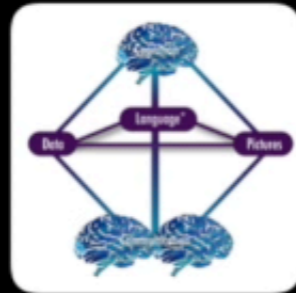
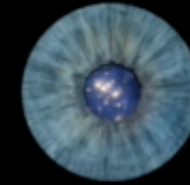


SEEING MORE OF THE UNIVERSE



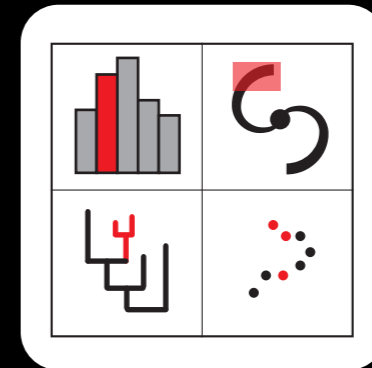
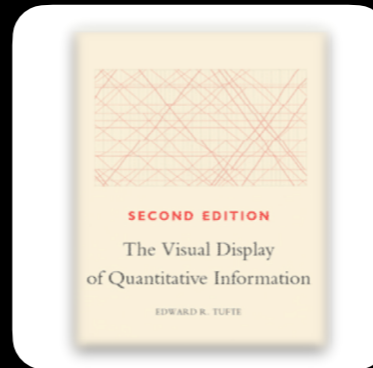
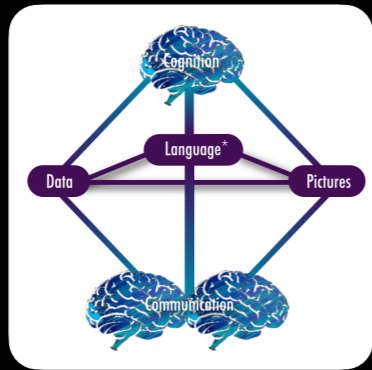
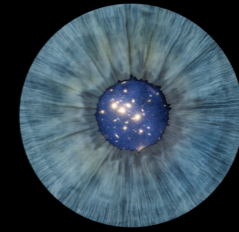
Explore

Explain

Alyssa A. Goodman

Harvard-Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

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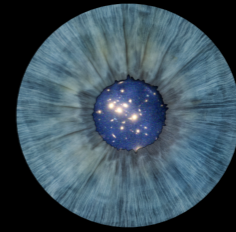
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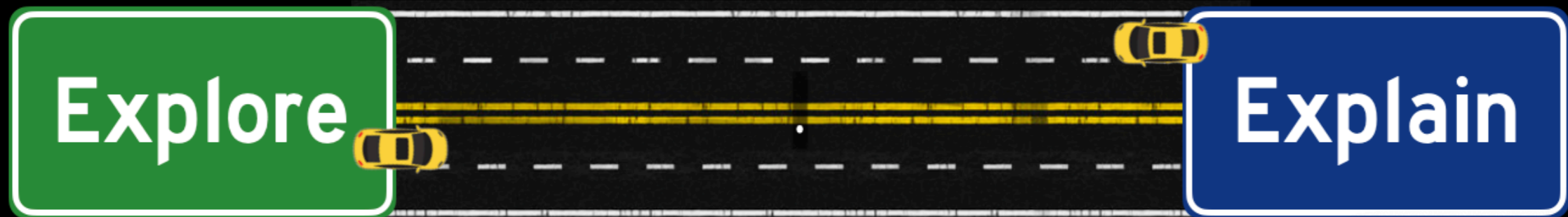
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“THE ROAD FROM EXPLANATION TO EXPLORATION, AND BACK...”



Alyssa A. Goodman

Harvard-Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

Traditionally, travel from exploration to explanation is called “Scholarly Publishing” if its *dry*, and “Public Outreach,” if it’s *beautiful*.

Explore



Explain

Explore



Explain

It's much harder to go the other way.

Explore



And, the *best* roads are two-way.

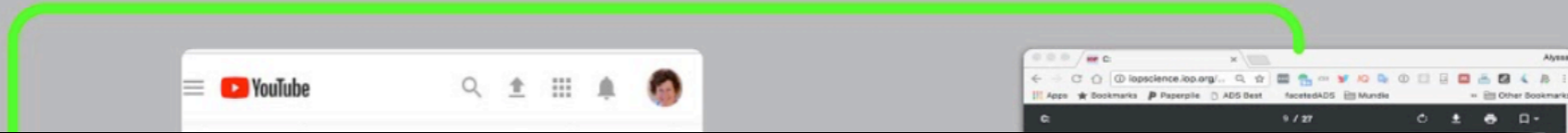


Explain

DATA,
CODE,
COLLABORATION



DATA-DRIVEN STORYTELLING



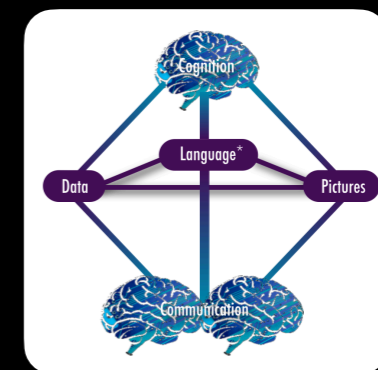
This is all possible, and happening now.

Not for everyone, though.

see *“New Thinking on, and with, Data Visualization”*
(Goodman, Borkin & Robitaille arxiv.org/abs/1805.11300)

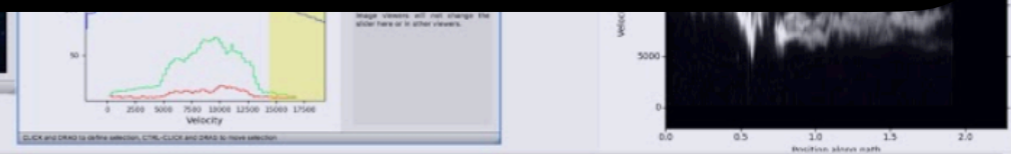
Learn more in our next episode...

“CONNECTING DATA, LANGUAGE AND PICTURES”



collaborative
software
development

plug-in
architecture



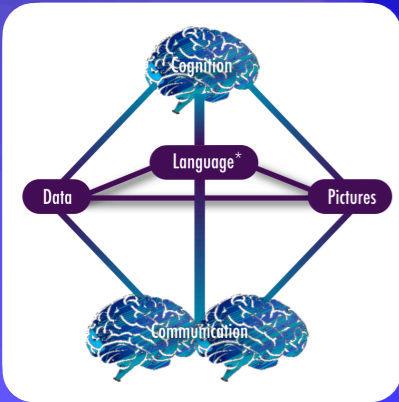
EXPLORATION



EXPLANATION



Want a fuller story? Try “The Road from Explanation to Exploration, and Back”



Alyssa Goodman

Harvard
Smithsonian Institution

AG's talk at the 2018
NAS Cybernetic Serendipity Colloquium
links below



Creativity and Collaboration: Revisiting Cybernetic Serendipity

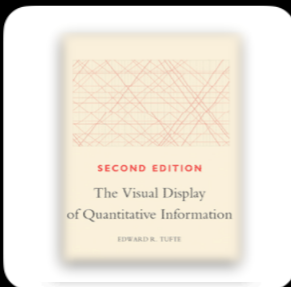
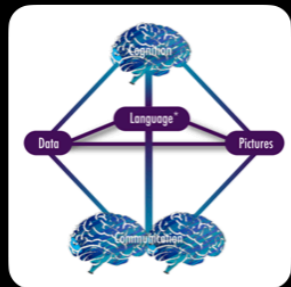
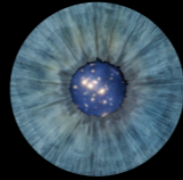
This colloquium was held March 13-14 2018 in Washington, DC
Organized by Ben Shneiderman, Maneesh Agrawala, Alyssa Goodman, Youngmoo Kim, and Roger Malina

Our ambition is to redirect the history of ideas, restoring the Leonardo-like close linkage between art/design and science/engineering/medicine. We believe that internet-enabled collaborations can make more people more creative more of the time.

Slides & video: scholar.harvard.edu/agoodman/presentations/road-exploration-explanation-and-back

Just video: tinyurl.com/AGExploreExplain

SEEING MORE OF THE UNIVERSE



Explore

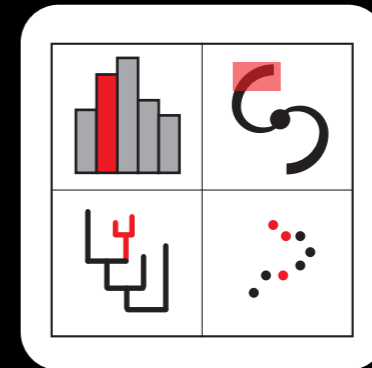
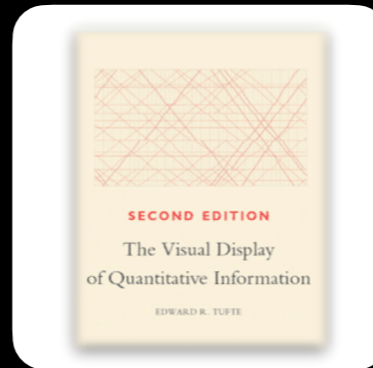
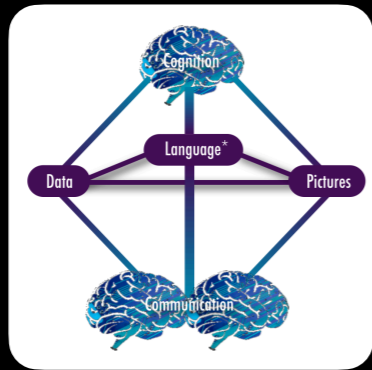
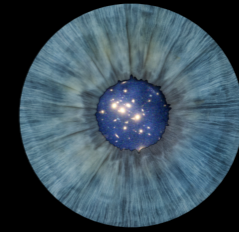
Explain

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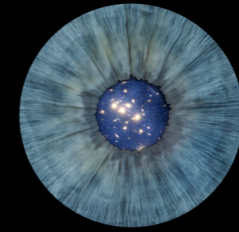
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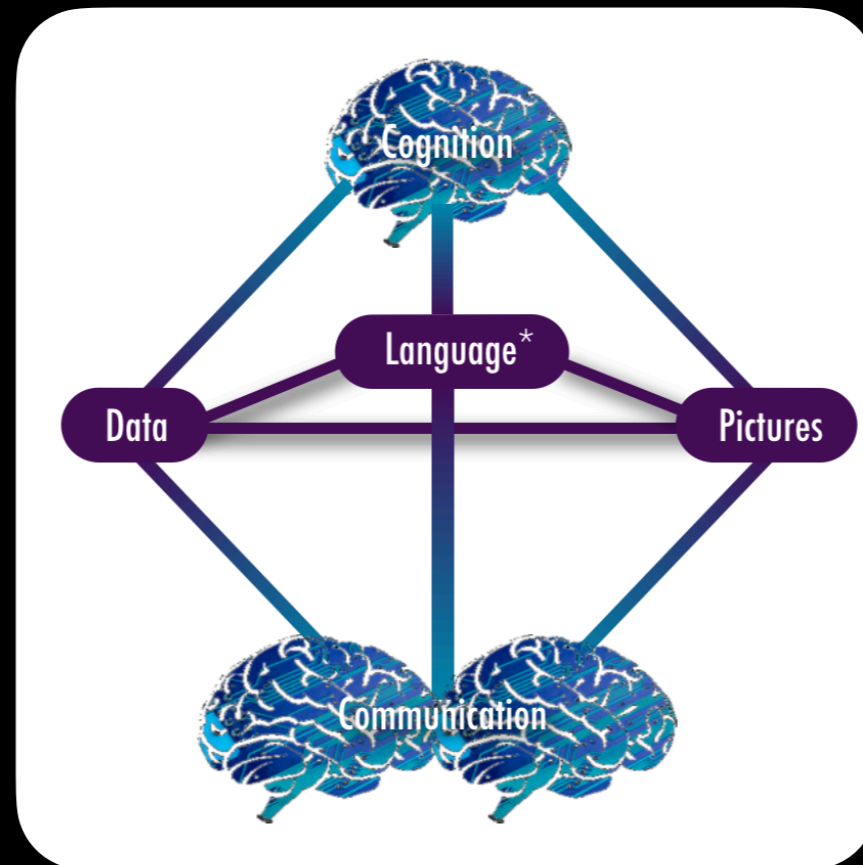
Alyssa A. Goodman

Harvard-Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

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“CONNECTING DATA, LANGUAGE AND PICTURES”



