LINKED-VIEW VISUALIZATION OF HIGH-DIMENSIONAL DATA IN GLUE

Alyssa A. Goodman

Harvard-Smithsonian Center for Astrophysics & Radcliffe Institute

with Chris Beaumont, Michelle Borkin, Penny Qian & Tom Robitaille

@aagie
@glueviz
@astrofrog

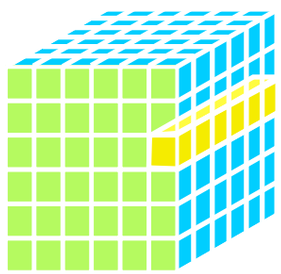
glueviz.org
github.com/glue-viz
Tom Robitaille, lead developer

James Webb
Space Telescope

“Linked Views”

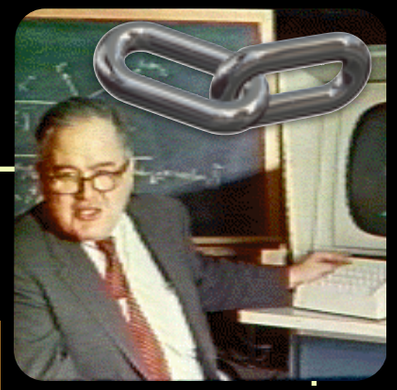
glue
multidimensional data exploration

Open Source Python, on GitHub

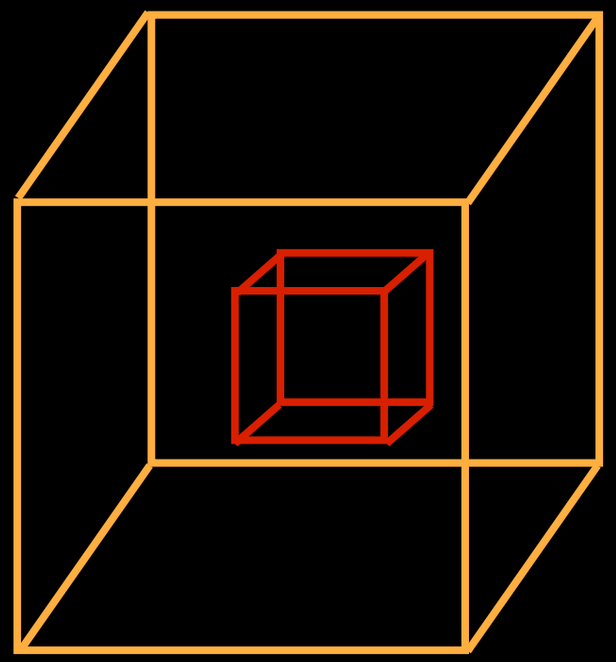


3D+

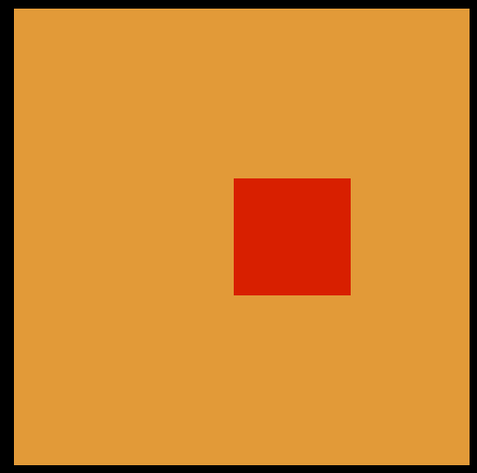
LINKED VIEWS OF HIGH-DIMENSIONAL DATA



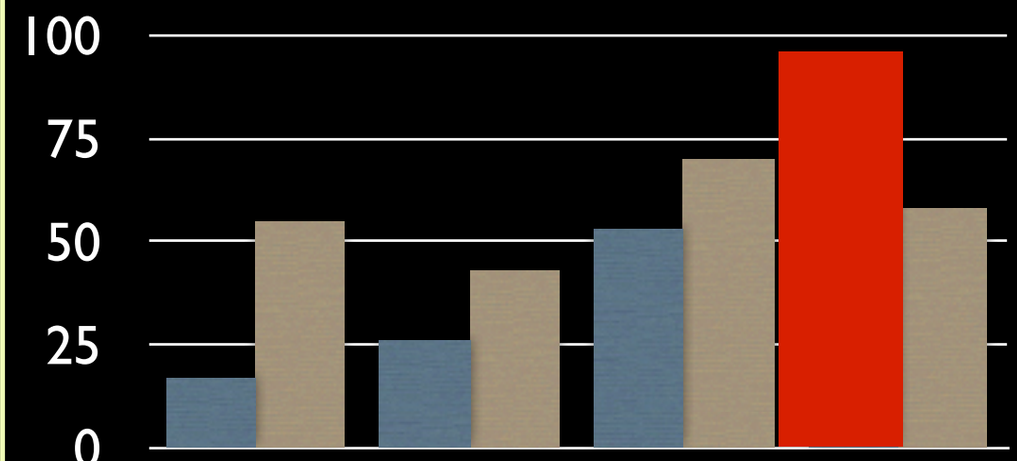
John Tukey



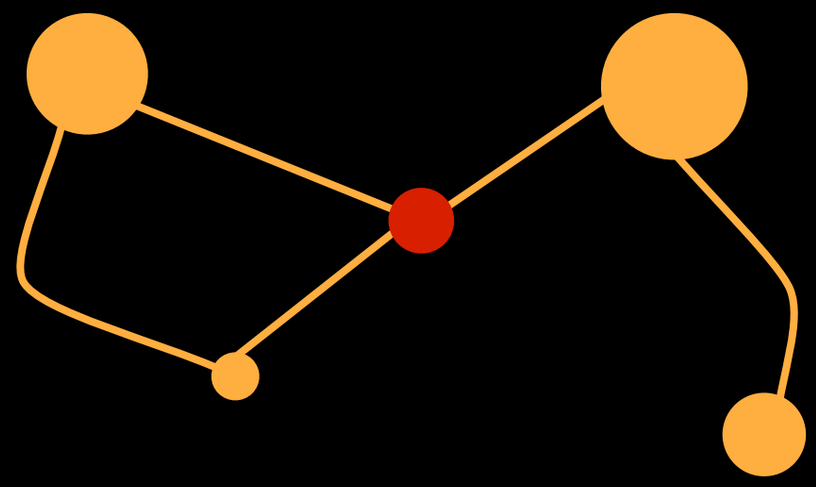
3D



2D

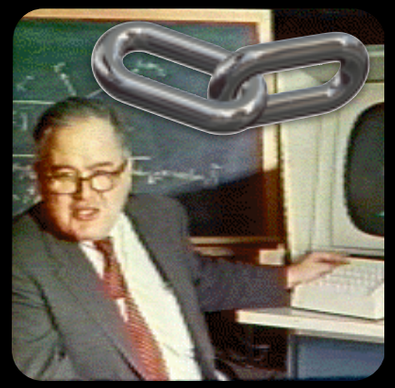


Data Abstraction



figure, by M. Borkin, reproduced from Goodman 2012, "Principles of High-Dimensional Data Visualization in Astronomy"

