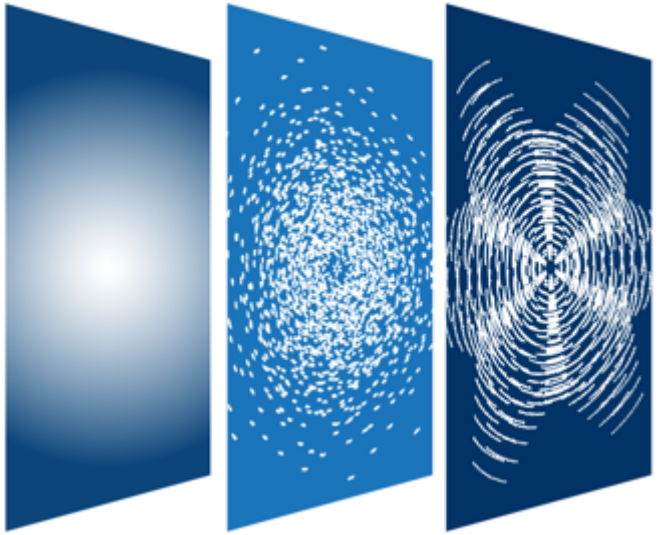


Visualization & the CASA Viewer

Juergen Ott

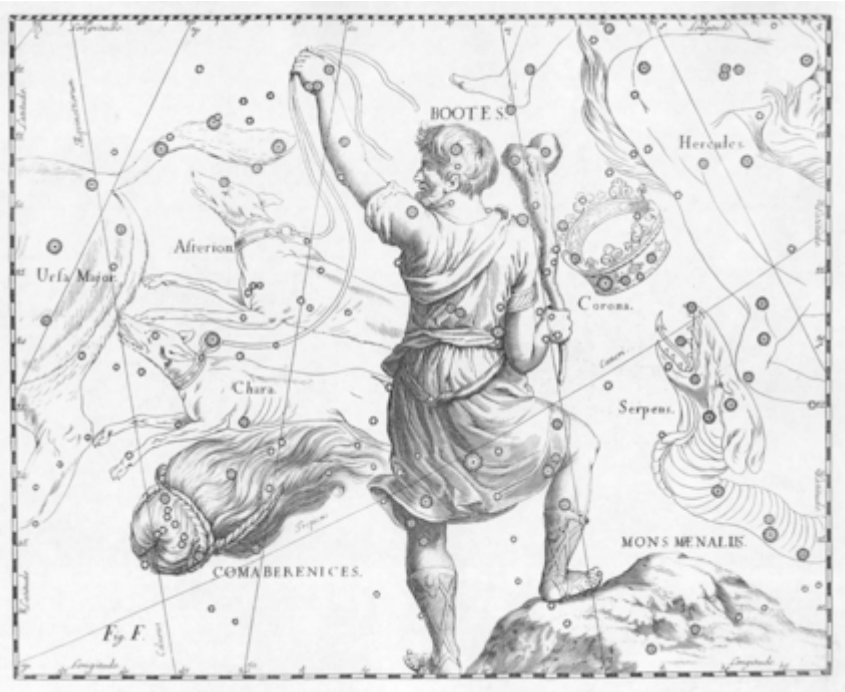
& the CASA team

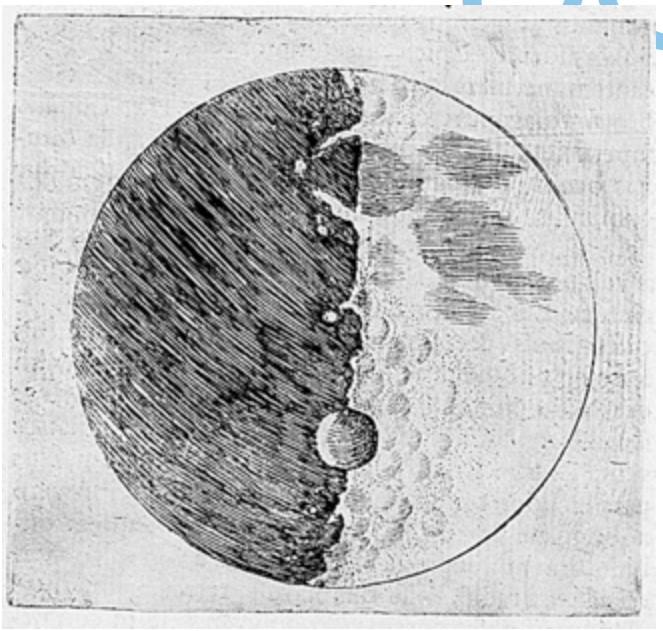
Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

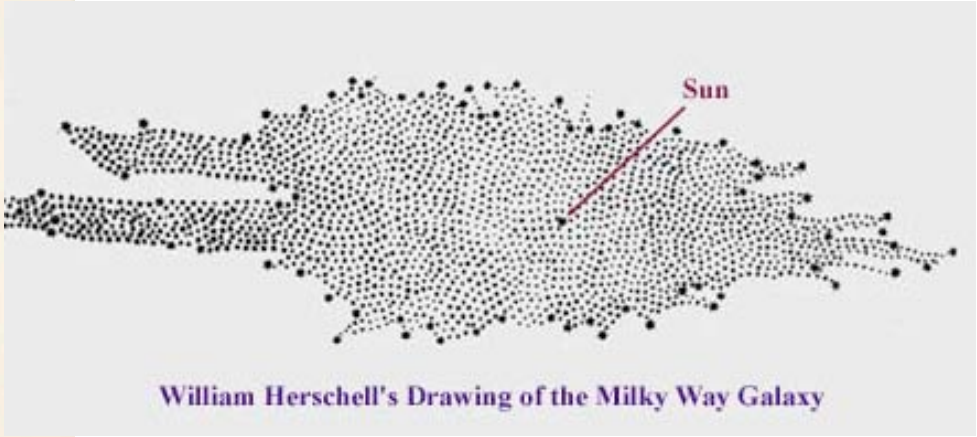
Visualization

Goals:

- exploration/exploitation of data and information
- enhancing understanding of concepts and processes
- gaining new (unexpected, profound) insights
- making invisible visible
- effective presentation of significant features
- quality control of measurements or simulations
- increasing scientific productivity
- medium of communication







William Herschell's Drawing of the Milky Way Galaxy

Visualization

- Astronomy datasets are n-dimensional
- An electric wave is described by Amp(RA, DEC, spectral/ velocity/energy, polarization, time [phase])

Visualization

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- An electric wave is described by Amp(RA, DEC, spectral/ velocity/energy, polarization, time [phase])
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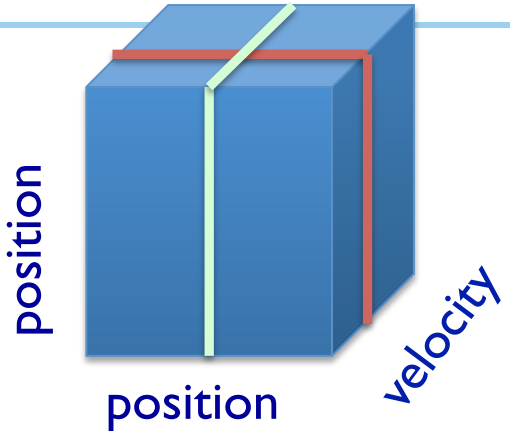
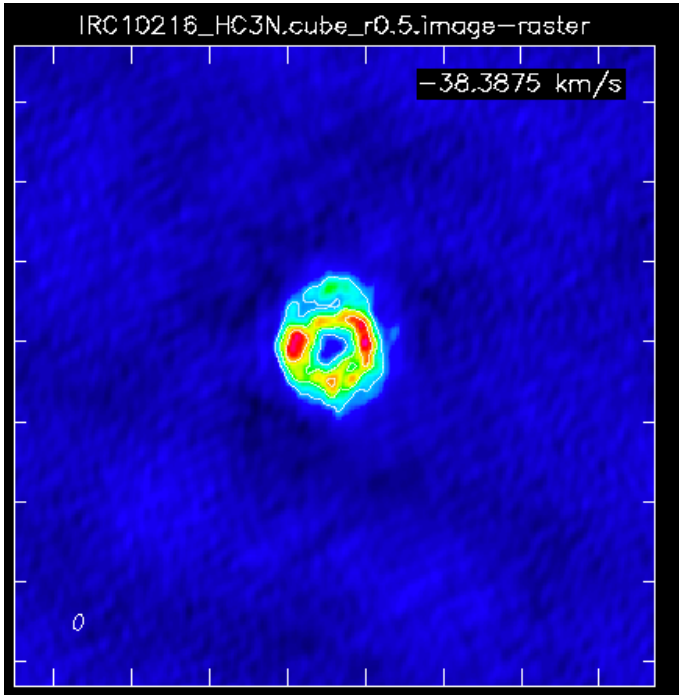
- Add other dimensions through other means
  - No other dimensions: projection of data, slices



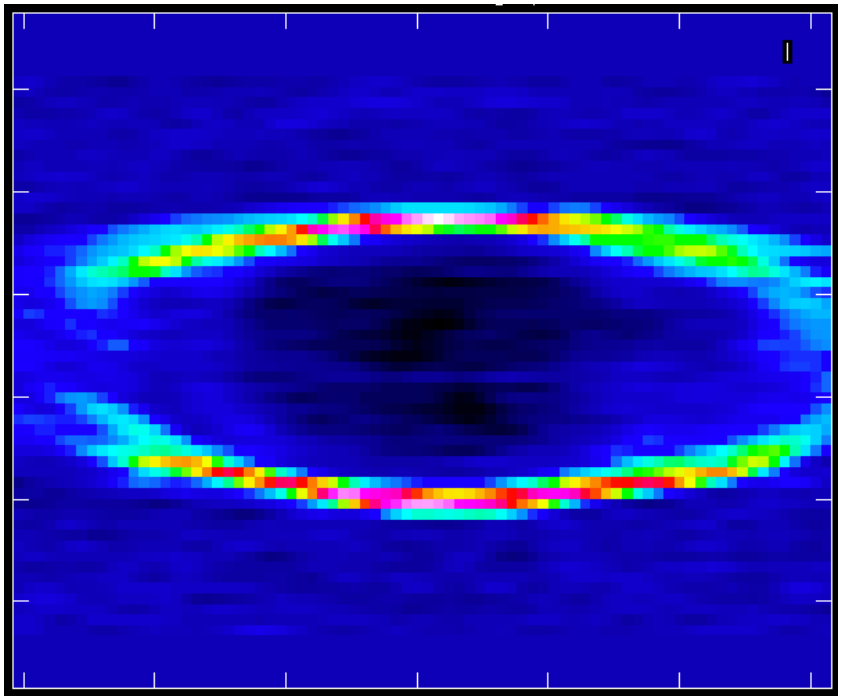
- Show only two dimensions at fixed values of all higher dimensions

- Channel map



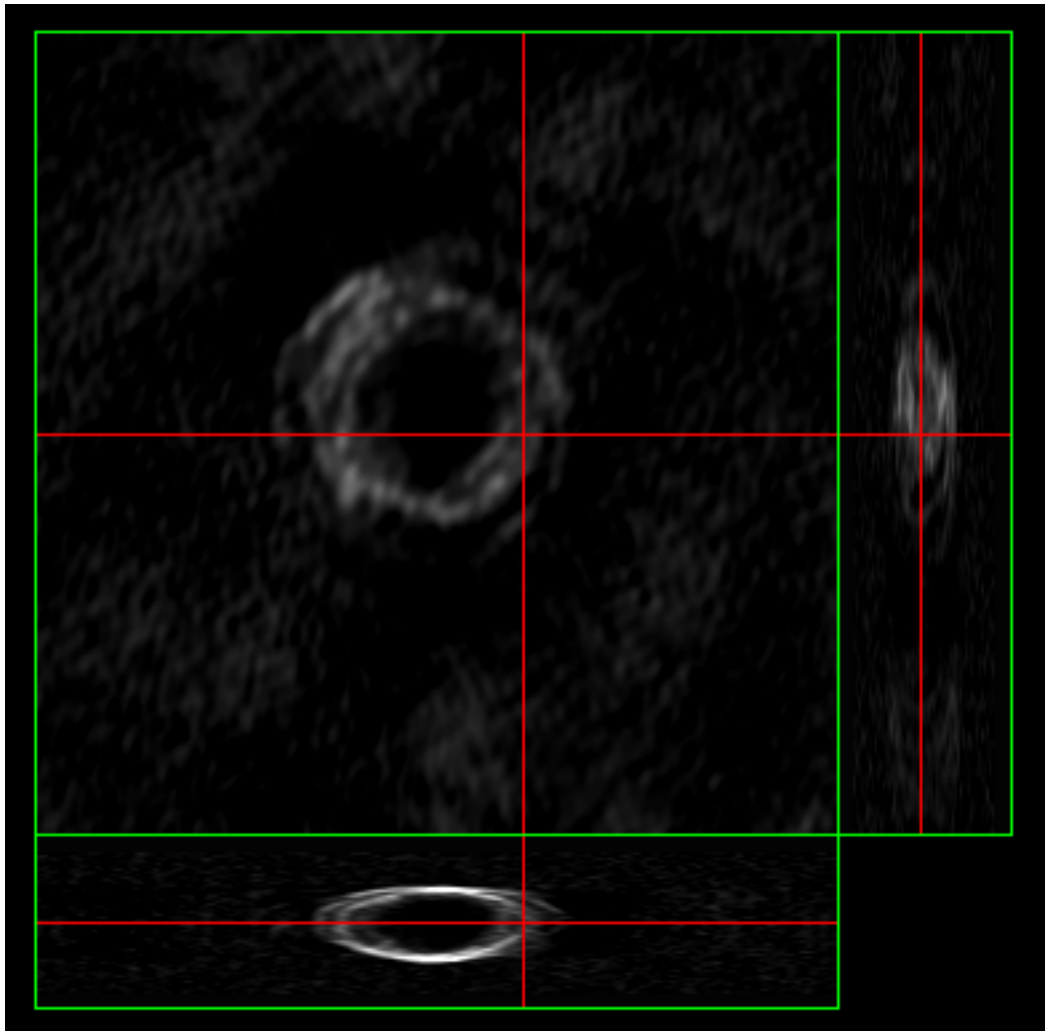
Fixed velocity, polarization, etc.

- Position-velocity map



One fixed position, polarization, etc.

