

Visualization of ALMA Archive Data Products with CARTA

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CARTA basics

- **CARTA** = Cube Analysis and Rendering Tool for Astronomy, is a next generation image visualization and analysis tool designed for ALMA, VLA, and SKA pathfinders.
- Webpage: <https://cartavis.org>
- User Manual: <https://carta.readthedocs.io/en/latest/>
- Helpdesk: support@carta.freshdesk.com
- Current release version = v3.0
 - v4 in beta; scheduled release: ~~Aug2023~~ => Sep2023
 - v4 won't be deployed in ALMA Archive until Jan 2024
- Supported OS:
 - Ubuntu 20.04, 22.04
 - RH7/CentOS7
 - RH8/AlmaLinux8
 - MacOS 11, 12, 13
- Originally developed from NA ALMA Development Study + Project (PI = Rosolowsky)
 - Cy1+4 Studies (2013, 2017)
 - Cy2 Project (2014-2016)
- Project taken over by IDIA in 2018. Proj. Sci=Kuo-Song Wang (ASIAA)

The screenshot shows the CARTA website interface. At the top, there's a navigation bar with links for HOME, FEATURES, GALLERY, ROADMAP, INSTALLATION, TEAM, and ABOUT. Below the navigation bar is a large image of a galaxy with numerous colored circles (blue, yellow, green, pink, red) overlaid, representing data points or analysis results. The word "CARTA" is prominently displayed in large blue letters. Below the image, there are buttons for "Installation", "User Manual", and "Helpdesk". A banner below the buttons reads "New preview release: v4-beta" and "v4-stable scheduled early August 2023".

CARTA key features

CARTA adopts a client-server architecture which is suitable for visualizing images with large file sizes (GB to TB) easily obtained from ALMA, VLA, or SKA pathfinder observations. It is impractical to process such a huge file with a personal computer or laptop. In a client-server architecture, computation and data storage are handled by remote enterprise-class servers or clusters with high performance storage, while processed products are sent to clients only for visualization with modern web features, such as GPU-accelerated rendering. This architecture also enables users to interact with the ALMA and VLA science archives by using CARTA as an interface.

CARTA has two flavors: Desktop version and Server version. The former is suitable for single-user usage with a laptop, a desktop, or a remote server in the "remote" execution mode. The later is suitable for institution-wide deployment to support multiple users with user authentication and additional server-side features.

Memory-efficient when loading images

With ~1 GB of ram, a 16000 pixel x 16000 pixel image or a 16000 pixel x 16000 pixel x 1000 channel cube (~1 TB in size) can be loaded in seconds.

Parallelization and GPU-accelerated rendering

Parallelization with CPUs is invoked in data processing. GPU-accelerated rendering is adopted for tiled raster images, contour images, and catalog overlays.

Spectral line cube analysis tools

Flexible multi-profile plotting capability is supported. Analysis tools such as profile fitting, profile smoothing, moment map generator, and spectral line query and labelling are out of box.

Customizable and reusable GUI layouts and preferences

CARTA is equipped with a highly customizable and reusable graphical user interface for various use cases.

Efficient catalog processing and rendering

Catalogs with millions of sources can be loaded and rendered in seconds. Catalog files are processed with parallelization techniques and are rendered with GPU acceleration.

Efficient visualization with HDF5 (IDIA schema) images

The HDF5 format with the IDIA schema improves the user's experience of viewing large image cubes significantly.



Current CARTA Key Features (v3.0)

(see <https://cartavis.org>)

Current release

The current release is v3.0, released on 23rd of August 2022, with the following features:

- Package support for x86_64 and aarch64 architectures
- Vector overlay rendering
- Loading images with the Lattice Expression Language (LEL)
- Loading CASA images with pixel values as complex numbers
- Initial implementation of image 2D Gaussian fitting
- Generating computed polarization quantities (eg. linear polarization intensity) of a Stokes cube on the fly
- Setting a new rest frequency when saving a subimage
- Logging moment map generation information in header history
- Line and polyline region spectral profiler
- Initial implementation of PV image generator
- Image file list filter
- High-resolution PNG export
- Enhanced spectral matching mode
- Custom rest frequency for velocity conversion
- Performance boost when loading a region file with massive amount of regions
- Telemetry
- Online catalog query from SIMBAD and VizieR
- Region export and import enhancement
- Initial implementation of intensity unit conversion
- Multiple panel view
- Pixel grid border rendering at high zoom levels
- Interactive raster rendering with a cutoff via the interactive colorbar
- Distance measuring tool
- Spatial profiler widget enhancement
- Histogram and statistics widget enhancement
- Cursor info widget
- Code snippets (experimental feature)
- Support gzipped FITS images (fits.gz and fz)
- HDF5 mip map support
- Remember last used directory
- Performance enhancement and bug fixes



Future Roadmap

Next release

Sep 2023

The next release will be v4.0 (~~~early August 2023~~) with the planned main new features:

