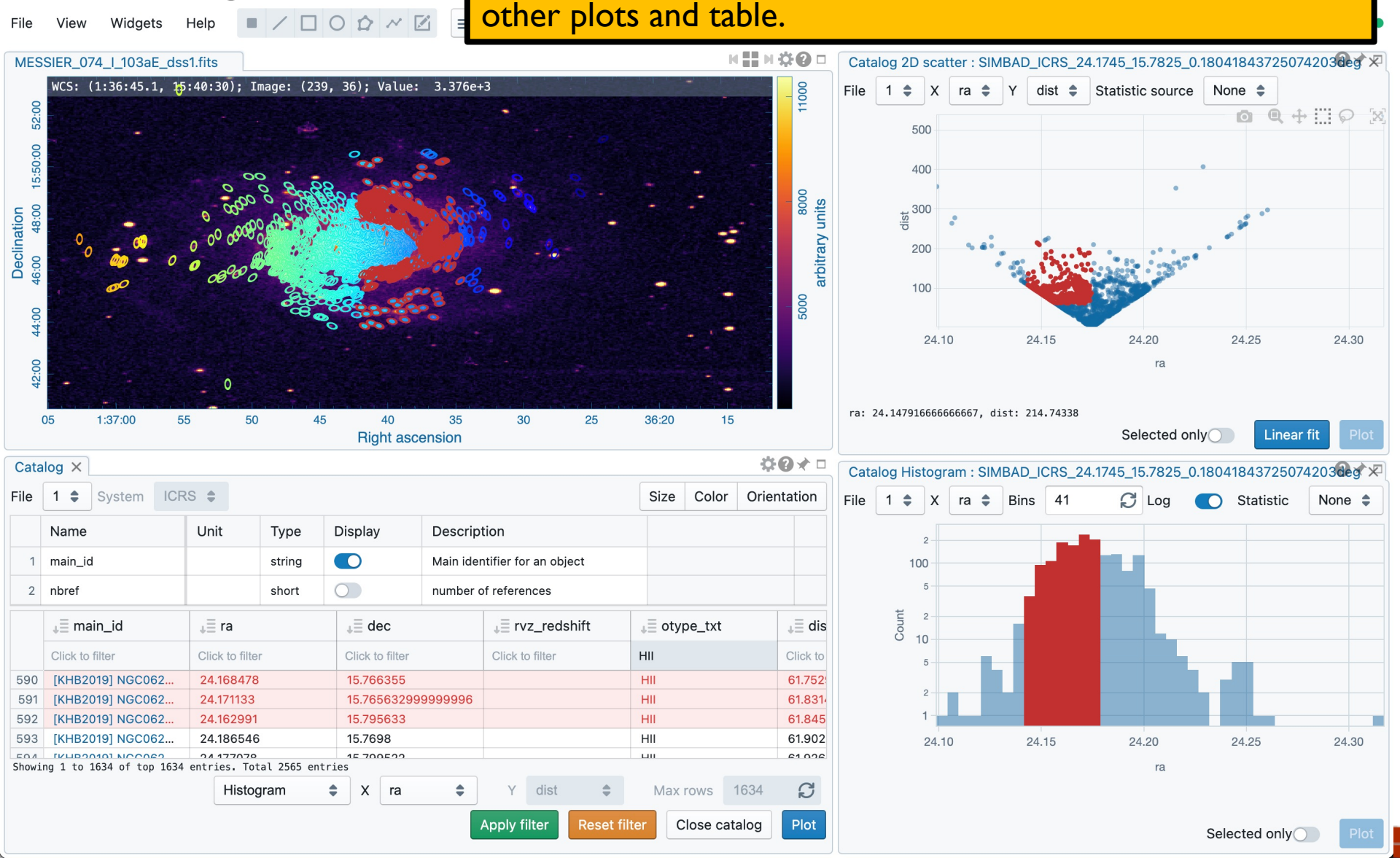
Catalog tool

In turn, selecting catalog entry (single or multiple), highlights the symbol in the image