- Cube unfolded



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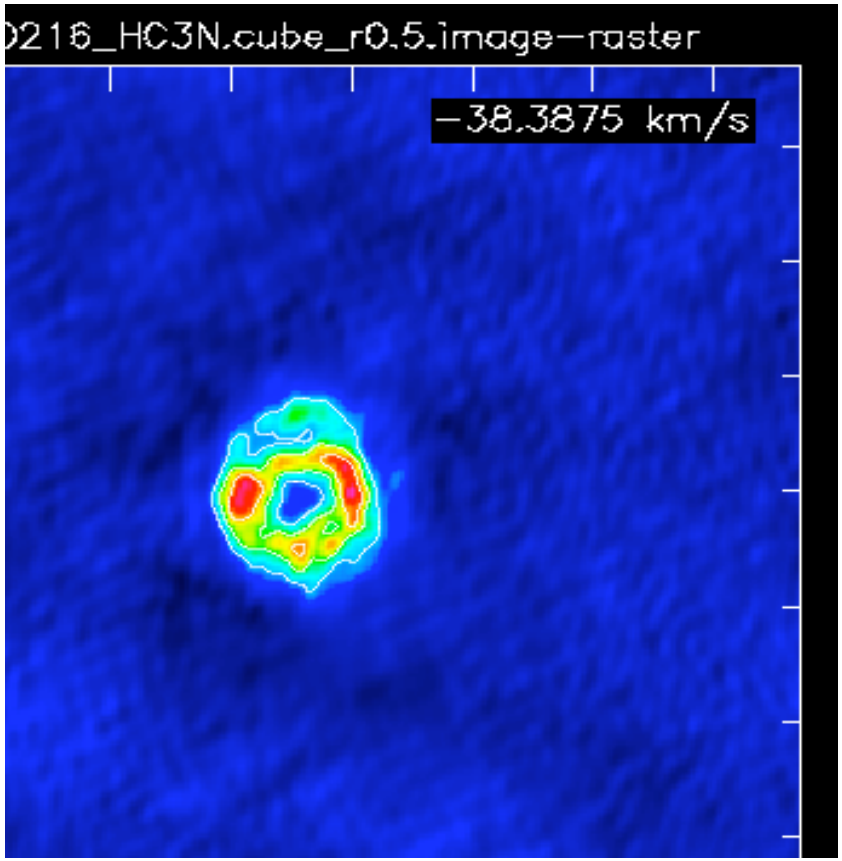
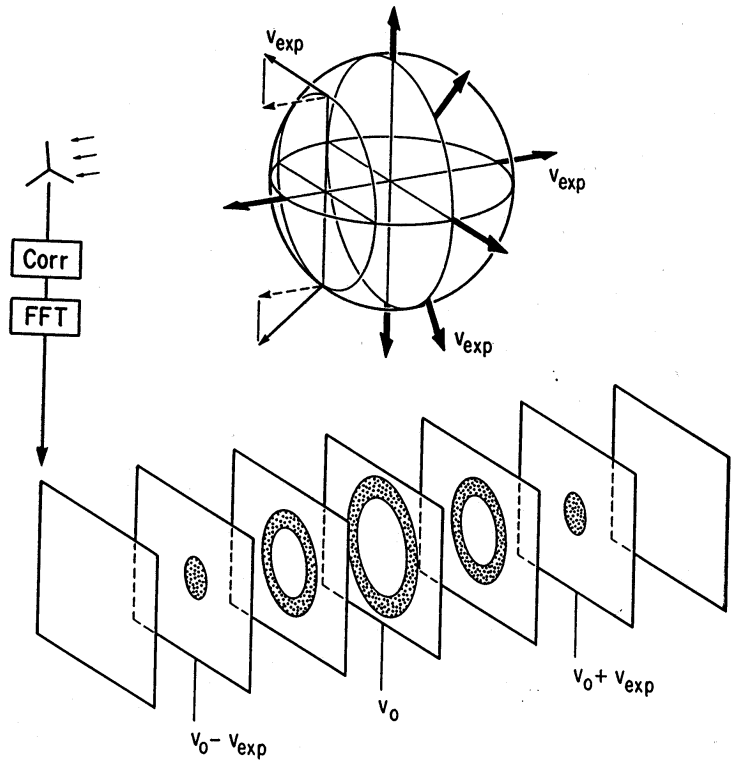
  - Time/movies

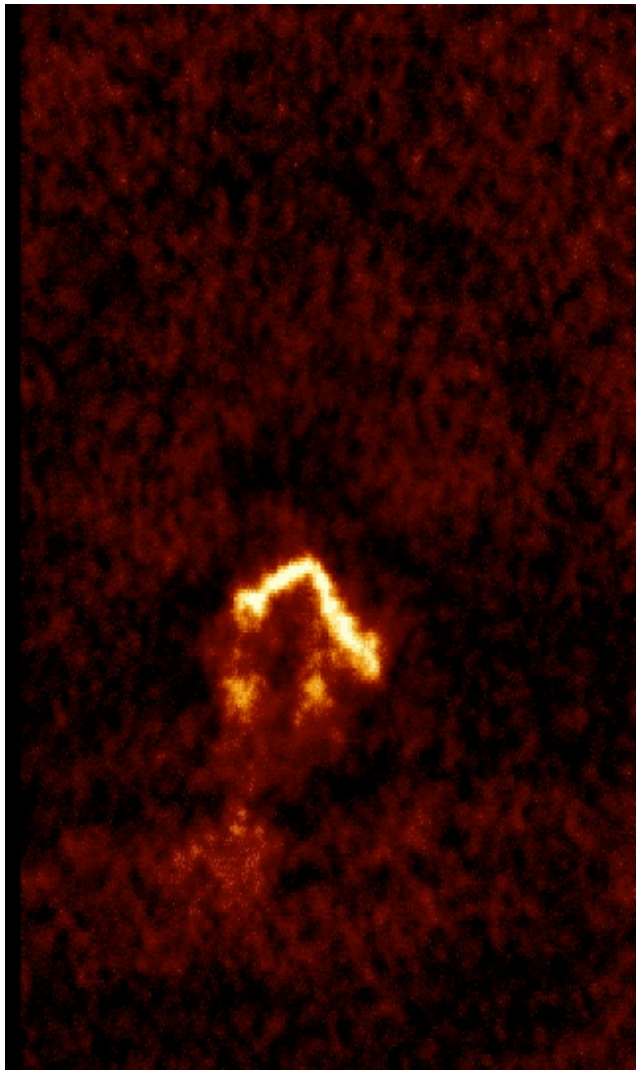
- Movies: Time is used to display information (e.g. velocity) along other dimensions

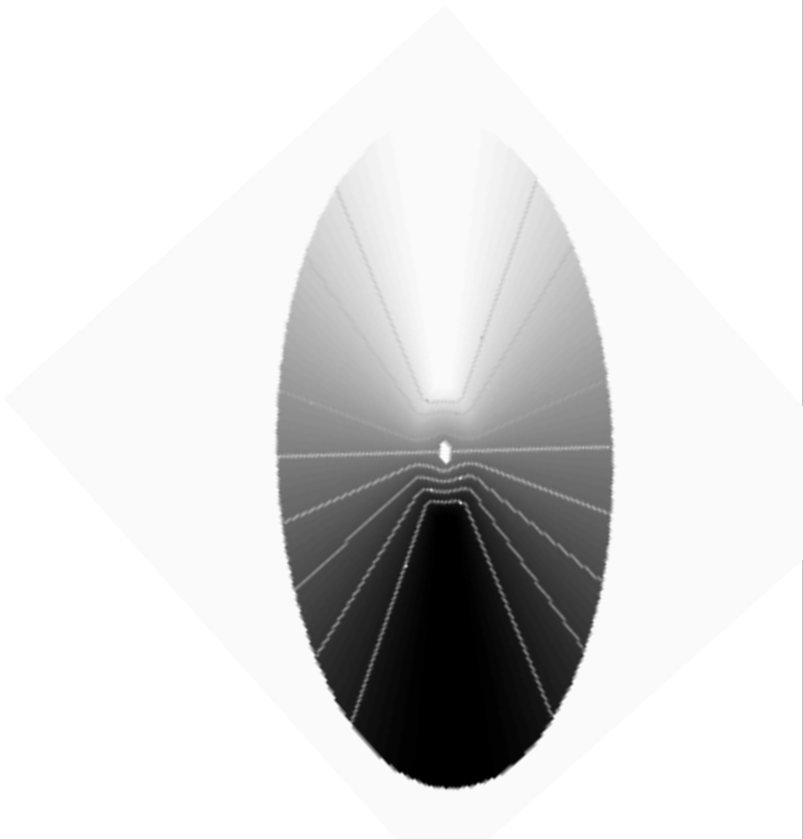




CASA

- Movies: Time is used to display information (e.g. velocity) along other dimensions





- Galaxy with a flat rotation curve

NRAO

Visualization

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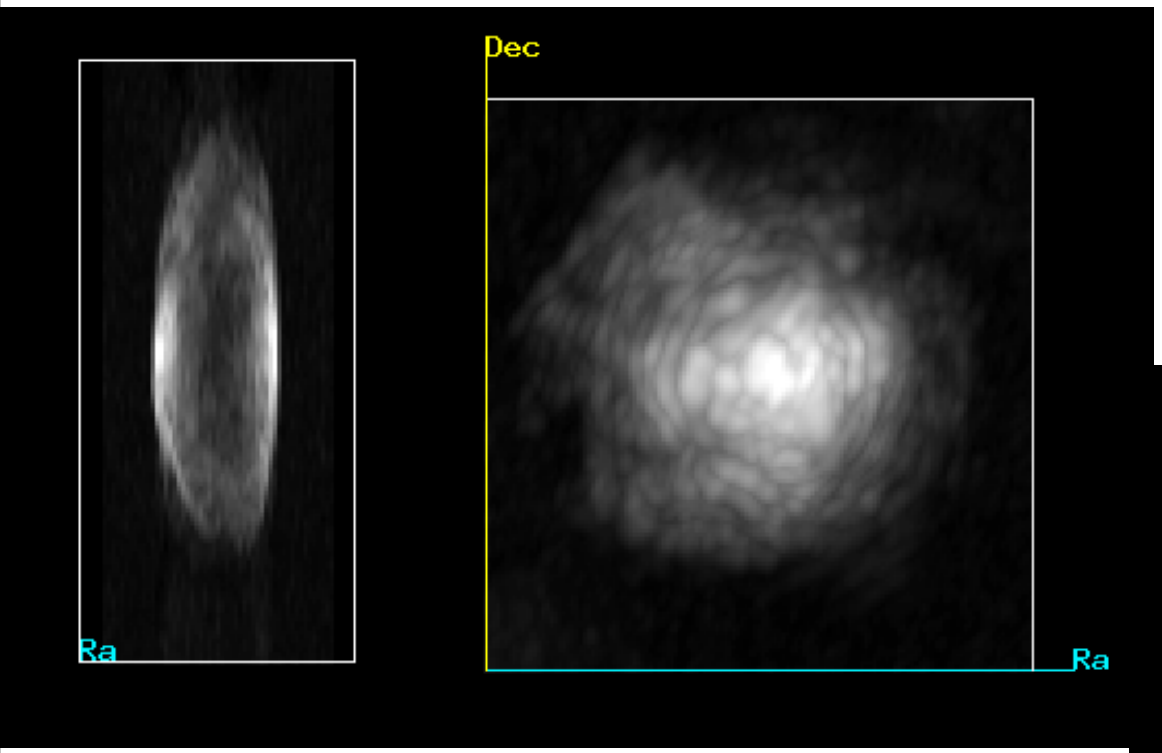
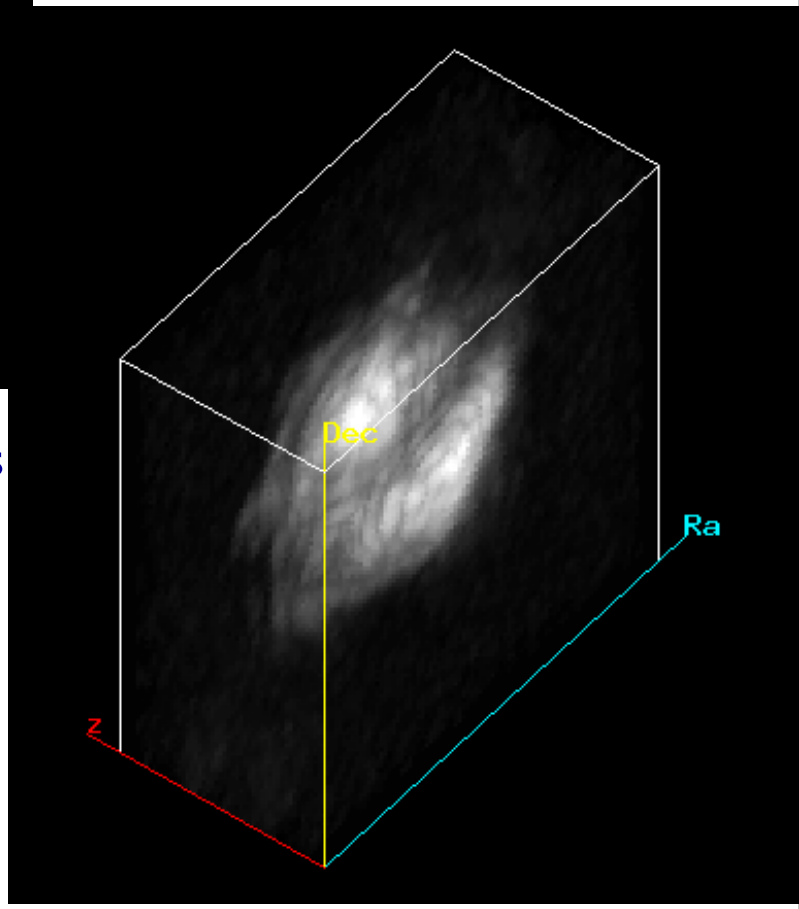
  - Projection can also show combinations of dimensions, rotation of cubes, volume rendering/opaqueness

CASA



- Warning:

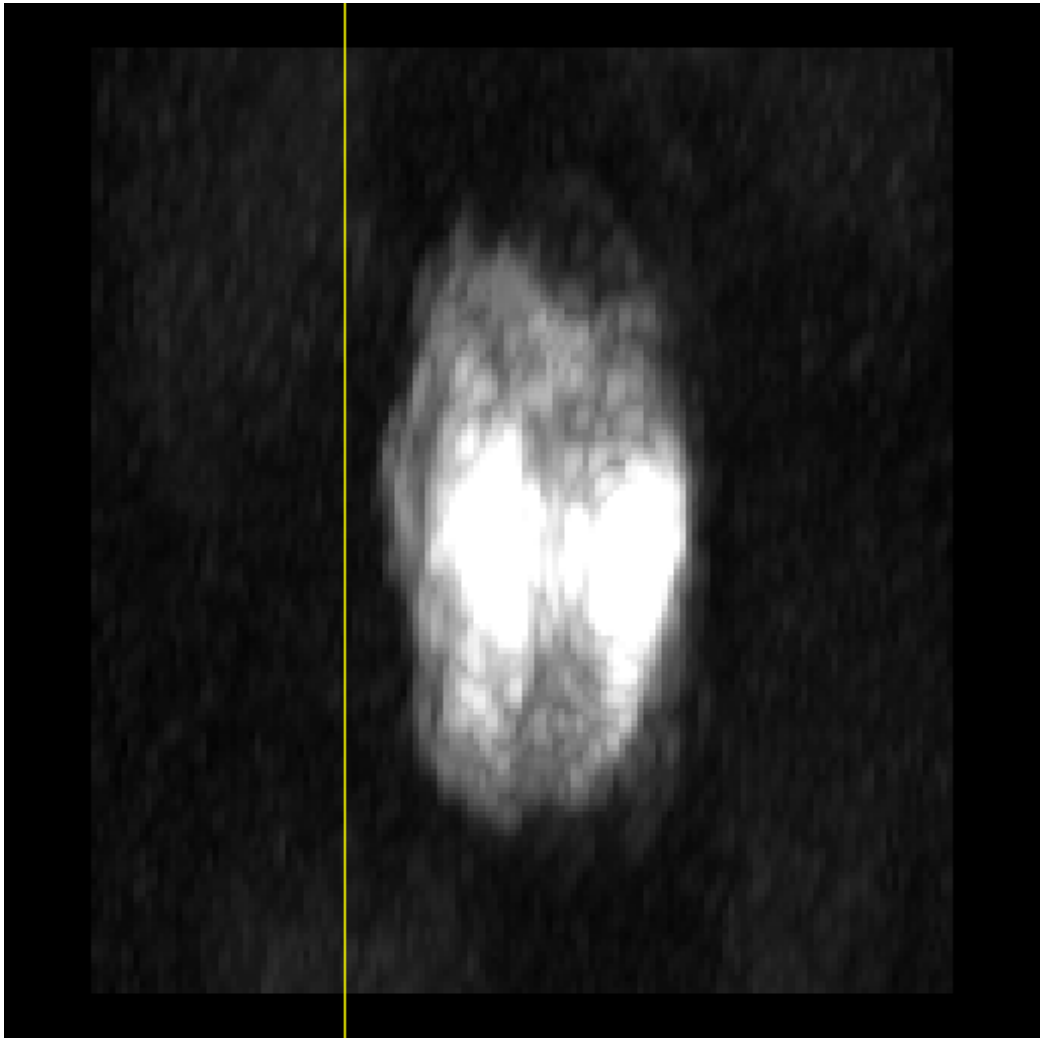
Rendering also allows for mixing of dimensions



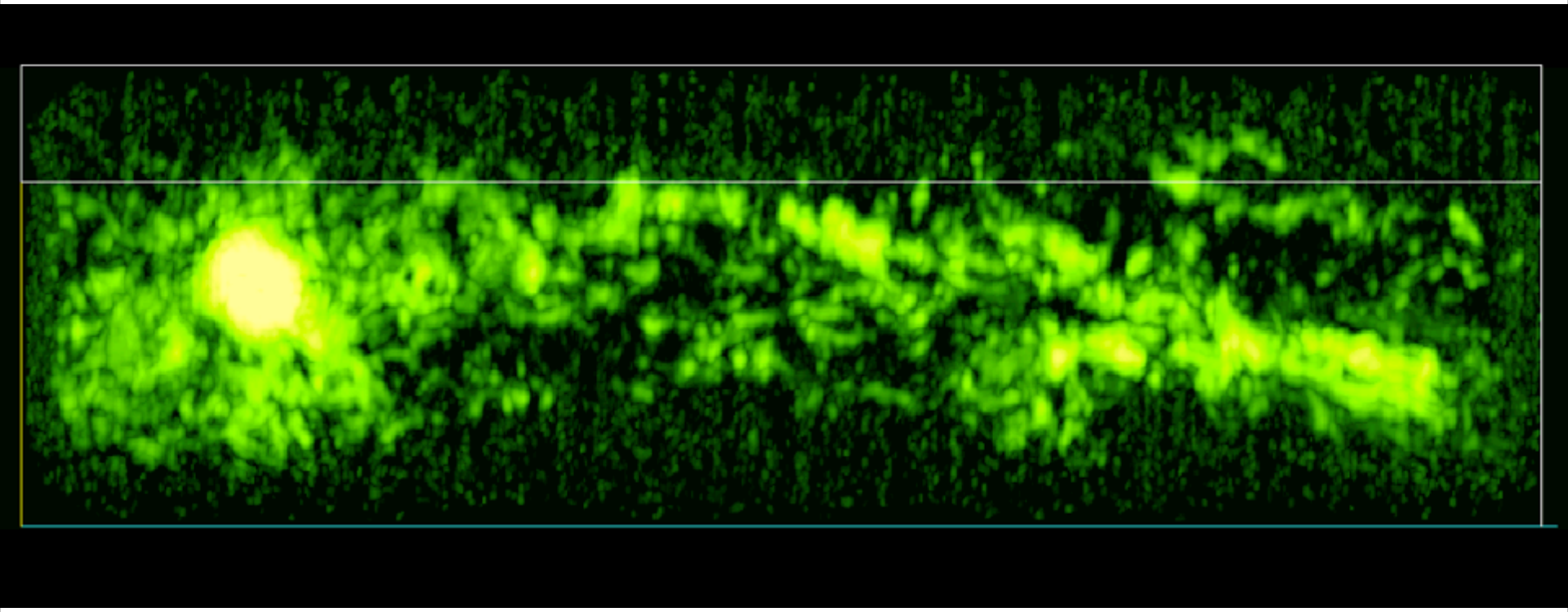
- Rendering requires transparency or opaqueness to be applied to a datacube. The displayed images are a **combination** of different planes.
- Many different algorithms/parameters possible.