- Save and restore state
- Share state
- Enhanced PV image generator
- Interactive PV image preview
- Visualization of rotated cubes
- Enhanced 2D image fitting
- Enhanced histogram widget
- Image annotation
- Python scripting interface (initial)

=> see

<https://docs.google.com/document/d/1TLFma7bP7yZ879N8tqmNmBZX9CbxaXktFv3GNOwQ9n4/edit#heading=h.r9k0m1abpf3w> for highlights

Future release

This is a non-exclusive list of features we would like to add in subsequent releases, but they are not 100% decided upon yet and depend on feedback from users, resourcing etc.:

- Collaborative tools
- Volume (pseudo 3D) rendering
- Profile, histogram, and image fitting tools
- Image source finder
- VO service (image and catalog)
- Smart layout
- New moment image generator
- RGB image blender
- Spatial profile fitting
- Channel-map view
- Python scripting interface
- JavaScript scripting interface



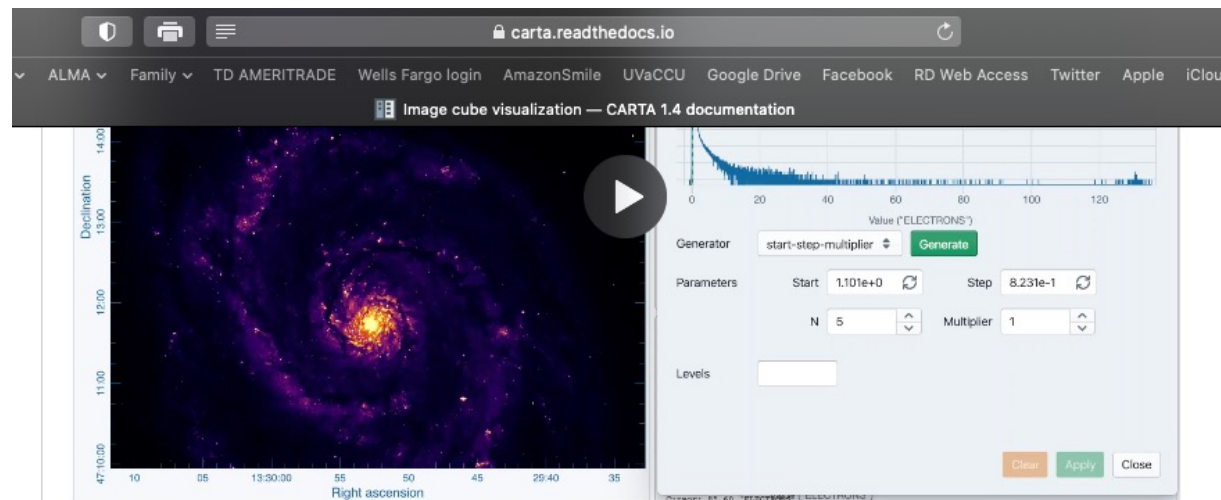
More Information

- Extensive online documentation with many videos demonstrating individual features:

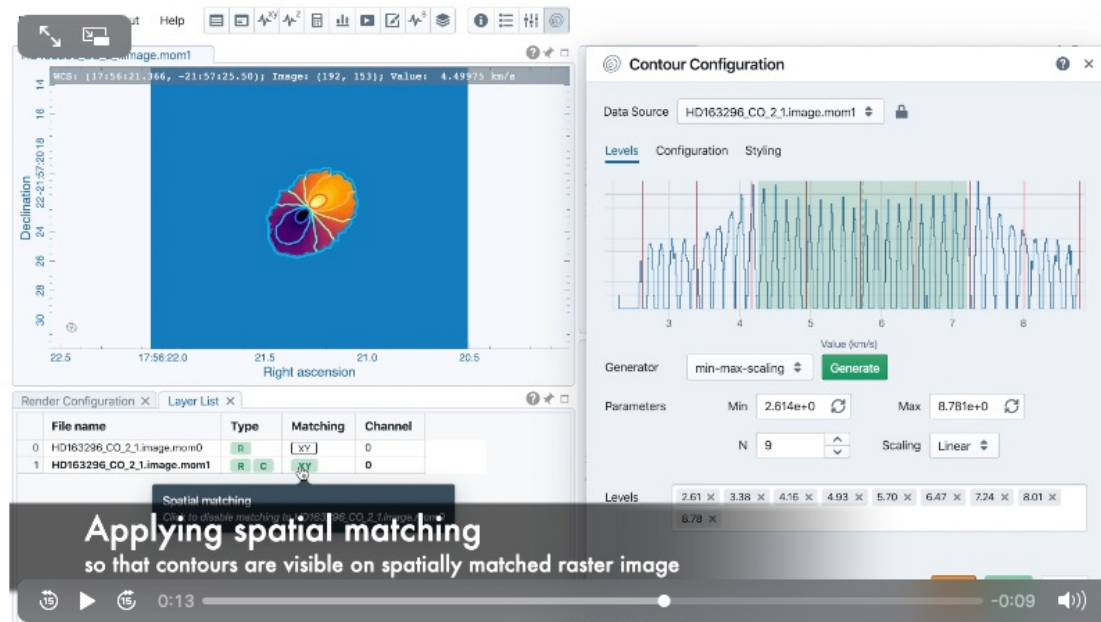
<https://carta.readthedocs.io/en/latest/>