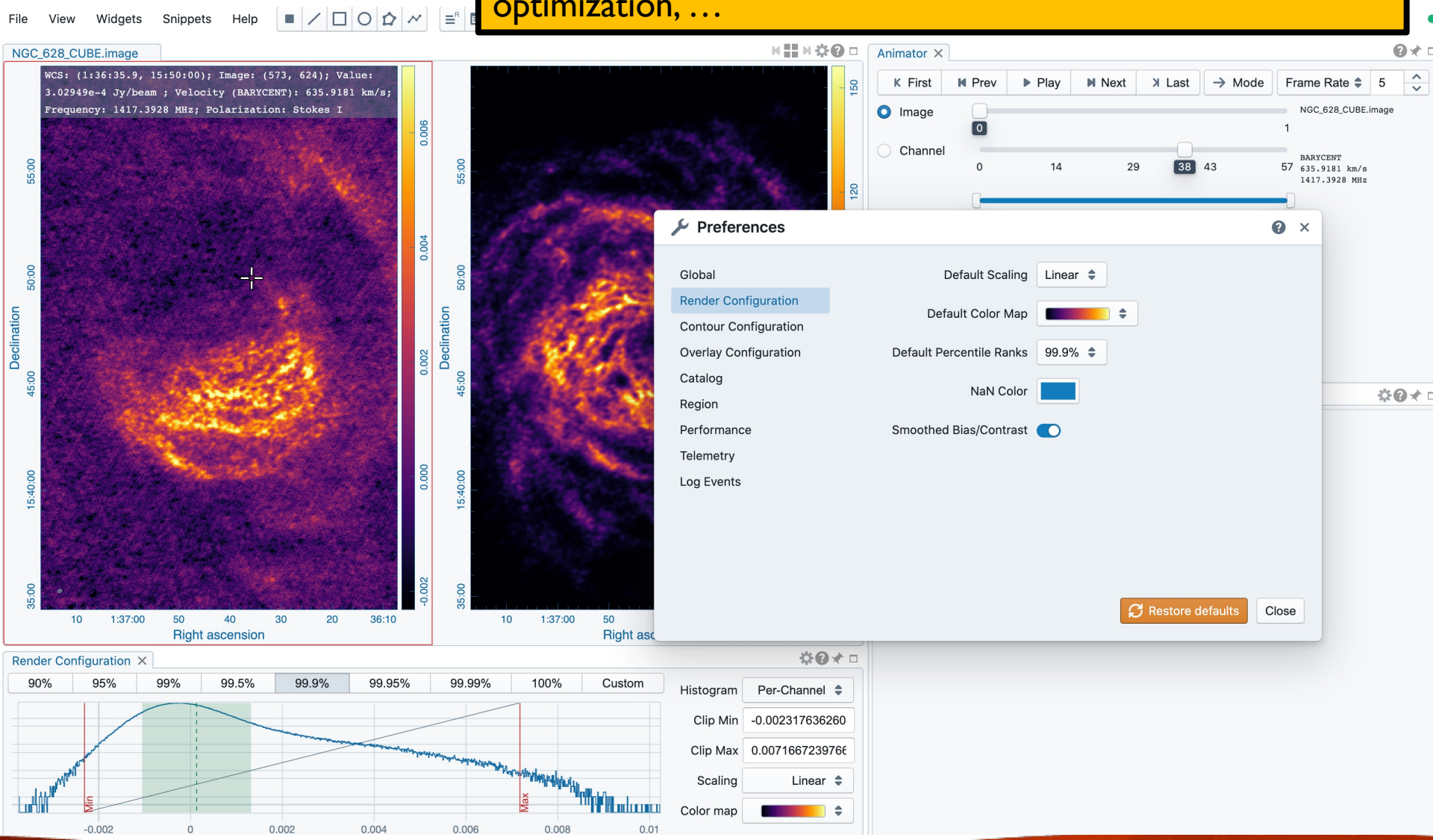
Catalog tool

Scatter plots and histograms can be made. Highlighting a portion in these diagrams will highlight corresponding data in other plots and table.