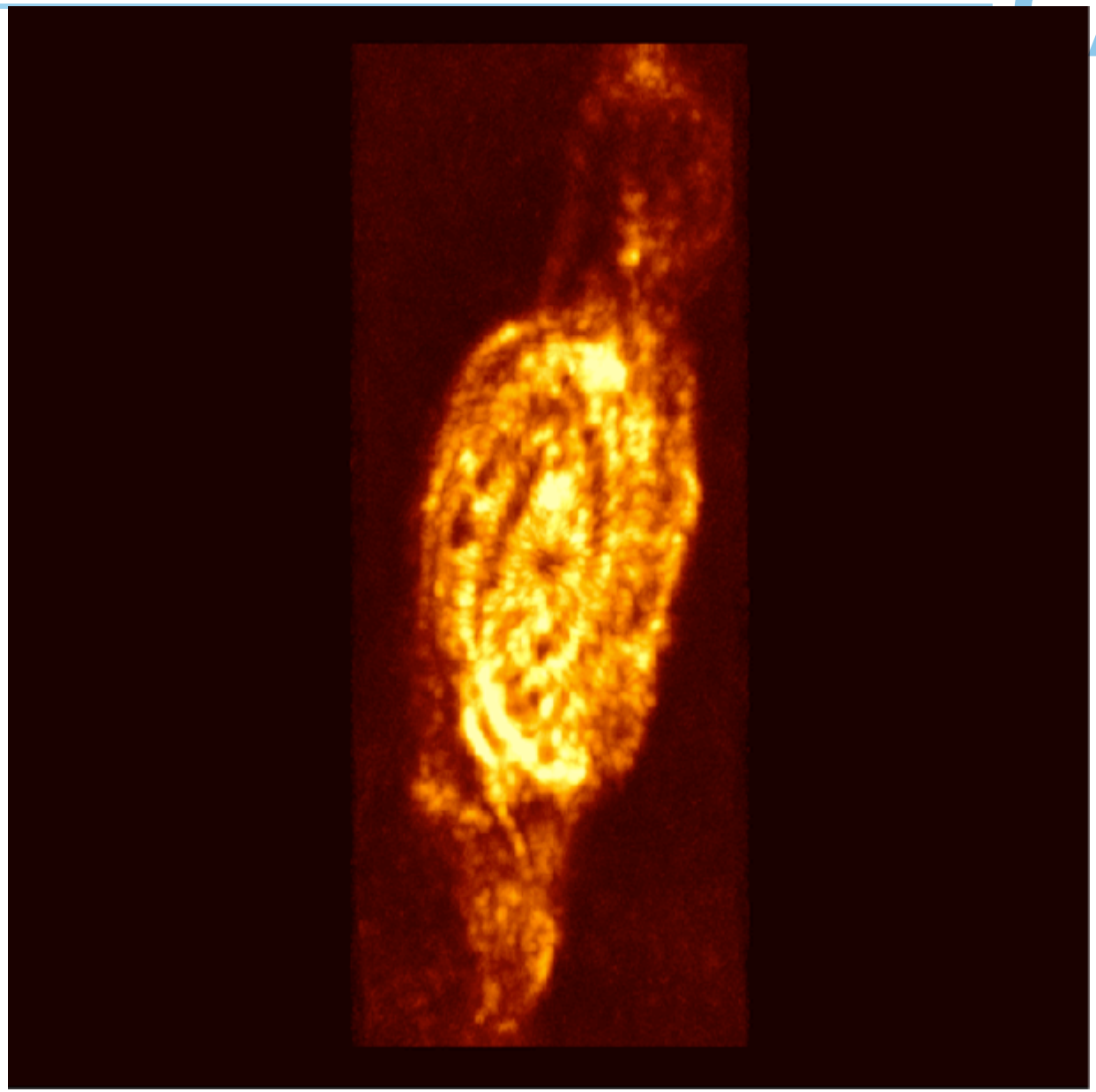
NRAO

CASA



CASA





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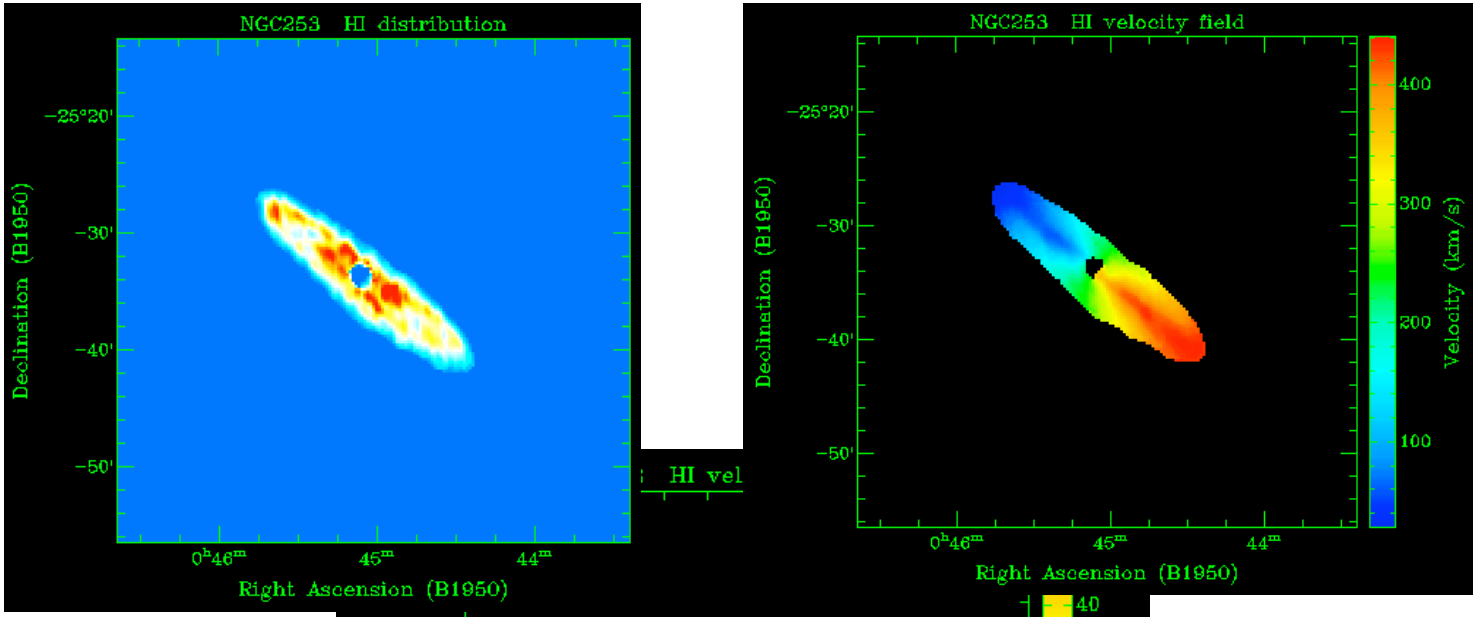
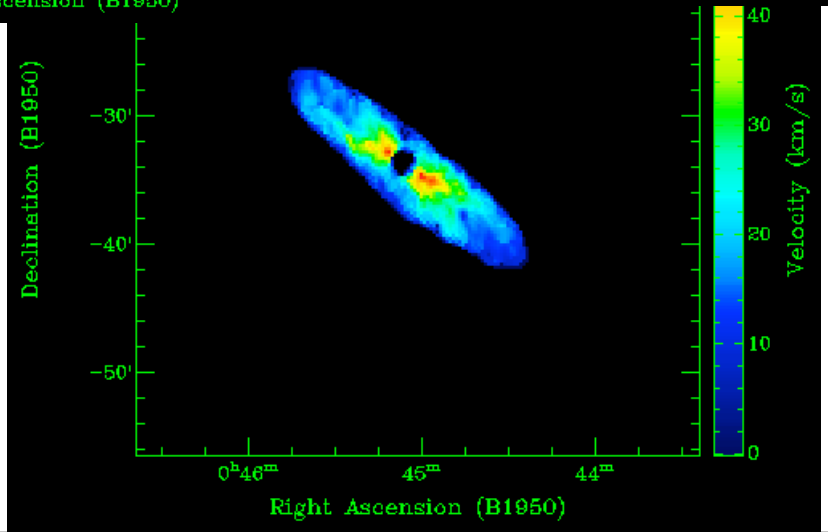
  - Collapse can be in different ways, e.g. moment maps, peak flux maps, medians, etc.

CASA





- Moment 0/ Integrated intensity
- Moment 1/ Intensity-weighted velocity
- Moment 2/ Velocity dispersion

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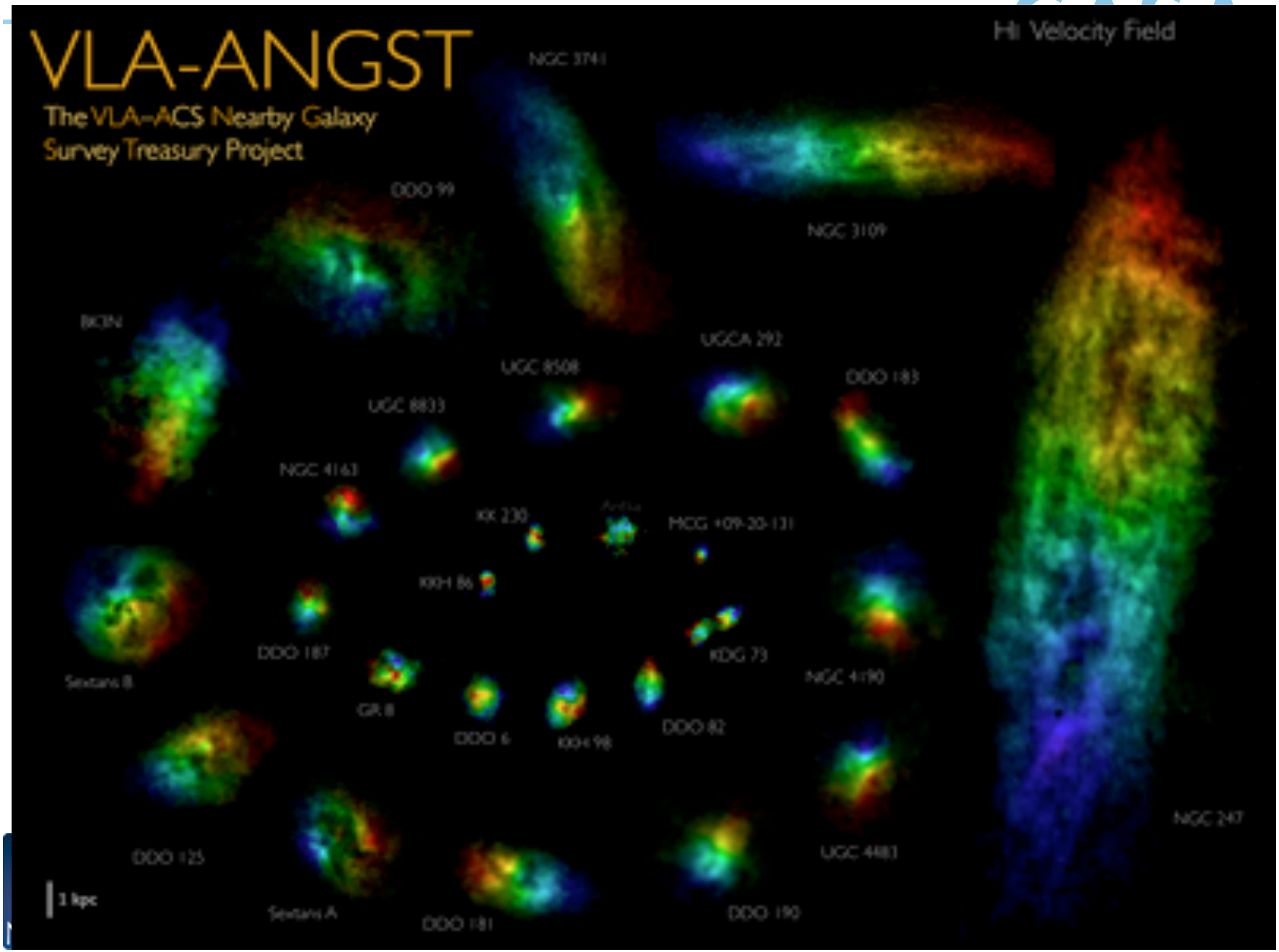
  - Can be combined, e.g. brightness/hue


VLA-ANGST
The VLA–ACS Nearby Galaxy Survey Treasury Project
HI Velocity Field
NGC 3741
DDO 99
NGC 3109
IKN
UGCA 292
UGC 8508
DDO 183
UGC 8833
NGC 4163
KK 230
MCG +09-20-131
KKH 86
DDO 187
KDG 73
Sextans B
NGC 4190
GR 8
DDO 6
KK98
DDO 82
NGC 247
DDO 125
UGC 4483
1 kpc
Sextans A
DDO 181
DDO 190

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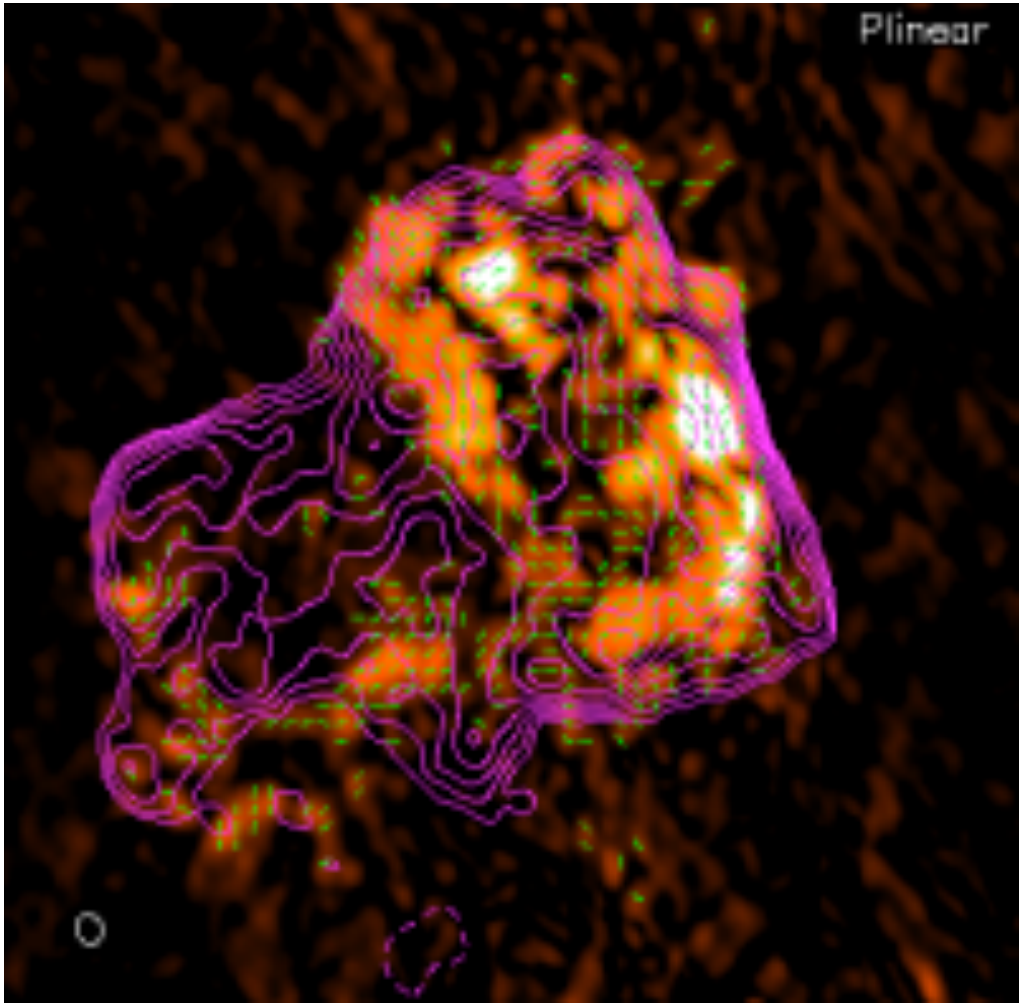
CASA