Alyssa A. Goodman

Harvard-Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

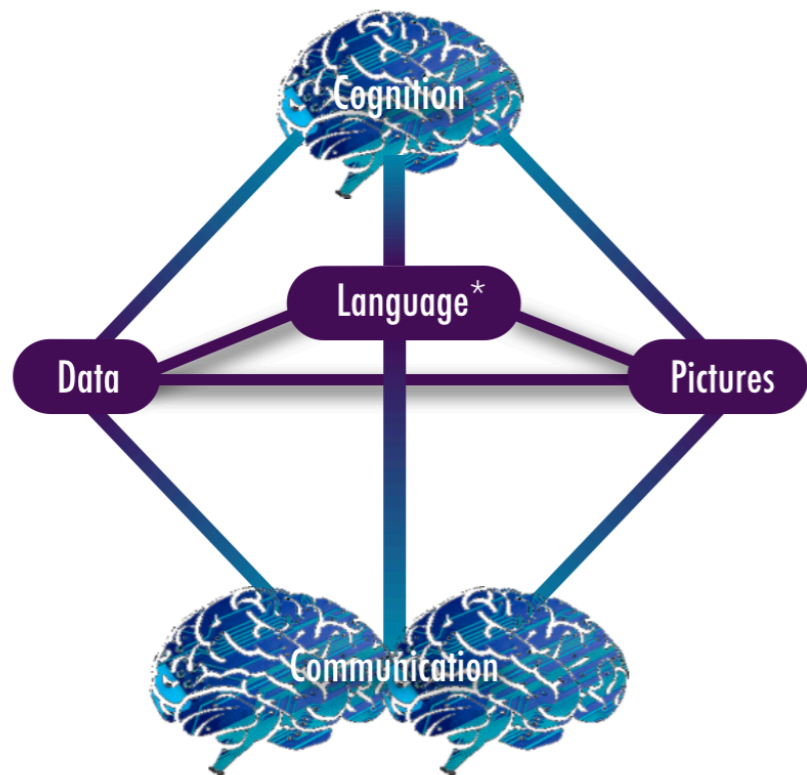
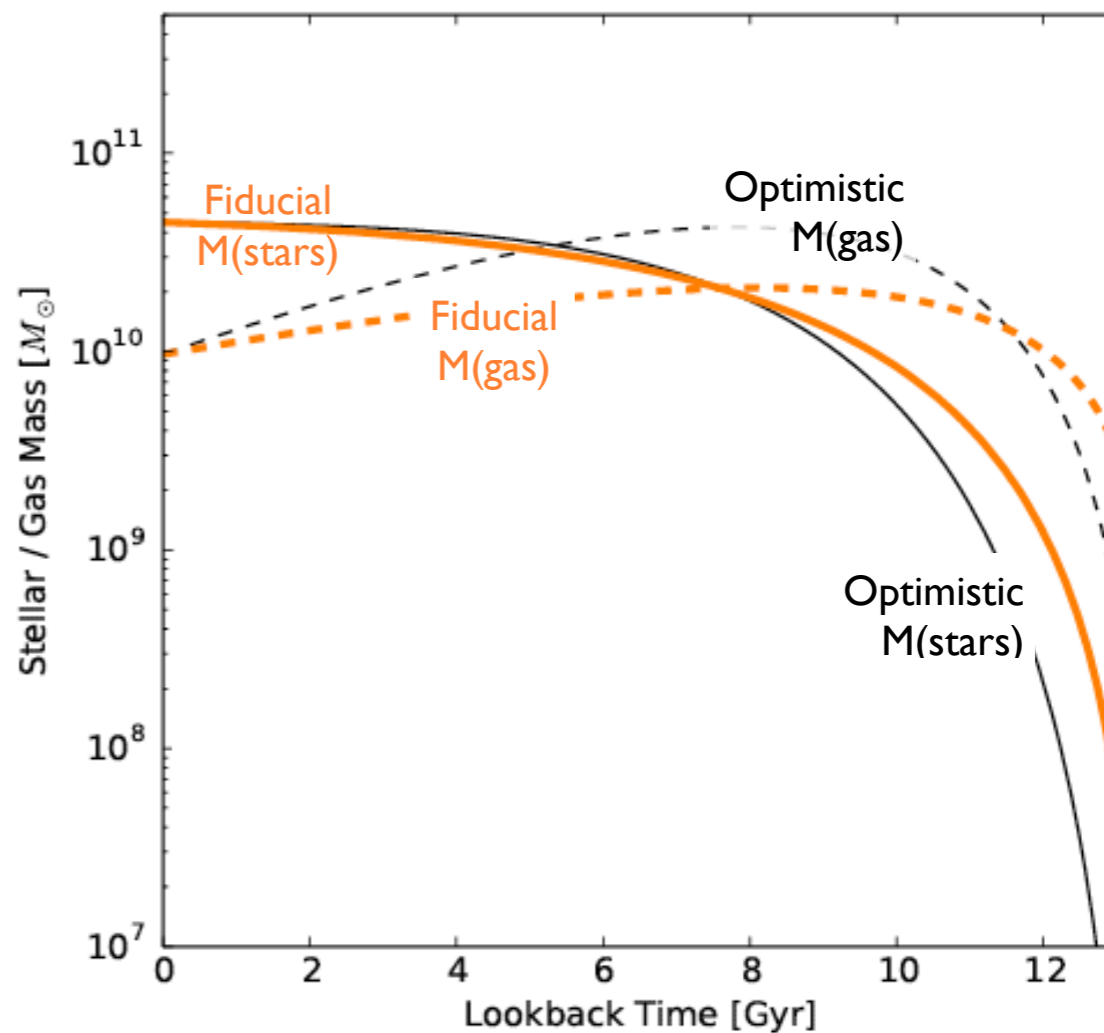
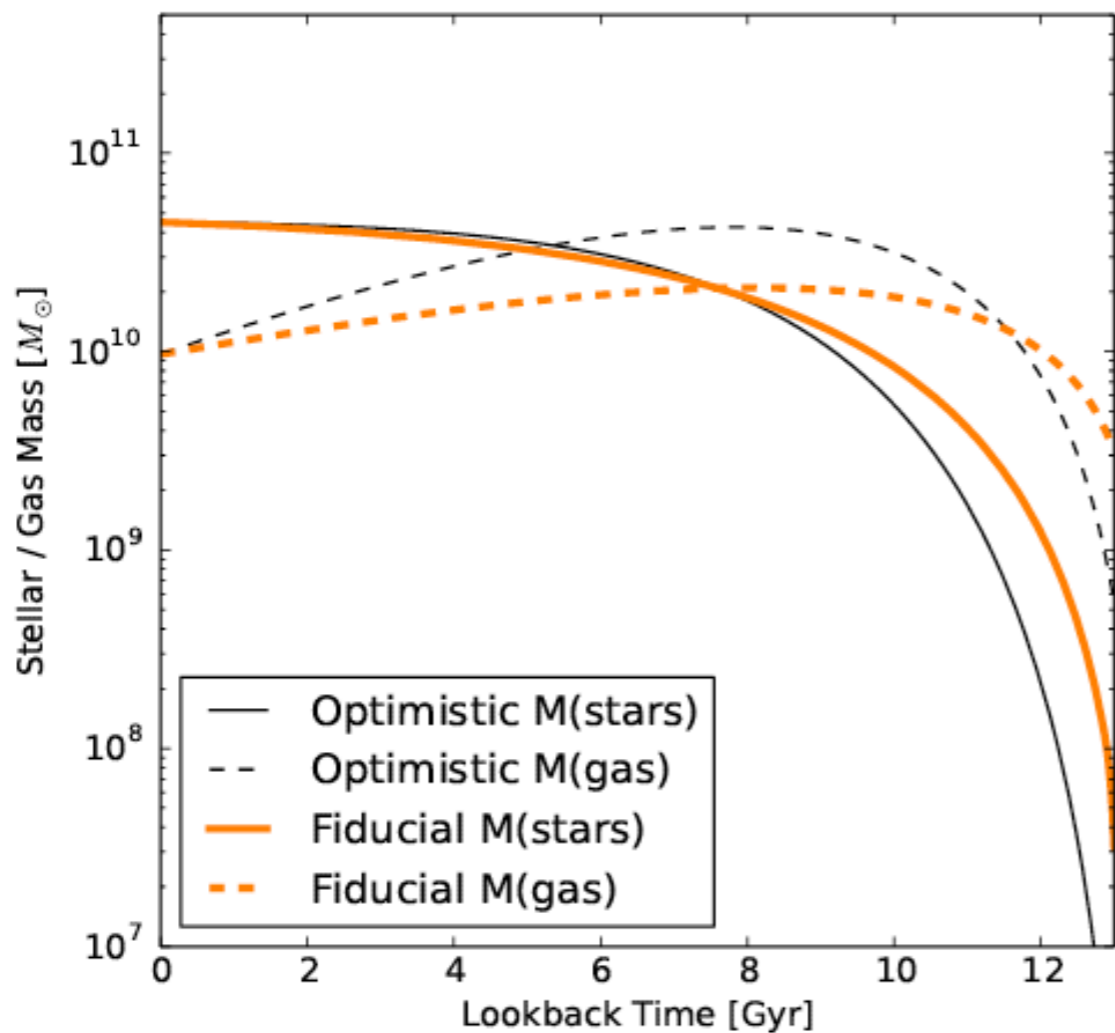
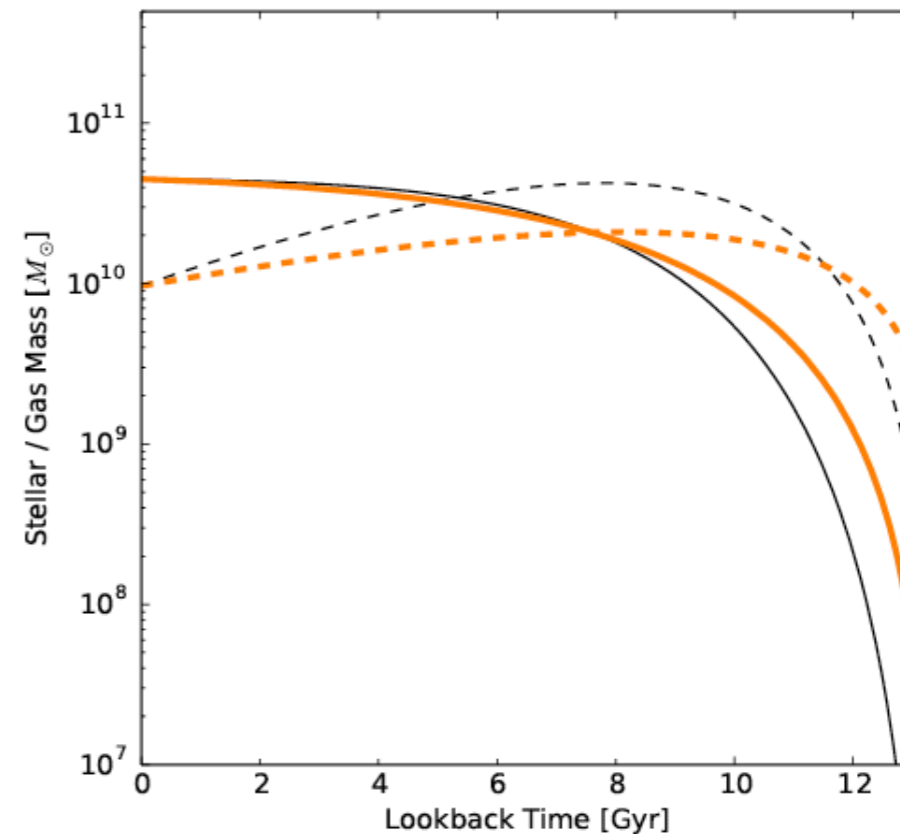
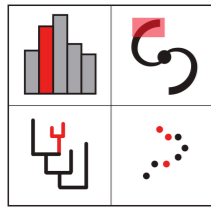


Figure Caption: The solid/solid black line shows the optimistic case for $M(\text{stars})/ M(\text{gas})$. The orange lines show the same quantities, for the fiducial case.





glue
multidimensional data exploration

plotly

enabled by d3.js (javascript) outputs

d3po

d3po is a project designed to allow an astronomer (or an interactive, publication-quality figure that has staged built can be previewed at d3po.org, and represents a figure from figure describes how metallicity affects color in cool stars, dragging in the scatter plots to understand the power of lin

Right now we are in search of alpha testers, who have figured their hands a little dirty (No javascript skills needed). In future figures interactively. We are also exploring [implementation](#) of version expected in January 2014.

Installing your own d3po server

```
git clone git@github.com:adnr/d3po.git
cd d3po
virtualenv --no-site-packages venv
source venv/bin/activate
pip install -r pip-requirements.txt
python run.py
```



1600 1700 1800 1900 2000
Discovery year

Four Centuries of Discovery | A Chasm in Mass | Little Siblings | Close Cousins | The Strangers

After Galileo discovered the first four moons of Jupiter, it took nearly three hundred years to discover the next one.

Authorea Beta

Document Format Insert B I h1 h2 h3 x² x₂ cite

The "Paper" of the Future

Authorea preprint 02/21/2017 DOI: 10.22541/au.148769949.92783646

- Alyssa Goodman (Harvard University)
- Josh Peek (Space Telescope Science Institute)
- Alberto Accomazzi (Harvard-Smithsonian Center for Astrophysics (CFA))
- Chris Beaumont (Harvard-Smithsonian Center for Astrophysics (CFA))
- Christine L. Borgman (UCLA - University of California, Los Angeles)
- Hope How-Huan Chen (Harvard University)
- Merce Crosas (Harvard University)
- Christopher Erdmann (North Carolina State University)

And 3 more...

Add Collaborator Manage

A 5-minute video demonstration 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 communicate 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.

Fig. 1

The Paper of the Future should include seamless linkages amongst **data**, **pictures**, and **language**, where "language" includes both words and math. When an individual attempts to understand each of these kinds of information, different cognitive functions are utilized: communication is inefficient if the channel is restricted primarily to language, without easy interconnection to data and pictures.

WATCH a DEMO video, and find S/W links, on **YouTube** at tinyurl.com/PotF-Demo

many thanks to Alberto Pepe, Josh Peek, Chris Beaumont, Tom Robitaille, Adrian Price-Whelan, Elizabeth Newton, Michelle Borkin & Matteo Cantiello for making the PotF possible.

PUBLISHING'S INTERACTIVE CUTTING-EDGE & (AUGMENTED) FUTURE



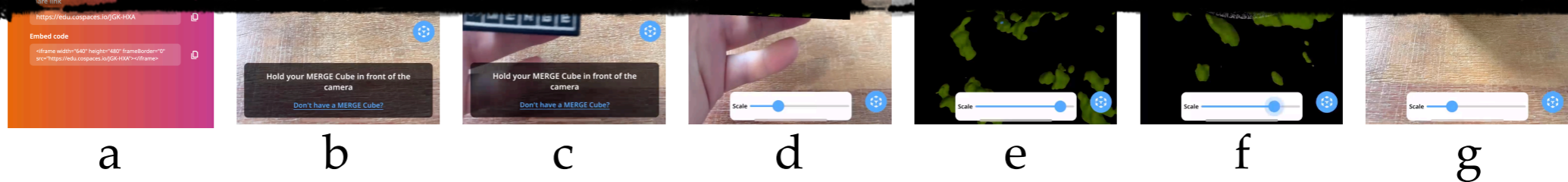
nature

PUBLISHED IN
NATURE
1-2020
ALVES ET AL.
(THE RADCLIFFE WAVE)

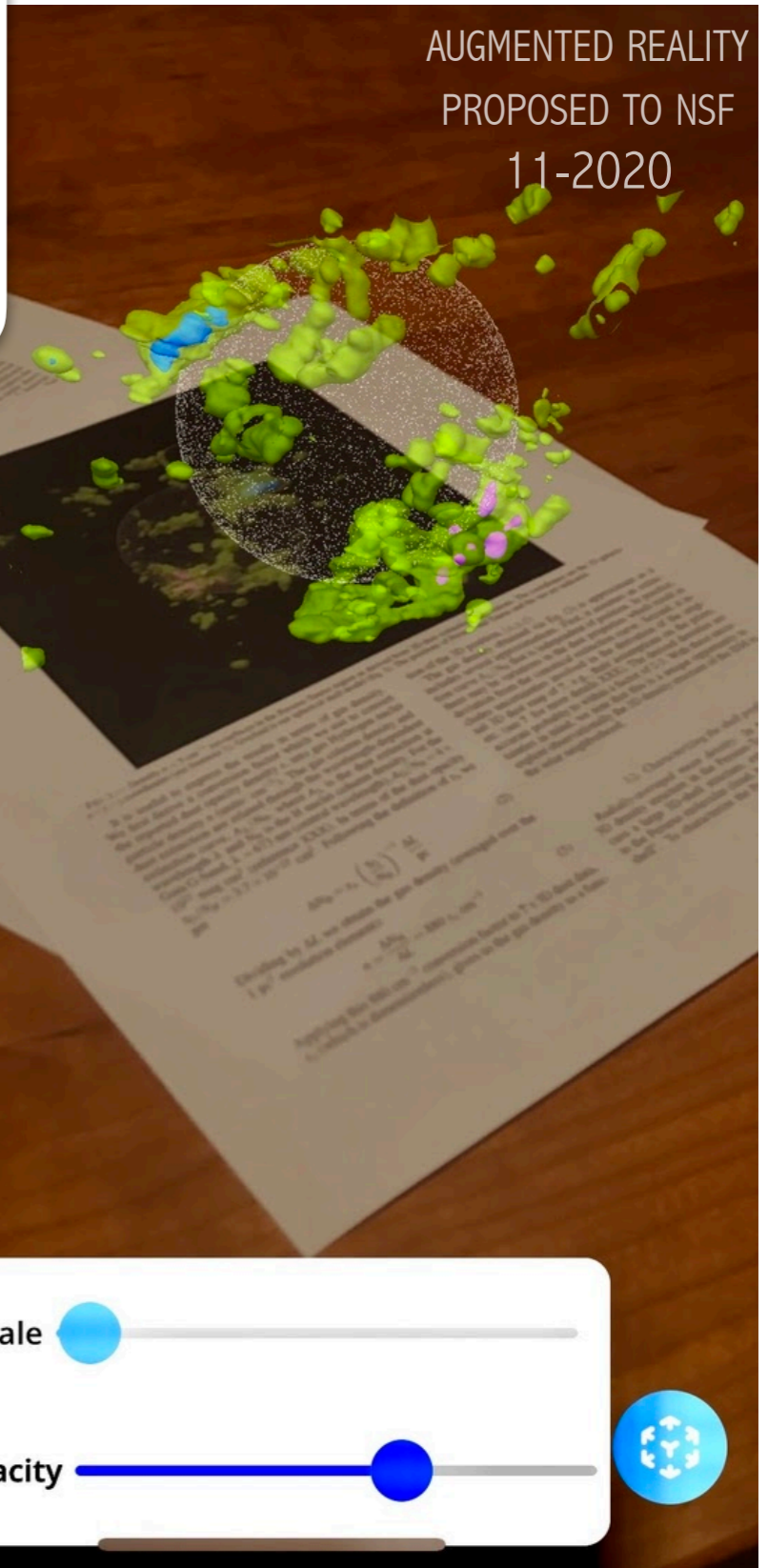
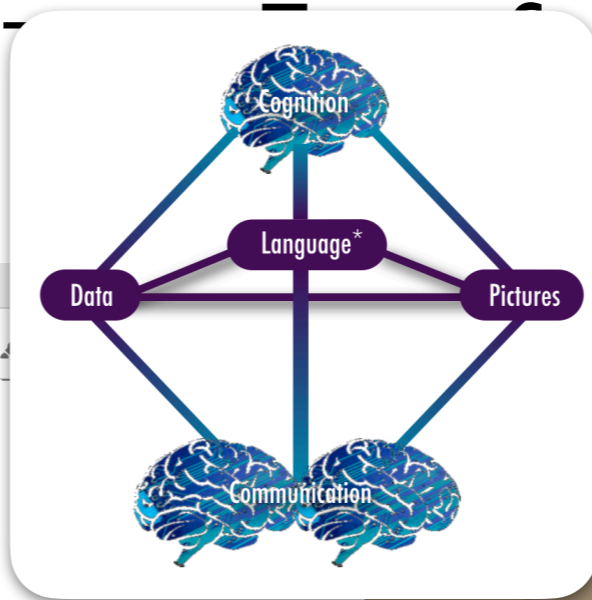
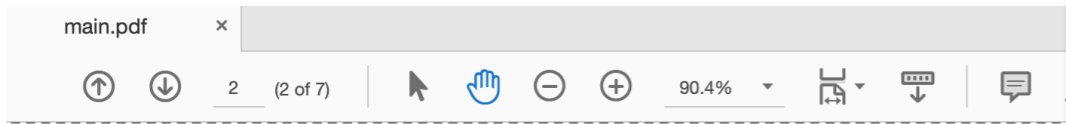


AUGMENTED REALITY
PROPOSED TO NSF
11-2020

This interactive 3D visualization of the Radcliffe Wave is available in the online version of the published *Nature* article. It was built using the plotly exporter plugin inside the glue visualization software. Click on any layer in the legend (at right) to turn it on and off, and see how the

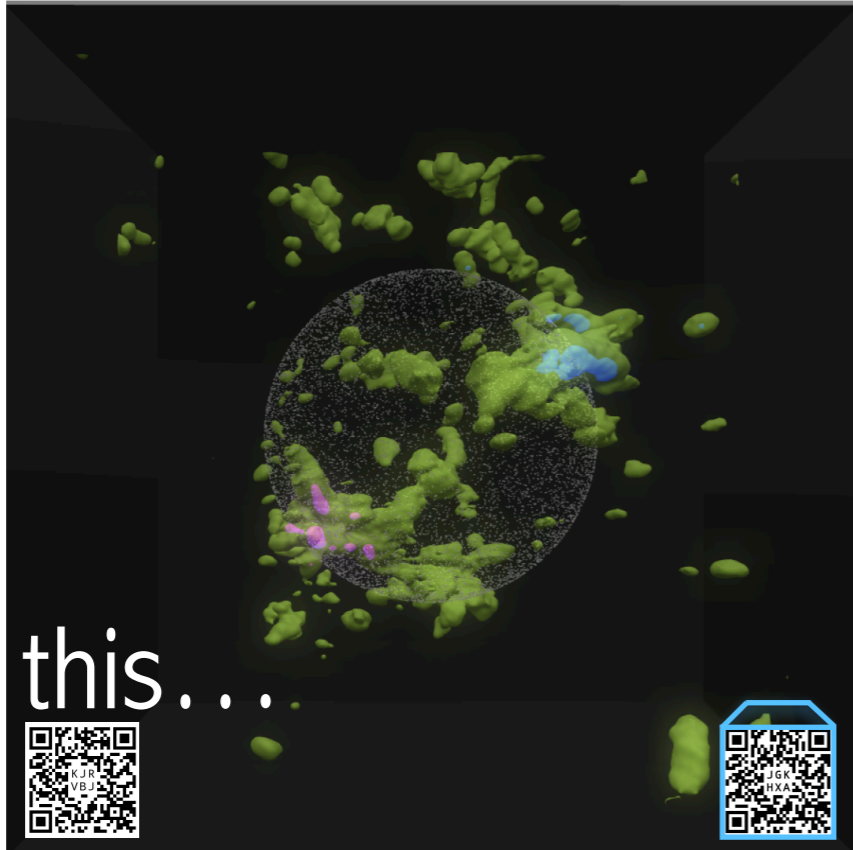


PUBLISHING'S INTERACTIVE CUT (AUGMENTED) FUTURE



2

scan this...



...see this

FIG. 1.— Density $n = 5 \text{ cm}^{-3}$ iso-surfaces in the Perseus-Taurus region as derived from 3D-dust extinction observations. The coordinates are the 3D galactic $x-y-z$ coordinates (see footnote 1). Overlaid is our spherical shell model (Eq. 5). The positions of Perseus and Taurus and the sun are indicated.