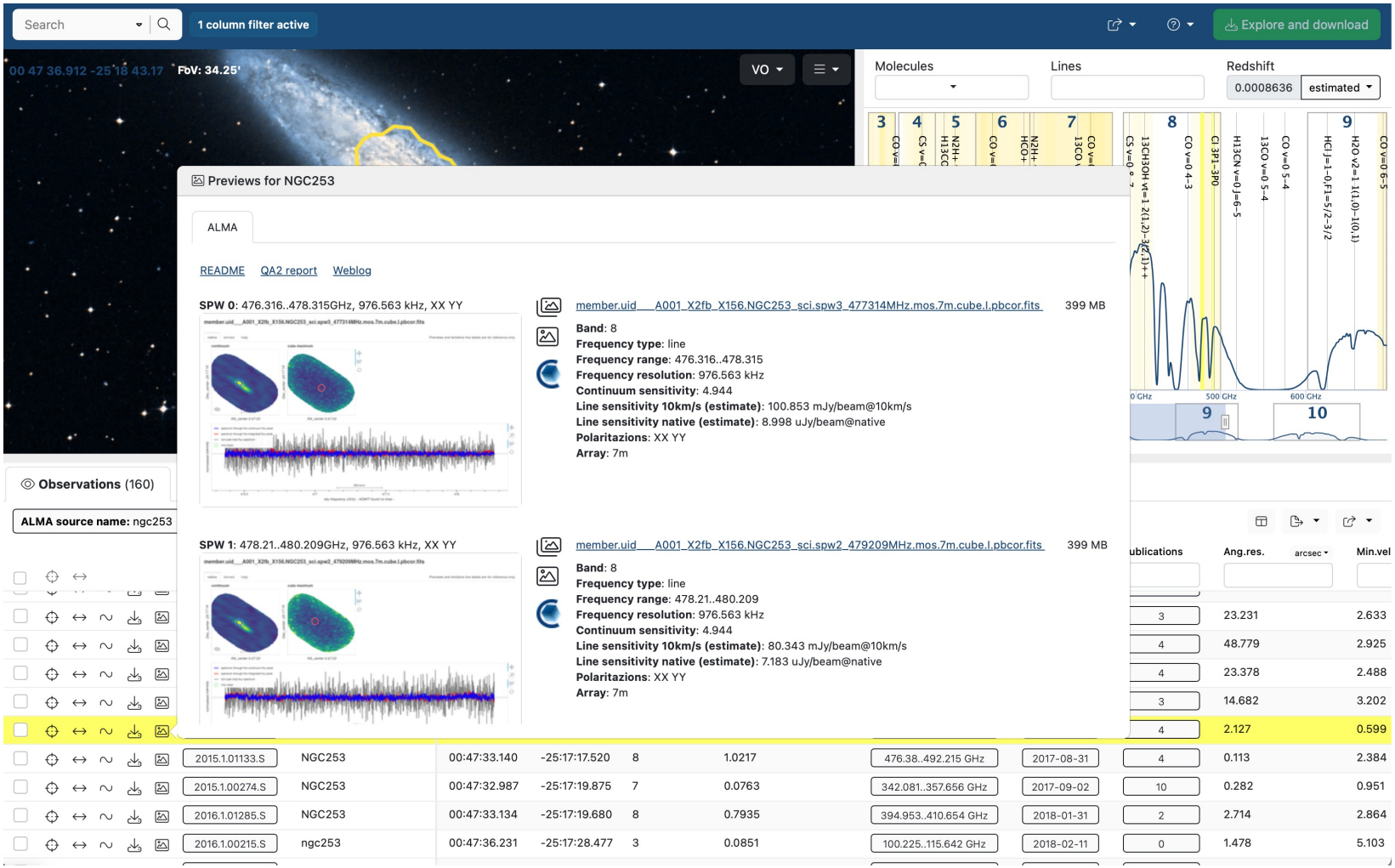


Preferences

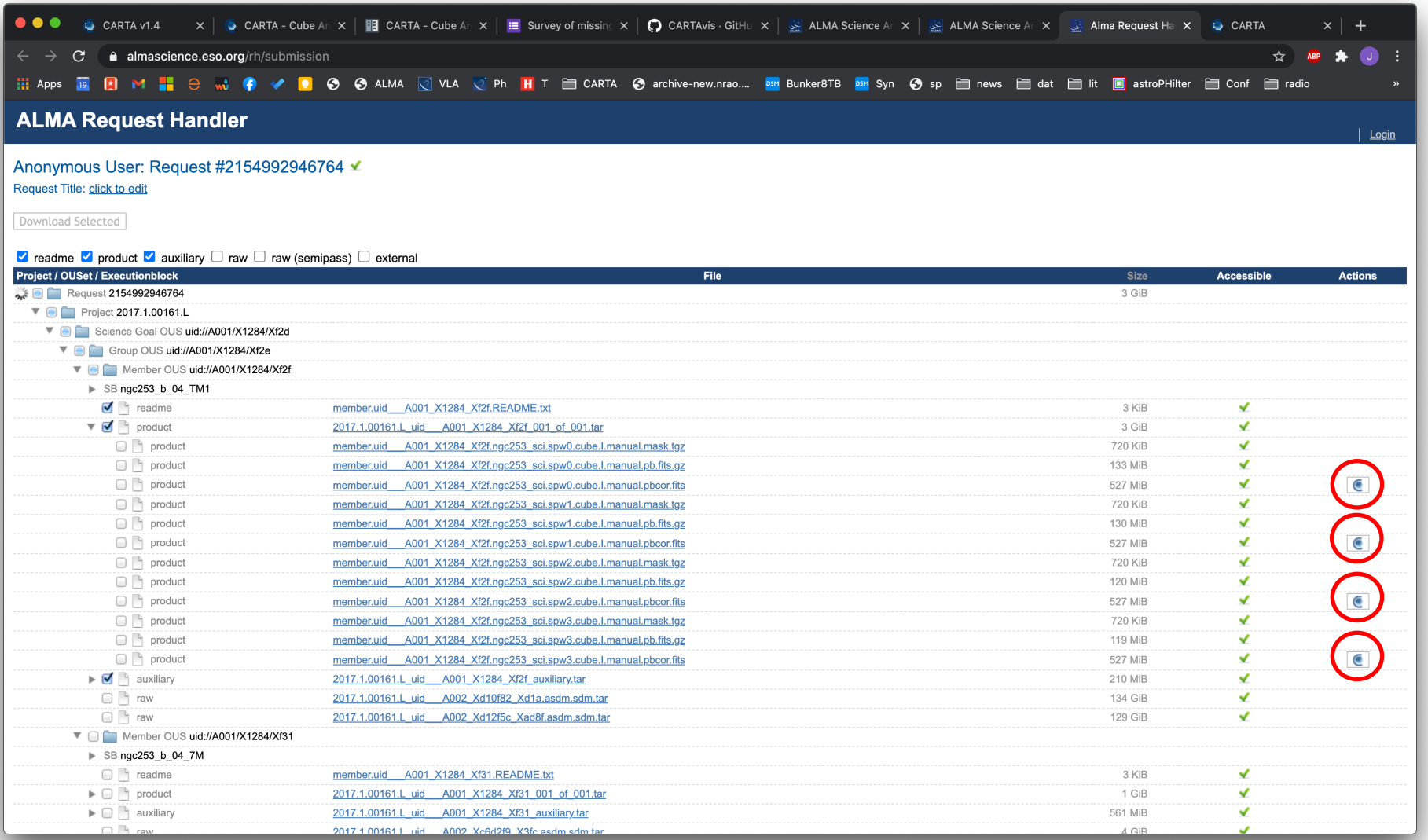
Many settable parameters, incl. startup behavior, preferred color map, contour config, color scheme, performance optimization, …