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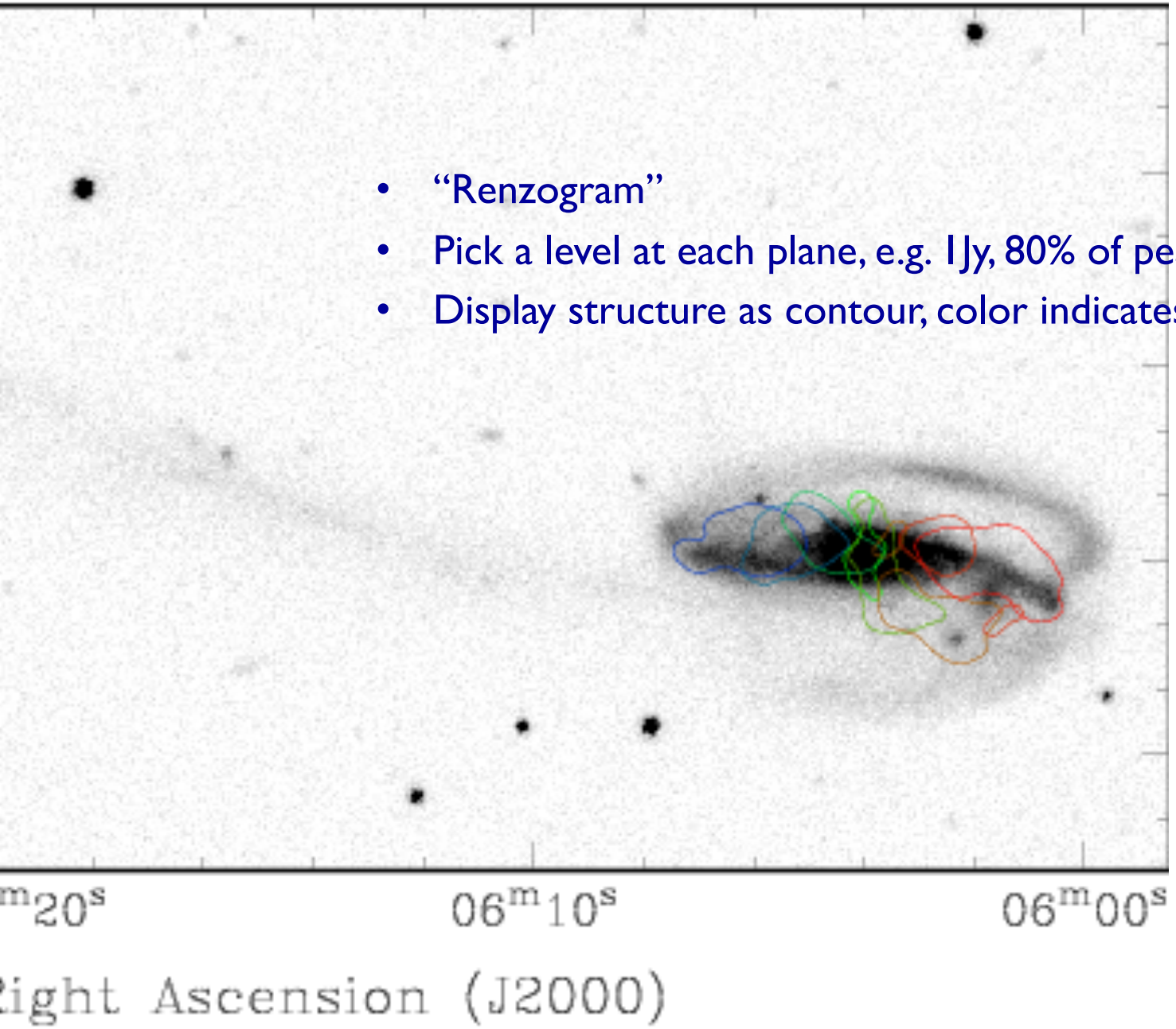
  - Contours, markers, vectors
  - Combinations, e.g. "Renzogram"

CASA

- "Renzogram"
- Pick a level at each plane, e.g. 1Jy, 80% of peak
- Display structure as contour, color indicates plane/velocity



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  - Polarization is used e.g. in 3d-movies

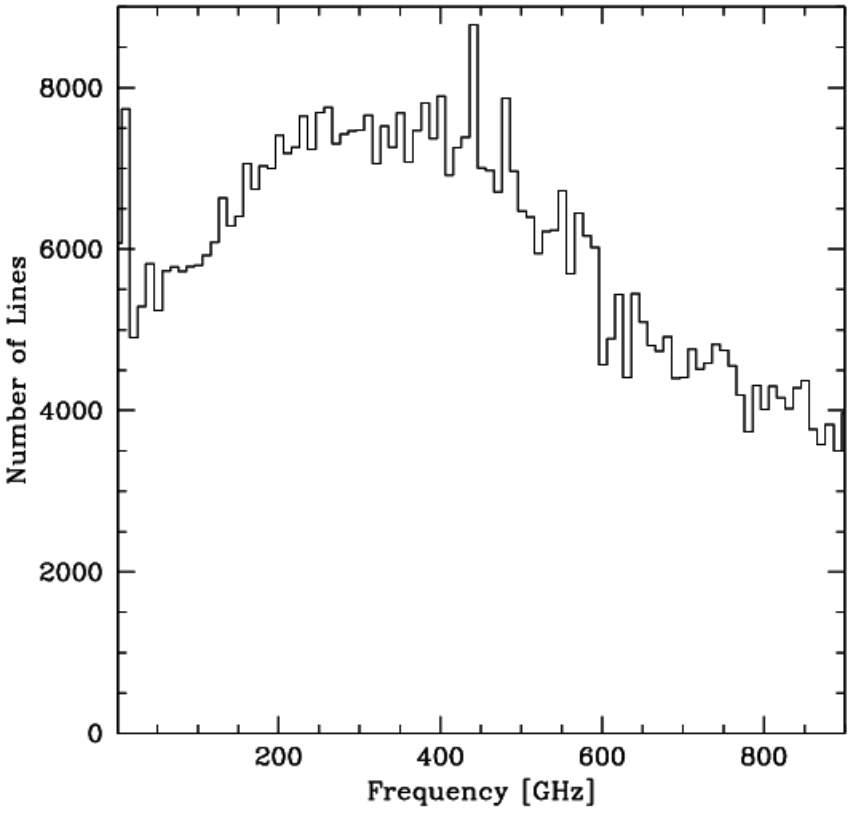
Visualization

- Astronomy datasets are n-dimensional
- An electric
  velocity/en
- Project a n
- Add other
  - No oth
  - Time/m
  - Project
    rotatio
  - Collaps
    flux ma
  - Can be combined, e.g. brightness/hue
  - Contours, markers, vectors
  - Combinations, e.g. "Renzogram"
  - Polarization is used e.g. in 3d-movies

Visualization

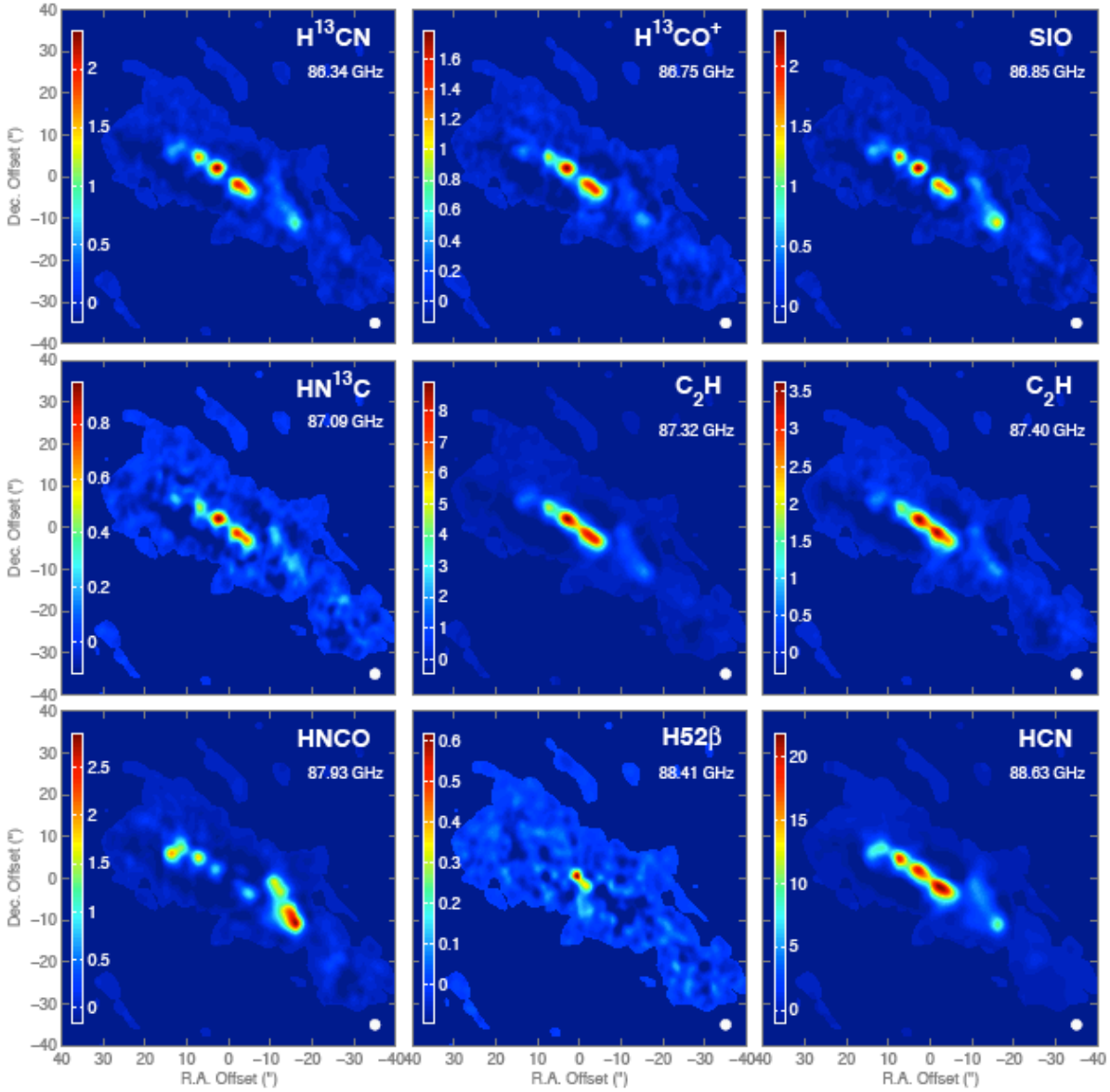
Problems:

- Third axis is usually NOT spatial but spectral
  → requires some experience to interpret
  and not get fooled
- Signal to noise
  → smoothing, tessellation, etc.
- Richness of spectrum
  → Many lines in bright objects
  → Requires careful separation
  → Hyperfine lines



NRAO

—CASA

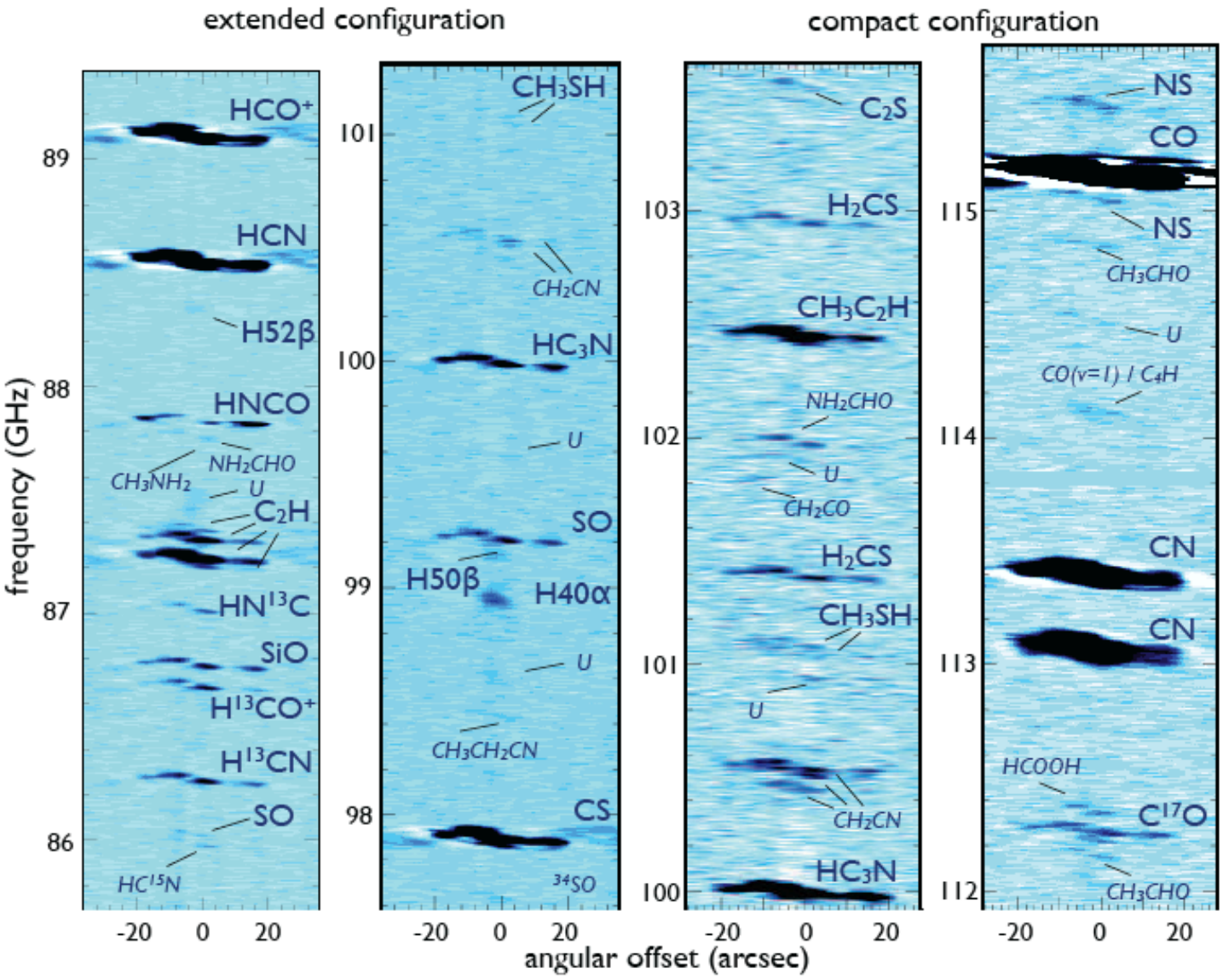


- Many lines

in single datacube

NGC 253, ALMA: Walter et al. 2014, in prep.

CASA



- Line identification

Function of

Frequency & position

NGC 253, ALMA: Walter et al. 2014, in prep.