JOHN TUKEY'S LEGACY



PRIM-9

PRIM-H

DataDesk®

XGobi

GGobi

RGGobi

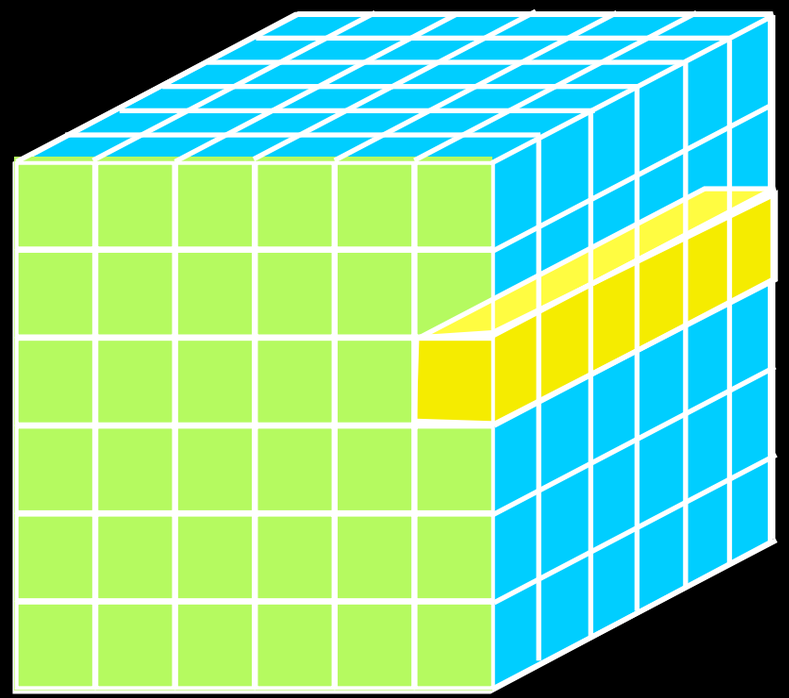
glue

Spotfire®

Polaris

tableau SOFTWARE

1970 1980 1990 2000 2010

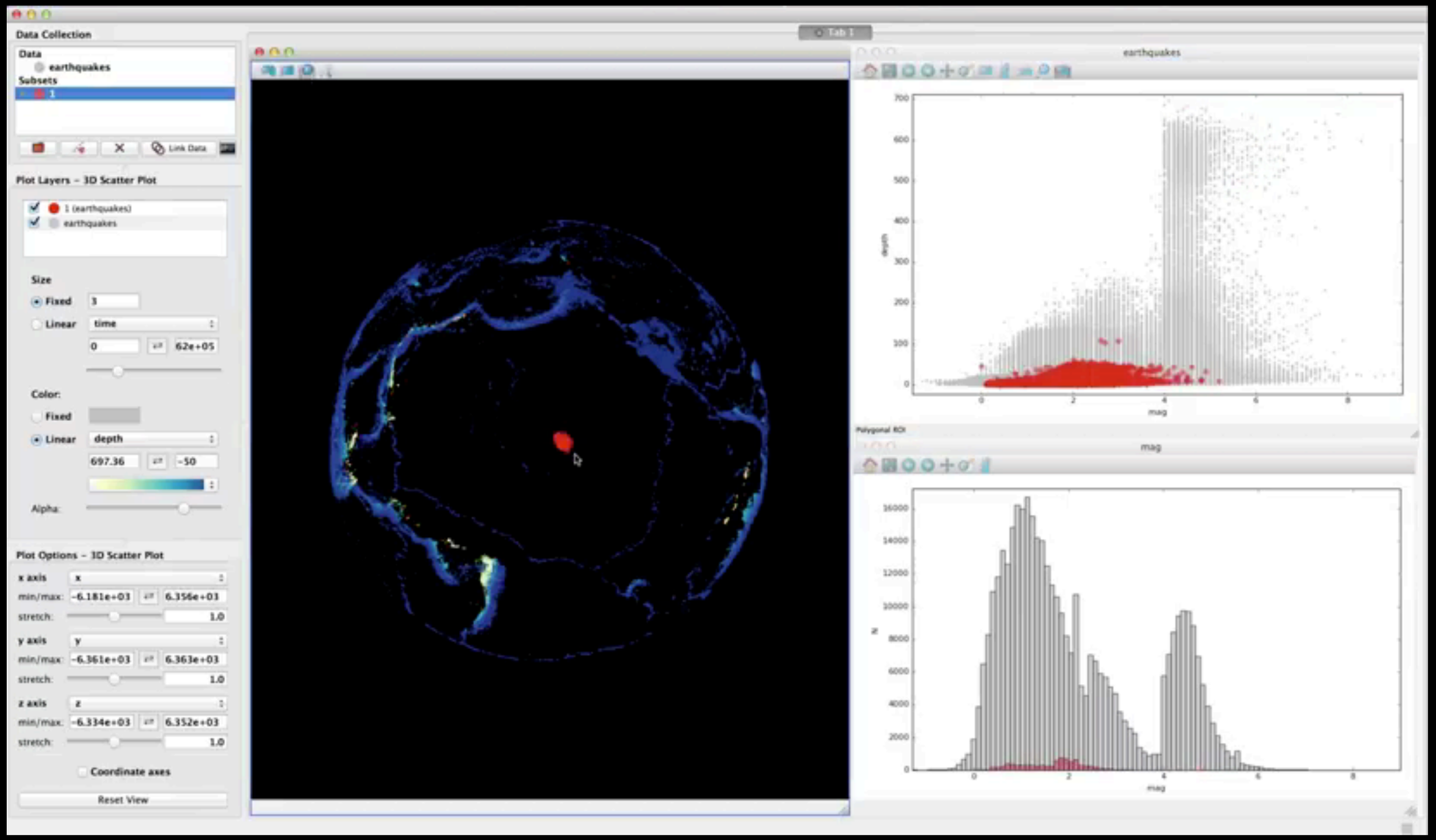


DATA-DIMENSIONS-DISPLAY

1D: Columns = “Spectra”, “SEDs” or “Time Series” (x-y Graphs)
2D: Faces or Slices = “Images”
3D: Volumes = “3D Renderings”, “2D Movies”
4D: Time Series of Volumes = “3D Movies”

LINKED VIEWS OF HIGH-DIMENSIONAL DATA (IN PYTHON)

GLUE



video by Tom Robitaille, lead glue developer

glue created by: C. Beaumont, M. Borkin, P. Qian, T. Robitaille, and A. Goodman, PI

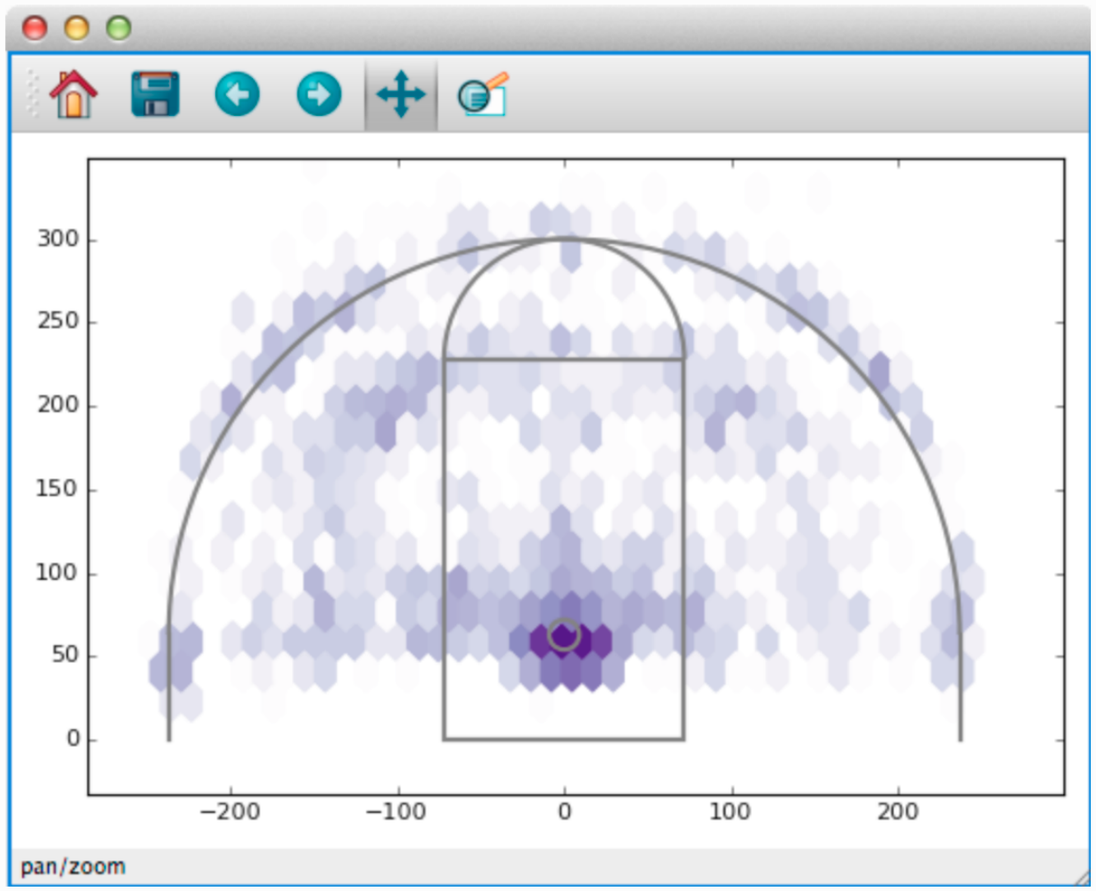
"BUT WAIT, THERE'S MORE..."

Glue

Search docs

Installing Glue
Getting started
User Interface Guide
3D viewers in Glue
Using the IPython terminal in Glue
Working with Data objects
Starting Glue from Python
Configuring Glue via a startup file
Customizing your Glue environment
Programmatically configuring plots
Building Custom Data Viewers
The Goal: Basketball Shot Charts
Shot Chart Version 1: Heatmap and plot
Shot Chart Version 2: Court markings
Shot Chart Version 3: Widgets
Shot Chart Version 4: Selection
Viewer Subclasses
Valid Function Arguments
UI Elements
Other Guidelines
Watching data for changes
Read the Docs v: stable

Building Custom Data Viewers



Glue's standard data viewers (scatter plots, images, histograms) are useful in a wide variety of data exploration settings. However, they represent a *tiny* fraction of the ways to view a particular dataset. For this reason, Glue provides a simple mechanism for creating custom visualizations using matplotlib.

Creating a `custom data viewer` requires writing a little bit of Matplotlib code but involves little to no GUI programming. The next several sections illustrate how to build a custom data viewer by

"BUT WAIT, THERE'S MORE..."