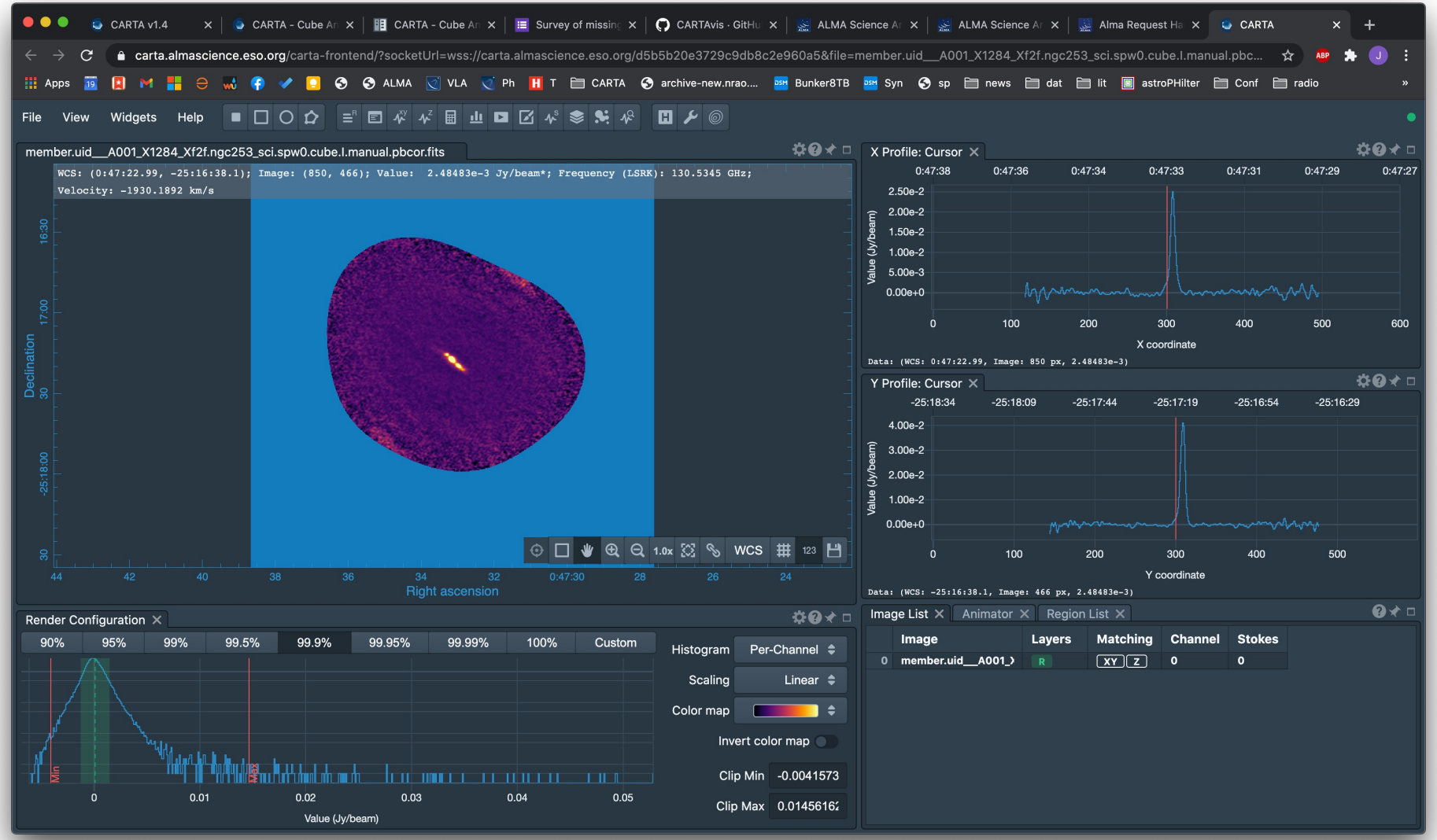
ALMA archive – CARTA Integration



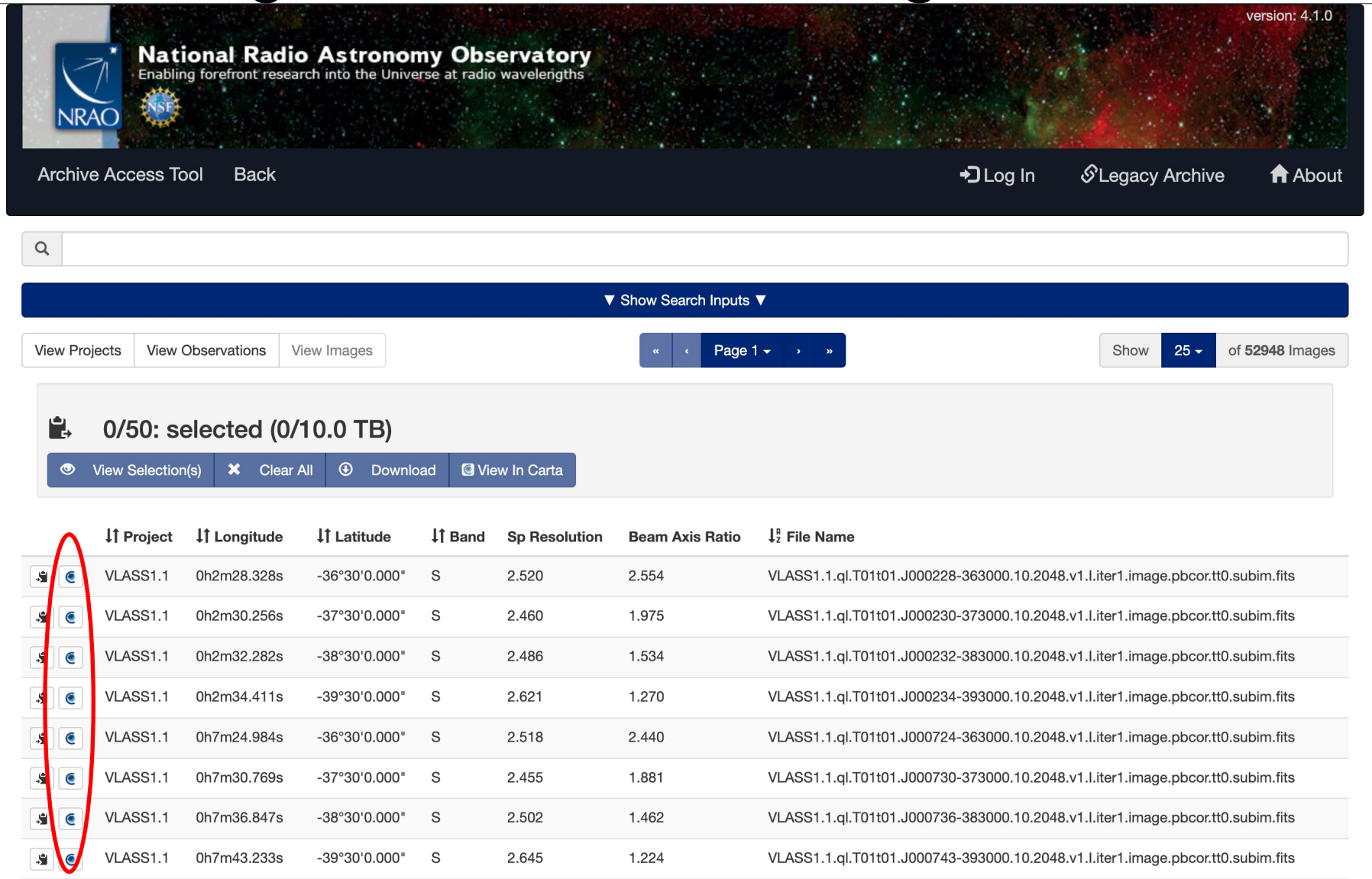
ALMA archive – CARTA Integration



ALMA archive – CARTA Integration

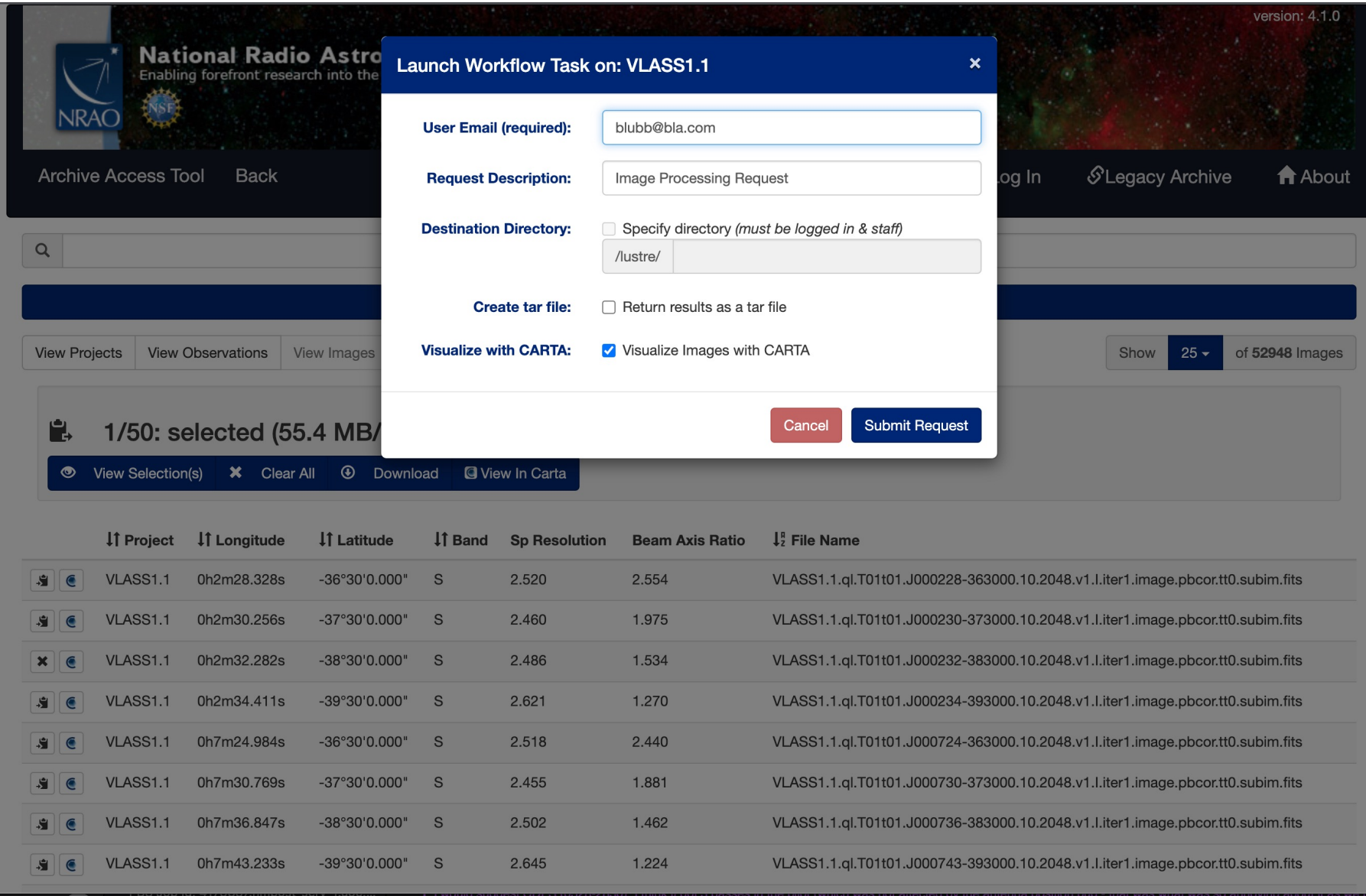


SRDP image archive – CARTA Integration

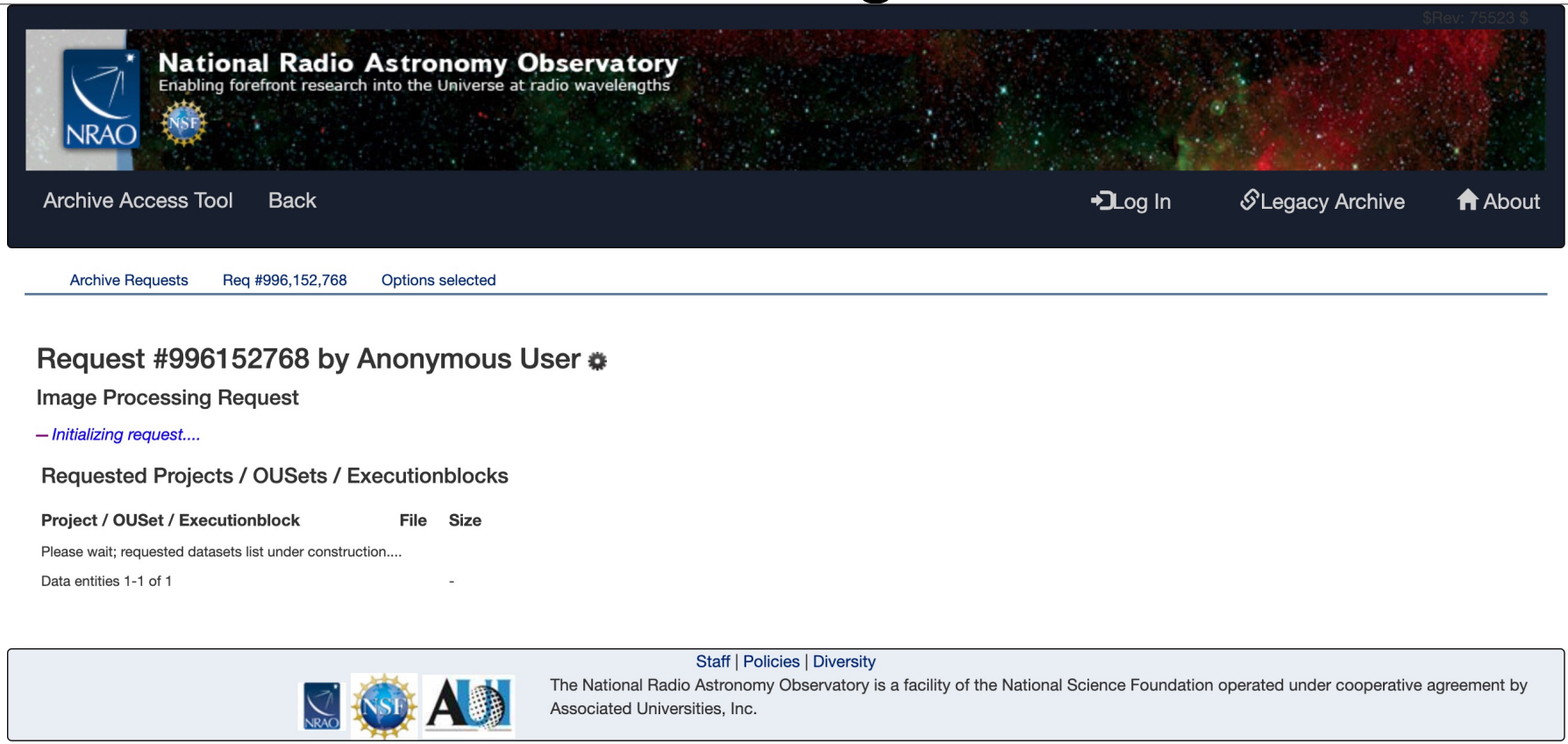


Project	Longitude	Latitude	Band	Sp Resolution	Beam Axis Ratio	File Name
VLASS1.1	0h2m28.328s	-36°30'0.000"	S	2.520	2.554	VLASS1.1.ql.T01t01.J000228-363000.10.2048.v1.I.iter1.image.pbcor.tt0.subim.fits