CASA

Common Astronomy Software Applications

- Data reduction packet for ALMA and Jansky VLA
- load, edit, calibrate, image, analyze, and visualize interferometric datasets
- Single dish component for ALMA
- ~14 developers at NRAO, ESO, NAOJ, plus a few associated programmers at ASTRON, CSIRO/CASS and other institutions
- Some CASA developers are computing scientists with dedicated algorithm development time
- CASA release about ~6 months, intermediate "stable" versions
- Linux and MacOS
- Python based layer for the user interface and easy scripting with C++ code underneath for performance

CASA

Common Astronomy Software Applications

- Data reduction packet for ALMA and Jansky VLA

ALMA: 50x12m + 12x7m +4x12m TP

Jansky VLA: 28x25m

Commonalities:

- Aperture synthesis radio Interferometers (i.e. they measure complex visibilities [amp/phase])
- Similar raw data format
- Same basic data reduction & imaging steps

CASA

Common Astronomy Software Applications

- Data reduction packet for ALMA and Jansky VLA

ALMA: 50x12m + 12x7m +4x12m TP

Differences:

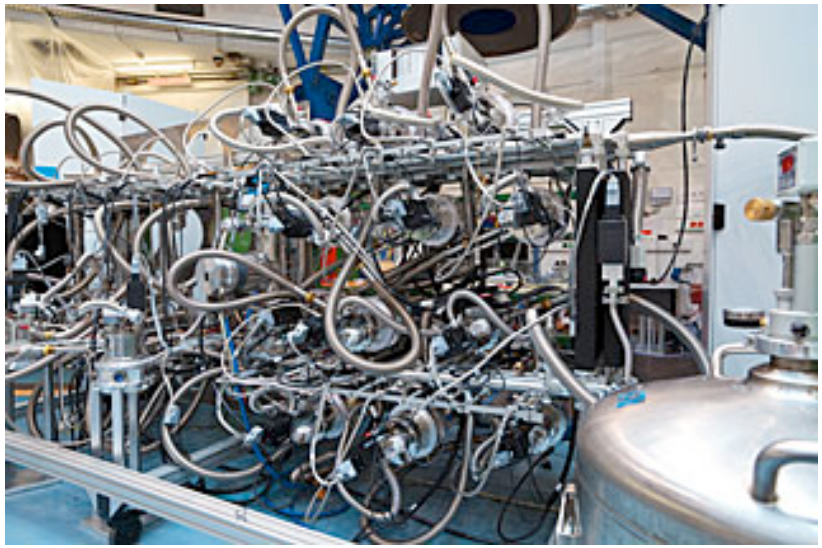
- Sub mm ([30] 84-720 [950+]GHz), large kλ
- Water vapor (opacity, phase rms, atm. lines)
- Hybrid imaging, short/zero spacing
- calibration on planets/moons

Jansky VLA: 28x25m

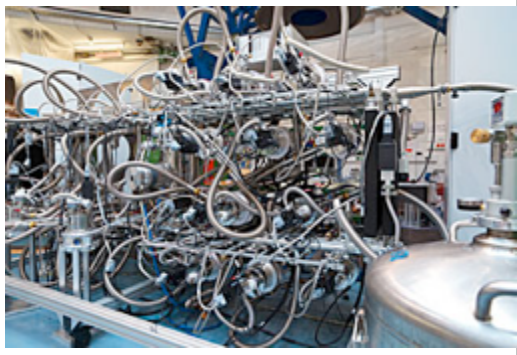
- cm ([0.07] 0.330-50 GHz)
- Sensitive to terrestrial Radio interference
- Large fractional bandwidth e.g. 1-2GHz
- High dynamic range imaging
- 1st JVLA sidelobe ~ VLA sensitivity

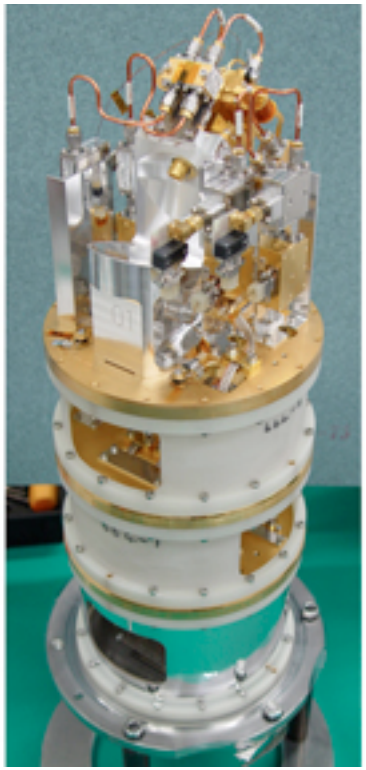
CASA viewer

- Display of multidimensional datasets
- Measurement sets (visibilities) and 4dim image cubes
- MS can be inspected and edited
- Images can be viewed and inspected, and hardcopies can be obtained
- Limited scriptability at this stage
- Image manipulation and analysis methods can be invoked, newly created datasets saved
- Viewer component is optimized to optical IFUs, in particular for MUSE data



CASA viewer

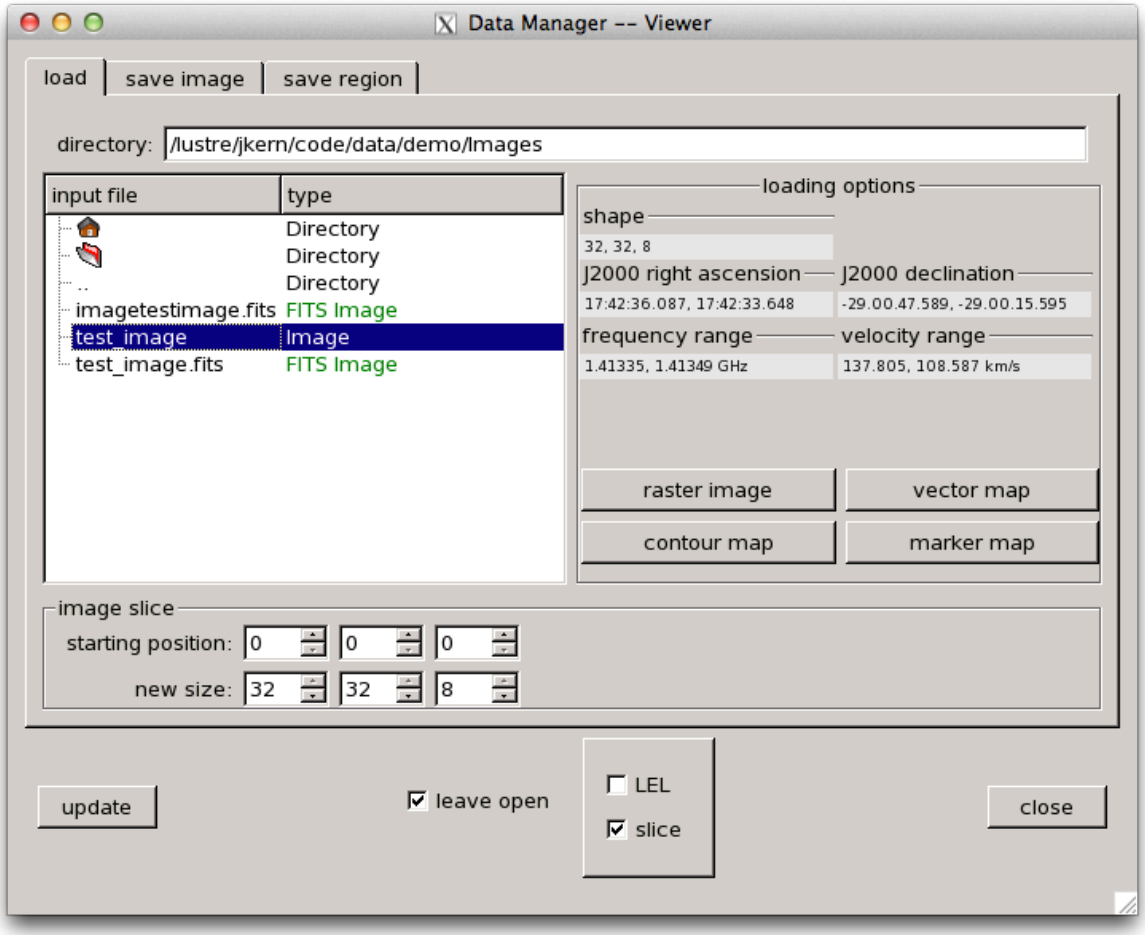




- Visualization is very similar with RA/DEC/Vel cubes
  BUT
- Optical data can come in different fashions
  (lenslet, slicer, fibers, etc.)
- global spectral template removal (simpler in radio)
- Measurement is in wavelengths for optical data,
  in frequencies for radio data
  - optical data: non-linear radio velocity frame
  - radio data: non-linear optical velocity frame
  - optical =/= radio velocity frame
- Changes in the psf and fov (primary beam) can be more
  drastic in the radio ($\Delta\nu/\nu$ up to 1)
- Errors in optical data pixel/spaxel based (error cubes)
  smoother error dependence on frequency and position in radio
- Optical: Poisson noise, Radio: Thermal noise (plus sidelobes)

NRAO

Image Access

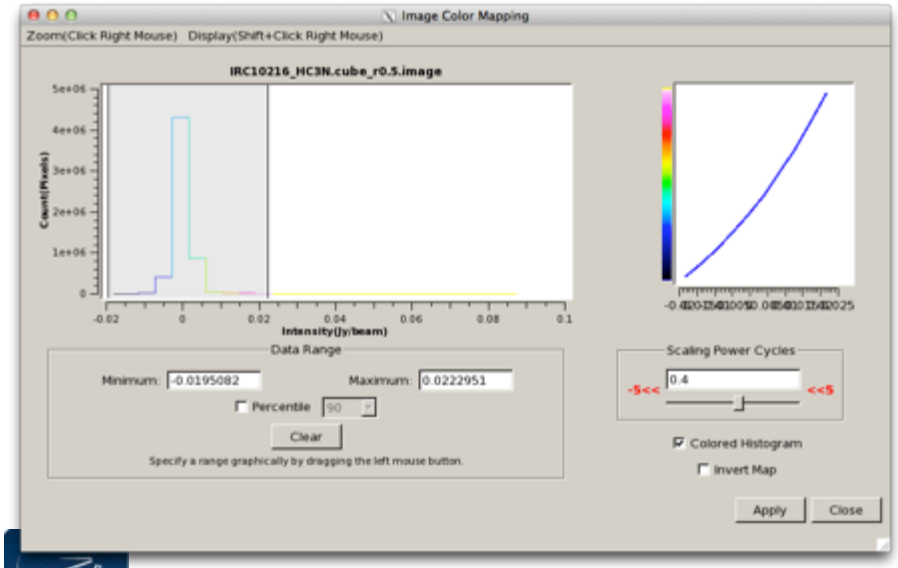


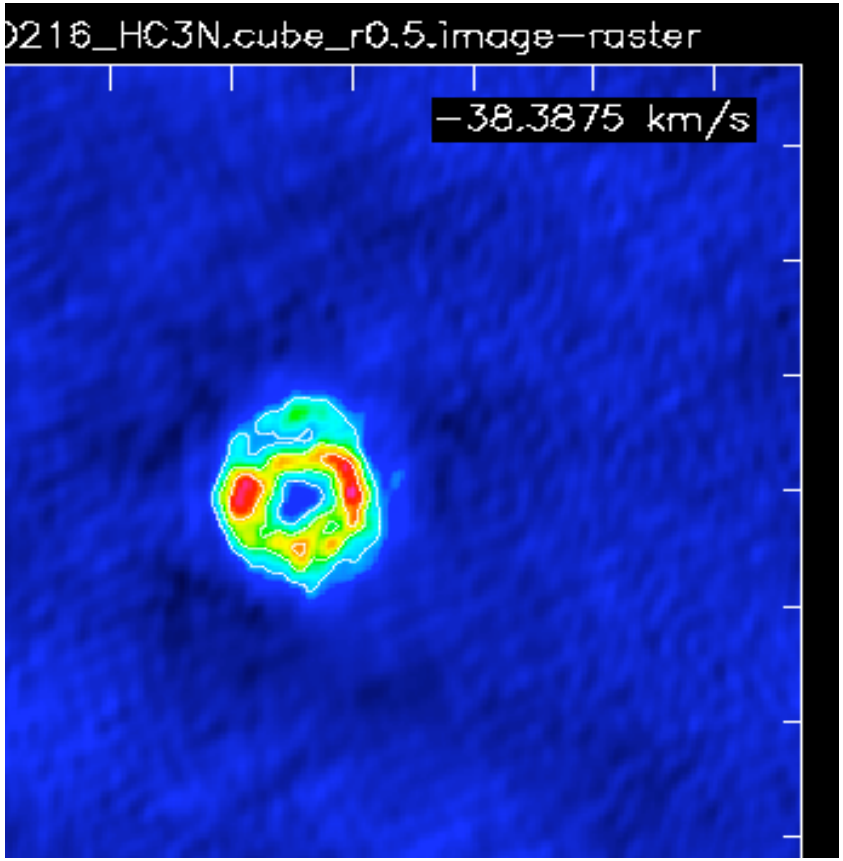
- Supported Image Formats:
  - FITS, Miriad, CASA
- Preview of image data
- Sub-image Capability
  - Efficient Preload
- Lattice Expression Language (LEL)

NRAO

Image / Cube Display

- Display one or more images
  - OTF Spatial Frame Transform
- Overlay contours and vectors on raster images
- Multiple Color Maps