It is useful to express the results in terms of gas density. We first derive a conversion factor which we use to convert the reported dust opacity density s , into gas Hydrogen nuclei particle density n (units: cm^{-3}). The gas column density and dust extinction are related through the wavelength-dependent extinction curve, A_λ/N_H , where A_λ is the dust extinction at wavelength λ and N_H is the H nuclei column density. For the Gaia G-band, $\lambda = 673 \text{ nm}$ (central wavelength), $A_G/N_H = 4 \times 10^{22} \text{ mag cm}^2$ (reference XXX). In terms of the dust opacity $\tau_G/N_H = 3.7 \times 10^{-22} \text{ cm}^2$. Following the definition of s_x we get

$$\Delta N_H = s_x \left(\frac{\tau_G}{N_H} \right)^{-1} \frac{\Delta L}{\text{pc}}. \quad (2)$$

Dividing by ΔL we obtain the gas density (averaged over the 1 pc^3 resolution element):

$$n = \frac{\Delta N_H}{\Delta L} = 880 s_x \text{ cm}^{-3}. \quad (3)$$

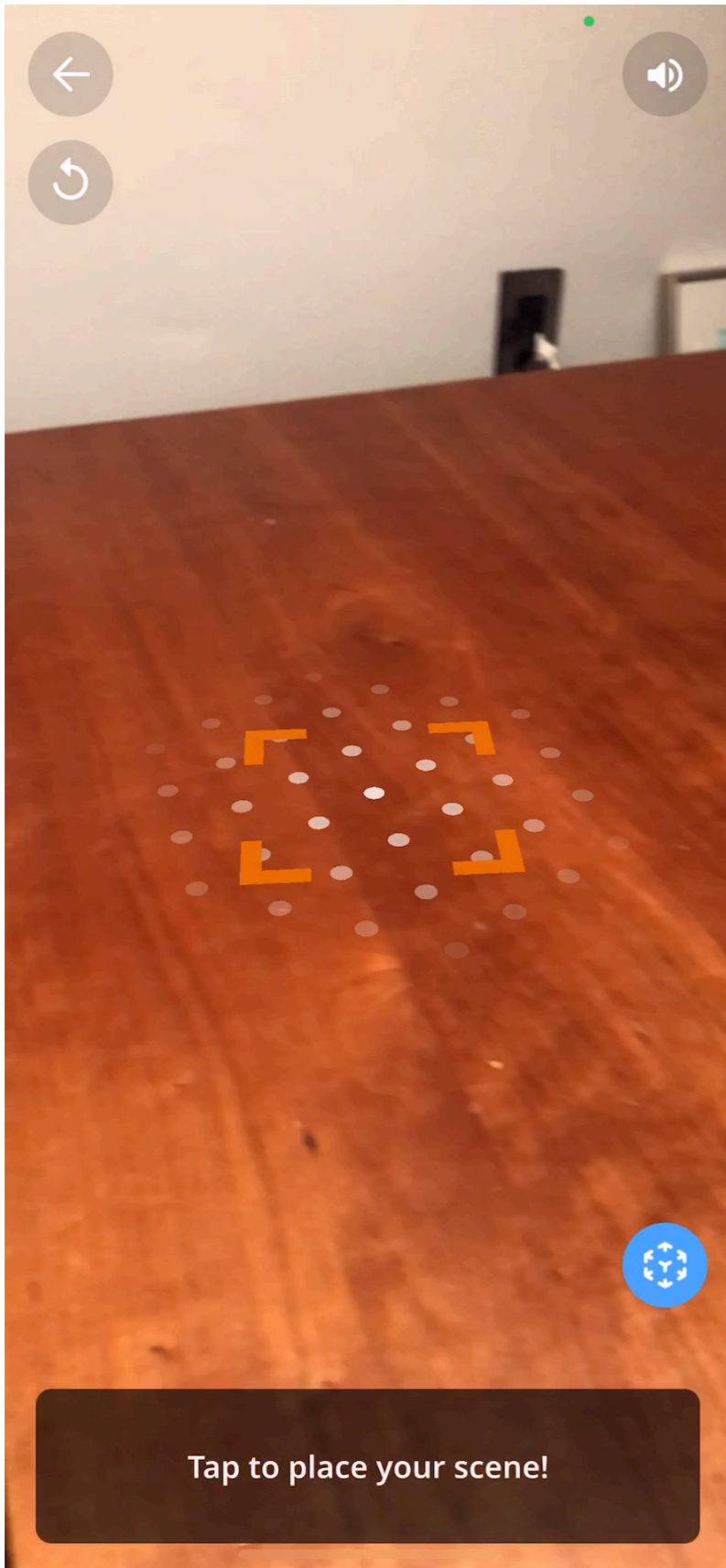
tion of the 3D position, (x, y, z) .

The gas density obtained via Eq. (3) is approximate as it includes several approximations. First, it assumes an extinction curve A_λ/N_H that is independent of position. In practice, there may be variations in the dust properties which result in deviation from the canonical extinction curve. Second, it includes uncertainties involved in the derivation of the original 3D dust map of ?, e.g., their assumptions on the priors, etc. (see ? for more details XXX). The derived densities are accurate probably to within a factor of 2-3. With these uncertainties in mind, we note that this is a unique opportunity to explore observationally the 3D density structure of the ISM in the solar neighborhood.

3.2. Characterizing the shell profile

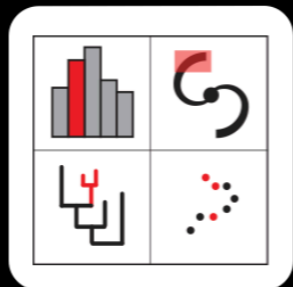
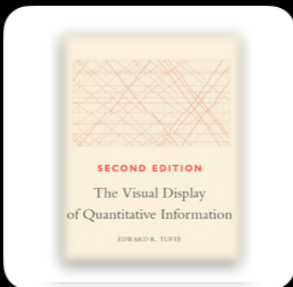
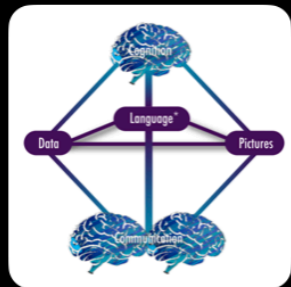
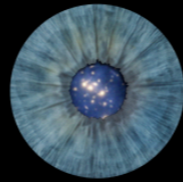
Radially-averaged mean density: In §4 we explore the 3D density structure in the Perseus-Taurus region, and discuss a large 3D-shell structure, extending from the Taurus

PUBLISHING'S INTERACTIVE CUTTING-EDGE & (AUGMENTED) FUTURE



DEMO DATA WILL APPEAR IN BIALY ET AL. 2021, AR TECHNOLOGY WILL PREMIERE IN ZUCKER ET AL. 2021

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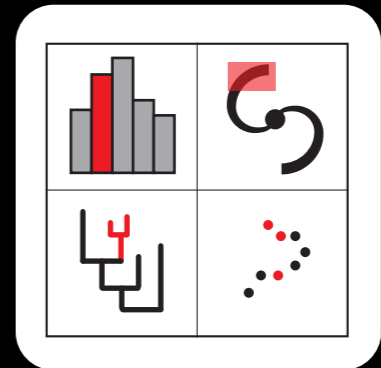
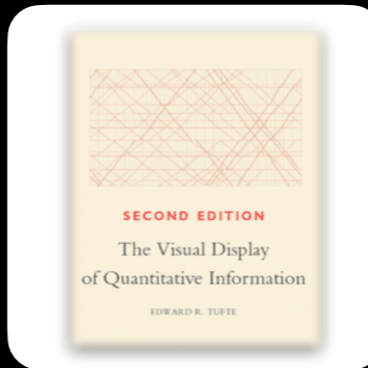
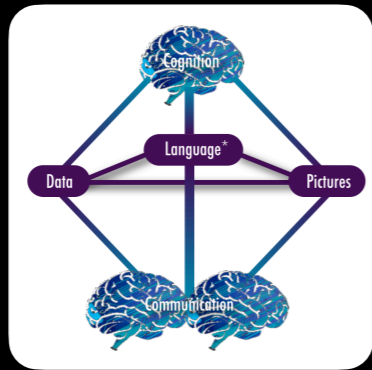
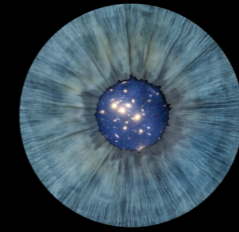
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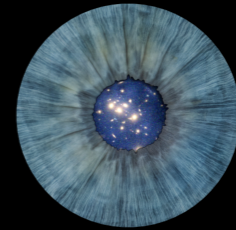
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Alyssa A. Goodman

Harvard-Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

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“TEN QUESTIONS TO ASK WHEN CREATING A VISUALIZATION”



Alyssa A. Goodman

Harvard-Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study



TEN QUESTIONS TO ASK WHEN CREATING A VISUALIZATION

The 10 Questions



1. **Who** | Who is your audience? How expert will they be about the subject and/or display conventions?
2. **Explore-Explain** | Is your goal to explore, document, or explain your data or ideas, or a combination of these?
3. **Categories** | Do you want to show or explore pre-existing, known, human-interpretable, categories?
4. **Patterns** | Do you want to identify new, previously unknown or undefined patterns?
5. **Predictions & Uncertainty** | Are you making a comparison between data and/or predictions? Is representing uncertainty a concern?
6. **Dimensions** | What is the intrinsic number of dimensions (not necessarily spatial) in your data, and how many do you want to show at once?
7. **Abstraction & Accuracy** | Do you need to show all the data, or is summary or abstraction OK?
8. **Context & Scale** | Can you, and do you want to, put the data into a standard frame of reference, coordinate system, or show scale(s)?
9. **Metadata** | Do you need to display or link to non-quantitative metadata? (including captions, labels, etc.)
10. **Display Modes** | What display modes might be used in experiencing your display?



Now, visit the [10QViz conversation!](#) There's so much more to talk about.



Arzu Çöltekin
10QViz co-founder
(with Alyssa Goodman)

Curious about the **origins** of 10QViz? Try the [About](#) page.

Want to learn **how best to use** and **participate** in 10QViz? Try the [How to](#) page.

Want to read about the **scholarship** behind 10QViz.org's questions? Try [Coltekin & Goodman 2018](#).



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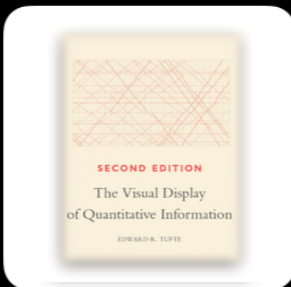
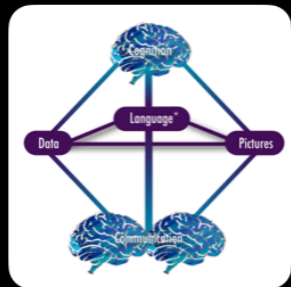
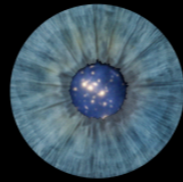


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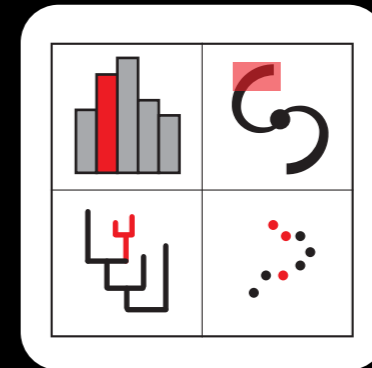
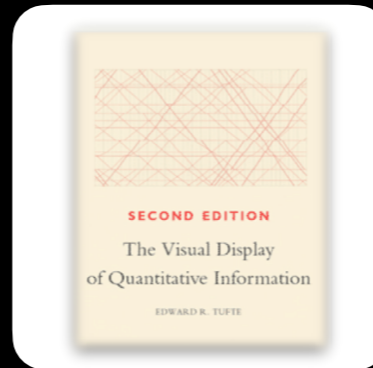
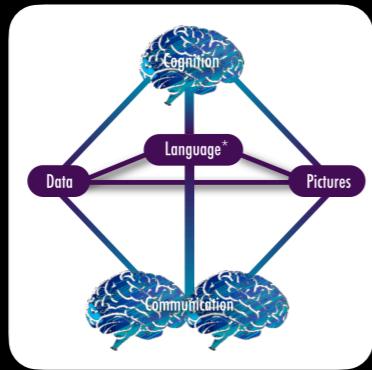
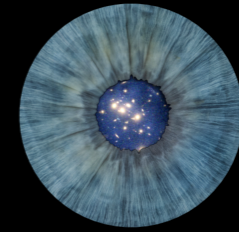
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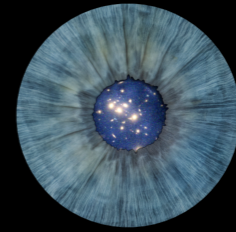
Explore

Explain

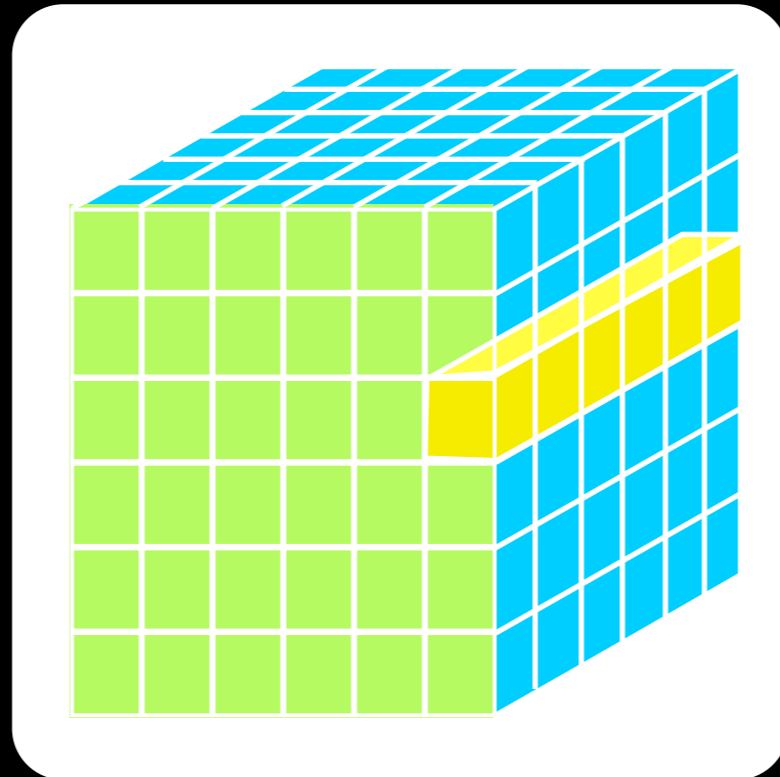
Alyssa A. Goodman

Harvard-Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

SEEING MORE OF THE UNIVERSE



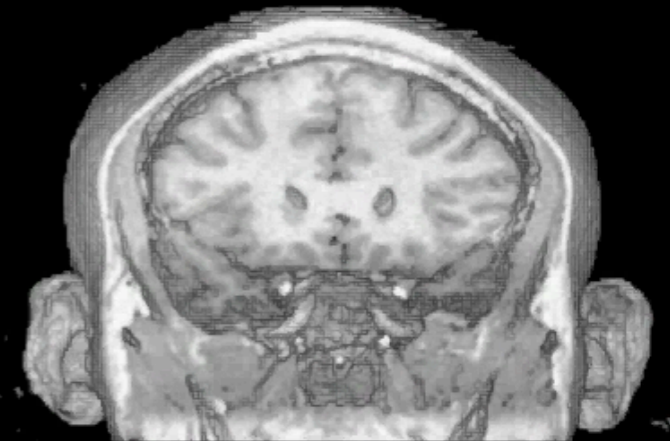
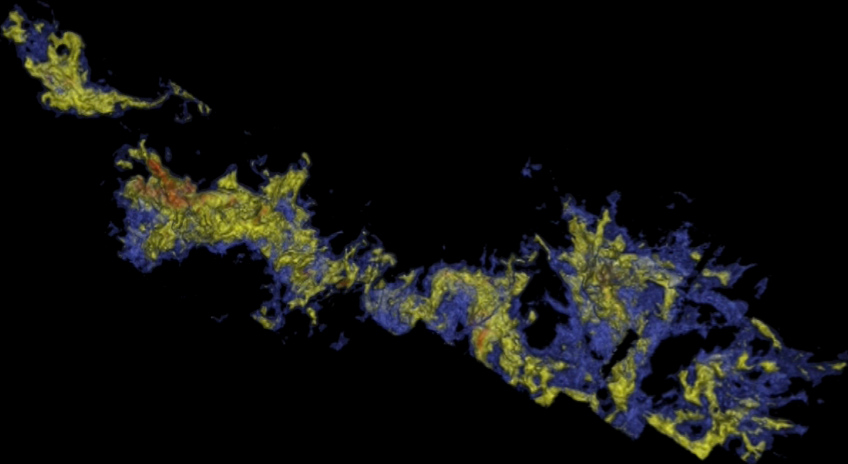
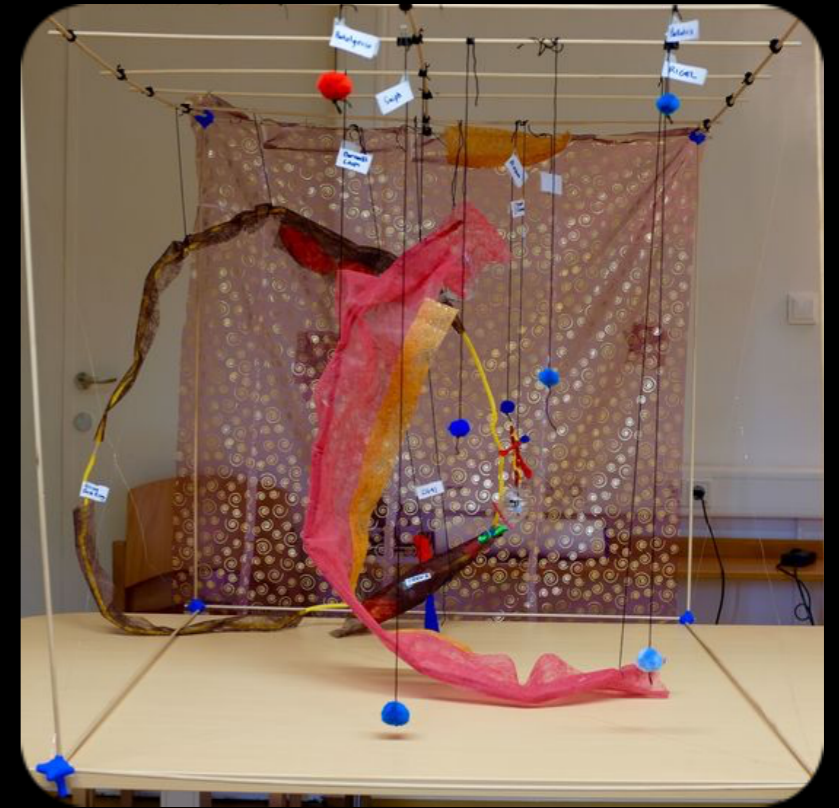
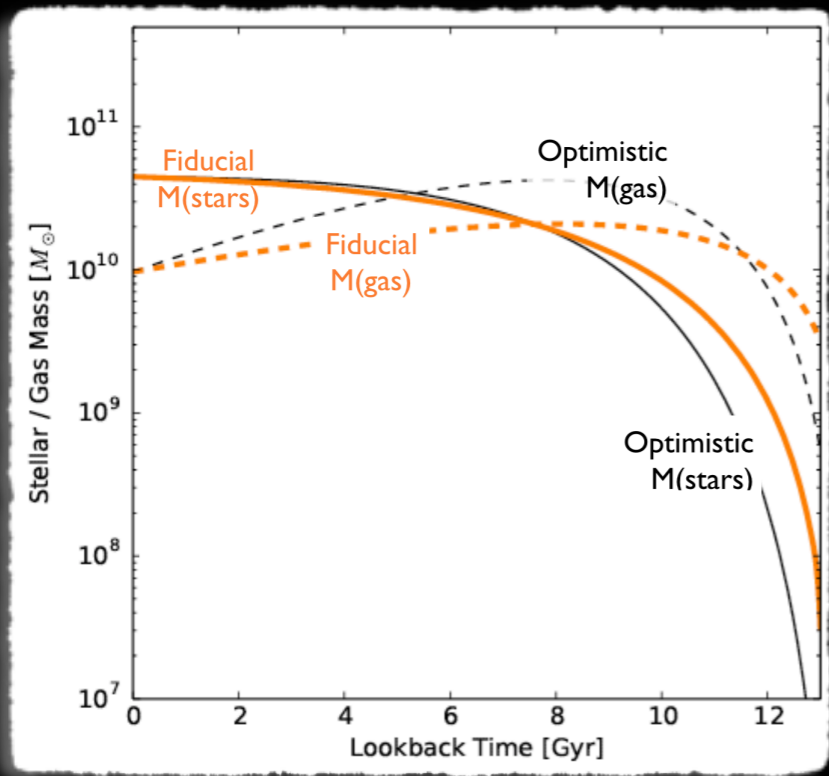
“DATA, DIMENSIONS, DISPLAY”