- Demo by the K.-S. Wang (CARTA Project Scientist): ALMA “iTrain” #12 (Feb 2022):

<https://www.youtube.com/watch?v=K71rFeAhQ5o>



In the above demonstration, a contour image is generated on top of its raster image. If users would like to plot a contour image on top of other raster image (e.g., velocity field as contour, integrated intensity image as raster), users need to enable WCS matching of the two raster images first (see [Match images in world coordinates](#)). Then users can generate the contour image just like the above example. When the contour image is generated, use the image list widget or the animator widget to switch to the integrated intensity image. Users should see the velocity field image as contours on top of the integrated intensity image as raster. In short, contour images are visible for raster images matched in world coordinates.



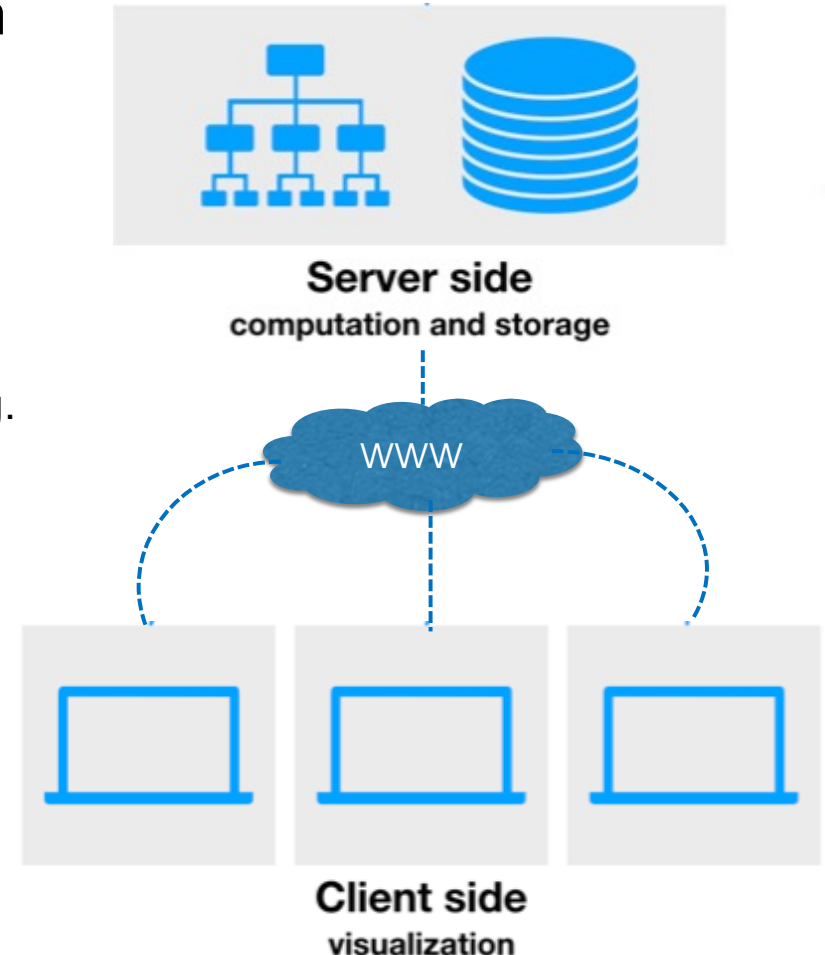
Applying spatial matching so that contours are visible on spatially matched raster image

If there are multiple images loaded in append mode, users may use the “Data Source” dropdown to select an image as the data source of contour calculations. If the state of the “lock” button is locked, the image viewer will show the selected image as a raster image and the image slider in the animator widget will be updated to the selected image too. To disable this synchronization, click the “lock” button to set the state to unlock.



CARTA Operation Modes

- Strength: Remote visualization platform
 - “Client-Server Architecture”:
 - Server side=backend, runs on system connected to systems where large data products are stored
 - Client side = frontend, web browser running on users system (remote from data). Takes advantage of GPU for accelerated rendering.
 - Implemented in both ALMA and NRAO Archives
- Also available as stand-alone visualization tool
- CARTA will become the replacement for most CASA Viewer functions (but not visibility viewing or interactive clean)





CARTA Demo

- V3 demo options: using ALMA Archive
 - *Note – data are *not* downloaded. Will lose any work. Use this to decide what to download*
 - Multiple Image/cubes Overlays
 - Countours
 - Moments?
- V4 demo options
 - (v3) Catalog widget & Spectral line query
 - (v3) Cube with multiple transitions
 - (v3) save subcube
 - (v4) Save/Restore workspace
 - (v4) Image annotations
 - (v4) interactive P-V preview