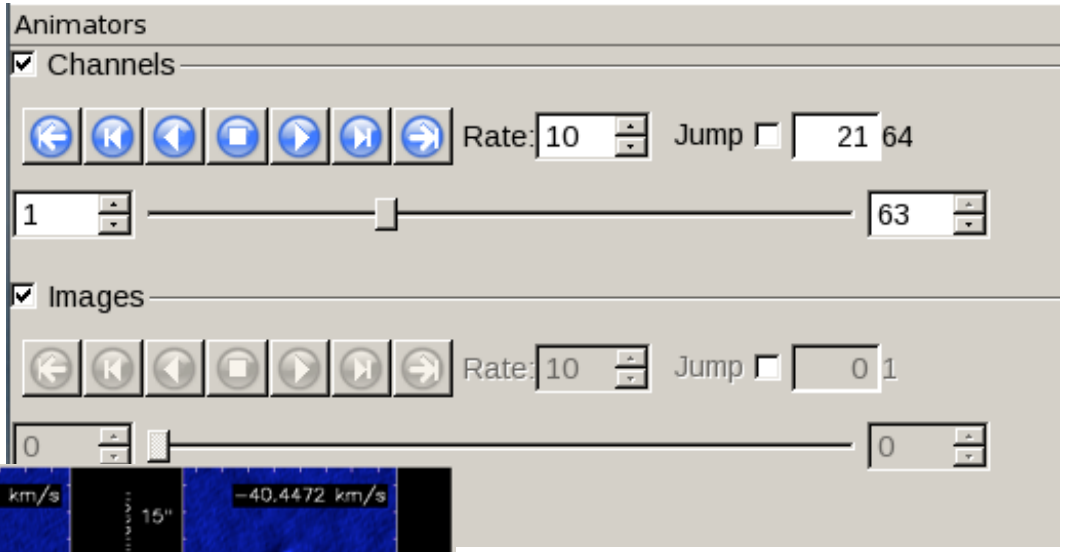


- Flexible adjustments of the transfer function

NRAO

Animators

- Step through planes of cube, or between images
- Standard tapedeck controls



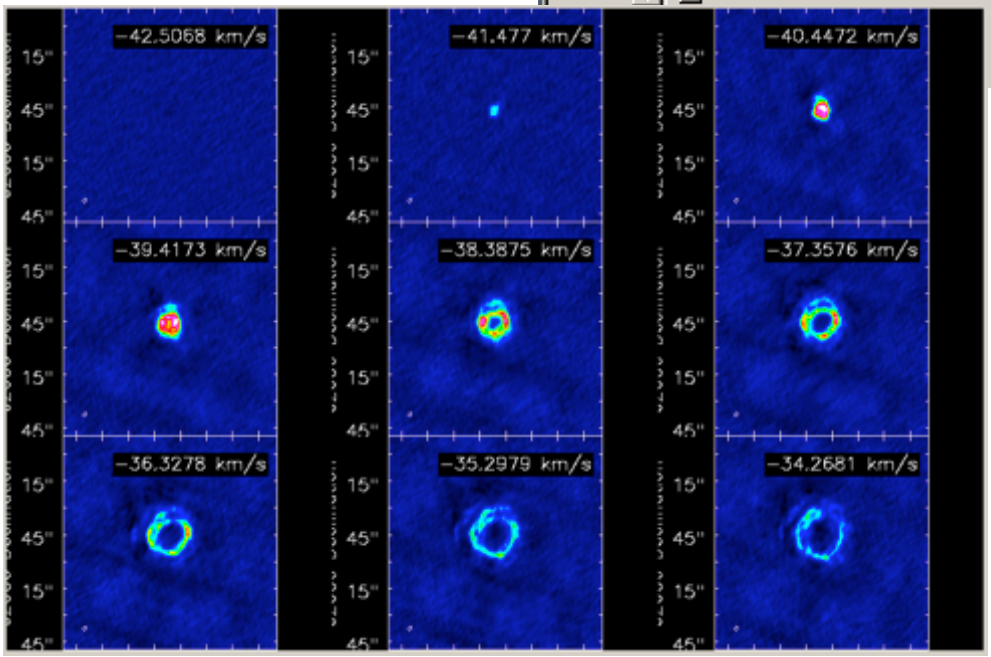
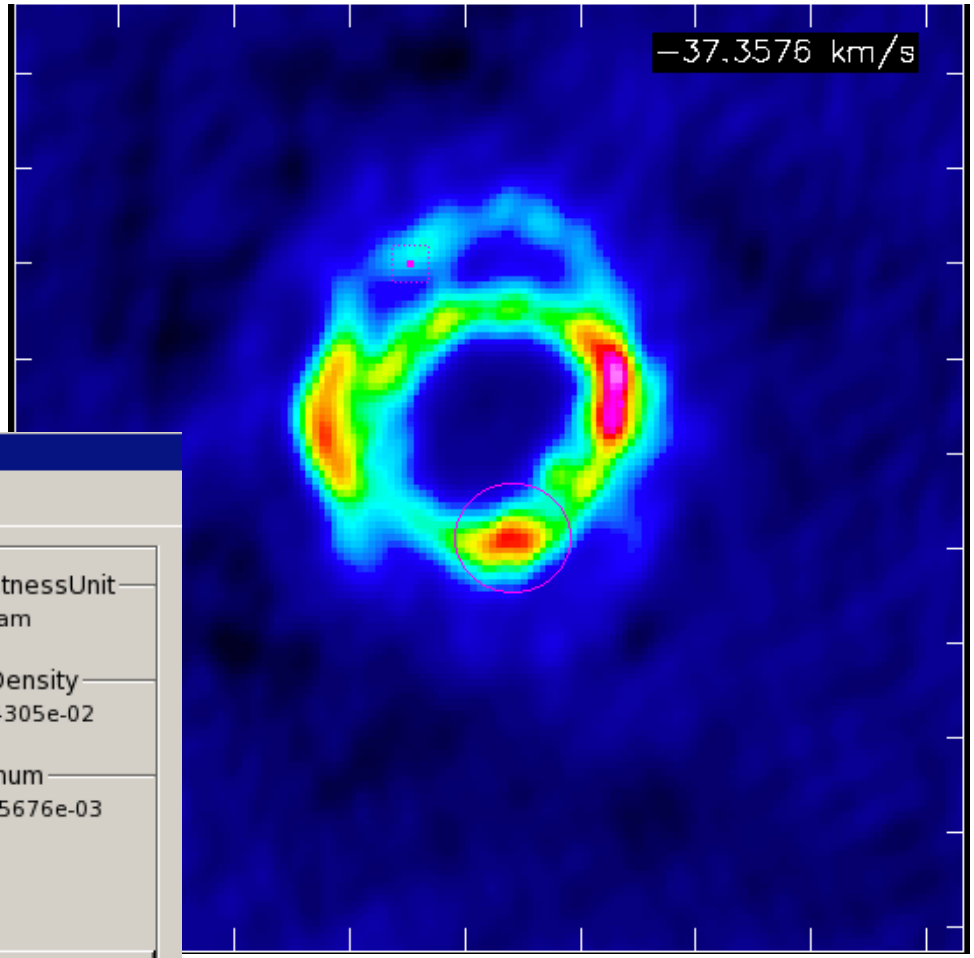


Image Exploration

- Multiple regions can be defined
  - Saving, dragging, iterating
- Statistics on full image stack can be shown
- Dragging regions, and reselection them is supported



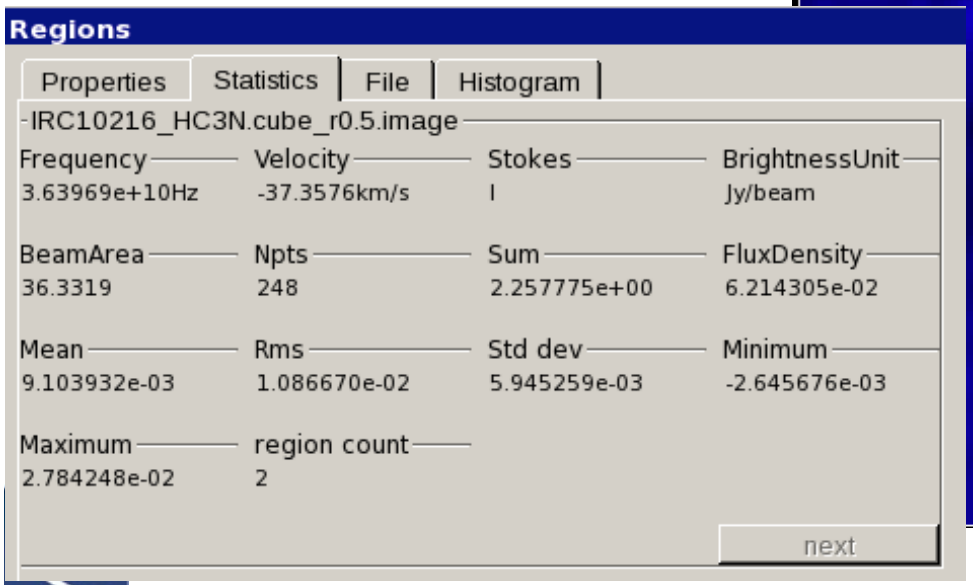
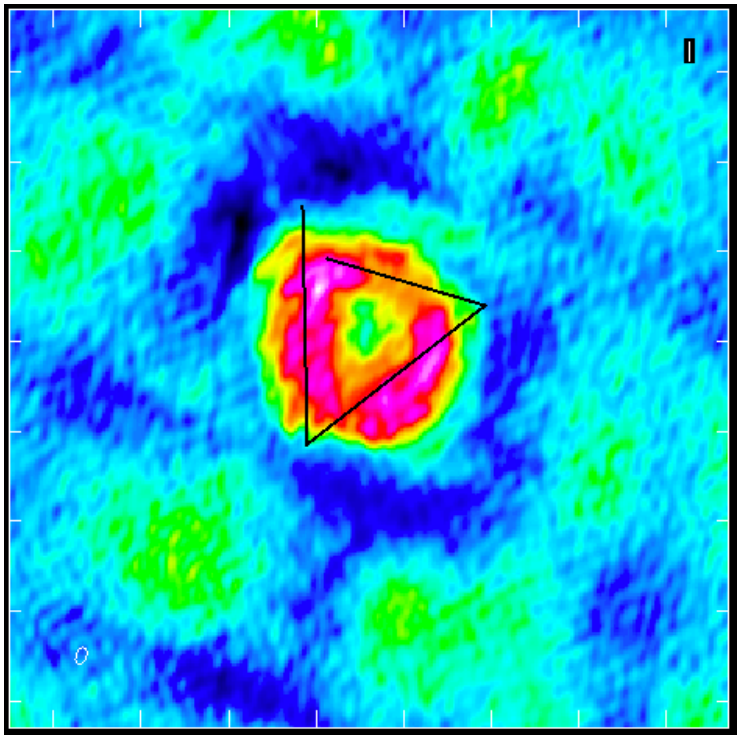
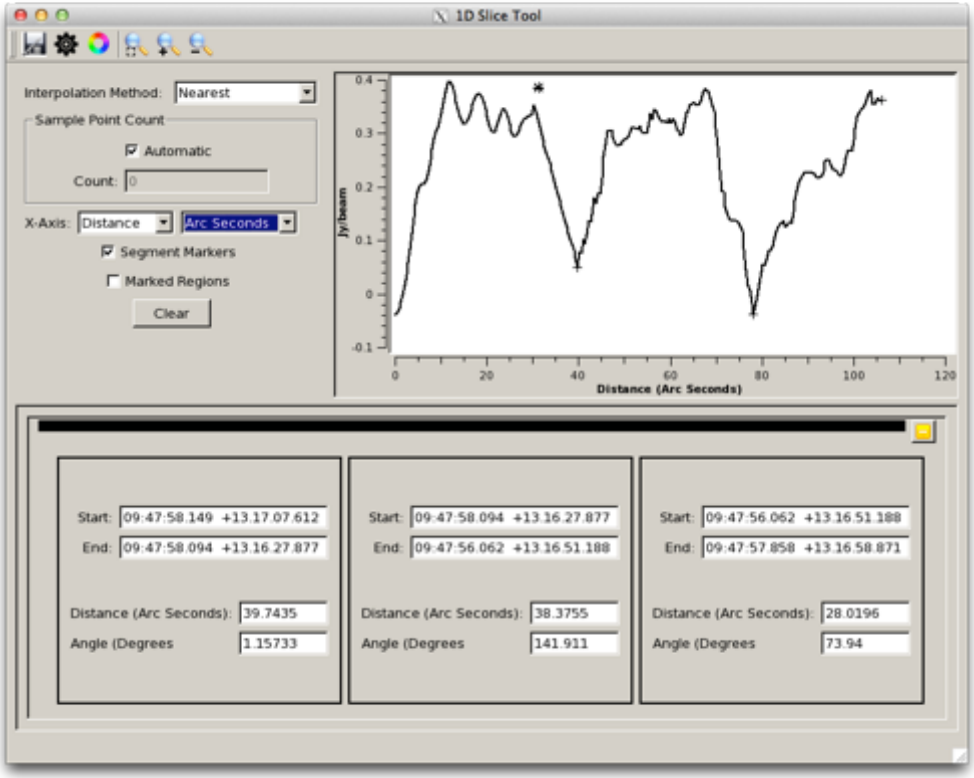