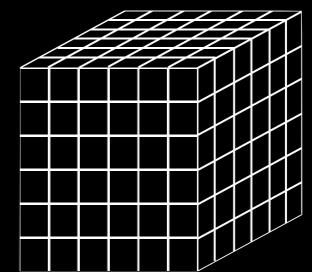
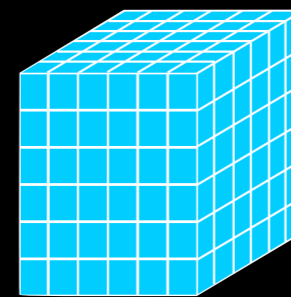
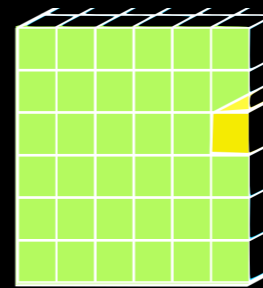
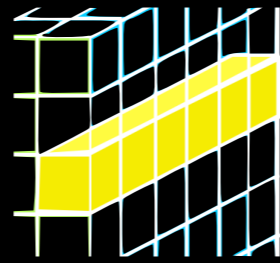
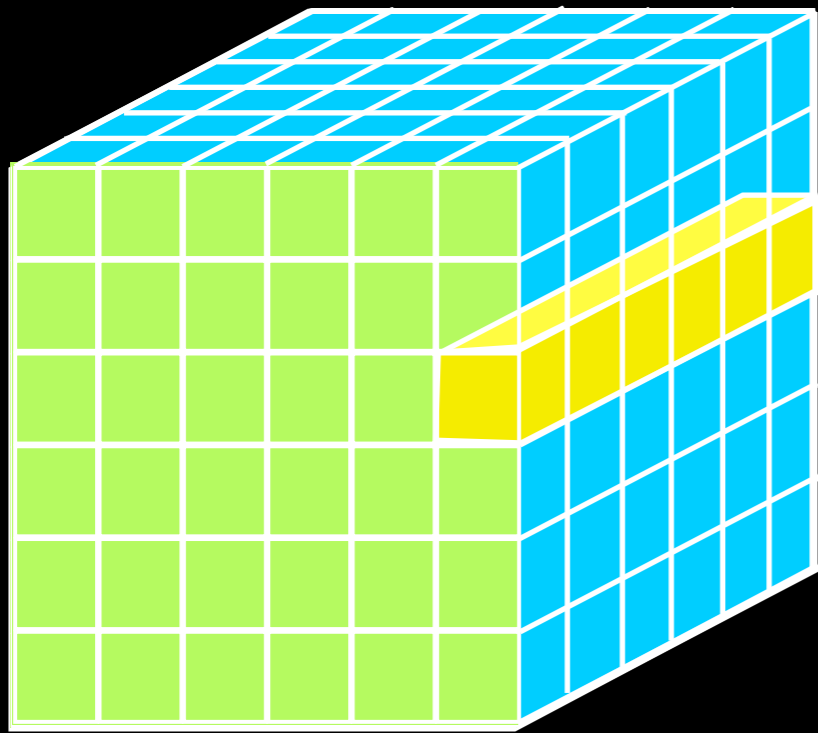
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"DATA, DIMENSIONS, DISPLAY"



"DATA, DIMENSIONS, DISPLAY"



1D: Columns = "Graphs"

2D: Faces or Slices = "Images"

3D: Volumes = "3D Renderings", "2D Movies"

4D: Time Series of Volumes = "3D Movies"

"DATA, DIMENSIONS, DISPLAY"



Home | **Explore** | Guided Tours | Search | Communities | View | Settings

Install Windows Client | Sign Out

Collections > Open Collections > Bar-pt1-pl003_sm > 1 of 1

Bar-pt1-pl003_sm

Layers

- ✓ Sky
 - Overlays
 - Constellations
 - Constellation Pictures
 - ✓ Constellation Figures
 - ✓ Constellation Boundaries
 - Constellation Names
 - Grids
 - Equatorial Grid
 - Galactic Grid
 - AltAz Grid
 - Ecliptic Grid
 - ✓ Ecliptic Overview
 - Precession Chart
 - ✓ 2d Sky
 - ✓ Show Solar System
 - ✓ 3d Solar System
 - ✓ Milky Way (Dr. R. Hurt)
 - ✓ Stars (Hipparcos, ESA)
 - ✓ Planets (NASA, ETAL)
 - Planetary Orbits
 - Moon & Satellite Orbits
 - Asteroids (IAU MPC)

Look At: Sky | Imagery: Digitized Sky Survey (Color) | Image Crossfade: [Slider]

Tracking: Bar-pt1-pl003_sm | 1 of 28

Perseus | 19:26:35

RA: 03h37m14s | Dec: +31:25:52

NGC 1333 | IC348 | Perseus A: A | NGC 1275 | Freewheeling | California Nebula | Barnard 3 | Barnard 3 | California Nebula | Image File

"DATA, DIMENSIONS, DISPLAY"



Home Explore Guided Tours Search Communities View Settings Install Windows Client Sign Out

Collections > Open Collections > Bar-pt1-pl003_sm > 1 of 1

Bar-pt1-pl003_sm

Layers

- ✓ Sky
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Look At: Sky Imagery: Digitized Sky Survey (Color) Image Crossfade: [Slider]

Tracking: Bar-pt1-pl003_sm 1 of 28

Perseus 19:26:35

RA: 03h37m14s Dec: +31:25:52

NGC 1333 IC348 Perseus A: A NGC 1275 Freewheeling California Nebula Barnard 3 Barnard 3 California Nebula Image File

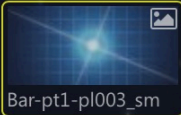


"DATA, DIMENSIONS, DISPLAY"

Home Explore **Guided Tours** Search Communities View Settings

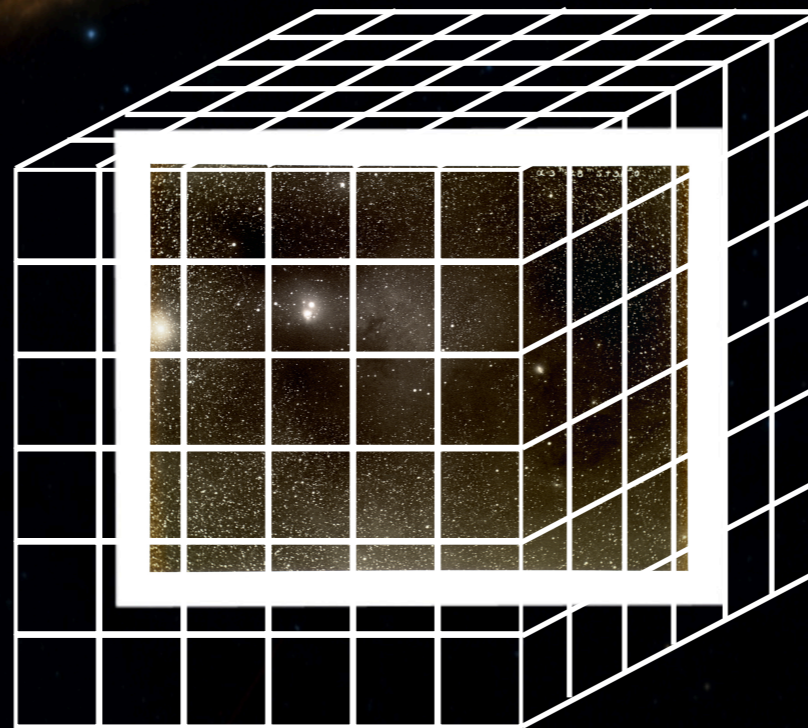
Install Windows Client Sign Out

Collections > Open Collections > Bar-pt1-pl003_sm > 1 of 1



Layers

- Sky
 - Overlays
 - Constellations
 - Constellation Pictures
 - Constellation Figures
 - Constellation Boundaries
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Look At: Sky Imagery: Digitized Sky Survey (Color) Image Crossfade: [Slider]

Tracking: Bar-pt1-pl003_sm 1 of 28

Perseus 19:26:35

RA: 03h37m14s Dec: +31:25:52


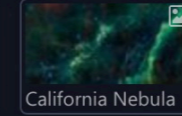
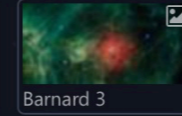
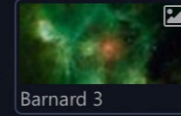
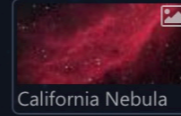


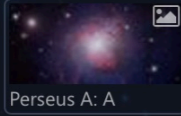
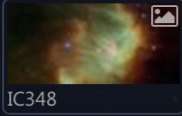






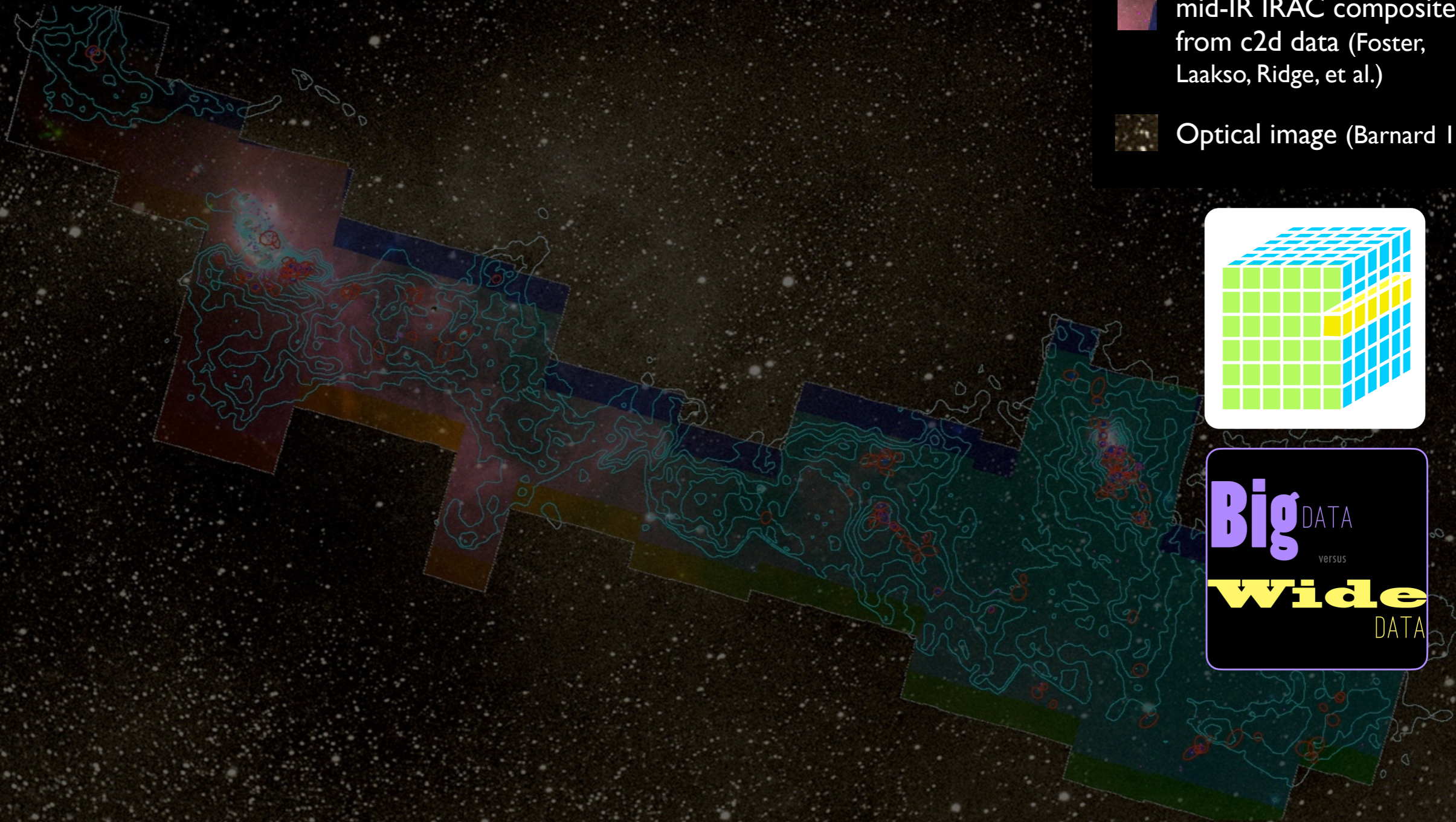


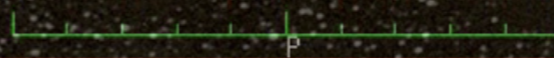
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view size: 1395 x 753
H/L: 63 WW: 127

"DATA, DIMENSIONS, DISPLAY"

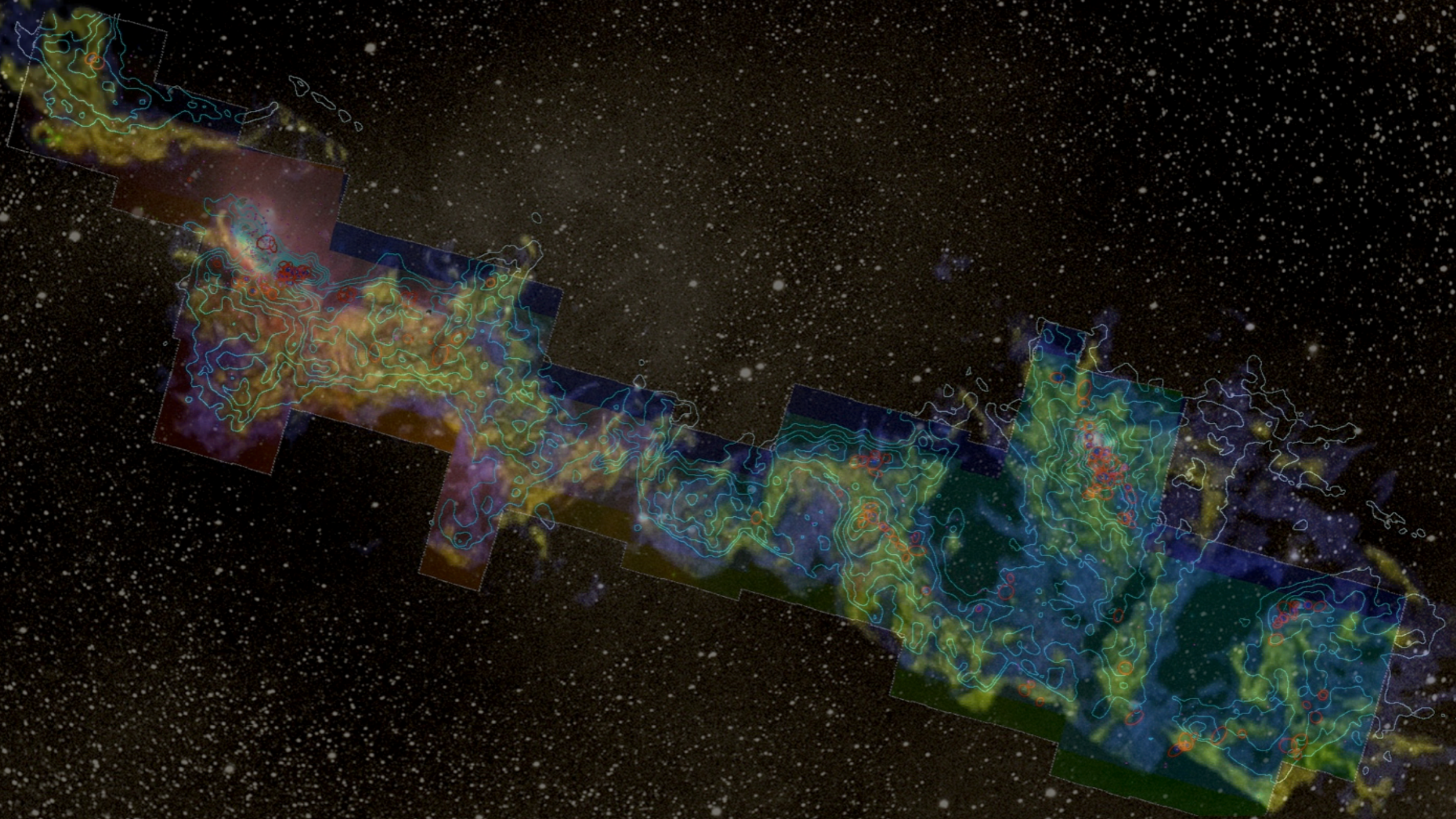
-  mm peak (Enoch et al. 2006)
-  sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)
-  ^{13}CO (Ridge et al. 2006)
-  mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al.)
-  Optical image (Barnard 1927)



Big DATA
versus
Wide DATA

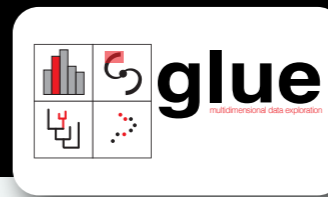


"DATA, DIMENSIONS, DISPLAY"



3D Viz made with VolView

"DATA, DIMENSIONS, DISPLAY" IN



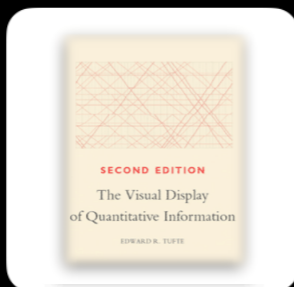
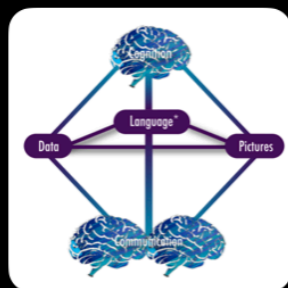
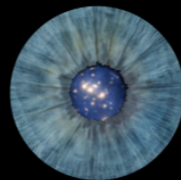
The screenshot displays the COMPLETE software interface with several panels:

- Data Collection:** Lists data sources like PerA_12coFCRAO_F_xyv and subsets like spec_probe and hot_highv.
- 2D Image:** Shows a spatial map of the Perseus region with a grid overlay.
- 1D Profile:** A plot of Data values vs Velocity, showing spectral profiles for different data sources.
- 2D Scatter:** A scatter plot of TIRAS vs V13CO with a red circle highlighting a cluster of points.
- 3D Volume Rendering:** A 3D visualization of the data volume.
- Plot Layers:** A list of layers with checkboxes and styling options (color, opacity, linewidth).
- Plot Options - 1D Profile:** Settings for the 1D profile plot, including function (Maximum), reference (PerA_12coFCRAO_F_xyv), and x-axis (Velocity).
- WorldWide Telescope:** A background image of the Perseus region with the WWT logo.

