CARTA 3beta: Cube Analysis and Rendering Tool for Astronomy

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CARTA

Cube Analysis and Rendering Tool for Astronomy

Project: ASIAA, IDIA, NRAO, U Alberta

Webpage: https://cartavis.org

Github: https://github.com/CARTAvis

Goal: To build a high performance, versatile image viewer for astronomy

Current release version 2.0 (3 beta recommended)

Usage cases:
• CASA viewer replacement (excluding interactive clean and visibility display)
• Archive interface for images from SKA precursors, ALMA, NRAO SRDP
• Stand alone analysis tool
• Scriptable interface (publication ready images, interaction for analysis)
• Collaborative tool
CARTA on cartavis.org

CARTA
Cube Analysis and Rendering Tool for Astronomy, is a next generation image visualization and analysis tool designed for ALMA, VLA, and SKA pathfinders.
CARTA on github.com/CARTAvis

CARTAvis

https://cartavis.github.io/  support@carta.freshdesk.com

Overview

Repositories 33

carta Public

To CARTA users, this repo holds the CARTA release packages. Please use this repo to log bugs and feature requests. These will be triaged by the development team and prioritised as necessary in the ...

11

Repositories

Find a repository...

Type  Language  Sort

carta-backend Public

Source code repository for the backend component of CARTA, a new visualization tool designed for the ALMA, the VLA and the SKA pathfinders.

C++  14  3  82  6  Updated 4 hours ago

carta-backend:ICD-test Public

Source code repository for the backend component of CARTA, a new visualization tool designed for the ALMA, the VLA and the SKA pathfinders.

TypeScript  14  4  196 (1 issue needs help)  5  Updated 8 hours ago

carta-frontend Public

Source code repository for the frontend component of CARTA, a new visualization tool designed for the ALMA, the VLA and the SKA pathfinders.

C++  14  3  82  6  Updated 4 hours ago

People

This organization has no public members. You must be a member to see who’s a part of this organization.

Top languages

C++  Python  TypeScript  JavaScript  Shell
CARTA

• A focus is on the 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

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

• OS: MacOS, Ubuntu, RHEL
• Attention: VNC does not support webGL, use the browser version over VPN.
• NRAO instructions: https://casadocs.readthedocs.io/en/latest/notebooks/carta.html
  • Connect to VPN
  • Run “carta --no_browser” at NRAO
  • Copy and paste the URL in a local browser
  • (alternative ssh options are provided on NRAO instructions page)
  • (possible to set LIBGL_ALWAYS_INDIRECT=1 in VNC session without VPN)

- CARTA server is considered for NRAO sites
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
• Contours with different generators, colors, color maps
• Catalog overlays
• Setting of rest frequency
• 3-beta3
  • Vector overlays
  • Complex image display
  • LEL image arithmetic before display
  • Generating computed polarization quantities (e.g. linear polarization intensity) of a Stokes cube on the fly
  • Setting a new rest frequency when saving a subimage
CARTA Features

Tools/Analysis:

- Regions: rotating box, ellipses, polygons, line, point, polyline
- Spatial (X,Y) and spectral (Z) profiles
- Spectral profiles can convert spectral axis labels (velocity, frequency, wavelength)
- Histogram
- Image/Region Statistics
- Stokes analysis widget
- Moment generator
- \( pV \) diagram (3beta)
- Spectral line labelling
- Spectral smoothing
- Distance measuring tool (3beta)
- Intensity conversion (3beta)
- 3-beta3:
  - 2D Gaussian fitting of sources in image
  - Line and polyline region spectral profiler
CARTA Features

Other:

- Server-client infrastructure for remote image access
- Server authentication
- Tiled rendering for performance
- Docking and Preferred layouts and layout saving
- Basic scripting is under active development
CASAvie\textit{w}er vs CARTA

Gaps relative to CASA\textit{v}iewer (green: CARTA development underway; black: future CARTA development; red: likely not implemented in CARTA)

- Position-velocity map generator \rightarrow under development for v3
- Complete set of fitting tools \rightarrow spectral: multiple Gaussians and Lorenzians already available with continuum polynomial; spatial: 2D Gaussian fit in v3-beta3
- Source finder tool
- Tabular axis support \rightarrow under development
- Spectral profile error bar plotting (MUSE/optical feature in CASA)
- Partial image cube loading
- Image and profile annotation
- Rotated cube view (input as ra-dec-channel, view as ra-channel vs dec)
- Scalable output (SVG or PDF)
- Creation of multi-channel plots
- Ability to reapply rest frequency for velocity conversion \rightarrow 3 beta
- Regions that extend across spectral and stokes planes
- Histogram fitting
- Complex Image support \rightarrow available in 3beta3
- Multi-panel display \rightarrow available in v3-beta1
- Distance measuring tool \rightarrow available in v3-beta1
- Markers \rightarrow they have not been widely used in the CASA\textit{v}iewer
- Interactive clean \rightarrow CASA will develop a visualization tool independent of CARTA
- Vector overlays \rightarrow available in v3-beta3
- Full support of CRTF \rightarrow was not even supported by the CASA\textit{v}iewer
- Save/reload states
- Saving sub-images \rightarrow done
CARTA – Start