"cuts" along arbitrary paths

flood-fill selection (2D, 3D)

export to d3po, plotly

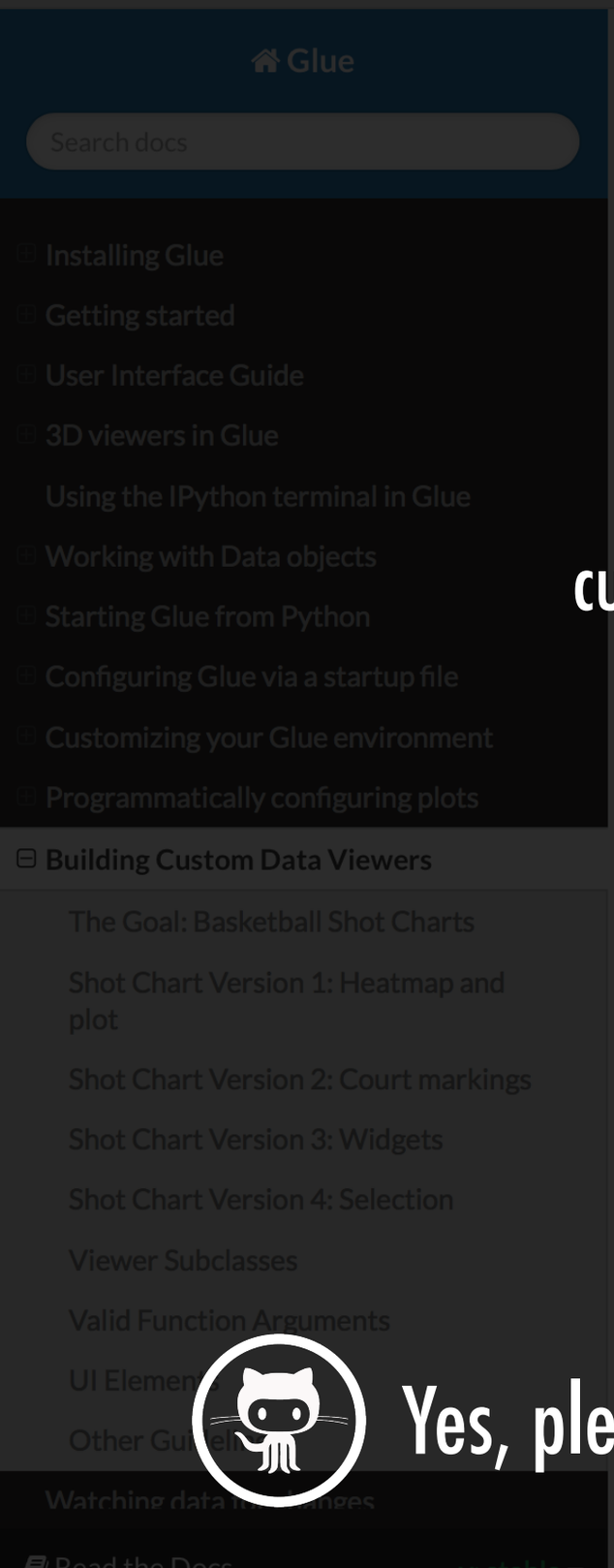
custom viewers (e.g. GIS, WorldWide Telescope, Super Mario)

plot manipulation/customization (via Matplotlib)

flexible import/export

saved sessions (.glu)

Anaconda Navigator install/upgrade



Yes, please do go start adding code now, at github.com/glue-viz.

Docs » Building Custom Data Viewers

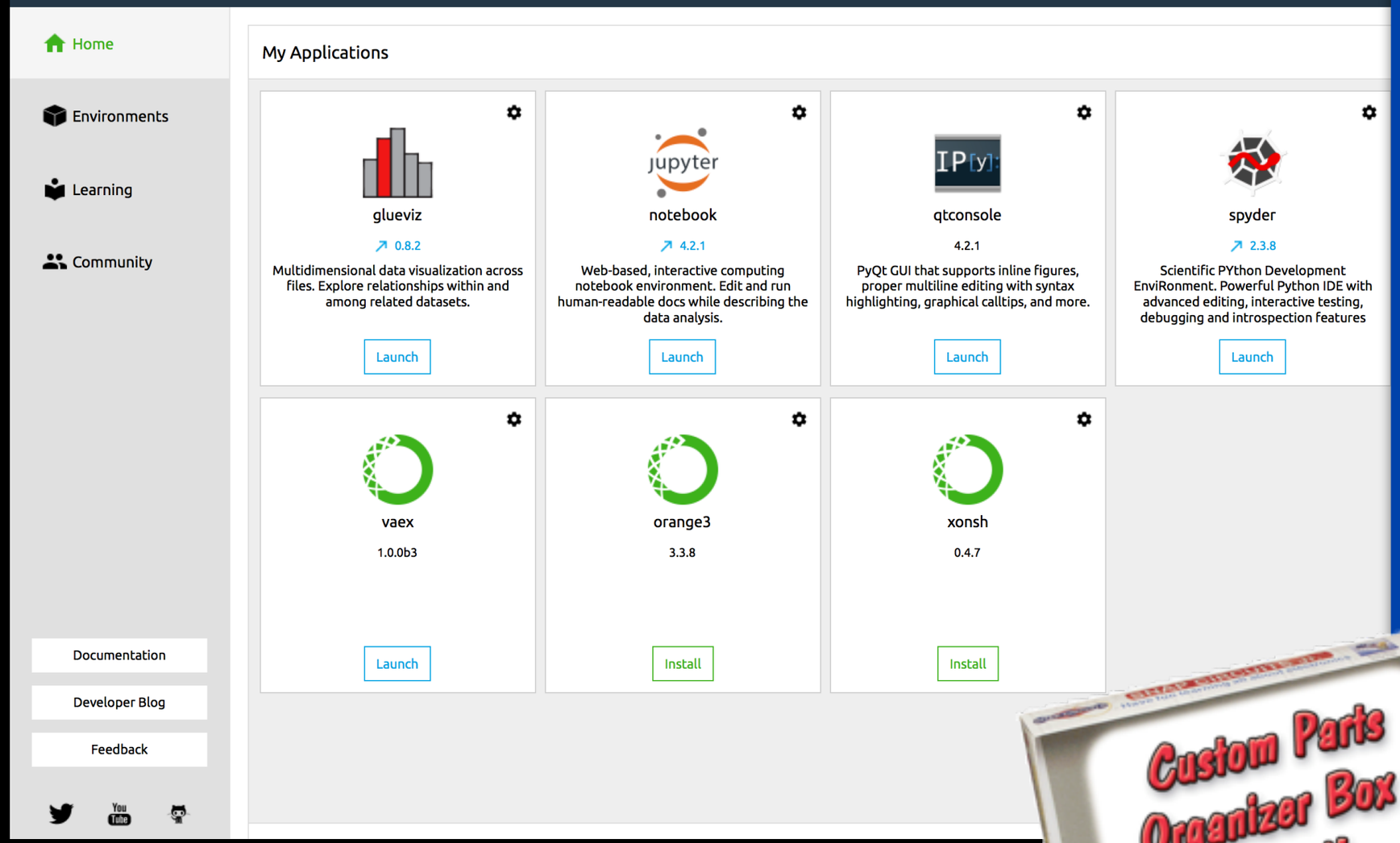
Edit on GitHub

Building Custom Data Viewers

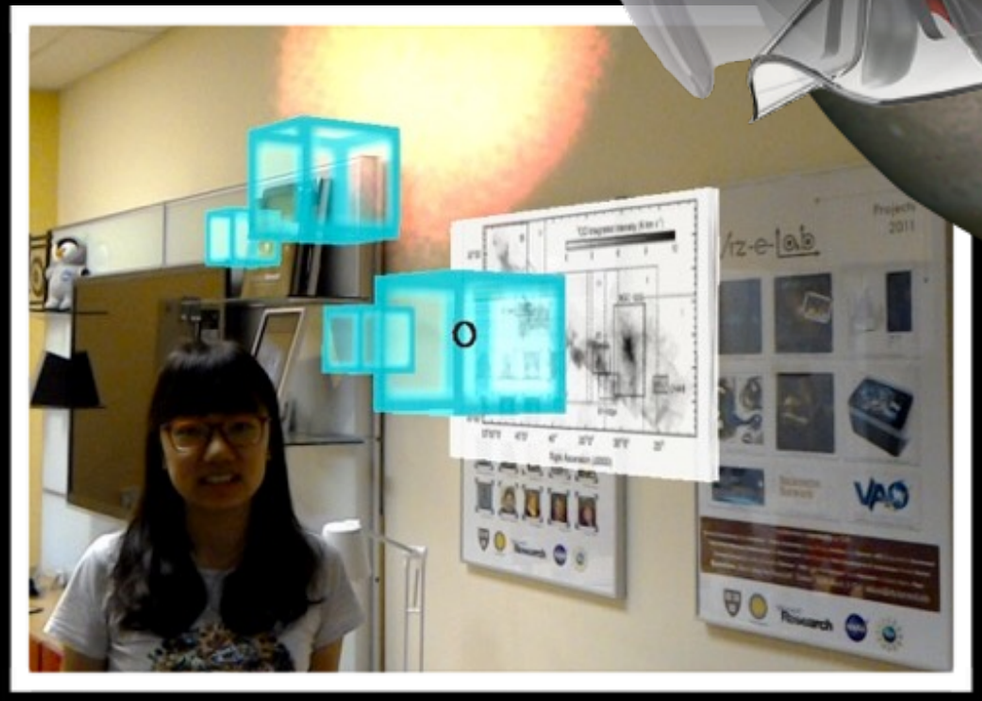
Glue's standard data viewers (scatter plots, images, histograms) are useful in a wide variety of data exploration settings. However, they represent a *tiny* fraction of the ways to view a particular dataset. For this reason, Glue provides a simple mechanism for creating custom visualizations using