COMPLETE

V. 2021—FULLY INTERACTIVE & TIED TO EVER-WIDER DATA VIA WWT SKY BROWSER

SEEING MORE OF THE UNIVERSE



Explore

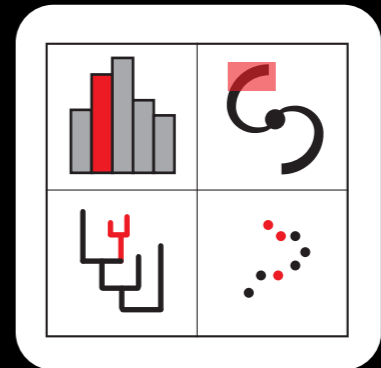
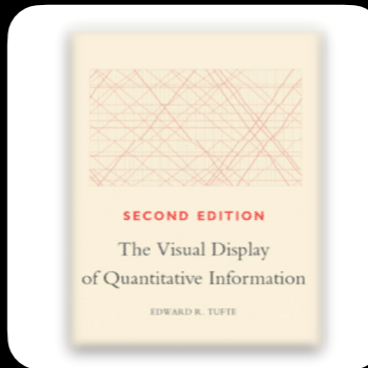
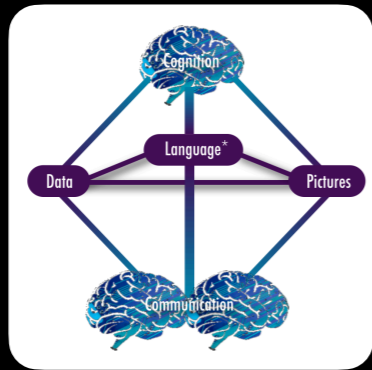
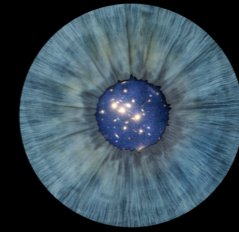
Explain

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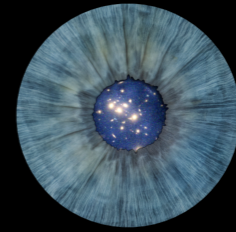
Explore

Explain

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SEEING MORE OF THE UNIVERSE



“BIG DATA VS. WIDE DATA”








Alyssa A. Goodman

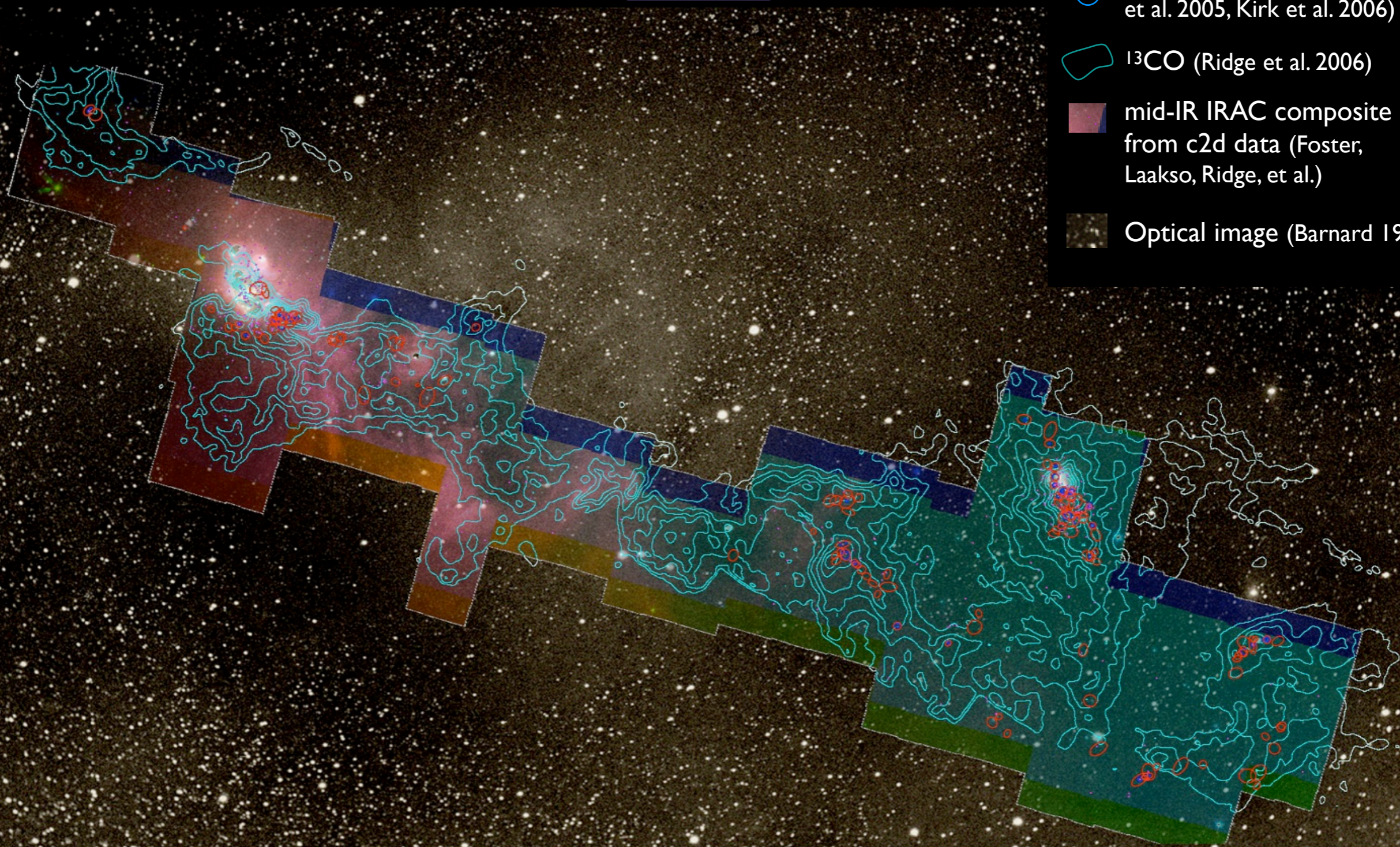
Harvard-Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

WIDE DATA

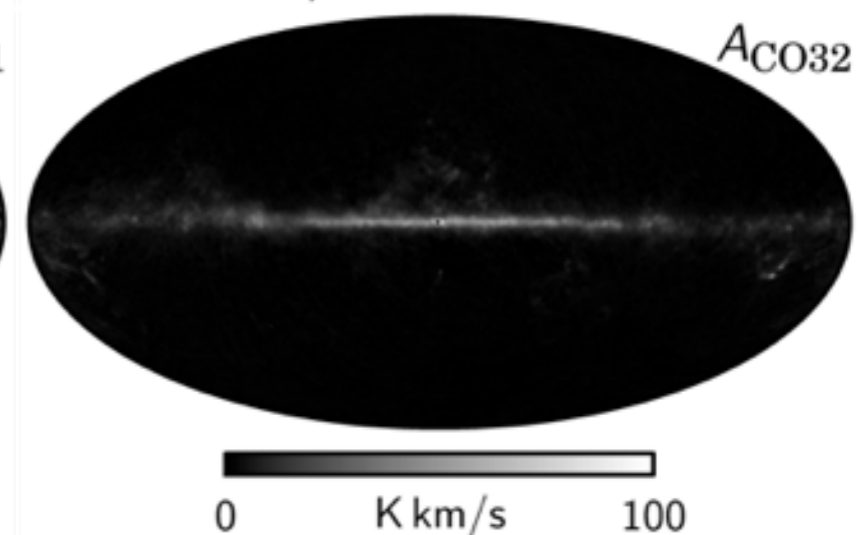
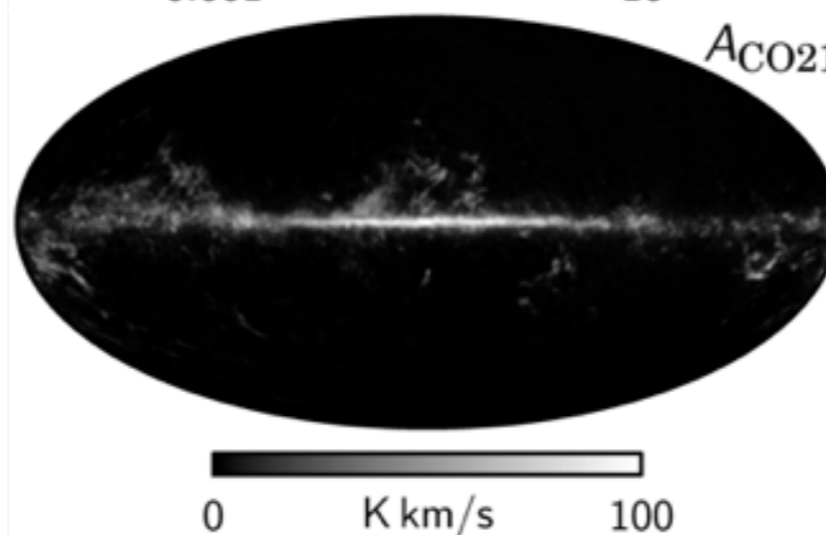
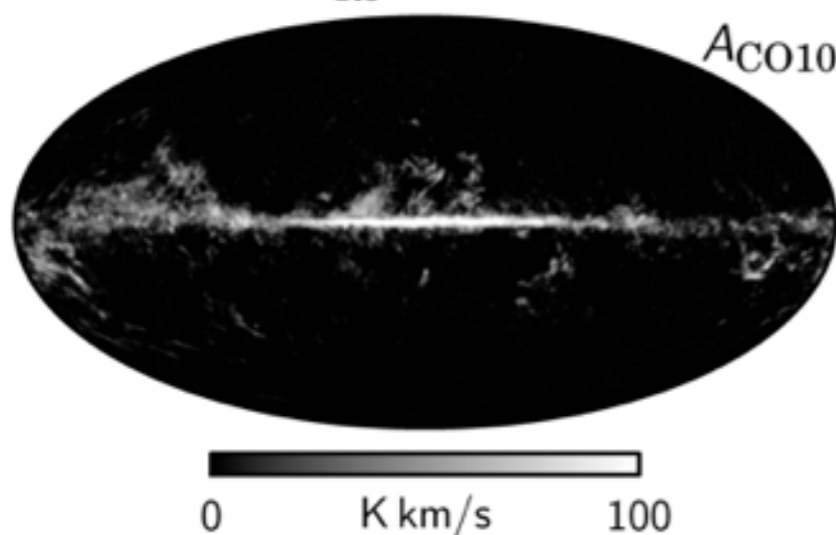
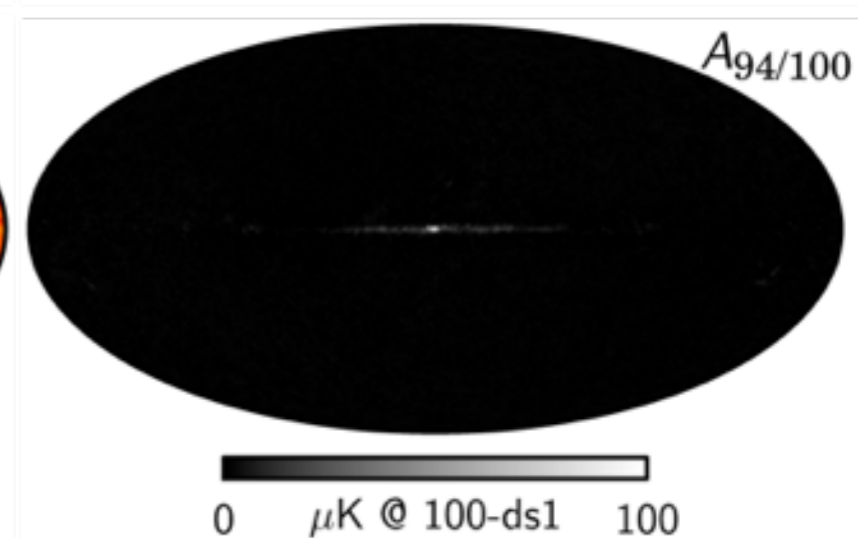
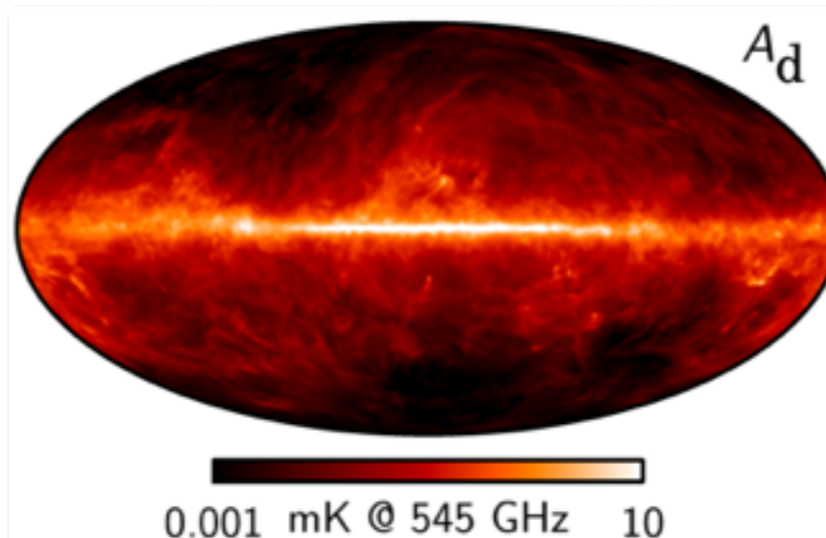
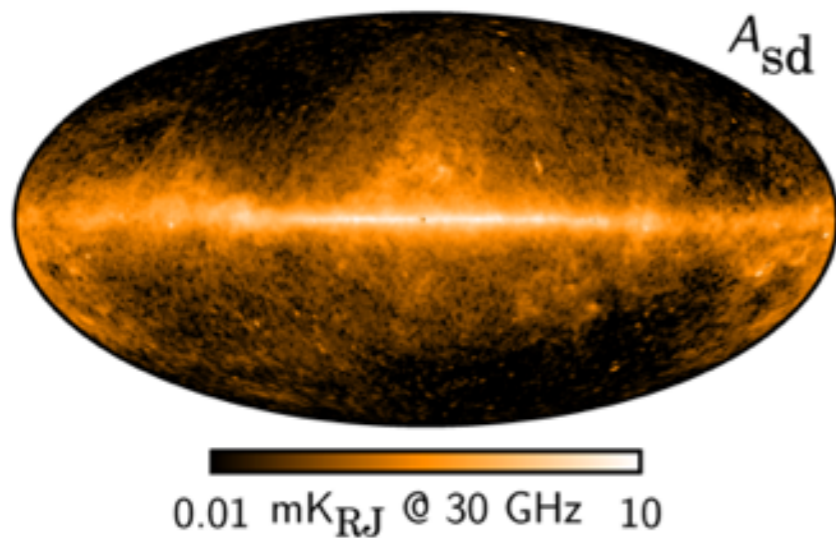
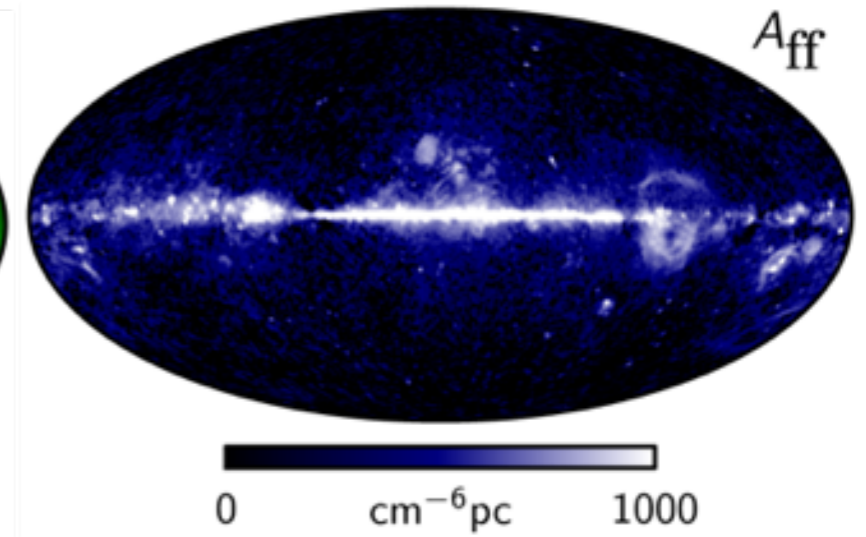
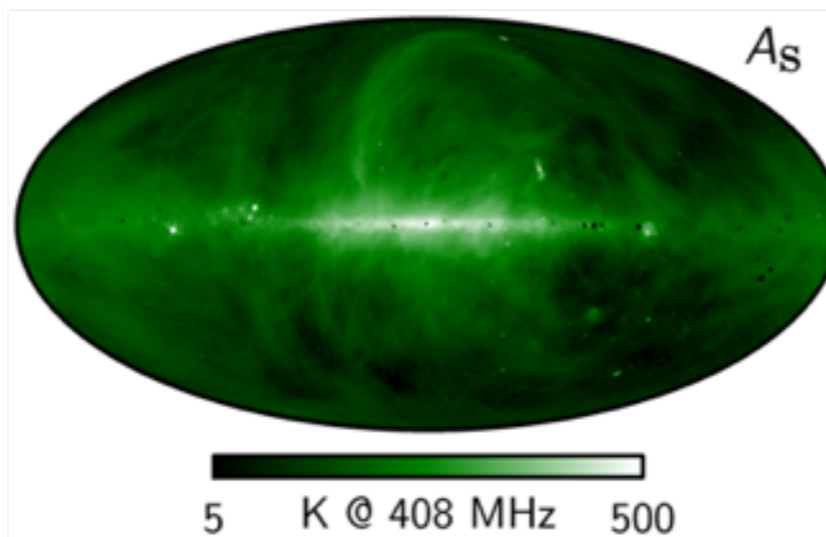
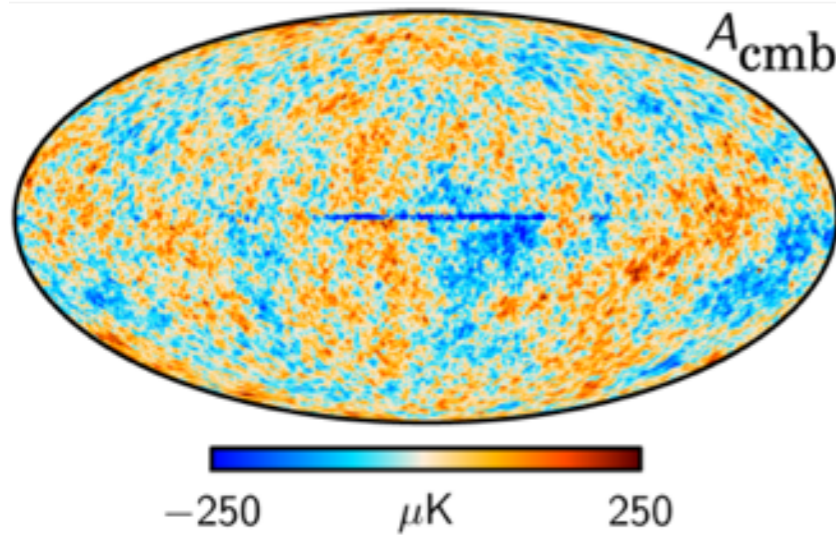