VLASS1.1	0h2m30.256s	-37°30'0.000"	S	2.460	1.975	VLASS1.1.ql.T01t01.J000230-373000.10.2048.v1.I.iter1.image.pbcor.tt0.subim.fits
VLASS1.1	0h2m32.282s	-38°30'0.000"	S	2.486	1.534	VLASS1.1.ql.T01t01.J000232-383000.10.2048.v1.I.iter1.image.pbcor.tt0.subim.fits
VLASS1.1	0h2m34.411s	-39°30'0.000"	S	2.621	1.270	VLASS1.1.ql.T01t01.J000234-393000.10.2048.v1.I.iter1.image.pbcor.tt0.subim.fits
VLASS1.1	0h7m24.984s	-36°30'0.000"	S	2.518	2.440	VLASS1.1.ql.T01t01.J000724-363000.10.2048.v1.I.iter1.image.pbcor.tt0.subim.fits
VLASS1.1	0h7m30.769s	-37°30'0.000"	S	2.455	1.881	VLASS1.1.ql.T01t01.J000730-373000.10.2048.v1.I.iter1.image.pbcor.tt0.subim.fits
VLASS1.1	0h7m36.847s	-38°30'0.000"	S	2.502	1.462	VLASS1.1.ql.T01t01.J000736-383000.10.2048.v1.I.iter1.image.pbcor.tt0.subim.fits
VLASS1.1	0h7m43.233s	-39°30'0.000"	S	2.645	1.224	VLASS1.1.ql.T01t01.J000743-393000.10.2048.v1.I.iter1.image.pbcor.tt0.subim.fits