Creating a `custom data viewer` requires writing a little bit of Matplotlib code but involves little to no GUI programming. The next several sections illustrate how to build a custom data viewer by

INTEGRATION



THE CHALLENGE OF 3D SELECTION



Au
Authorea

The "Paper" of the Future

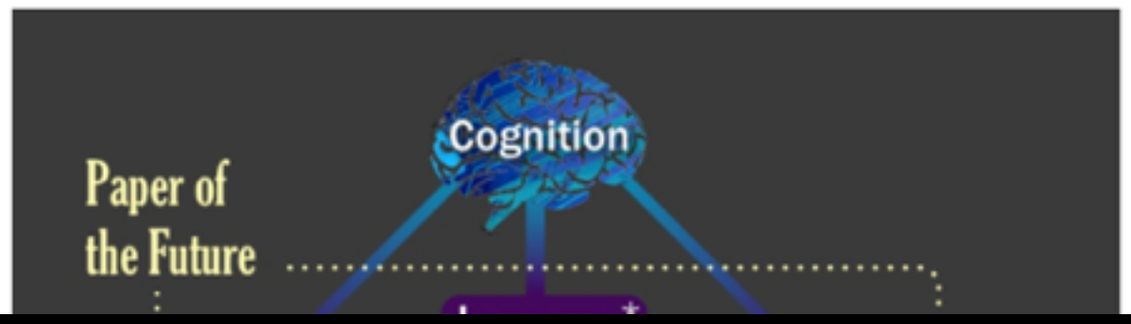
Alyssa Goodman, Josh Peek, Alberto Accomazzi, Chris Beaumont, Christine L. Borgman, How-Huan Hope Chen, Merce Crosas, Christopher Erdmann, August Muench, Alberto Pepe, Curtis Wong + Add author Re-arrange authors

A 5-minute video demonsration of this paper is available at this YouTube link.

1 Preamble

A variety of research on human cognition demonstrates that humans learn and communicate best when more than one processing system (e.g. visual, auditory, touch) is used. And, related research also shows that, no matter how technical the material, most humans also retain and process information best when they can put a narrative "story" to it. So, when considering the future of scholarly communication, we should be careful not to do blithely away with the linear narrative format that articles and books have followed for centuries: instead, we should enrich it.

Much more than text is used to commuicate in Science. Figures, which include images, diagrams, graphs, charts, and more, have enriched scholarly articles since the time of Galileo, and ever-growing volumes of data underpin most scientific papers. When scientists communicate face-to-face, as in talks or small discussions, these figures are often the focus of the conversation. In the best discussions, scientists have the ability to manipulate the figures, and to access underlying data, in real-time, so as to test out various what-if scenarios, and to explain findings more clearly. **This short article explains—and shows with demonstrations—how scholarly "papers" can morph into long-lasting rich records of scientific discourse**, enriched with deep data and code linkages, interactive figures, audio, video, and commenting.



Konrad Hinsen 3 days ago · Public
Many good suggestions, but if the goal is "long-lasting rich records of scientific discourse", a more careful and critical attitude towards electronic artifacts is appropriate. I do see it concerning videos, but not a word on the much more critical situation in software. Archiving source code is not sufficient: all the dependencies, plus the complete build environment, would have to be conserved as well to make things work a few years from now. An "executable figure" in the form of an IPython notebook wil...
more

Merce Crosas 3 days ago · Public
Konrad, good points; this has been a concern for the community working on reproducibility. Regarding data repositories, Dataverse handles long-term preservation and access of data files in the following way: 1) for some data files that the repository recognizes (such as R Data, SPSS, STATA), which depend on a statistical package, the system converts them into a preservation format (such as a tab/CSV format). Even though the original format is also saved and can be accessed, the new preservation format gua...
more

Konrad Hinsen 1 day ago · Public
That sounds good. I hope more repositories will follow the example of Dataverse. Figshare in particular has a very different attitude, encouraging researchers to deposit as much as possible. That's perhaps a good strategy to change habits, but in the long run it could well backfire when people find out in a few years that 90% of those deposits have become useless.

Christine L. Borgman 4 months ago · Private
"publications"

d3po/Authorea: Peek, Price-Whelan, Pepe, Beaumont, Borkin, Newton; PoF: Goodman, Peek; WWT: Wong, Fay et al.; Astrometry.net: Hogg, Lang, Roweis et al.

[video, demos]

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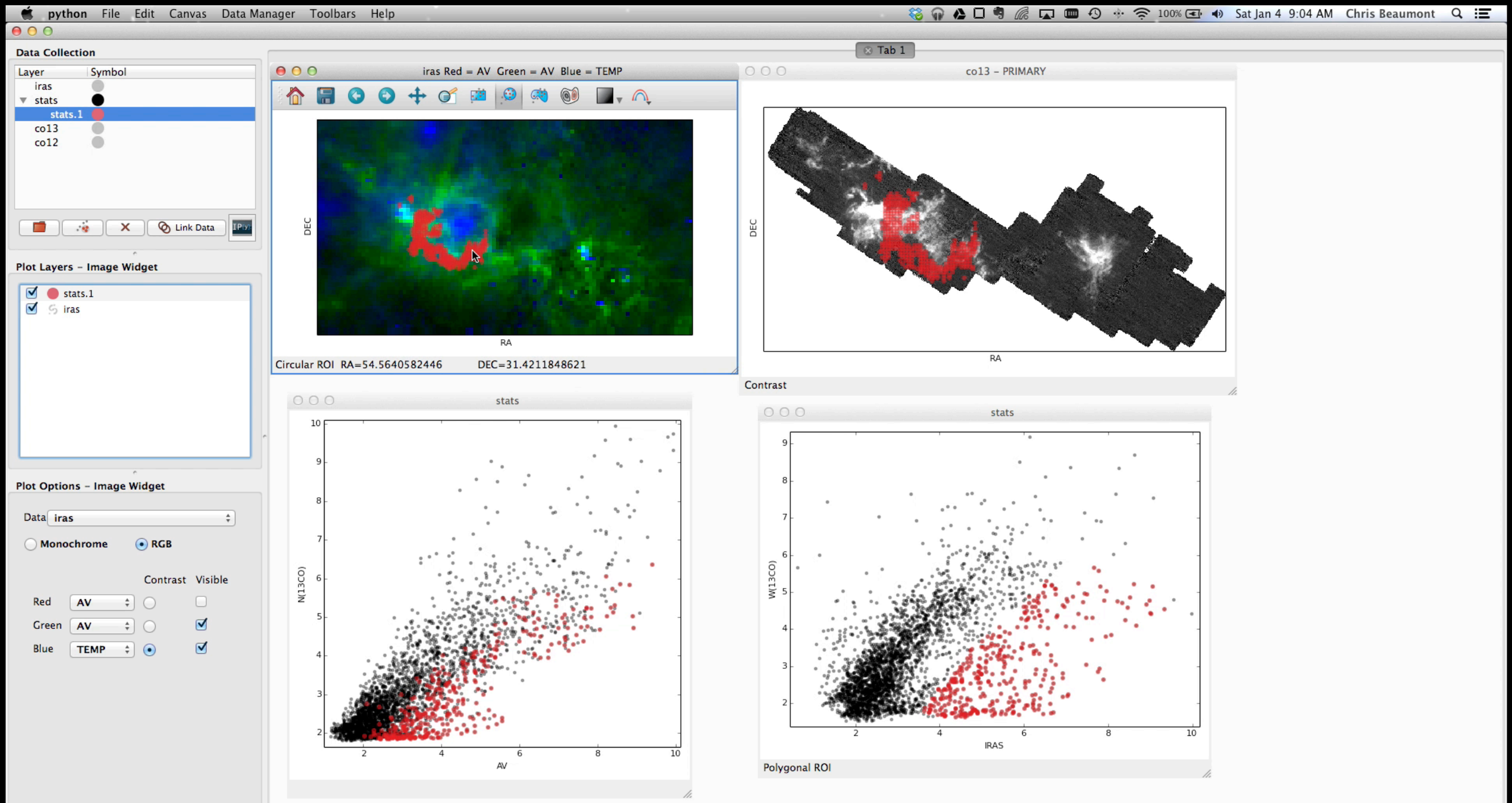
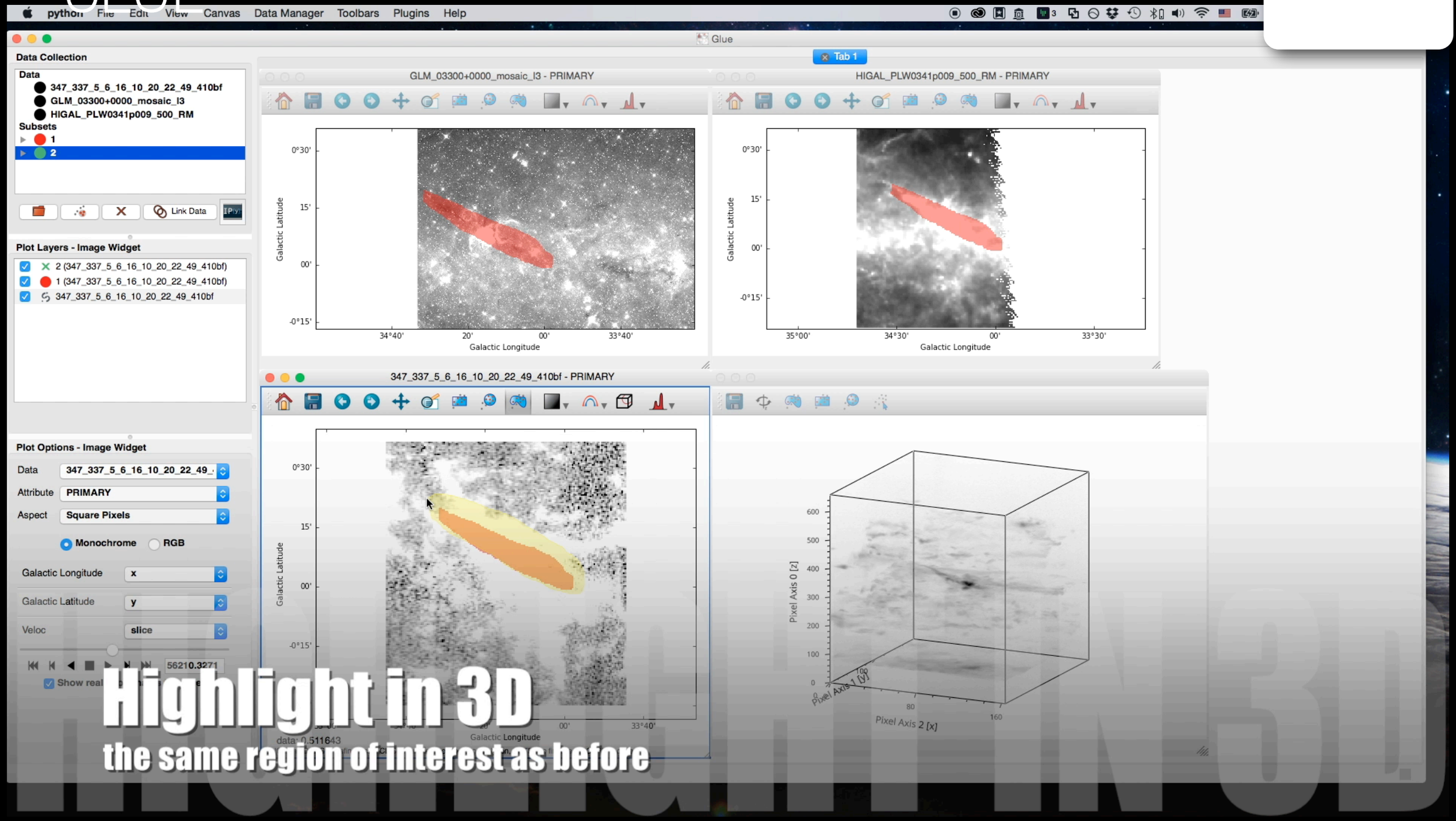
GLUE