COMPLETE

-  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)



WIDE DATA



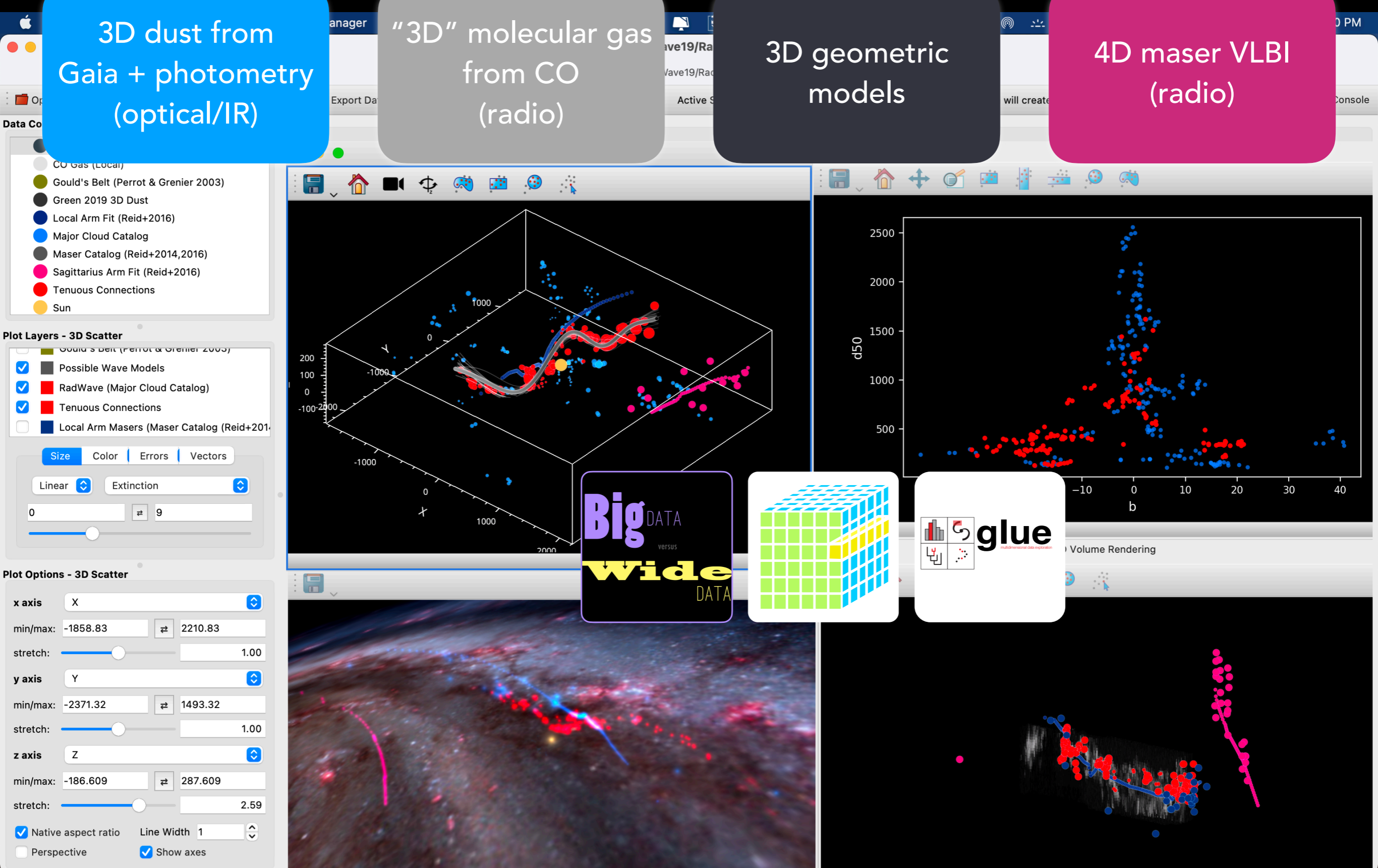
WIDE DATA DISCOVERY: THE RADCLIFFE WAVE

3D dust from Gaia + photometry (optical/IR)

"3D" molecular gas from CO (radio)

3D geometric models

4D maser VLBI (radio)



Big DATA
versus
Wide DATA

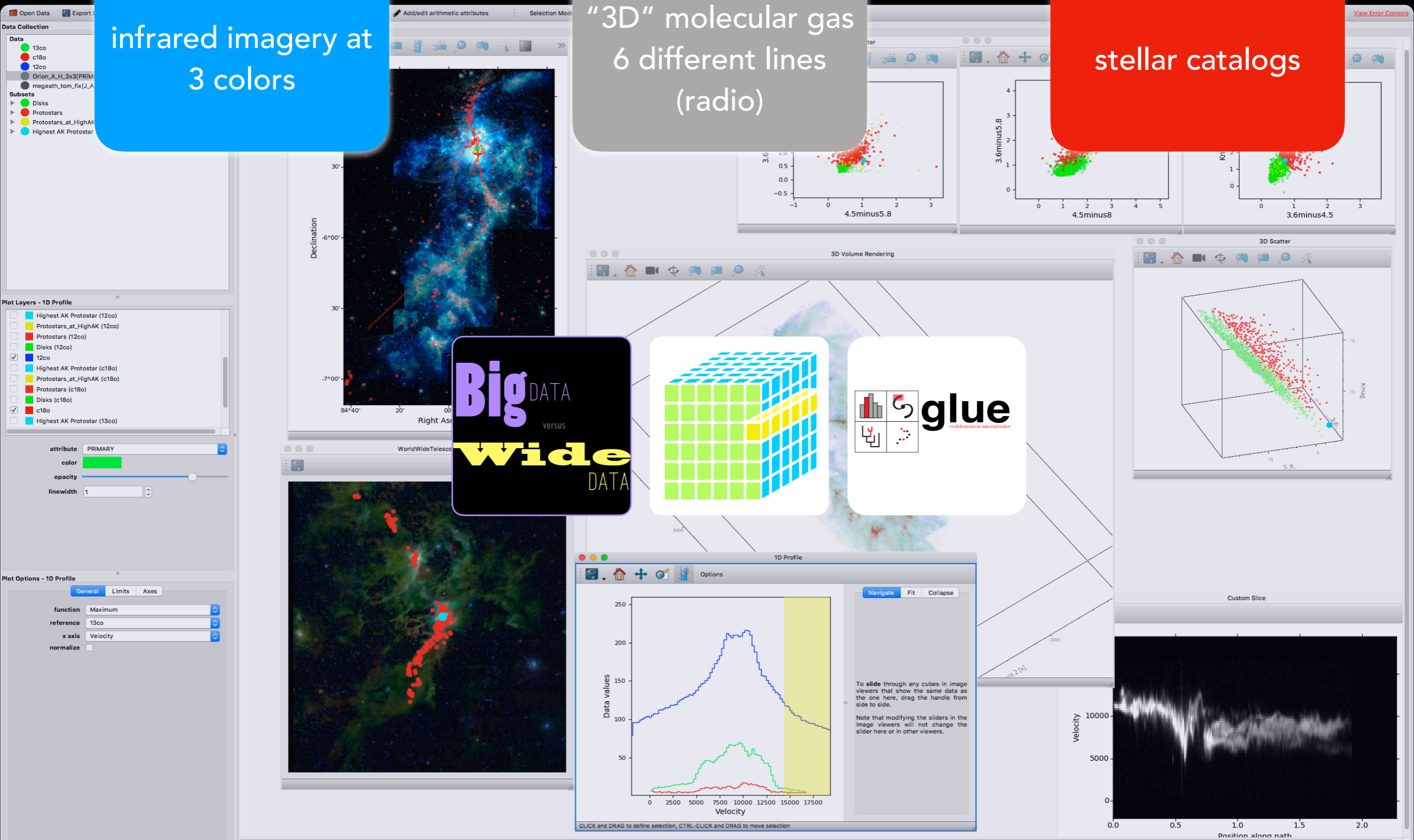


EVEN "BIGGER & WIDER" DATA: ORION IN GLUE

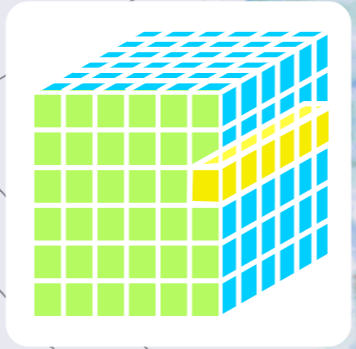
infrared imagery at
3 colors

"3D" molecular gas
6 different lines
(radio)

stellar catalogs



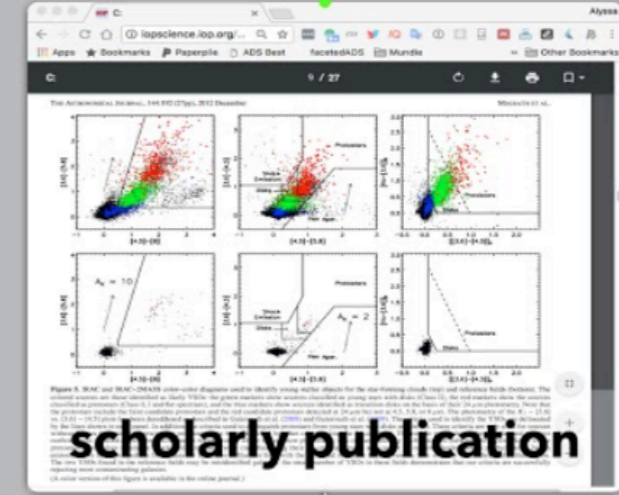
Big DATA
VERSUS
Wide DATA



DATA,
CODE,
COLLABORATION

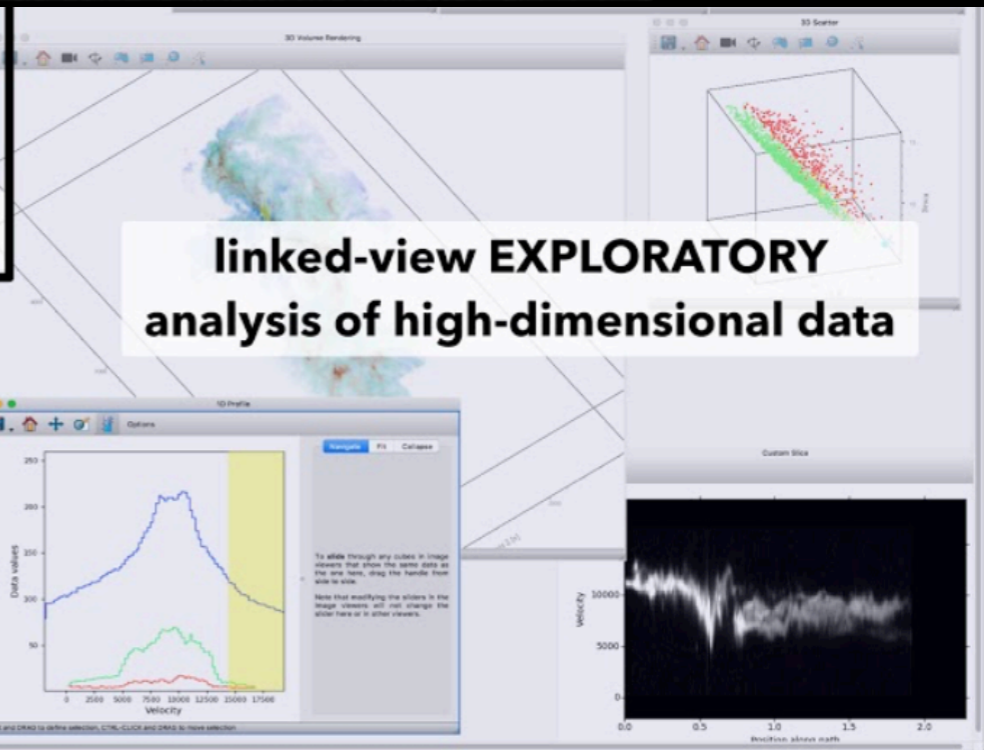
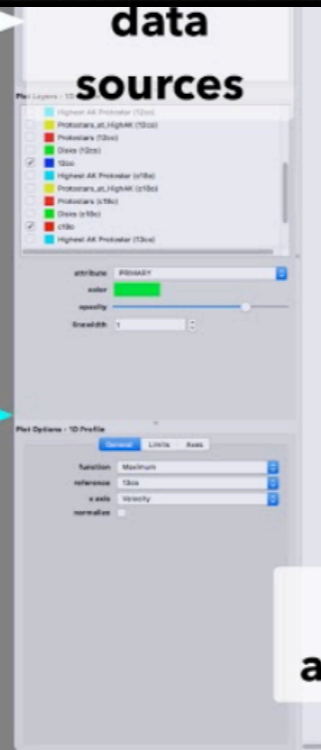


DATA-DRIVEN STORYTELLING



Explore

Explain



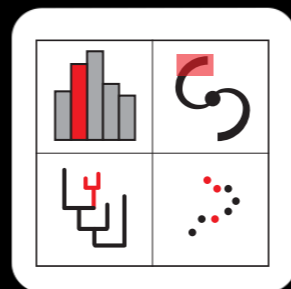
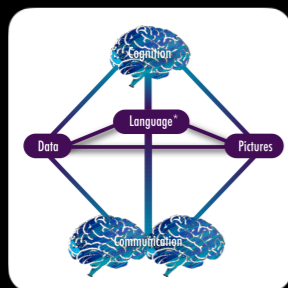
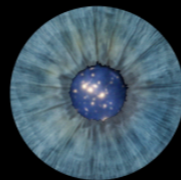
EXPLORATION



EXPLANATION



SEEING MORE OF THE UNIVERSE



Explore

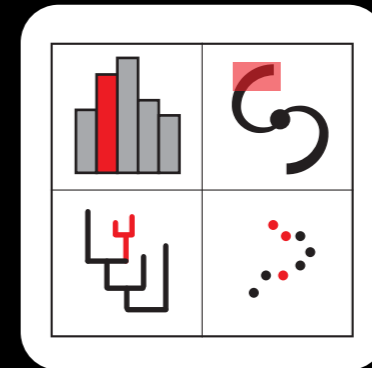
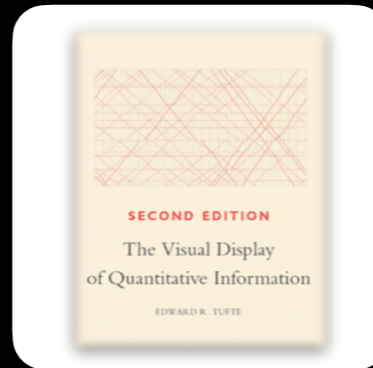
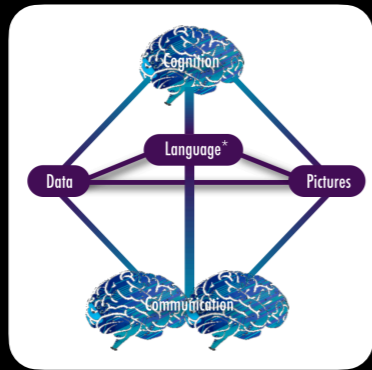
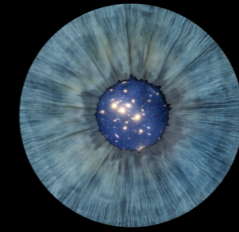
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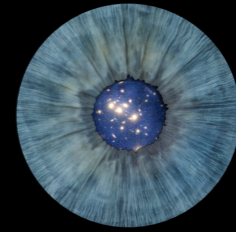
Explore