Image Exploration

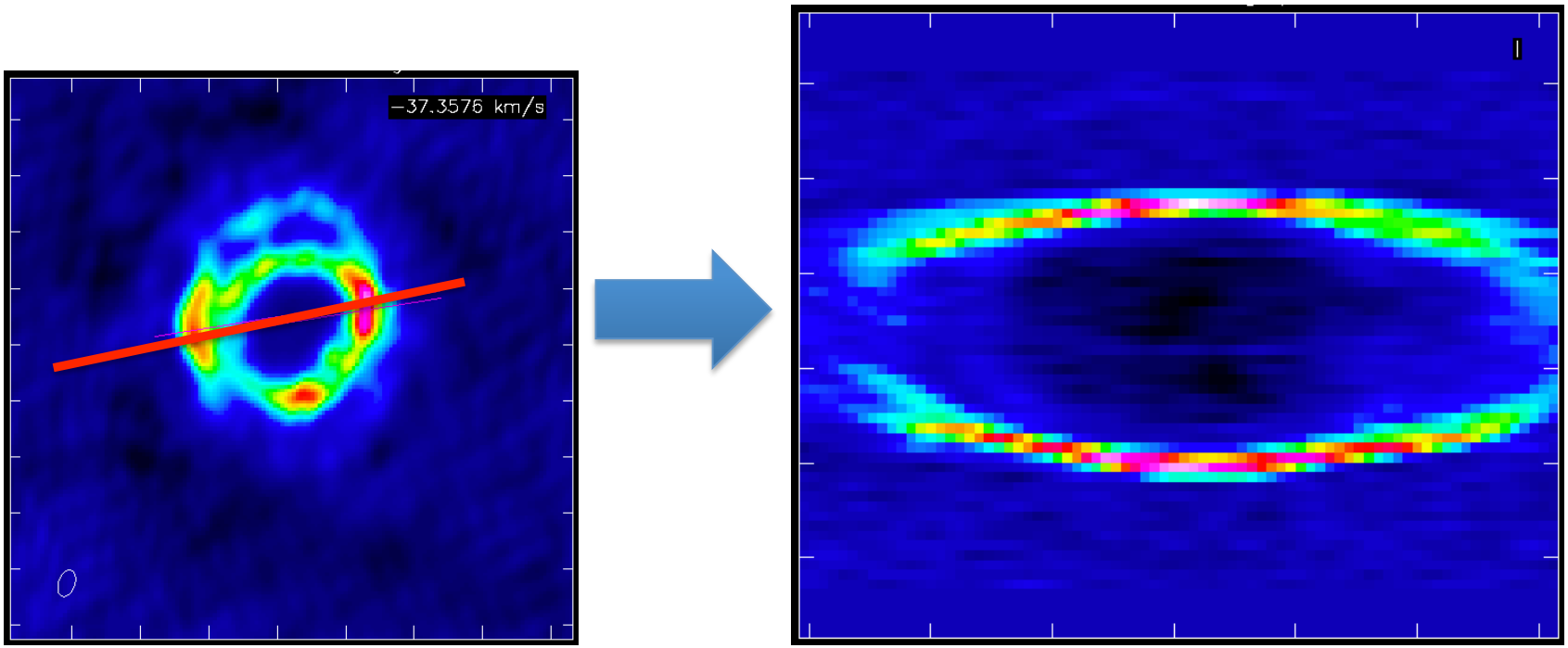
- Multi-Path Spatial Image Profiling





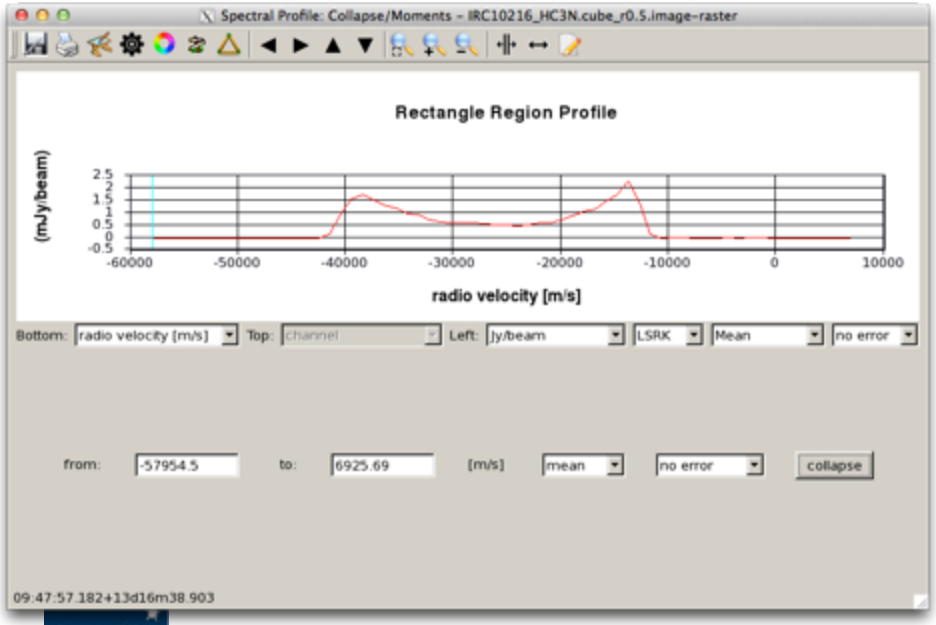
Cube Exploration

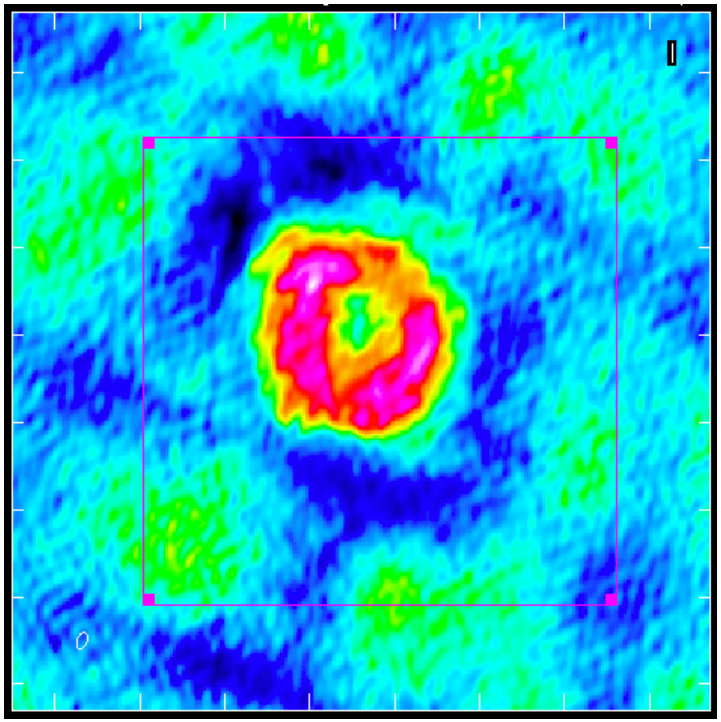
- Position-Velocity Diagram



Integrated CASA Processing

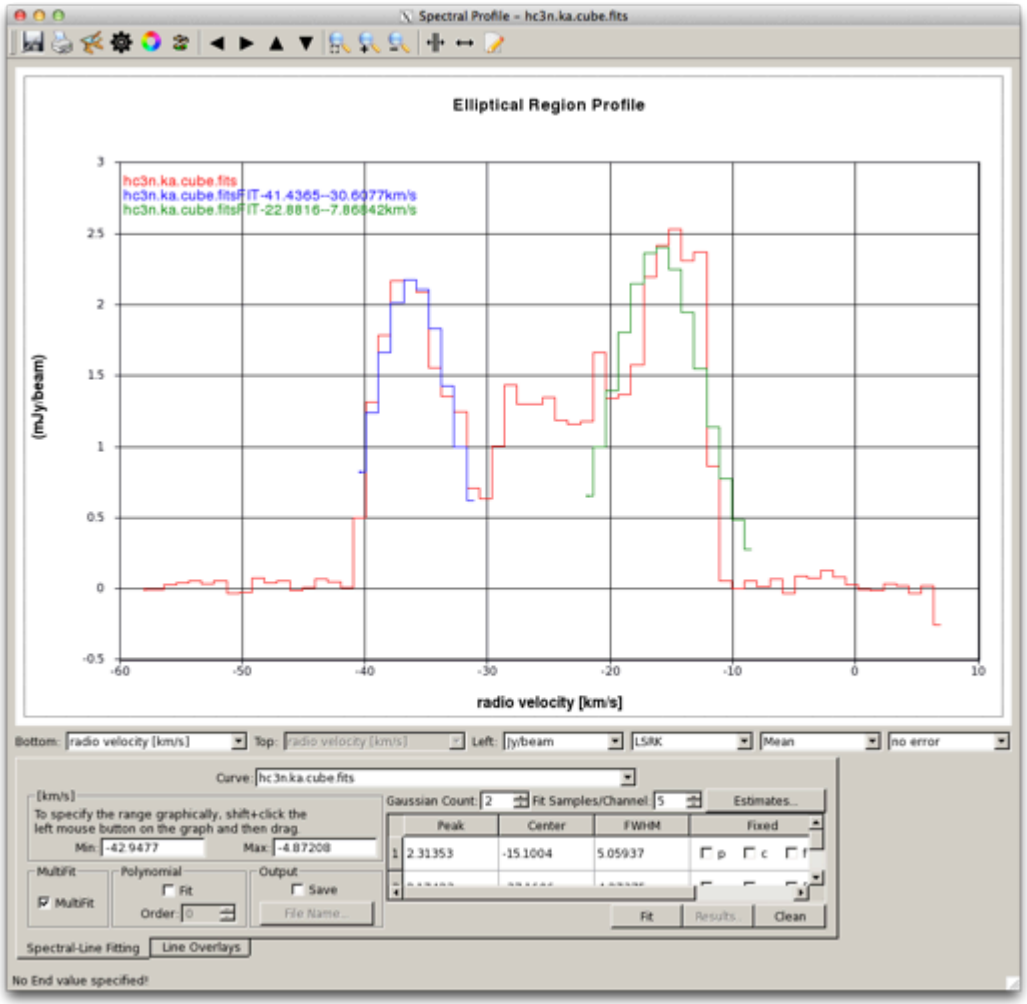
- The CASA viewer uses the CASA package to provide more sophisticated integrated processing capabilities
  - Moments Collapse
  - Source Finding, extraction



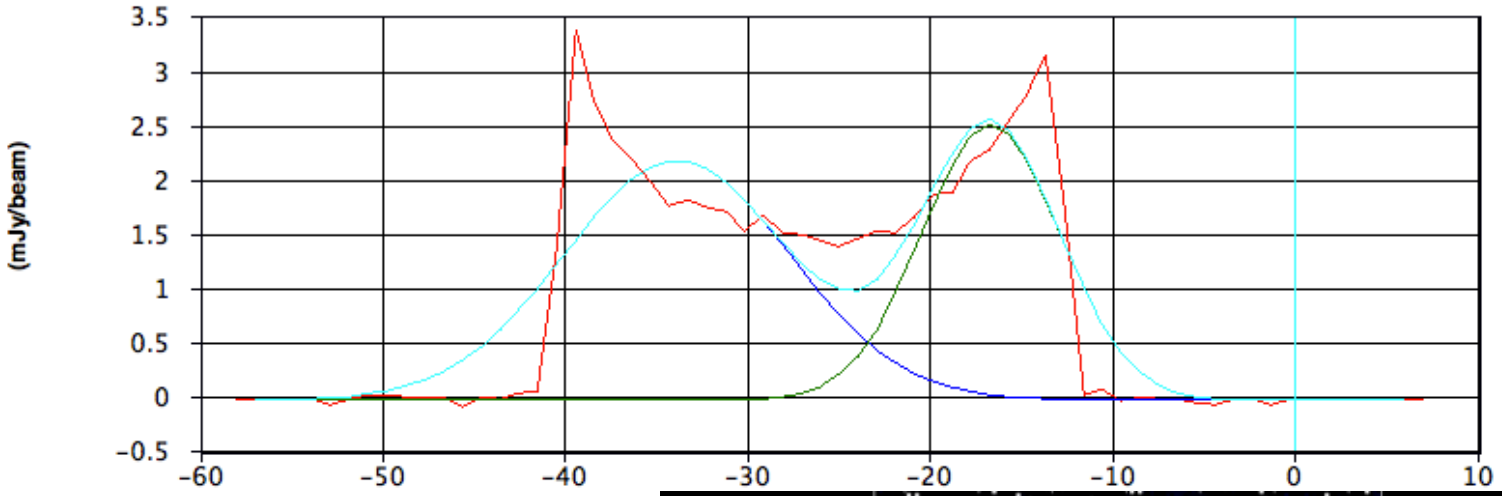


Spectral Processing

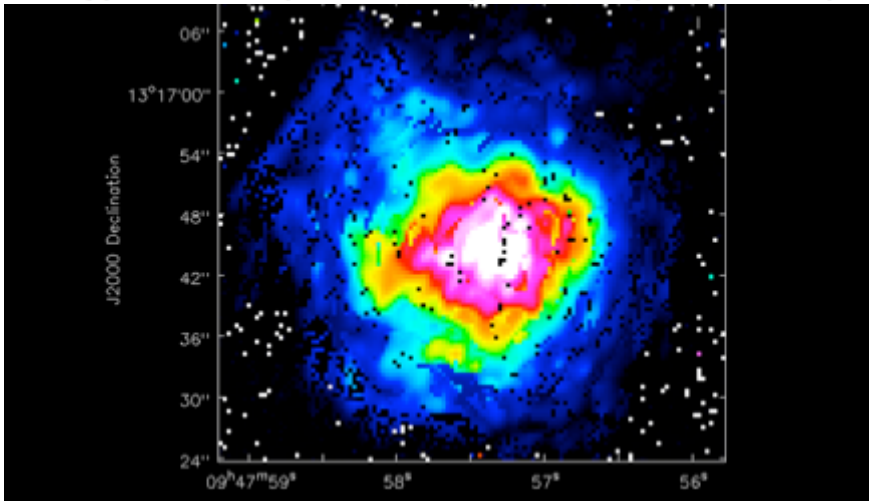
- Spectral Profile Generation
  - For each region
- Fitting
  - Polynomial and Gaussian
  - Graphical Estimates
- OTF Spectral Smoothing
- Line Labeling
  - Splatalog
- Change Rest Frequencies



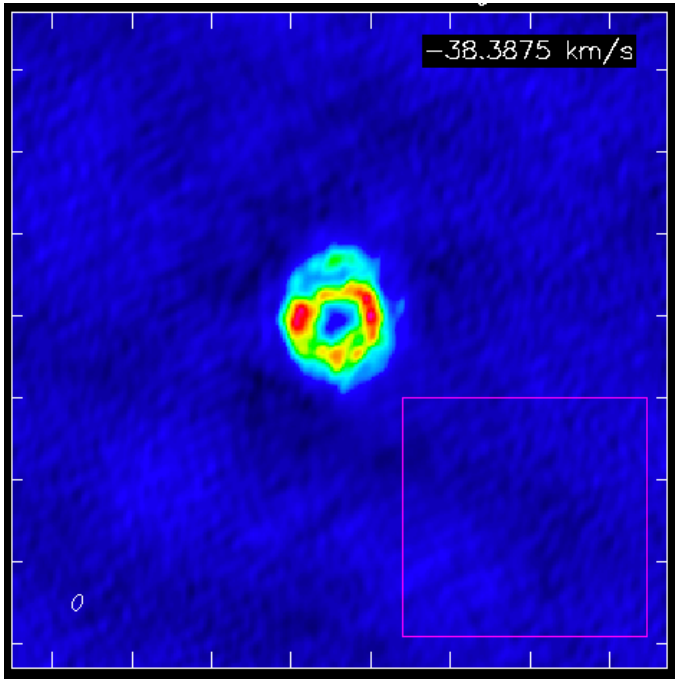
Spectral Processing

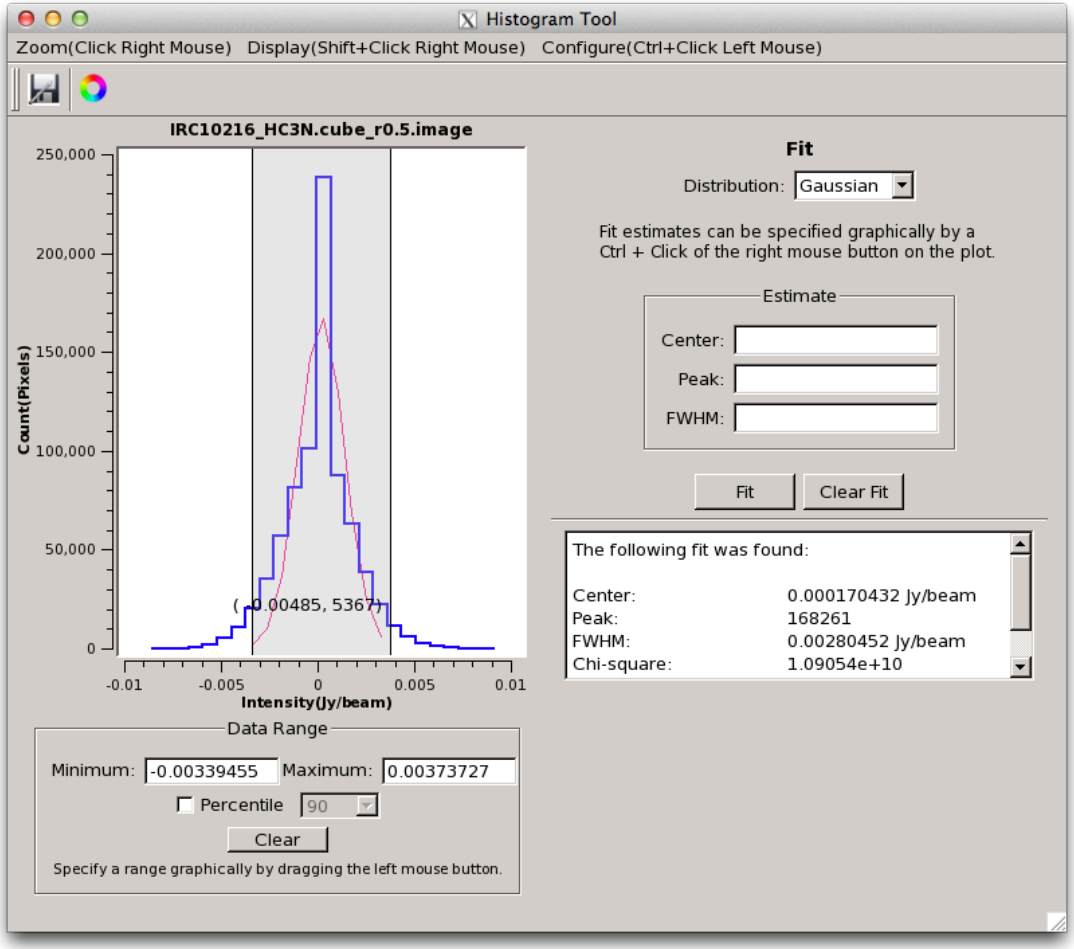


- CASA can fit multiple Gaussians
  - Over a region
  - Pixel by pixel



Histogram Generation





Limitations

- CASA viewer not optimized for remote operations
- The rendering and advanced visualization tools are not yet implemented as other issues were more pressing
- Only rudimentary scripting abilities
- Image renderer has only limited publication quality
- Monolithic approach, closed development
- Lots of new features recently, now time to improve stability

- Future:
  - Virtual Observatory integration
  - merging the CASA viewer with CyberSKA development

  ALMA funding process underway, PI: Erik Rosolowsky (U Alberta)

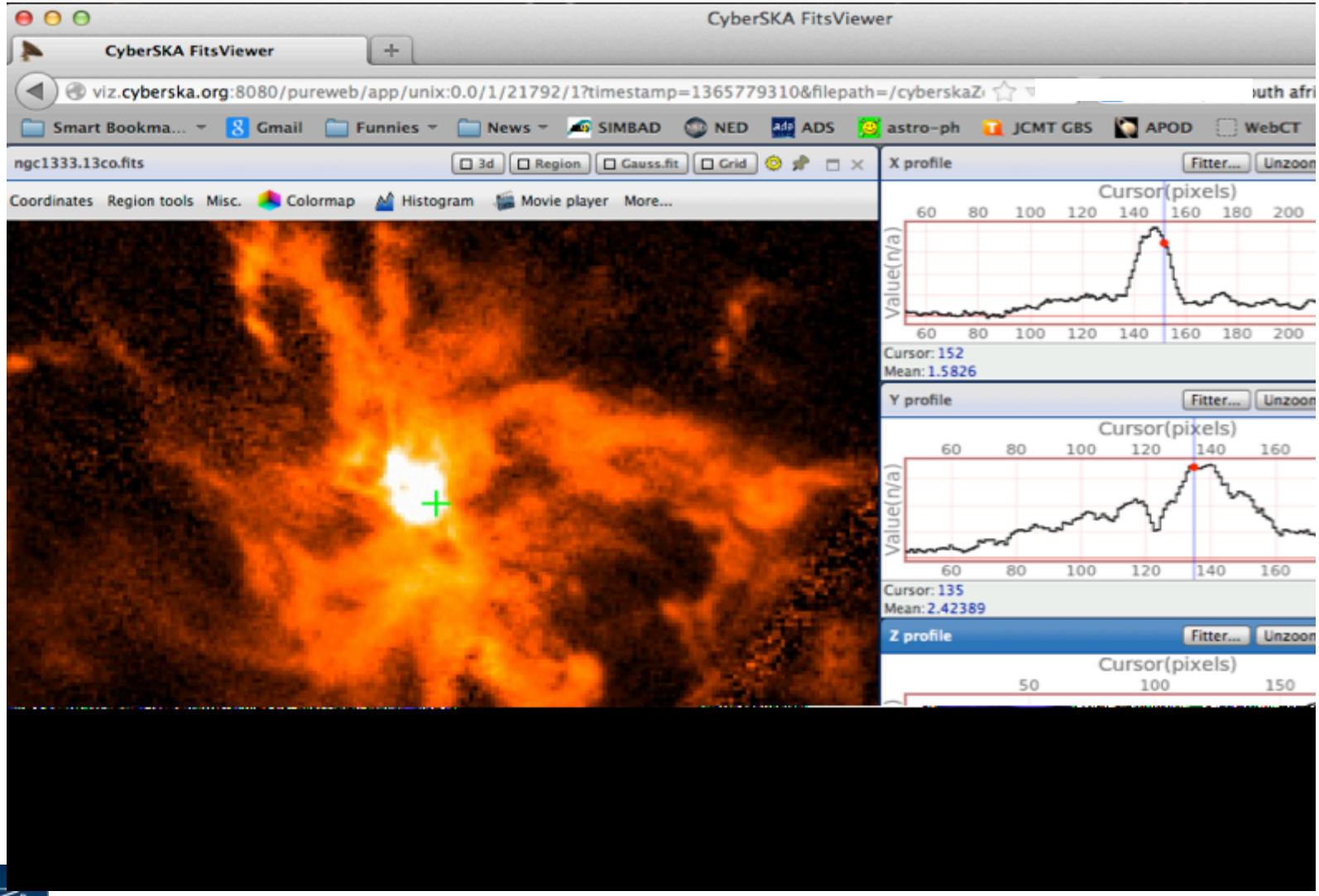
VO Integration

- NRAO is collaborating with VAO to add VO support directly to the CASA Viewer.
  - Data discovery and selection: Either within the viewer or through VO web portals
  - Seamless display of data from VO service
  - Advanced cube access including:
    - Sub-selection (Spatial or Spectral)
    - Basic Collapse Options