Christopher Beaumont, w/A. Goodman, T. Robitaille & M. Borkin

LINKED VIEWS OF HIGH-DIMENSIONAL DATA (IN PYTHON)

GLUE



video by Penny Qian, wth Catherine Zucker, graduate students

glue created by: C. Beaumont, M. Borkin, P. Qian, T. Robitaille, and A. Goodman, PI

LINKED VIEWS OF HIGH-DIMENSIONAL DATA (IN PYTHON)

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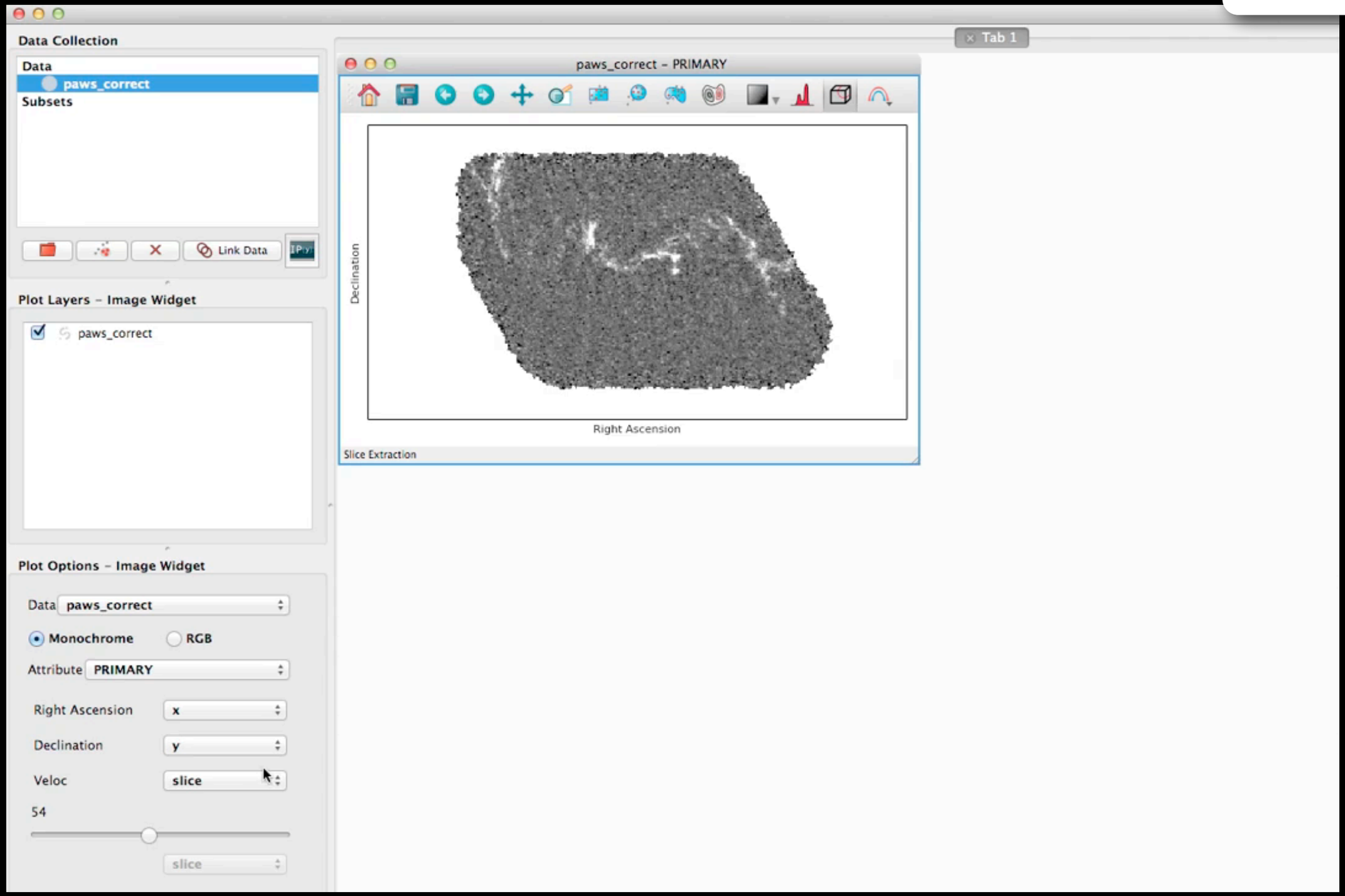