Explain

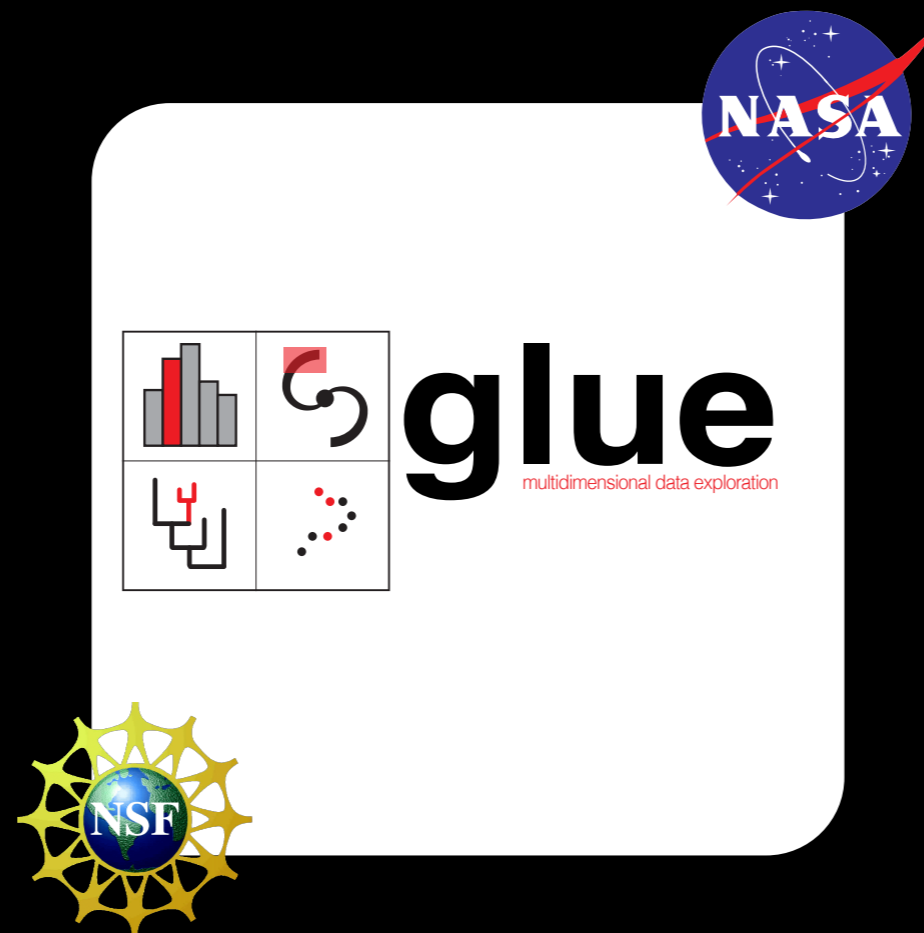
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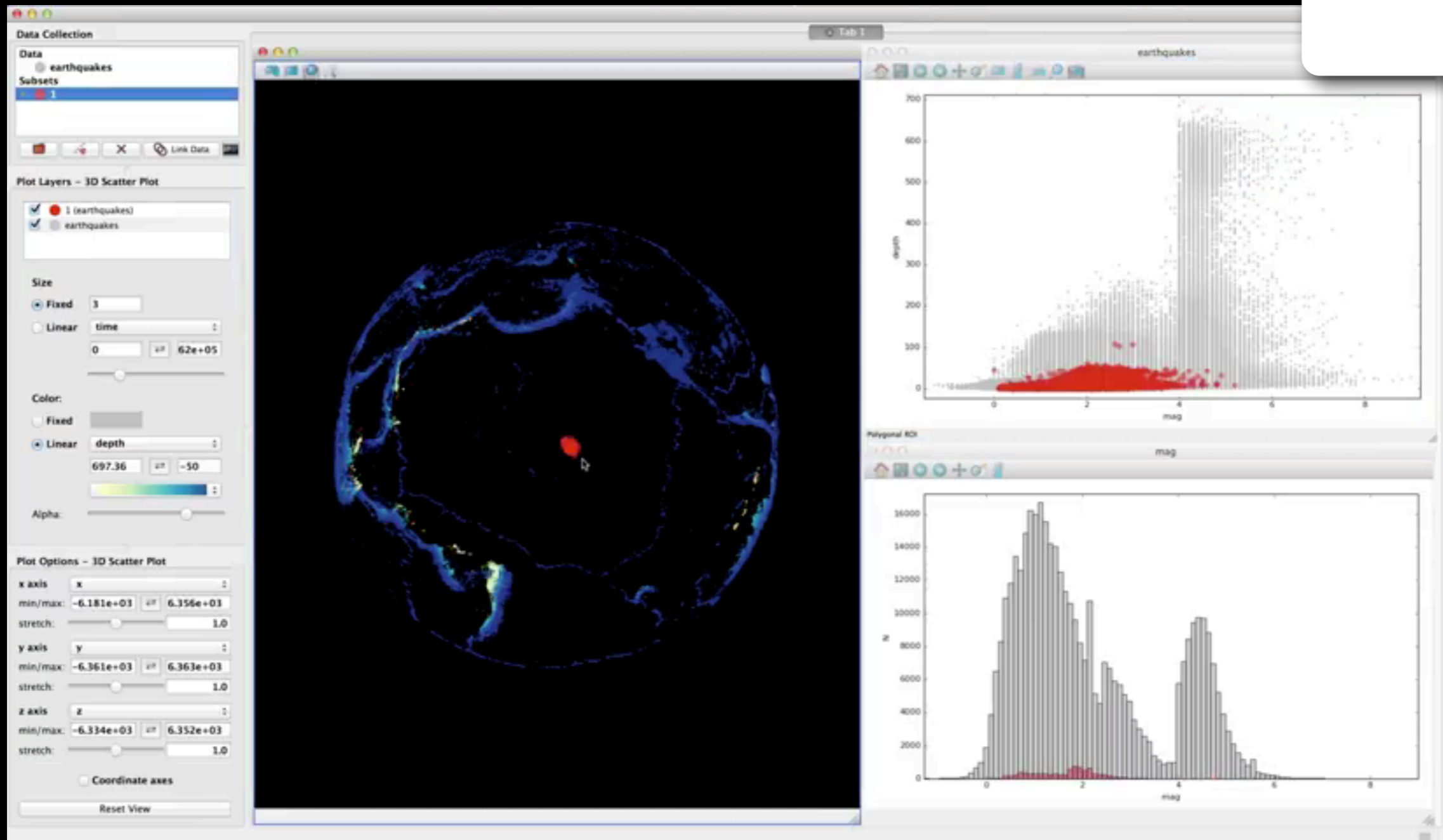
“LINKED-VIEWS, IN GLUE”



Alyssa A. Goodman

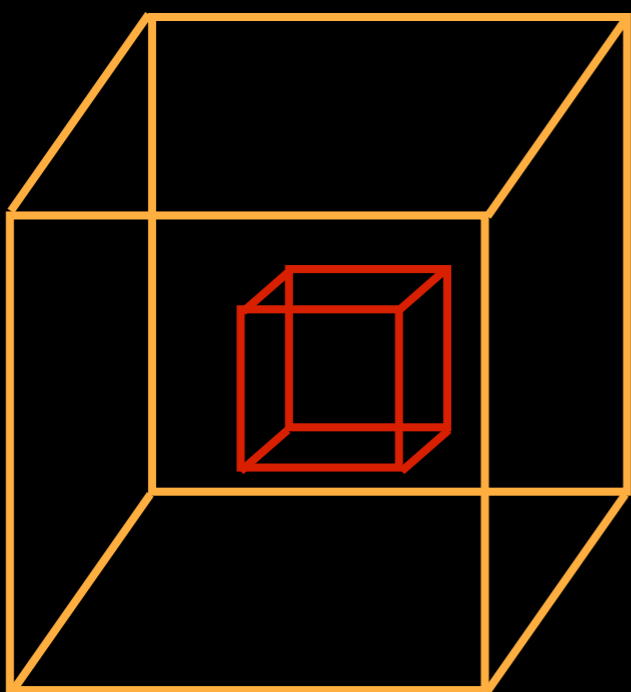
Harvard-Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

LINKED VIEWS OF HIGH-DIMENSIONAL DATA, IN PYTHON

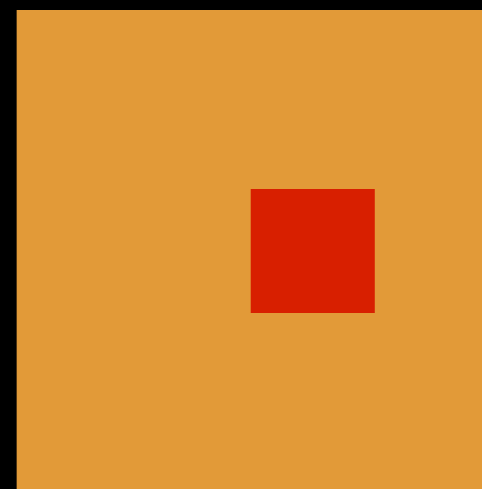


video by Tom Robitaille, lead glue developer
glue created by: C. Beaumont, M. Borkin, A. Goodman (PI), T. Robitaille, C. Zucker, et al.

LINKED VIEWS OF HIGH-DIMENSIONAL DATA

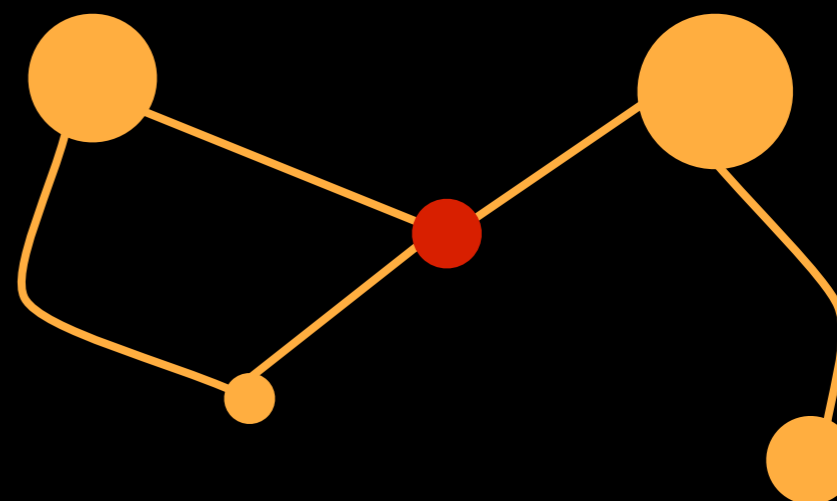


3D

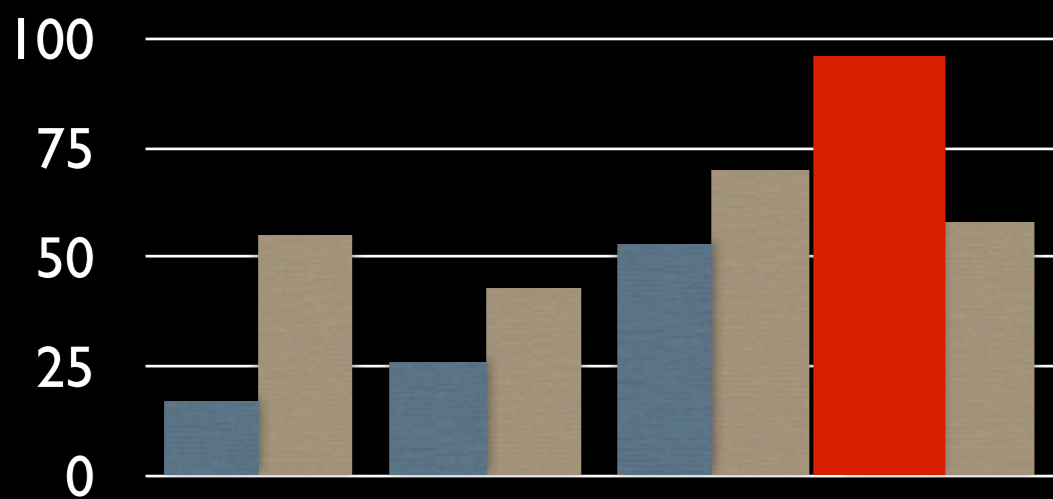


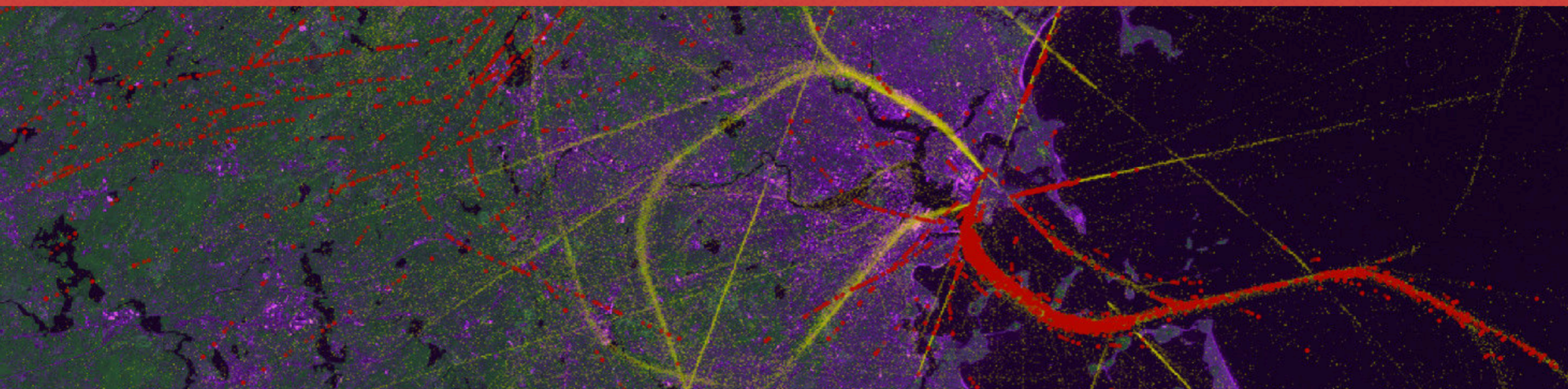
2D

Data Abstraction

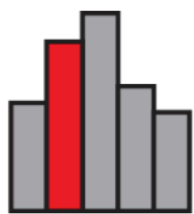


Statistics





Glue is an open-source Python library to explore relationships within and between related datasets



Linked Visualizations

With Glue, users can create scatter plots, histograms and images (2D and 3D) of their data. Glue is focused on the



Flexible linking across data

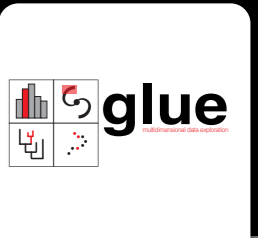
Glue uses the logical links that exist between different data sets to overlay visualizations of different data, and to



Full scripting capability

Glue is written in Python, and built on top of its standard scientific libraries (i.e., Numpy, Matplotlib, Scipy). Users can

LINKED VIEWS OF HIGH-DIMENSIONAL DATA, IN PYTHON



- fastplanes
- nearglound
- Descending
- Climbing
- Landing
- A Day in the Life of Logan

- Plot Layers - 2D Scatter
- A Day in the Life of Logan (airplane_positions)
 - Landing (airplane_positions)
 - Climbing (airplane_positions)
 - Descending (airplane_positions)
 - nearglound (airplane_positions)