MacOS installed stand-alone:
carta (or click the icon in the Applications folder)

Linux or remote (beta version needs to be downloaded from cartavis.org first):
(base) jott@Desktop ~> CARTA-v3.0.0-beta.3-redhat7.AppImage --no_browser
touch: cannot touch /users/jott/.local/share/icons/hicolor/xdg-icon-resource-dummy
[2022-04-04 14:49:41.296] [warning] Port 3003 is already in use. Trying next port.
The number of OpenMP worker threads will be handled automatically.
[2022-04-04 14:49:41.297] [info] CARTA is accessible at http://146.88.3.182:3008/?token=ec1836fc-2cd7-468d-9744-a1ac3e8cc995

→ Copy and past this URL in your local browser (VPN connection needed if outside NRAO)
carta --no_browser at NRAO will launch v2.0
File loading

File Browser

- **Filename**
  - fft-cube.im
  - fft.test
  - IRC0216.36GHzcont.image.fits
  - IRC0216_HC3N_cube_r0.5.image
  - IRC0216_HC3N_cube_r0.5.image-copy
  - IRC0216_HC3N_cube_r0.5.image.fits
  - IRC0216_HC3N_cube_r0.5.image.mir
  - m82-car-2000.fits
  - m82-tan-2000.fits
  - NGC628_dss.fits
  - NGC628_galex.fits
  - NGC628_CUBE-bin3.image
  - NGC628_CUBE.image
  - NGC628_CUBE_THINGS_copy.fits
  - NGC628_CUBE_THINGS_copy.mir
  - NGC628_CUBE_THINGS_copy.mir-manipulated

- **Type**
  - FITS
  - CASA

- **Size**
  - 261.0 MB
  - 4.4 MB
  - 368.6 kB
  - 19.4 MB
  - 19.4 MB
  - 18.7 MB
  - 19.3 MB
  - 4.0 MB
  - 4.0 MB
  - 371.5 kB
  - 371.5 kB
  - 79.8 MB
  - 251.0 MB
  - 247.7 MB
  - 243.3 MB

- **Date**
  - 26 May 2021
  - 26 May 2021
  - 29 Sep 2020
  - 5 Jan 2020
  - 18 Mar 2020
  - 18 Mar 2020
  - 18 Mar 2020
  - 18 Mar 2020
  - 18 Mar 2020
  - 18 Mar 2020

- **File Information**
  - **Name**: IRC0216.36GHzcont.image.fits
  - **Size**: 368.6 kB
  - **Shape**: [300, 300, 1, 1]
  - **Number of channels**: 1
  - **Number of polarisations**: 1
  - **Coordinate type**: Right Ascension, Declination
  - **Projection**: SIN
  - **Image reference pixels**: [151, 151]
  - **Image reference coords**: [09:47:57.3820, +01:31:40.6600]
  - **Image ref coords (deg)**: [146.989 deg, 13.278 deg]
  - **Pixel increment**: -0.4", 0.4"
  - **Pixel unit**: Jy/beam
  - **Celestial frame**: FK5, J2000
  - **Spectral frame**: LSRK
  - **Velocity definition**: RADIO
  - **Restoring beam**: 2.81862" X 1.53258", -19.1115 deg

- **Options**
  - Fuzzy search
  - Close
  - Load

No file loaded

Load a file using the menu
Help

? = help menu

1) Navigation
- Pan image
- Pan image (inside region)
- Pan image (inside region)
- Zoom image

2) Regions
- Toggle region creation mode
- Toggle current region lock
- Unlock all regions
- Delete selected region
- Delete selected region
- Deselect region/Cancel region creation
- Switch region creation mode
- Symmetric region creation
- Region properties

3) Frame controls
- Next image
- Previous image
- Next channel
- Previous channel
- Next Stokes cube
Help available for each widget

The image viewer widget serves as the core component of CARTA. It allows you to visualize images in rasters and in contours. Region of interests can be defined interactively with the image viewer and subsequent image analysis can be performed with other widgets. Catalogue files can be loaded and visualized in the image viewer with the Catalogue widget.

Images can be loaded via File -> Open image (will close all loaded image first). You may load multiple images via File -> Append image. All images are loaded as raster by default. Contour layers can be further generated via the contour configuration dialog.

Information of world coordinates and image coordinates at the cursor position is shown at the top of the image viewer. To freeze/unfreeze the cursor position, press F key.