video by Chris Beaumont, glue developer

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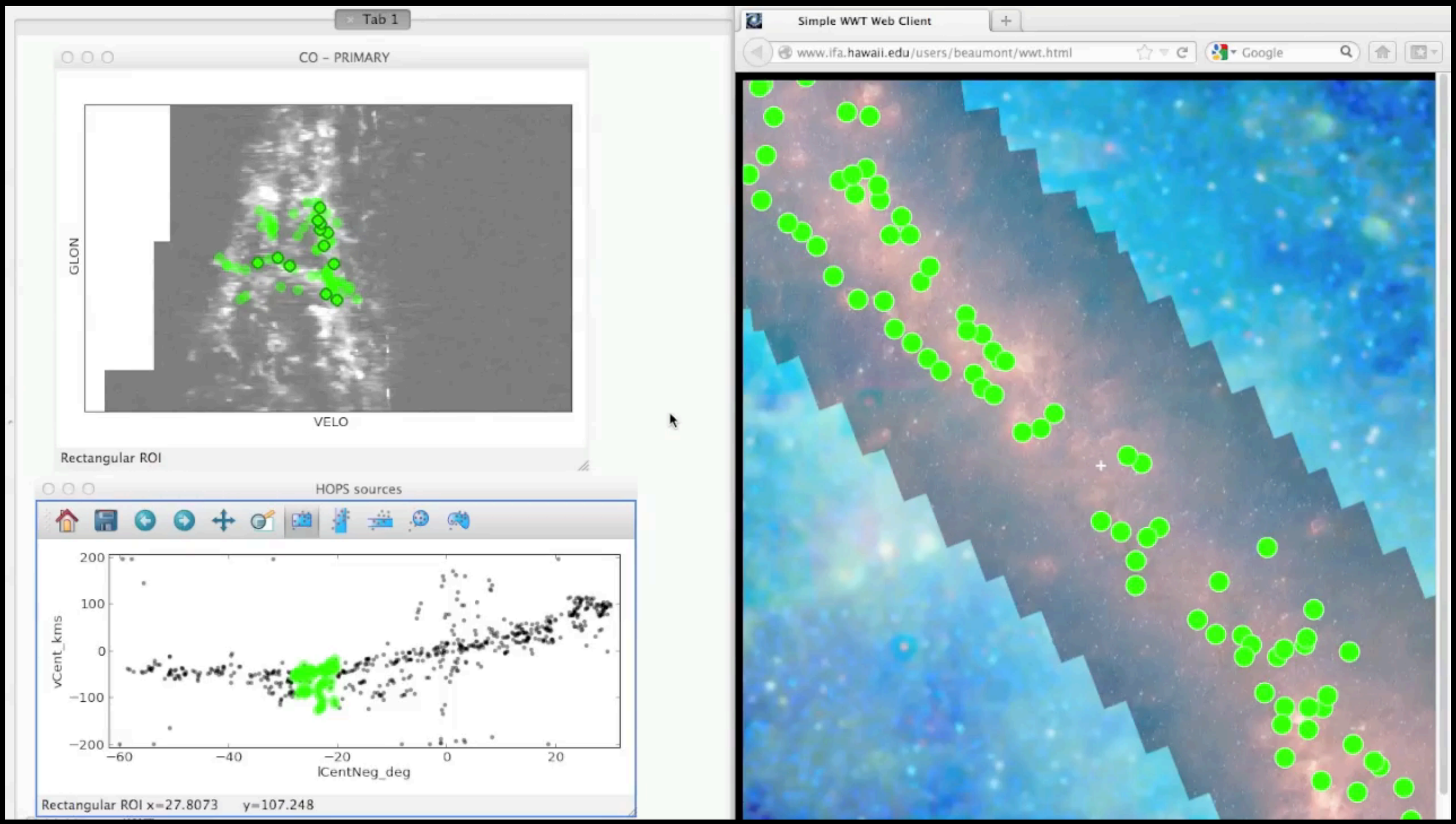

Video courtesy of Chris Beaumont

2009

3D PDF

HIGH-DIMENSIONAL DATA IN A "PAPER"

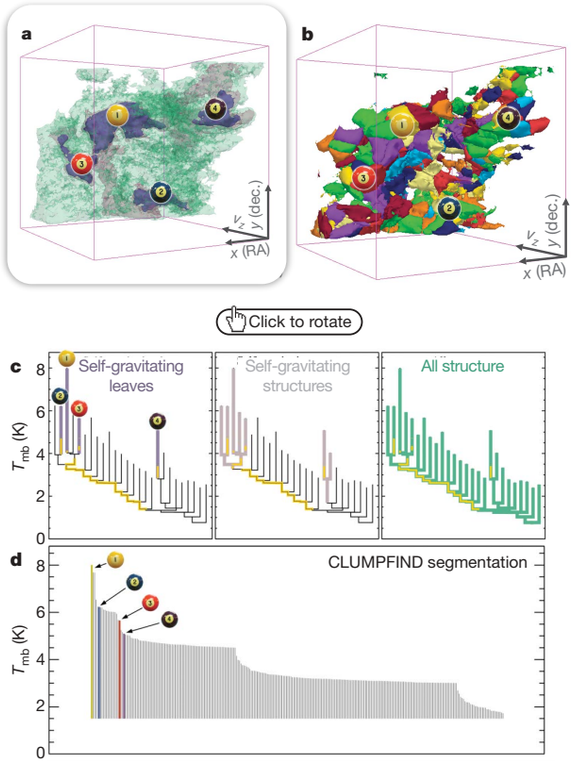

Figure 2 | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. a, 3D visualization of the surfaces indicated by colours in the dendrogram shown in **c**. Purple illustrates the smallest scale self-gravitating structures in the region corresponding to the leaves of the dendrogram; pink shows the smallest surfaces that contain distinct self-gravitating leaves within them; and green corresponds to the surface in the data cube containing all the significant emission. Dendrogram branches corresponding to self-gravitating objects have been highlighted in yellow over the range of T_{mb} (main-beam temperature) test-level values for which the virial parameter is less than 2. The x–y locations of the four 'self-gravitating' leaves labelled with billiard balls are the same as those shown in Fig. 1. The 3D visualizations show position–position–velocity (p–p–v) space. RA, right ascension; dec., declination. For comparison with the ability of dendrograms (**c**) to track hierarchical structure, **d** shows a pseudo-dendrogram of the CLUMPFIND segmentation (**b**), with the same four labels used in Fig. 1 and in **a**. As 'clumps' are not allowed to belong to larger structures, each pseudo-branch in **d** is simply a series of lines connecting the maximum emission value in each clump to the threshold value. A very large number of clumps appears in **b** because of the sensitivity of CLUMPFIND to noise and small-scale structure in the data. In the online PDF version, the 3D cubes (**a** and **b**) can be rotated to any orientation, and surfaces can be turned on and off (interaction requires Adobe Acrobat version 7.0.8 or higher). In the printed version, the front face of each 3D cube (the 'home' view in the interactive online version) corresponds exactly to the patch of sky shown in Fig. 1, and velocity with respect to the Local Standard of Rest increases from front (-0.5 km s^{-1}) to back (8 km s^{-1}).

data, CLUMPFIND typically finds features on a limited range of scales, above but close to the physical resolution of the data, and its results can be overly dependent on input parameters. By tuning CLUMPFIND's two free parameters, the same molecular-line data set[8] can be used to show either that the frequency distribution of clump mass is the same as the initial mass function of stars or that it follows the much shallower mass function associated with large-scale molecular clouds (Supplementary Fig. 1).

Four years before the advent of CLUMPFIND, 'structure trees'[9] were proposed as a way to characterize clouds' hierarchical structure using 2D maps of column density. With th…ly 2D work as inspiration, we have developed a structure-id…ithm that abstracts the hierarchical structure of a… an easily visualized representation calle… well developed in other data-intensive … application of tree methodologies so fa… and almost exclusively within the a… 'merger trees' are being used with in…

Figure 3 and its legend explain th… schematically. The dendrogram qua… ima of emission merge with each… explained in Supplementary Meth… determined almost entirely by th… sensitivity to algorithm paramet… possible on paper and 2D screen… data (see Fig. 3 and its legend… cross, which eliminates dimens… preserving all information … Numbered 'billiard ball' lab… features between a 2D map … online) and a sorted dendr…

A dendrogram of a spectr… of key physical properties … surfaces, such as radius (R), ve… (L). The volumes can have any shape, and it… the significance of the especially elongated features … (Fig. 2a). The luminosity is an approximate proxy for mass, such that $M_{lum} = X_{13CO} L_{13CO}$, where $X_{13CO} = 8.0 \times 10^{20}$ cm^2 K^{-1} km^{-1} s (ref. 15; see Supplementary Methods and Supplementary Fig. 2). The derived values for size, mass and velocity dispersion can then be used to estimate the role of self-gravity at each point in the hierarchy, via calculation of an 'observed' virial parameter, $\alpha_{obs} = 5\sigma_v^2 R/GM_{lum}$. In principle, extended portions of the tree (Fig. 2, yellow highlighting) where $\alpha_{obs} < 2$ (where gravitational energy is comparable to or larger than kinetic energy) correspond to regions of p–p–v space where self-gravity is significant. As α_{obs} only represents the ratio of kinetic energy to gravitational energy at one point in time, and does not explicitly capture external over-pressure and/or magnetic fields[16], its measured value should only be used as a guide to the longevity (boundedness) of any particular feature.

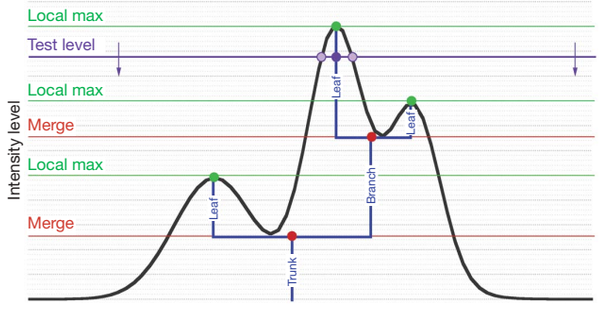

Figure 3 | Schematic illustration of the dendrogram process. Shown is the construction of a dendrogram from a hypothetical one-dimensional emission profile (black). The dendrogram (blue) can be constructed by 'dropping' a test constant emission level (purple) from above in tiny steps (exaggerated in size here, light lines) until all the local maxima and mergers are found, and connected as shown. The intersection of a test level with the emission is a set of points (for example the light purple dots) in one dimension, a planar curve in two dimensions, and an isosurface in three dimensions. The dendrogram of 3D data shown in Fig. 2c is the direct analogue of the tree shown here, only constructed from 'isosurface' rather than 'point' intersections. It has been sorted and flattened for representation on a flat page, as fully representing dendrograms for 3D data cubes would require four dimensions.