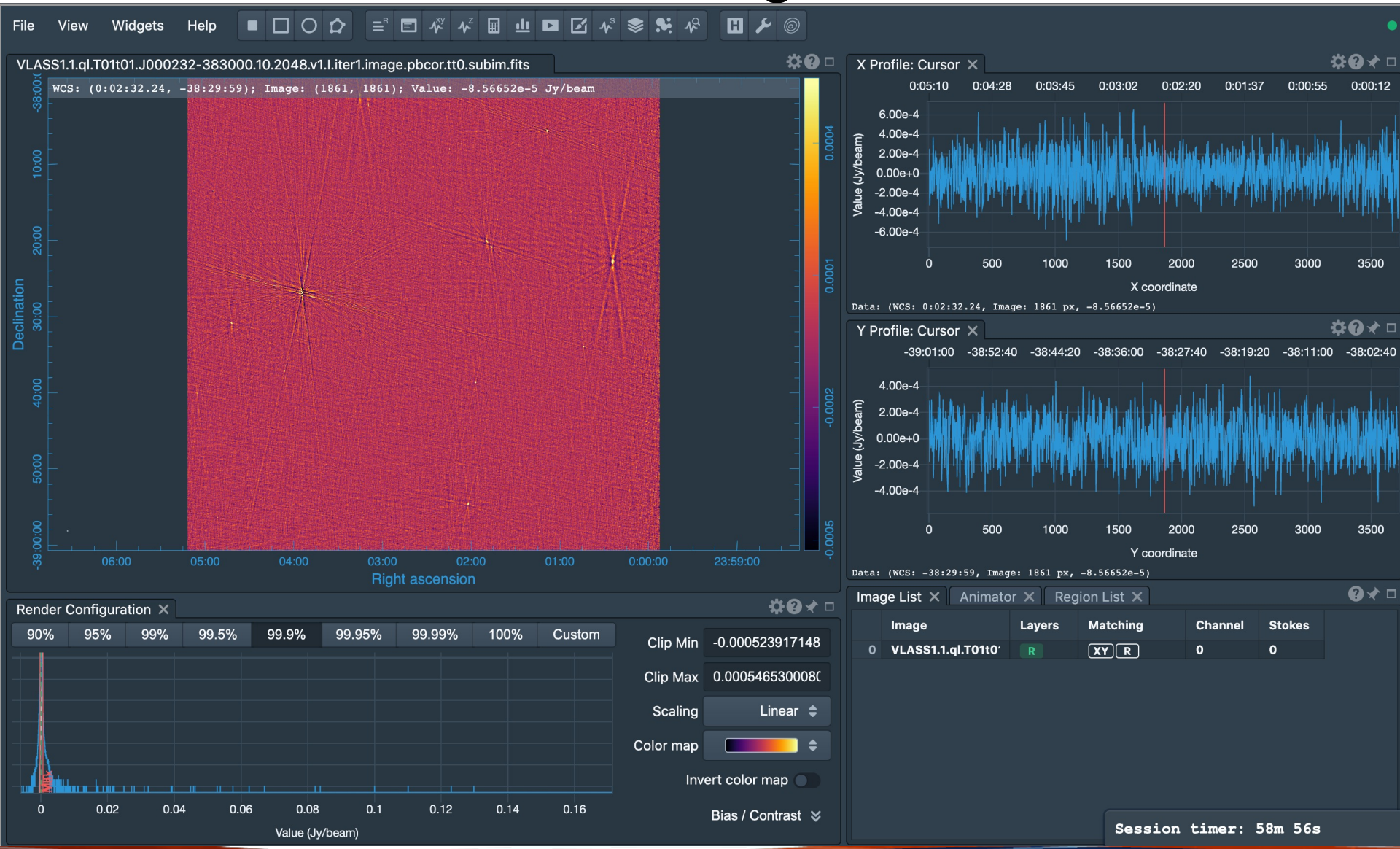
SRDP image archive – CARTA Integration



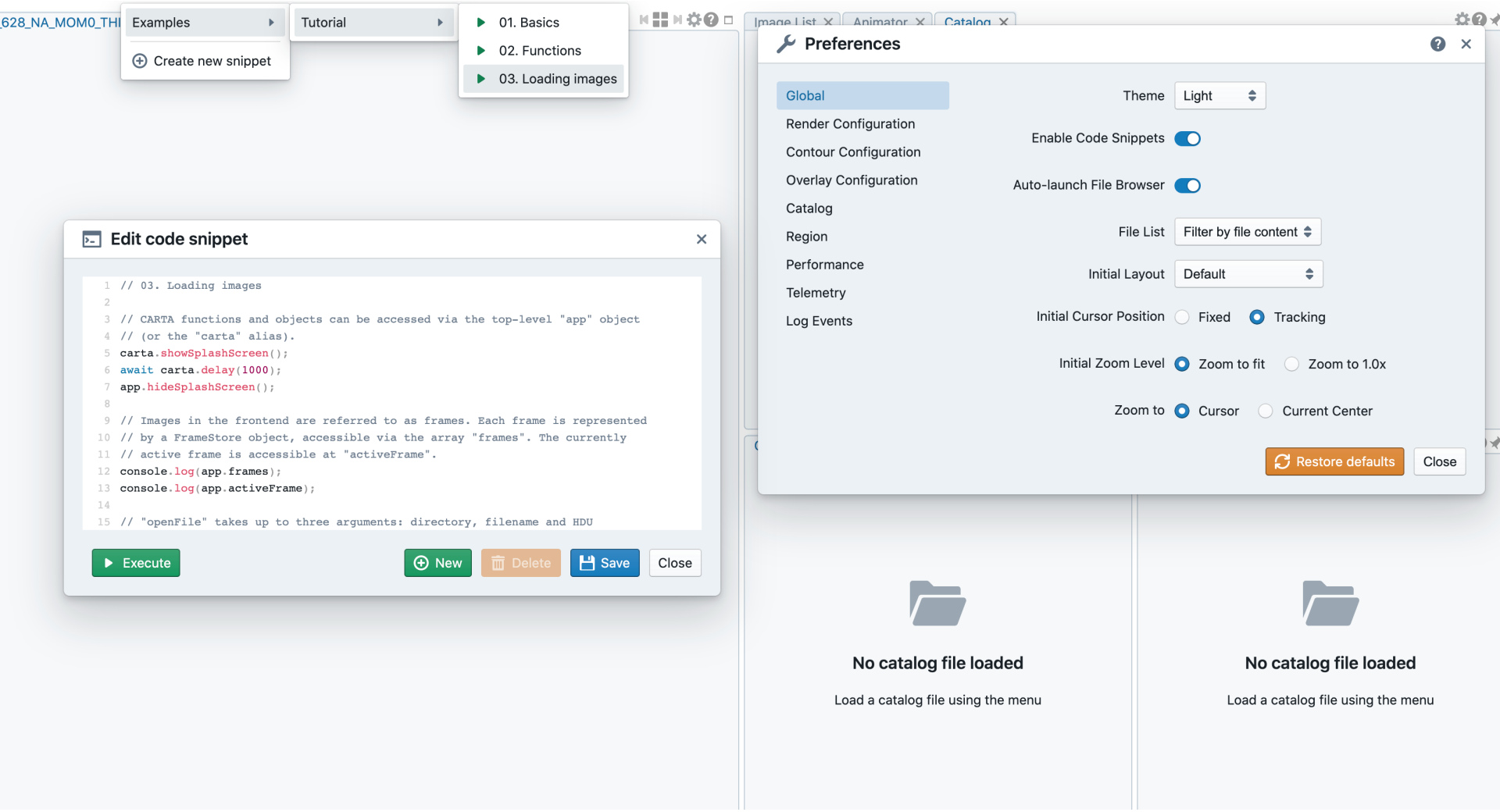
SRDP archive – CARTA Integration



SRDP archive – CARTA Integration



Python Scripting in progress/Code snippet



CARTA v5 plan, available this fall 2024

- Readiness for ALMA WSU
- python scripting (maybe available earlier)
- rgb image overlay
- distance measure incl. x, y
- Astronomical filters in spectra line library
- pV along a polyline
- Catalog density plots
- Image fitting guess of initial values
- Copy/paste regions
- Histogram fitting
- Spatial profile fitting
- Support of non-radio fits files
- Full support of workspaces and workspace sharing
- Channel-map view

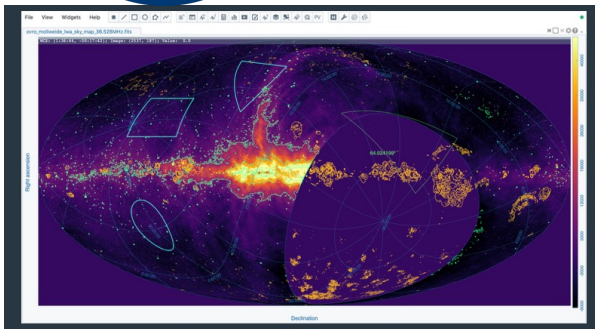
- RHEL8 resolves the issues we had with vnc/slim desktops

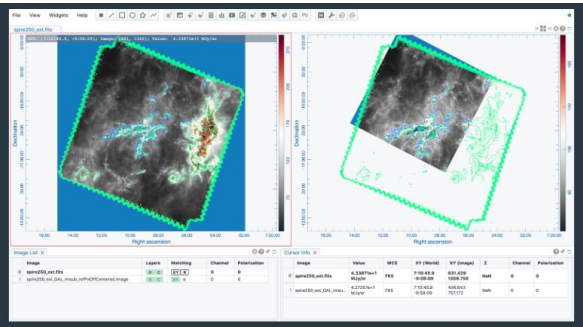
- Homepage: Cartavis.org; organizations: ASIAA, IDIA, NRAO, U Alberta
- **At NRAO:** check https://info.nrao.edu/computing/guide/cluster-processing/software for information best: server 'carta –no_browser' at NRAO machine, then past URL in browser, may need VPN if not at NRAO.