Image tool buttons
A set of tool buttons is provided at the bottom-right corner when hovering over the image viewer. You may use these buttons to

- Select a source from catalog overlay
- Create regions
- Change image zoom scale
- Trigger WCS matching
- Change grid overlay reference frame
- Enable/disable grid lines and coordinate labels
- Export image

Catalog selection
Create region
Pan and select mode
Zoom in
Zoom out
Zoom to fit screen resolution
Export image
Toggle labels
Toggle grid
Overlay coordinate
WCS matching
Zoom to fit image view

Zoom and pan
Zoom actions can be triggered in different ways. The most common one is to use mouse and scroll wheel. By scrolling up, image is zoomed in, while by scrolling down, image is zoomed out. Alternatively, you may use the tool buttons at the bottom-right corner of the image viewer to zoom in, zoom out.
Widgets:

- open and close
- pin
- move
- tab
- rearrange
- resize
- float
Widgets:
- Pre-defined layouts
- Layouts can be saved and restored
Widgets:
- Region list
- Log
- Spatial (xy profile)
- Spectral (z) profile
- Statistics
- Histogram
- Animator
- Render config
- Stokes
- Image list
- Catalog
- Spectral line query
- Catalog cursor
- Position-Velocity cut

Regions:
- Point
- Line
- Rectangle
- Ellipse
- Polygon
- Polyline

Settings/Info:
- Header
- Preferences
- Contours
- Vector Overlay
- 2D Gaussian fitting
- Online catalogue query
Image display widget

Position of cursor, value, velocity

- distance tool
- catalog source selection
- Regions
- Pan
- Zoom in
- Zoom out
- Zoom to 1x
- Zoom to fit
- WCS matching
- Overlay coordinate
- Grid
- Labels
- Export
Distance Measurement

The image shows a map of a galactic structure with labeled coordinates and distances. The coordinates are in Right Ascension and Declination, with a scale value of 6.548643'. The polarization is indicated as Stokes I.
Image display widget - multipanel

Open image alt + O
Append image alt + L
Save image alt + S
Close image alt + W
Import regions
Export regions
Import catalog alt + G
Export image
Preferences
Server

NGS.im

Image: (508, 509); Value: 1.5518e+1 "Jy/beam"; Polarization: Stokes I

Galactic longitude
Image display widget - multipanel
Image display widget - multipanel

WCS image registration will align coordinates of different images
Master is outlined; aligned images in green
Alignment in XY (spatial) and/or Z (spectral), and or R (color scale)
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.
Rendering

- Color map
- Scaling
- Per plane or per cube scaling
- Global scaling through the image list widget
- Bias/Contrast

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
- Marker is the position of the cursor/animator (freeze with 'f')
- Selection of region and image in each widget
- For spectral profile, regions can be selected, as well as statistics, axis labels (velocity, frequency, channel, wavelength, ..)
- 3d Position is marked by a red vertical line
Animator(s)  
Images  
Channels  
Stokes
Regions can be created (rectangle, ellipse, polygon), deleted, rotated, moved.

Analysis can be done on selected regions.
### Saving subimages

Select portion of image

(3beta3: assign new rest frequency if desired)
Cursor Widget

Align WCS first to see multiple image values
Contours

- Match the coordinates for multiple images in the image list. This can be done spatially and spectrally
- Set reference image
- Set matched images
- Also: delete images from list

Multiple images can be loaded (append)

Contour overlay:
Create contours in various ways: percentage, min max, scaling, direct input, etc. The contour levels are shown on an image histogram and can be edited
Styling allow color map as well as constant color
Spectral smoothing

Various smoothing methods include Boxcar, Hanning, decimation, binning, Gaussian, Savitzky-Golay
Set new rest frequency

Image list setting
Spectral line labeling

Based on splatalogue, select line strength, frequency range and redshift
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. Fit region can be selected in spectrum or entered directly. Options: Gaussians, Lorenzians.
Spectral Line Fitting

Fit results can be copied/pasted
Spectral Line Fitting

Fitting result:
Component #1:
Center = 704.602400 (km/s)
Center Error = 0.726620 (0.102%) Amplitude = 0.001960 (Jy/beam)
Amplitude Error = 0.000534 (27.232%) FWHM = 5.439166 (km/s)
FWHM Error = 1.734660 (31.892%) Integral = 0.011330 (Jy/beam * km/s)
Integral Error = 0.003117 (27.460%)
Position-Velocity
CARTA – Stokes Analysis Widget

Projection handling:
To avoid regridding, WCS matching moves and rotates the image to the master image. This produces a small error for large fields, only visible in blinking. But the contours are rastered correctly when overlaid as contours.