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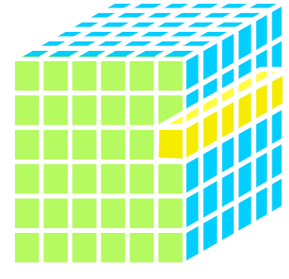


Goodman et al. 2009, Nature, cf: Fluke et al. 2009

Vol 457|1 January 2009|doi:10.1038/nature07609

LETTERS

A role for self-gravity at multiple length scales in the process of star formation

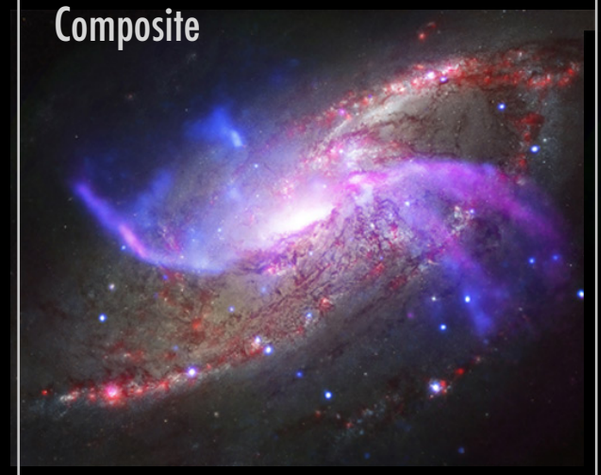
Alyssa A. Goodman[1,2], Erik W. Rosolowsky[2,3], Michelle A. Borkin[1]†, Jonathan B. Foster[2], Michael Halle[1,4], Jens Kauffmann[1,2] & Jaime E. Pineda[2]

Self-gravity plays a decisive role in the final stages of star formation, where dense cores (size ~0.1 parsecs) inside molecular clouds collapse to form star-plus-disk systems[1]. But self-gravity's role at earlier times (and on larger length scales, such as ~1 parsec) is unclear; some molecular cloud simulations that do not include self-gravity suggest that 'turbulent fragmentation' alone is sufficient to create a mass distribution of dense cores that resembles, and sets, the stellar initial mass function[2]. Here we report a 'dendrogram' (hierarchical tree-diagram) analysis that reveals that self-gravity plays a significant role over the full range of possible scales traced by ^{13}CO observations in the L1448 molecular cloud, but not everywhere in the observed region. In particular, more than 90 per cent of the compact 'pre-stellar cores' traced by peaks of dust emission[3] are projected on the sky within one of the dendrogram's self-gravitating 'leaves'. As these peaks mark the locations of already-forming stars, or of those probably about to form, a self-gravitating cocoon seems a critical condition for their exist-

overlapping features as an option, significant emission found between prominent clumps is typically either appended to the nearest clump or turned into a small, usually 'pathological', feature needed to encompass all the emission being modelled. When applied to molecular-line