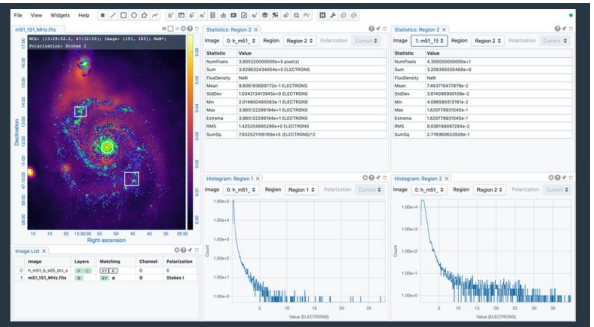
CARTA

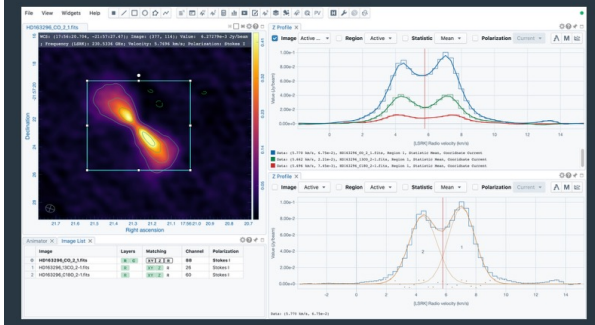
- CARTA is a fairly new, powerful, fast image viewer, analysis and collaborative tool
- It is pretty intuitive to use and the upcoming python scripting will make it very flexible for many applications, including publication readiness
- CARTA is ready to tackle the image cubes of the current and next generation of telescopes, including ALMA WSU/2030, ngVLA, SKA
- CARTA is already implemented in various data archives (ALMA, NRAO, SKA precursors)
- CARTA is replacing the CASA viewer (which is sunsetting and will be removed from CASA soon)
- CARTA is the ASASS Software price winner 2024!
- For questions, comments, suggestions, please contact either the CARTA helpdesk (support@carta.freshdesk.com), Juergen (jott@nrao.edu), or John Hibbard (jhibbard@nrao.edu) at NRAO

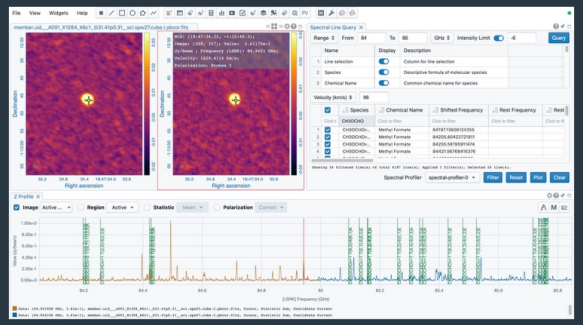
www.cartavis.org

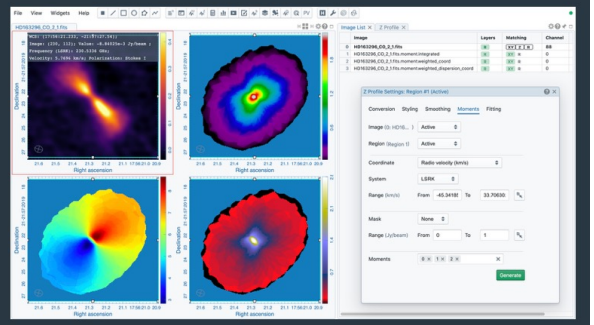


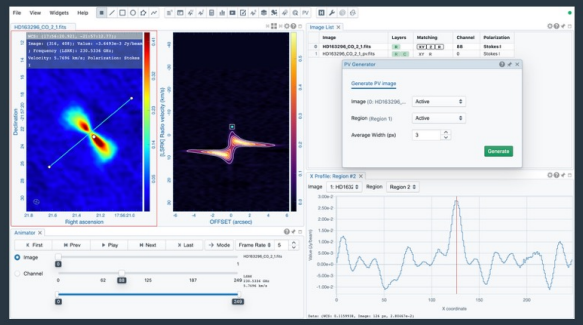


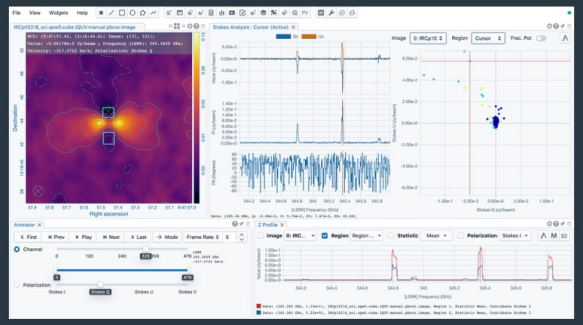


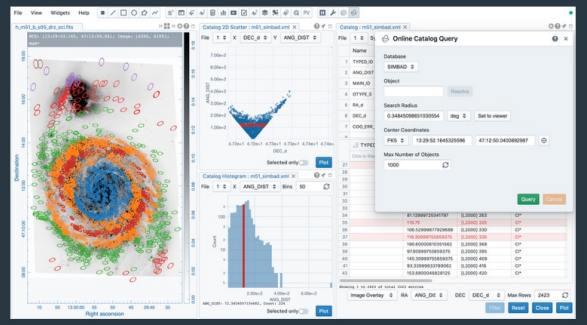












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