Regions: They project correctly when moving across the sky in different coordinate systems.
CARTA – Catalog tool

Catalog: SIMBAD_ICRS_24.1698_15.7629_0.39603062065956496deg

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<th>Unit</th>
<th>Type</th>
<th>Display</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<td>vlsr</td>
<td></td>
<td>double</td>
<td></td>
<td>velocity in Local Standard of Rest r...</td>
</tr>
<tr>
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<td>string</td>
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<td>string</td>
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<td>double</td>
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<tr>
<td>dec</td>
<td>deg</td>
<td>double</td>
<td></td>
<td>Declination</td>
</tr>
<tr>
<td>dist</td>
<td>arcsec</td>
<td>double</td>
<td></td>
<td>Distance to the center coordinate (...)</td>
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<tr>
<td>RA_HMS</td>
<td>H:m:s</td>
<td>string</td>
<td></td>
<td>RA in sexagesimal format (H:M:S, c...)</td>
</tr>
</tbody>
</table>

Click to filter

Showing 1 to 1000 of total 1000 entries

Histogram $X$ ra $Y$ dec

Max Rows 1000

Filter Reset Close Plot
CARTA – Catalog tool
CARTA – Catalog tool
CARTA – Catalog tool
Preferences
Python scripting in progress/Code snippet

```python
// 03. Loading images
3 // CARTA functions and objects can be accessed via the top-level "app" object
4 // (or the "carta" alias).
5 carta.showSplashScreen();
6 await carta.delay(1000);
7 app.hideSplashScreen();
8 // Images in the frontend are referred to as frames. Each frame is represented
9 // by a FrameStore object, accessible via the array "frames". The currently
10 // active frame is accessible at "activeFrame".
11 console.log(app.frames);
12 console.log(app.activeFrame);
13 // "openFile" takes up to three arguments: directory, filename and HDU
```

Preferences

- **Global**
  - **Theme**
    - Light
  - **Render Configuration**
  - **Contour Configuration**
  - **Overlay Configuration**
  - **Catalog**
  - **Region**
  - **Performance**
  - **Telemetry**
  - **Log Events**
    - **Initial Cursor Position**
      - Fixed
      - Tracking
    - **Initial Zoom Level**
      - Zoom to fit
      - Zoom to 1.0x
    - **Zoom to**
      - Cursor
      - Current Center

No catalog file loaded
Load a catalog file using the menu

No catalog file loaded
Load a catalog file using the menu
New in v3-beta3 (released just a few days ago…)

Vector field rendering
New in v3-beta3 (released just a few days ago…)

LEL image loading (mathematical expressions)
New in v3-beta3 (released just a few days ago…)

Complex-valued images
New in v3-beta3 (released just a few days ago...)  
2D Gaussian Fitting
New in v3-beta3 (released just a few days ago…)

Calculation of polarization quantities (like linear polarization intensity, polarization angle from Stokes IQUV cube)
New in v3-beta3 (released just a few days ago…)

Line and Polyline spatial profiles
ALMA archive
ALMA archive
### SRDP image archive

#### View Projects | View Observations | View Images

**0/50: selected (0/10.0 TB)**

<table>
<thead>
<tr>
<th>Project</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Band</th>
<th>Sp Resolution</th>
<th>Beam Axis Ratio</th>
<th>File Name</th>
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<td>1.224</td>
<td>VLASS1.1.q101101.J000743-393000.10.2048.v1.l.iter1.image.pbcort0.subim.fits</td>
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SRDP image archive
Request #996152768 by Anonymous User

Image Processing Request

-- Initializing request....

Requested Projects / OUSets / Executionblocks

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<thead>
<tr>
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<th>File</th>
<th>Size</th>
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<tbody>
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<td>Please wait; requested datasets list under construction....</td>
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</tbody>
</table>

Data entities 1-1 of 1
SRDP archive
CARTA

Future development:

- Channel map view
- Position-velocity map generator in progress
- Collaborative tools (server) developing the science and use cases
- Volume (3D) rendering
- Improved Profile, histogram, and image fitting tools
- Scripting interface with Python3 (ongoing)
- Three-color (RGB) blender
- Ultra-efficient HDF5-IDIA format
- Source finder
- VO support in progress
- Publication quality export → scripting and high-res png
- Dynamic pV cuts
- Transposed cubes
- Partial image cube loading
- Image smoothing
- Collaboration tools
- VR integration (IDaVie)
CARTA

• CARTA is the new visualization tool, actively developed for radio images (but may be used for any fits image [cube]). It replaces the CASAviewer that is not supported anymore.

• Performance and architecture of CARTA are ideal for displaying large images hosted locally (VLA, ALMA, ...) or remotely (SKA, ngVLA, VLASS, ...)

• A few CASA viewer features (like cube rotation, source finding) are not implemented in CARTA yet and are now prioritized against other, new features.

• CARTA is integrated in the ALMA and NRAO/SRDP archives

• For questions, comments, suggestions, please contact the CARTA helpdesk support@carta.freshdesk.com

• CARTA homepage: cartavis.org
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