ASTRONOMICAL MEDICINE

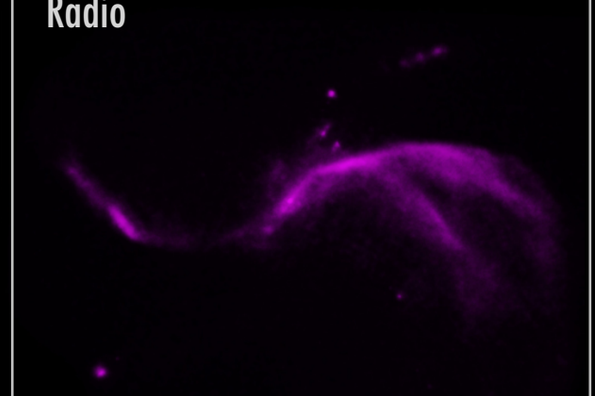
Composite



X-ray

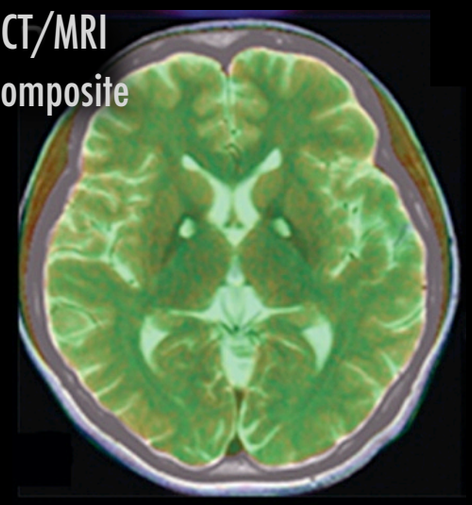
Optical

Radio

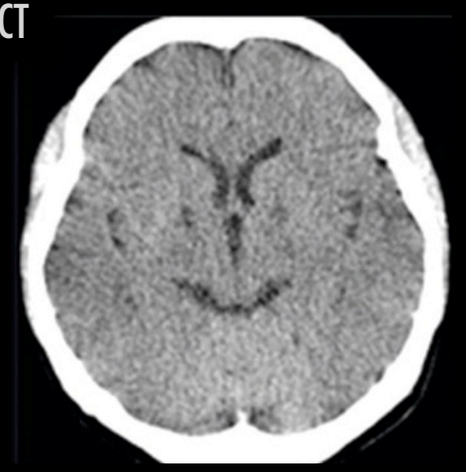


chandra.harvard.edu/photo/2014/m106/

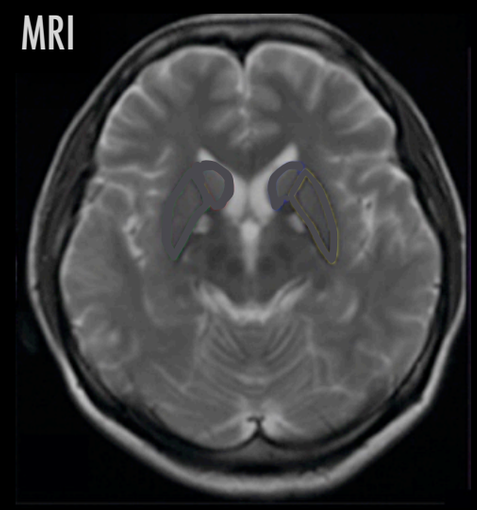
CT/MRI composite



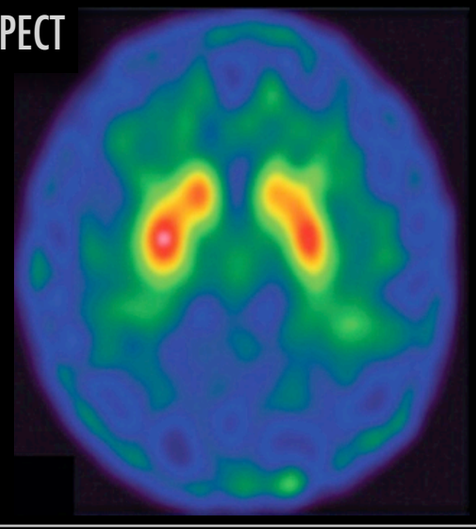
CT



MRI



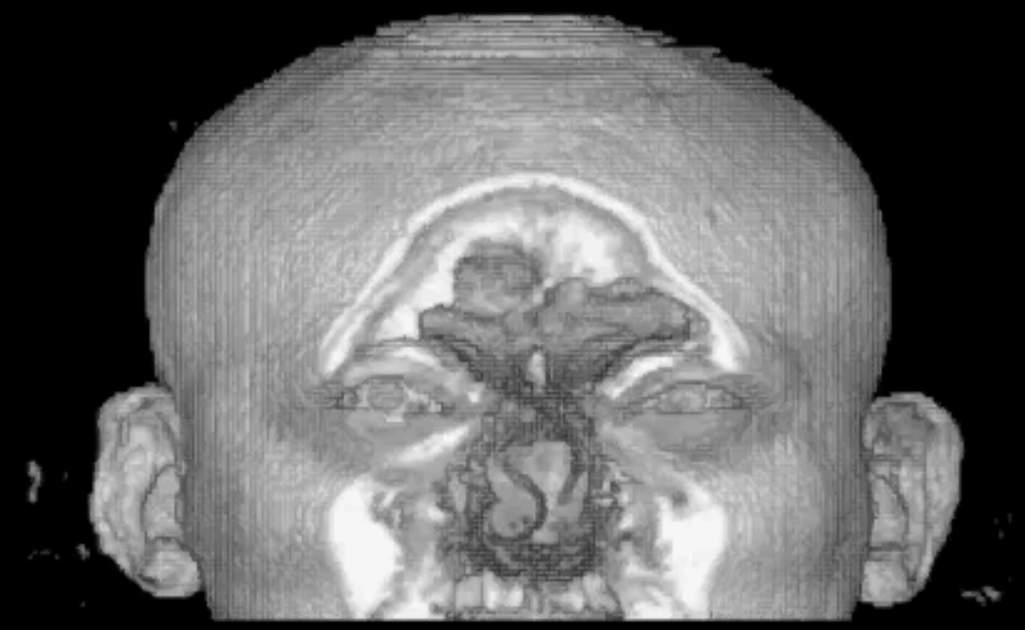
SPECT



Chang, et al. 2011, brain.oxfordjournals.org/content/134/12/3632

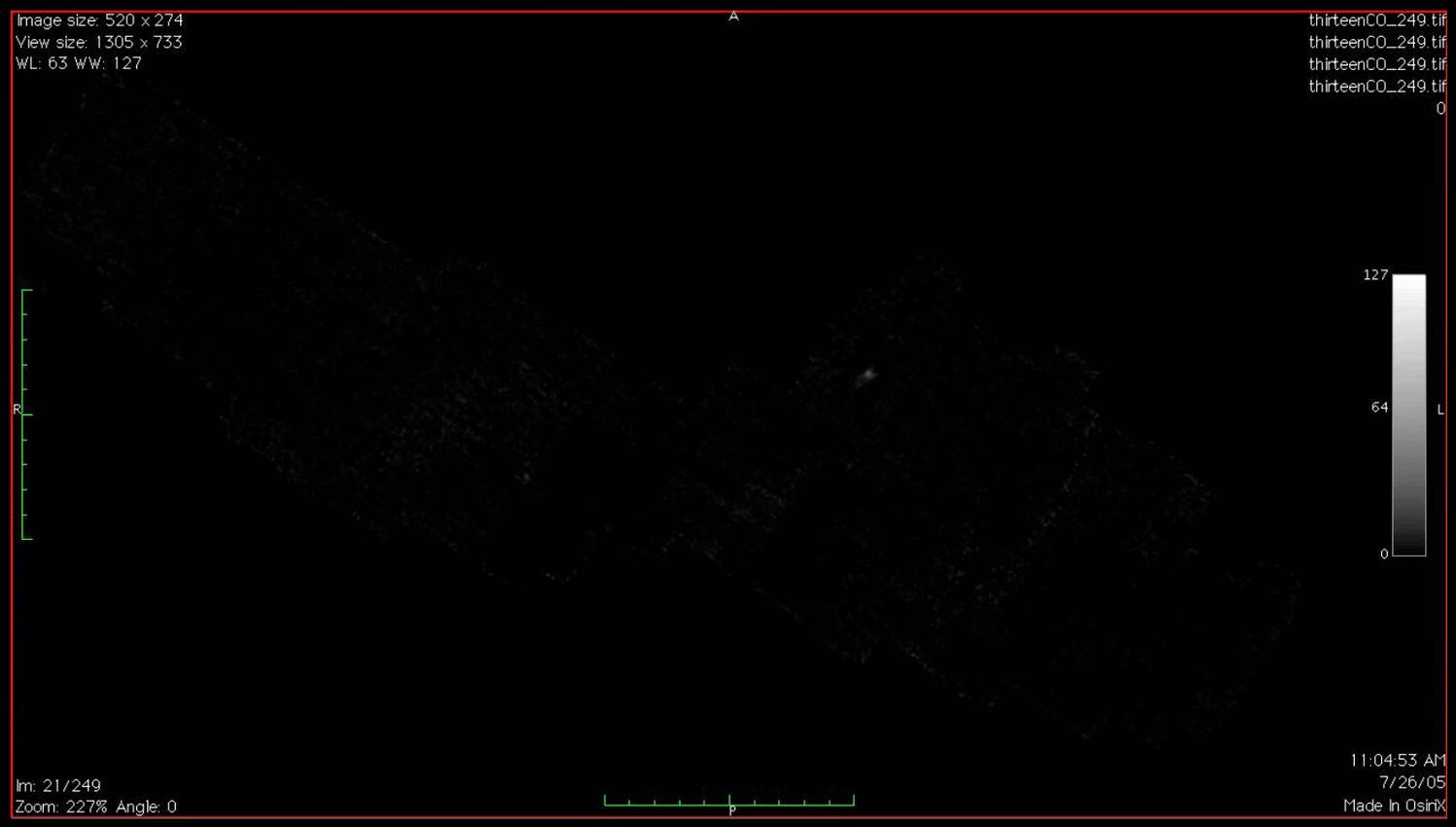
ASTRONOMICAL MEDICINE

“KEITH”



“z” is depth into head

“PERSEUS”



“z” is line-of-sight velocity

ASTRONOMICAL MEDICINE

mage size: 520 x 274
iew size: 1305 x 733
L: 63 WW: 127

mm peak (Enoch et al. 2006)

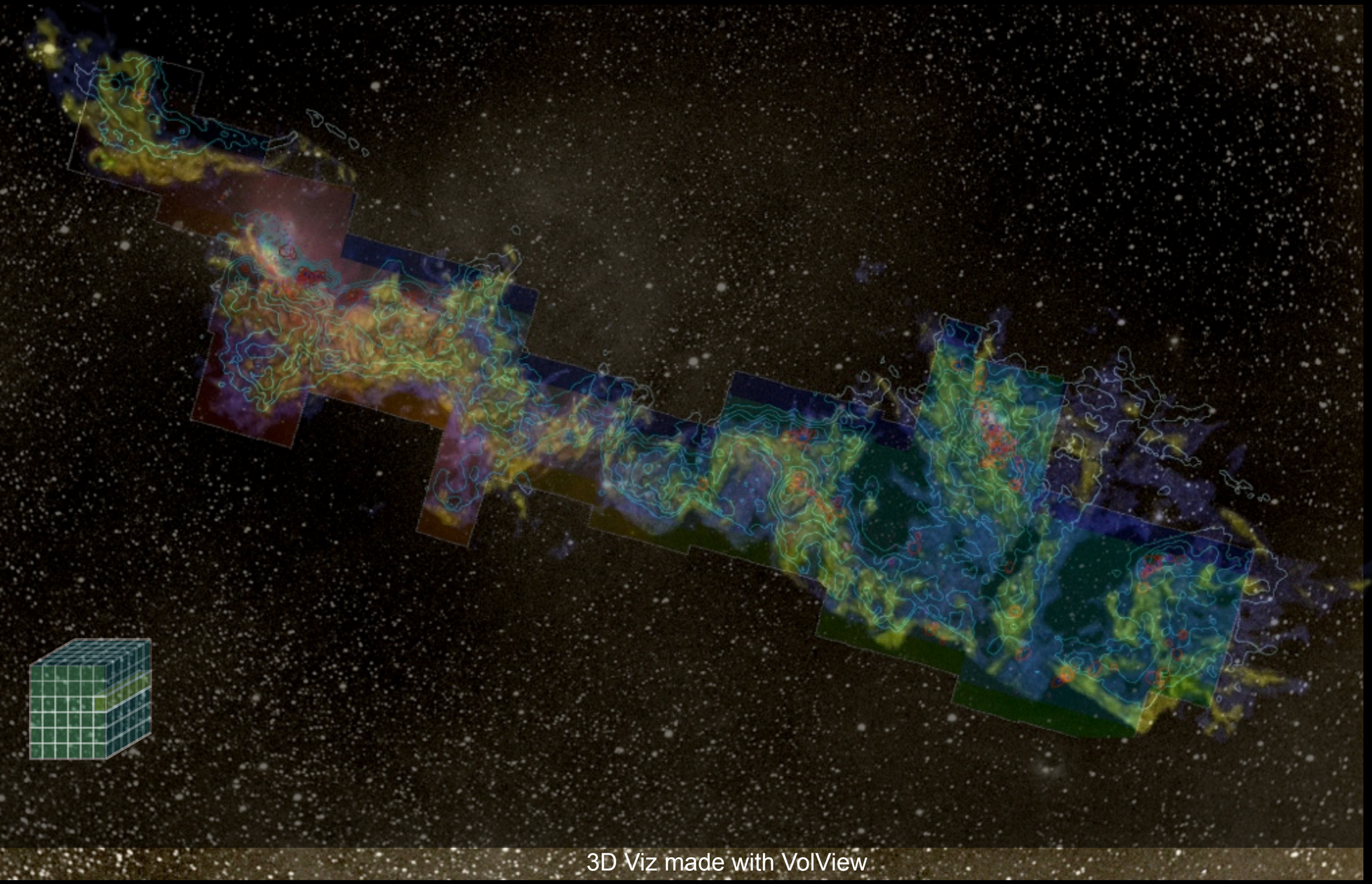
sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)

^{13}CO (Ridge et al. 2006)

mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al.)

Optical image (Barnard 1927)

m: 1/249
oom: 227% Angle: 0



3D Viz made with VolView

COMPLETE