CyberSKA

Browser-based

CASA

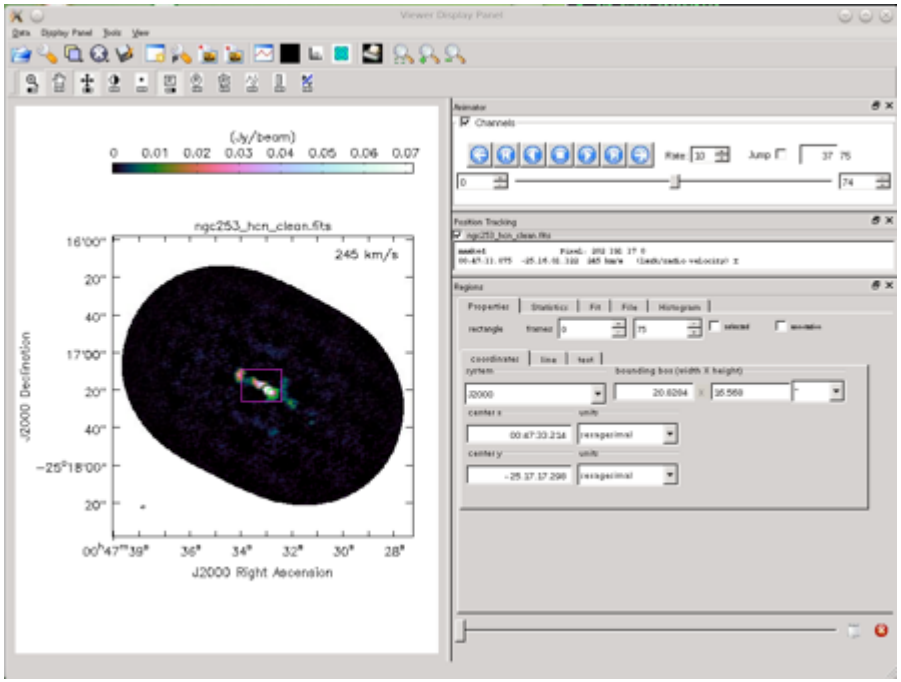


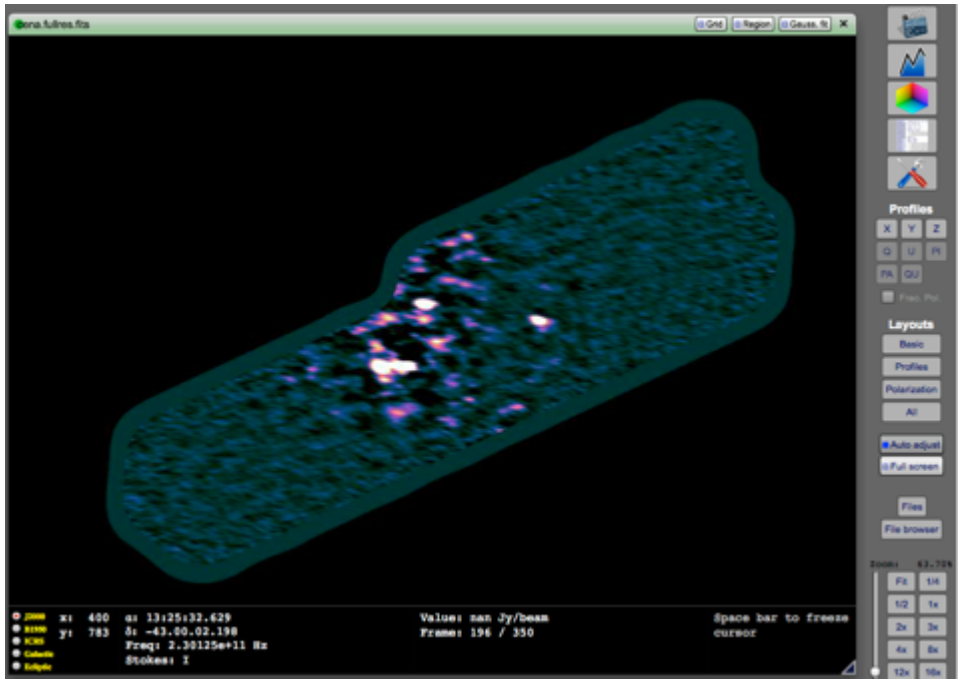
Cube-enabled

- PI: Erik Rosolowsky

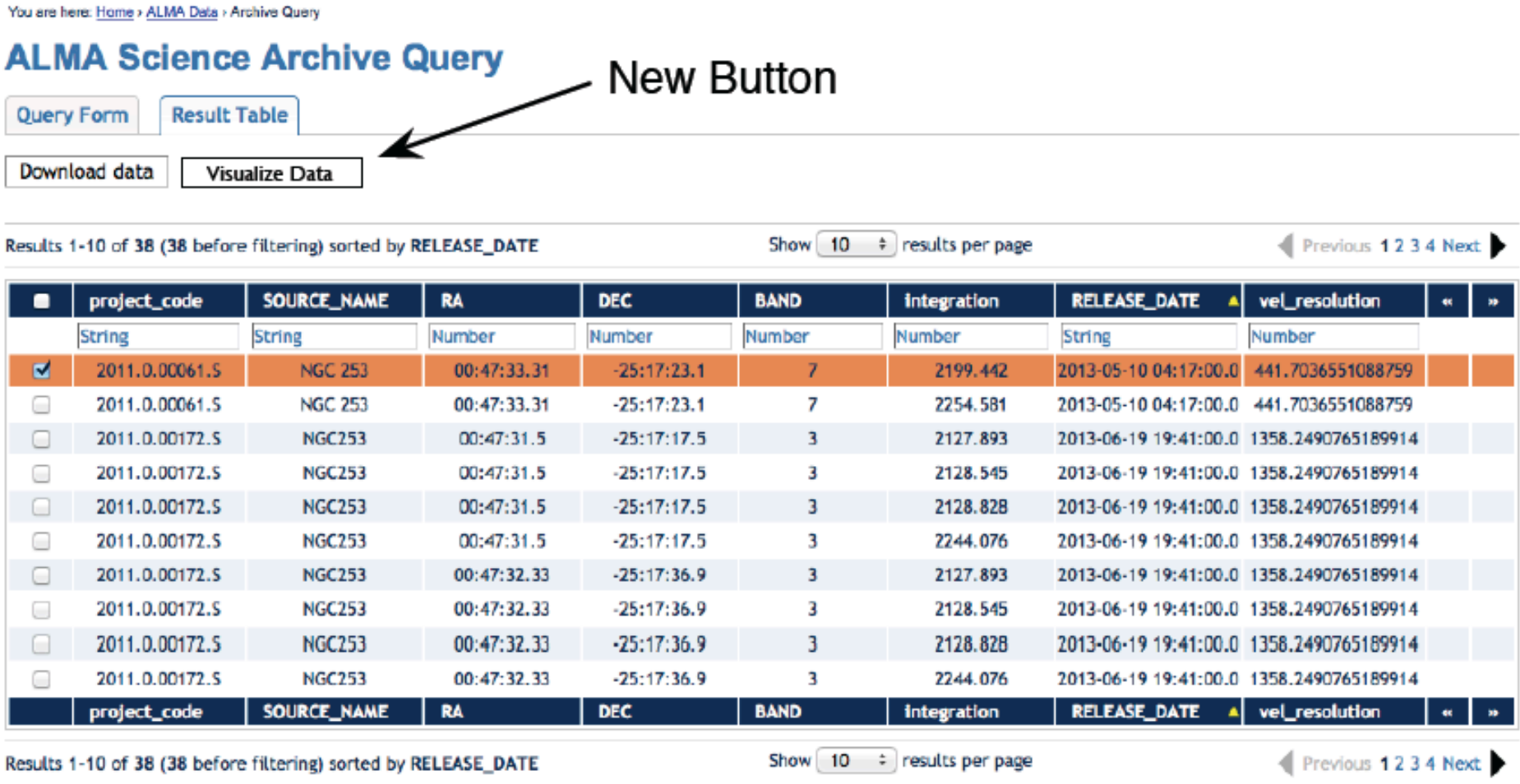
Best of Both Worlds

- **CASA Viewer**
  - Fully-featured
  - Meets ALMA use cases
  - Well-developed analytics
  - Expert user-base
- **CyberSKA Viewer**
  - Handles Big data
  - Web-enabled
  - Additional features
  - Plugin architecture





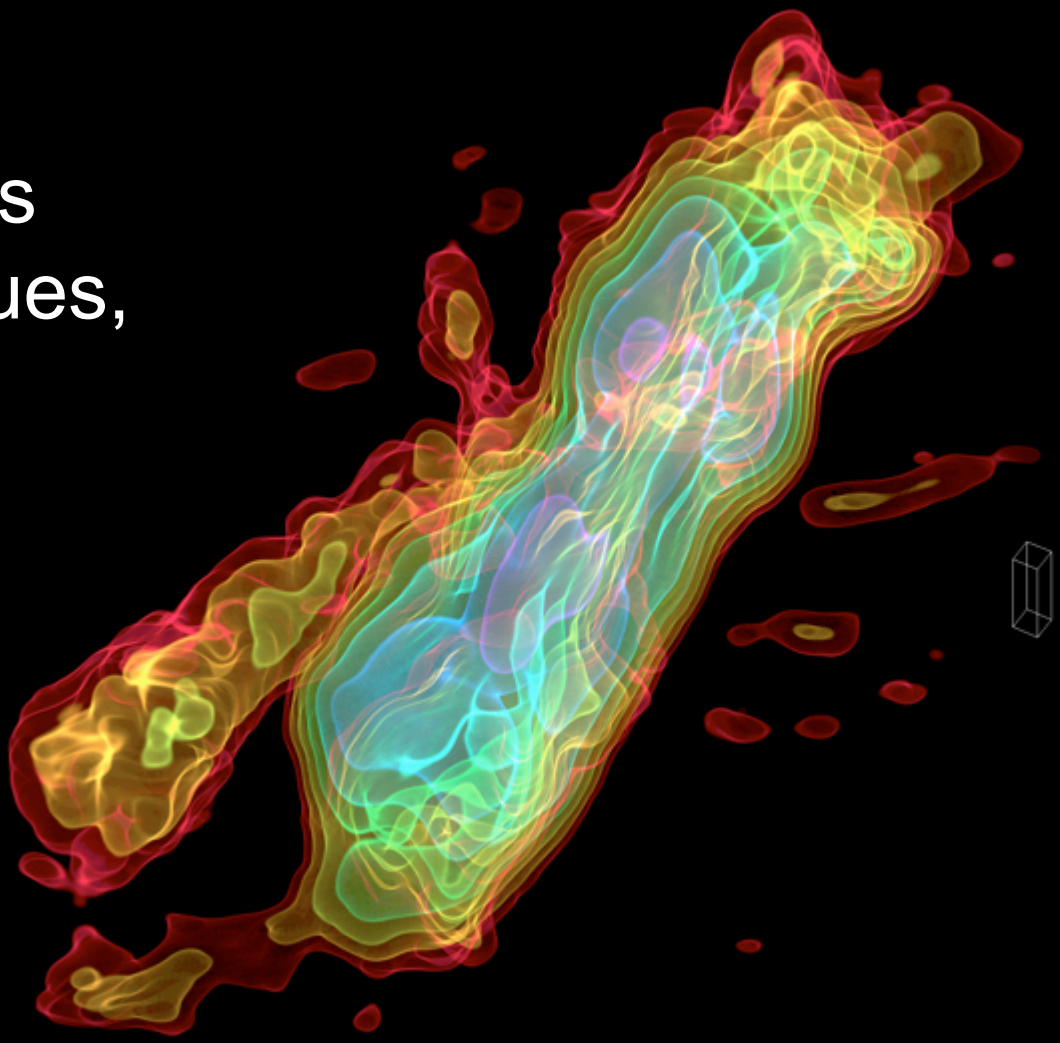
- Server-client architecture, e.g. for archival data



NRAO

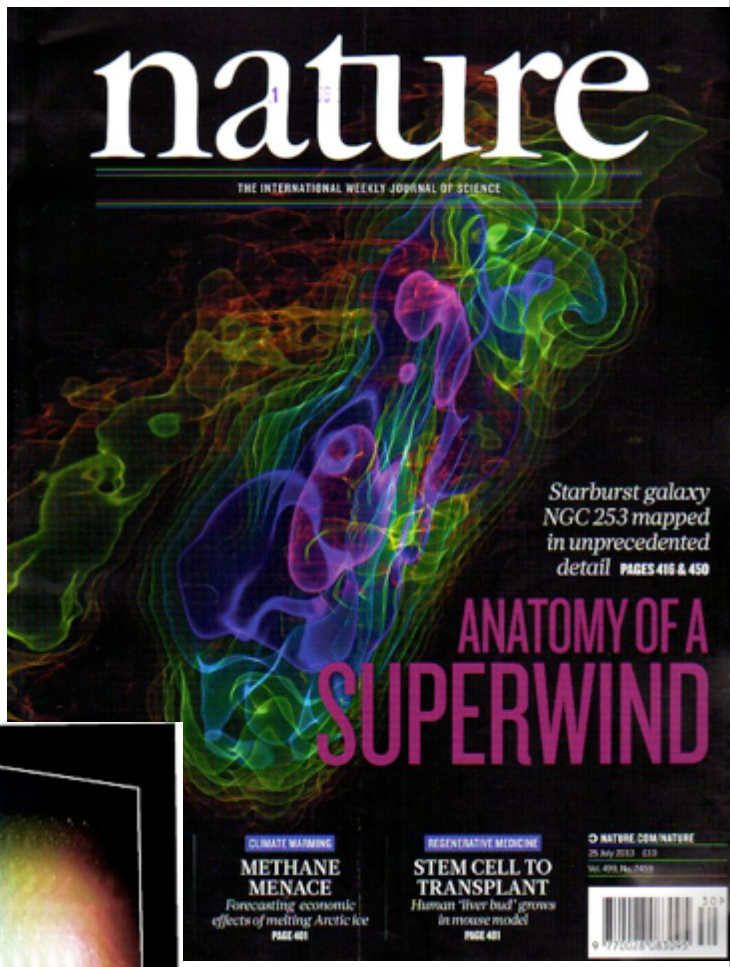
Pluggable

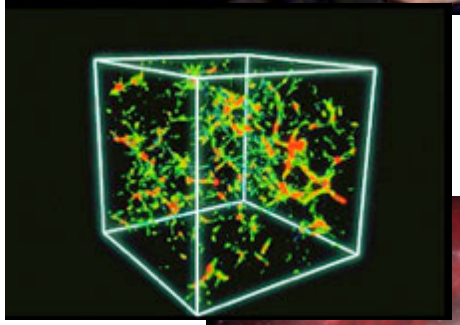
Anyone can write plugins
for visualization techniques,
renderers, etc.
Repository of plugins

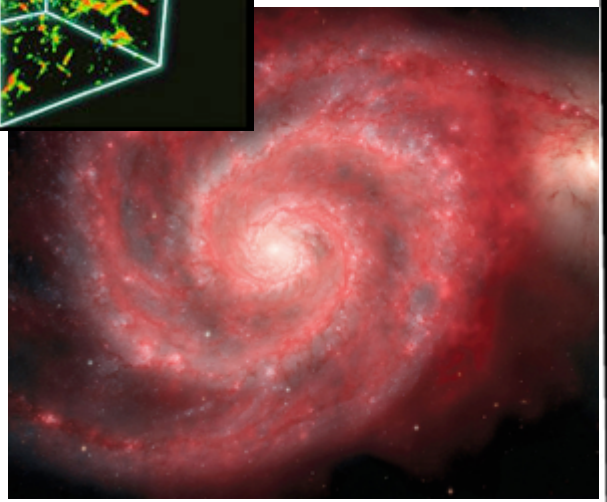


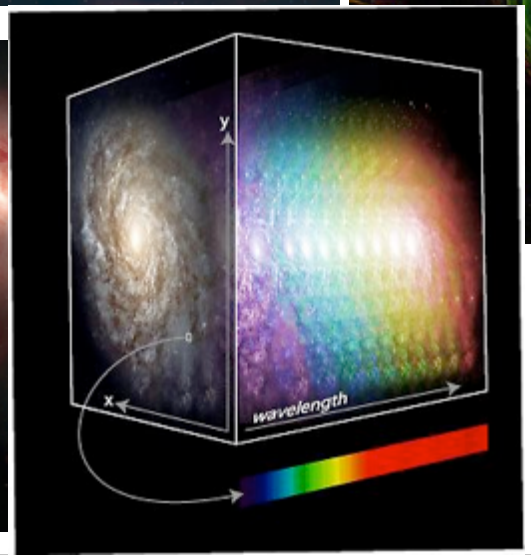
- CASA viewer demo at the ALMA workshop

CASA









NRAO