Color Points Line Errors Vectors

color Fixed

opacity

Plot Options - 2D Scatter

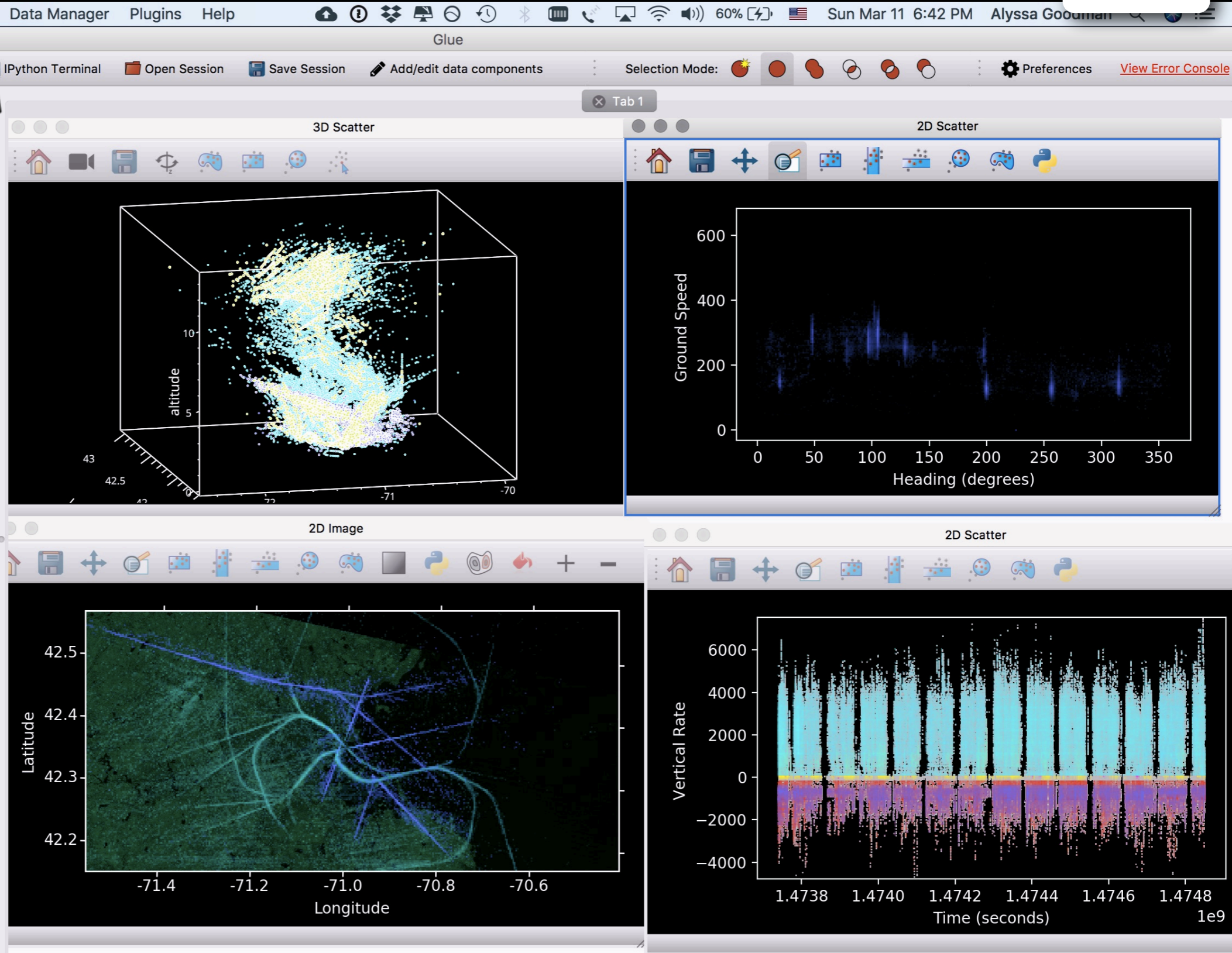
General Limits Axes

x label: Heading (degrees)

y label: Ground Speed

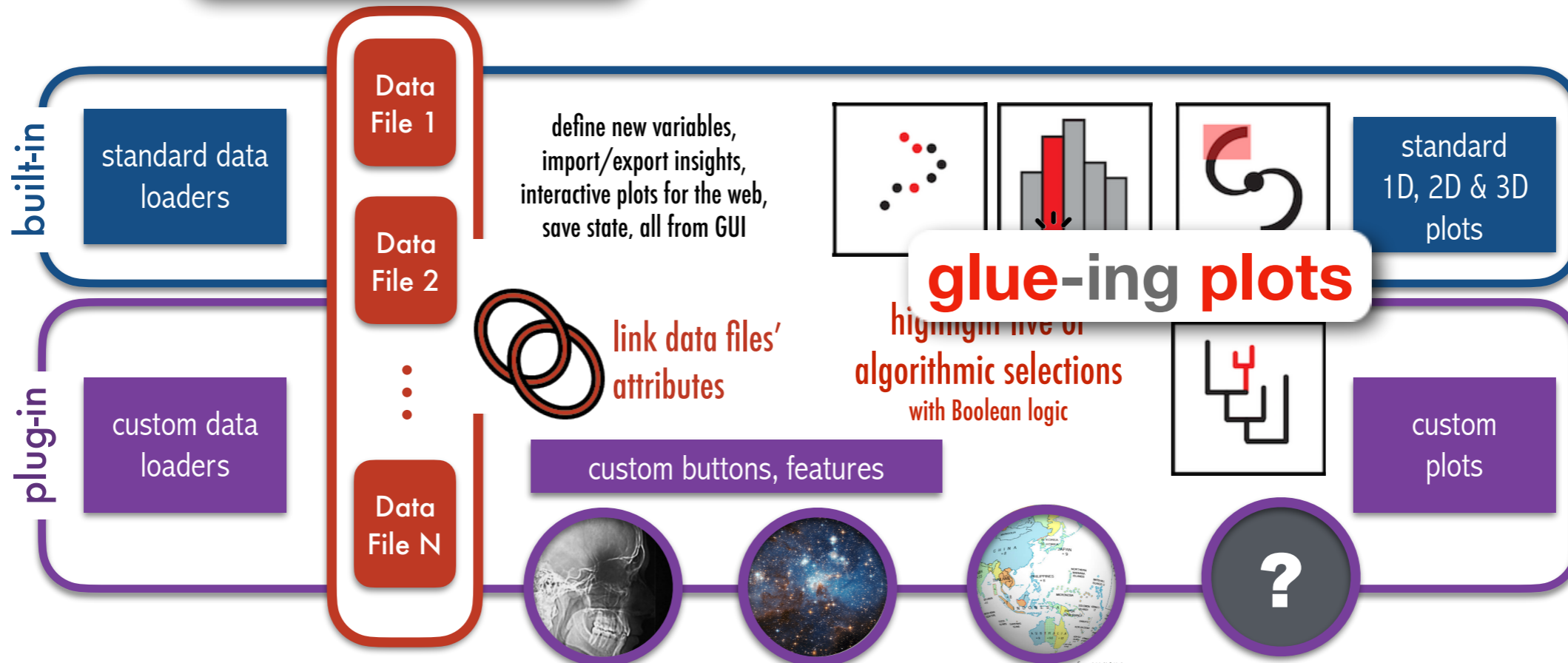
	x	y
axis label size	10	10
axis label weight	medium	medium
tick label size	10	10

Apply to all plots





glue-ing data



+options

user config.py file
(loaders, colors, plot types, +)



access to all matplotlib functions through built-in IPython terminal



run & interact with glue from Jupyter notebook & other tools

glue-ing tools

Data Collection

Data

- PerA_12coFCRAO_F_xyv
- PerA_13coFCRAO_F_xyv
- Perseus_Av_NICER
- PerA_AvTemMIPS_F_Av
- PerA_AvTemMIPS_F_T
- Perseus_fcrao_iras_2mass

Subsets

- spec_probe
- hot_highv
- near B5

Plot Layers - 1D Profile

- hot_highv (PerA_AvTemMIPS_F_Av)
- hot_highv (Perseus_Av_NICER)
- hot_highv (PerA_13coFCRAO_F_xyv)
- hot_highv (PerA_12coFCRAO_F_xyv)
- spec_probe (PerA_AvTemMIPS_F_T)
- spec_probe (PerA_AvTemMIPS_F_Av)
- spec_probe (Perseus_Av_NICER)
- spec_probe (PerA_13coFCRAO_F_xyv)
- spec_probe (PerA_12coFCRAO_F_xyv)
- PerA_AvTemMIPS_F_T
- PerA_AvTemMIPS_F_Av
- Perseus_Av_NICER
- PerA_13coFCRAO_F_xyv
- PerA_12coFCRAO_F_xyv

attribute: PRIMARY

color: [red bar]

opacity: [slider]

linewidth: 1

Plot Options - 1D Profile

General Limits Axes Legend

function: Maximum

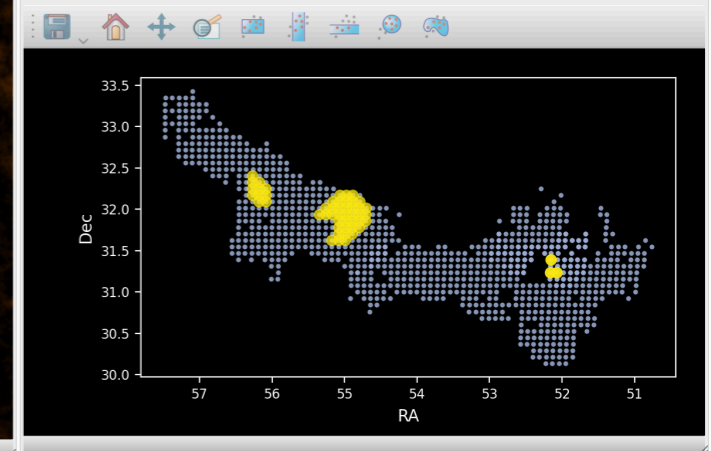
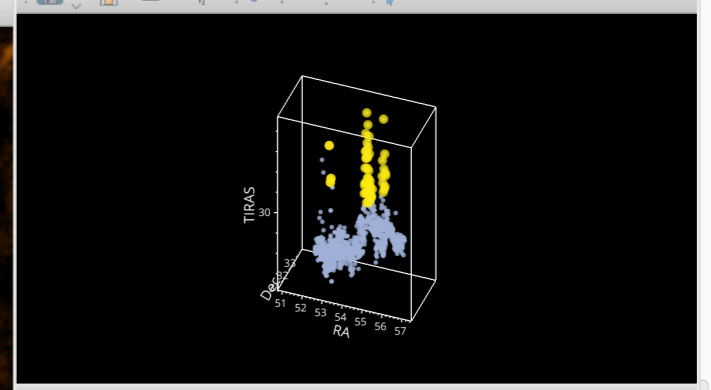
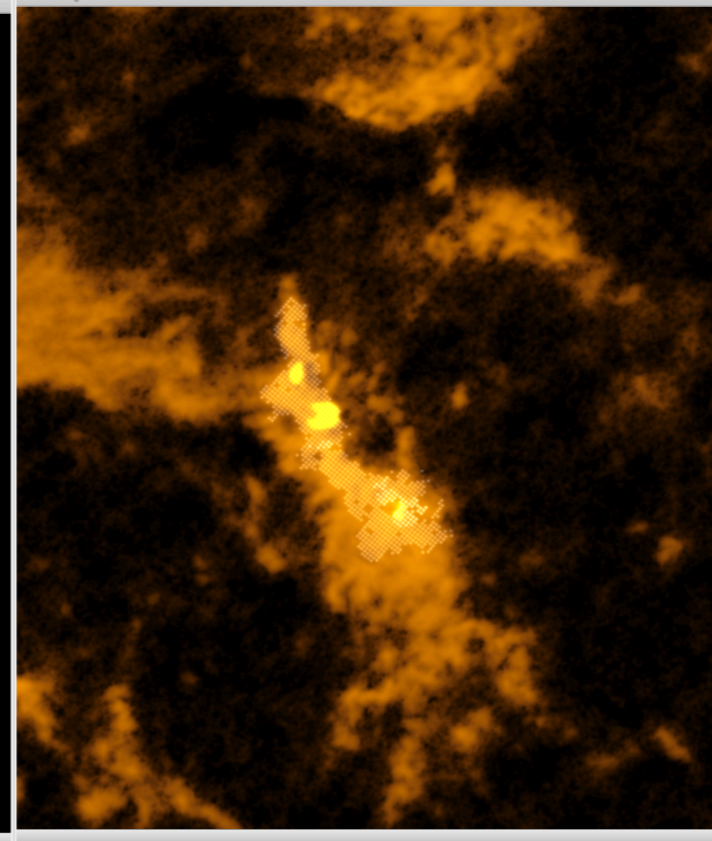
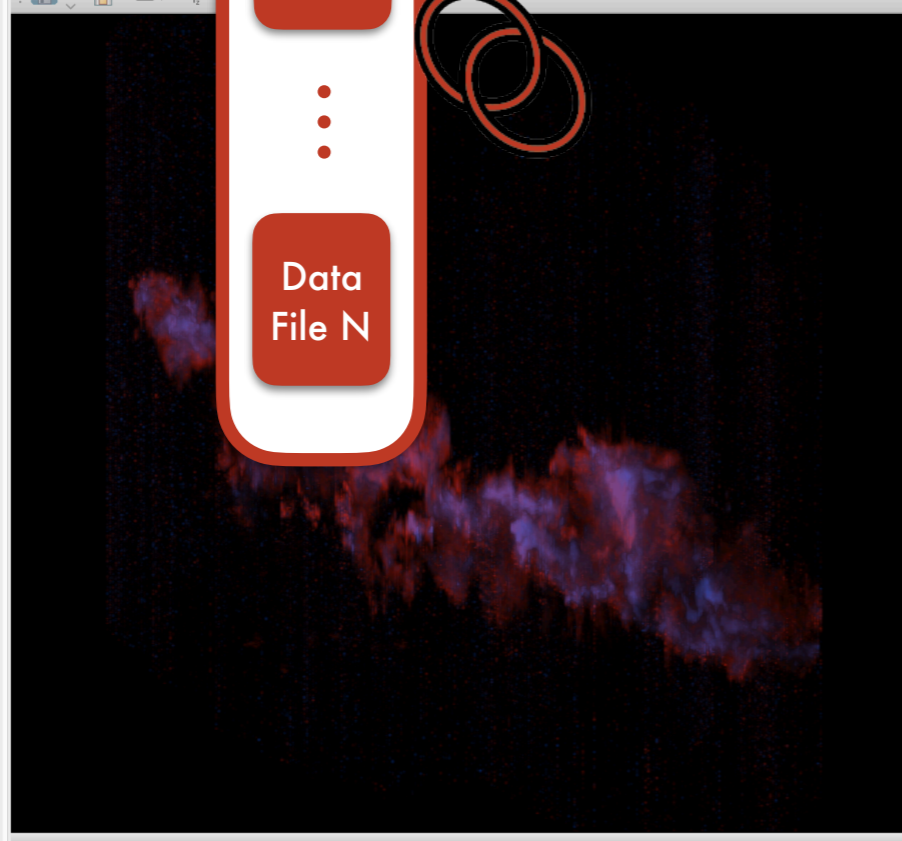
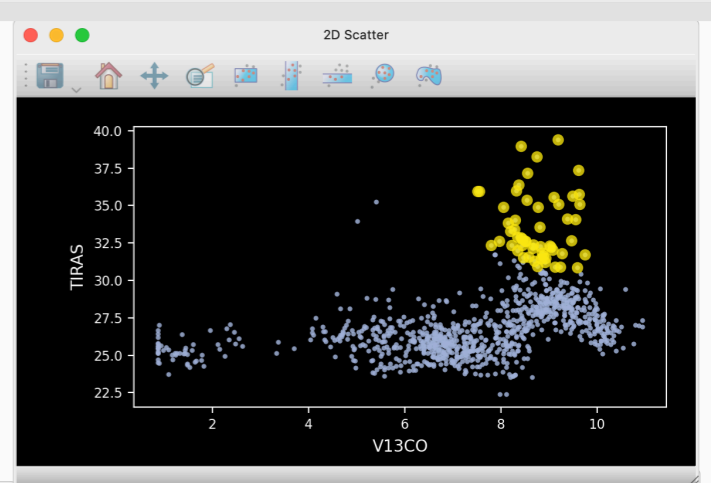
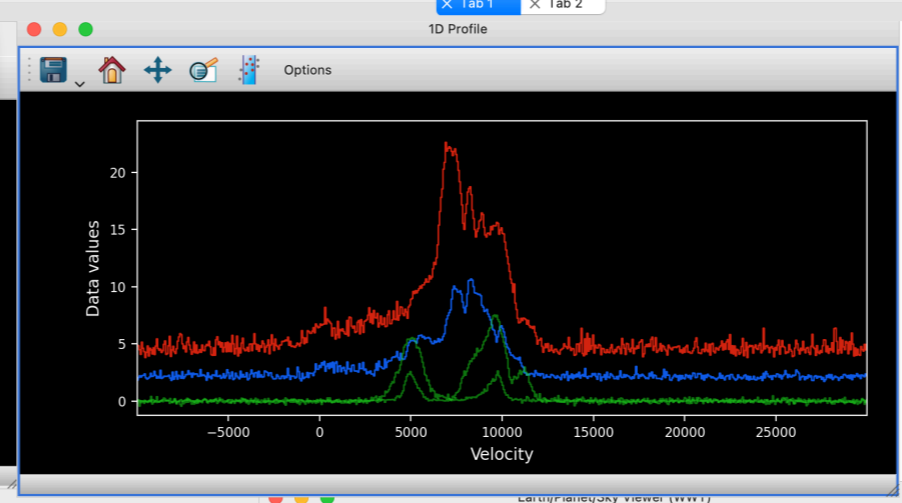
reference: PerA_12coFCRAO_F_xyv

x axis: Velocity

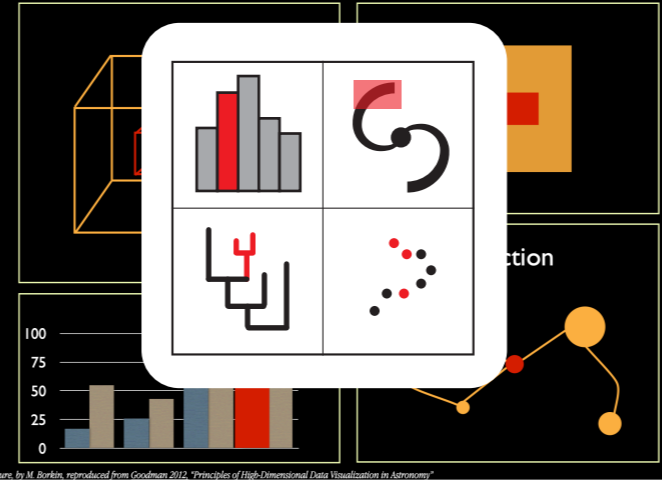
normalize:

glue-ing data

- Data File 1
- Data File 2
- ⋮
- Data File N



Linked Views of High-dimensional Data



Glueviz interface showing Data Collection, Subsets, Plot Layers - 1D Profile, and Plot Options - 1D Profile.

Data Collection

- PerA_12coFCRAO_F_xyv
- PerA_13coFCRAO_F_xyv
- Perseus_Av_NICER
- PerA_AvTemMIPS_F_Av
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Plot Layers - 1D Profile

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- hot_highv (PerA_12coFCRAO_F_xyv)
- spec_probe (PerA_AvTemMIPS_F_T)
- spec_probe (PerA_AvTemMIPS_F_Av)
- spec_probe (Perseus_Av_NICER)
- spec_probe (PerA_13coFCRAO_F_xyv)
- spec_probe (PerA_12coFCRAO_F_xyv)
- PerA_AvTemMIPS_F_T
- PerA_AvTemMIPS_F_Av
- Perseus_Av_NICER
- PerA_13coFCRAO_F_xyv
- PerA_12coFCRAO_F_xyv

Plot Options - 1D Profile

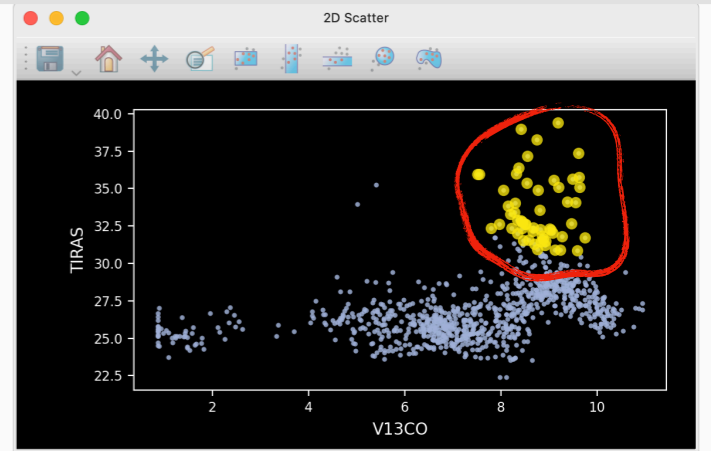
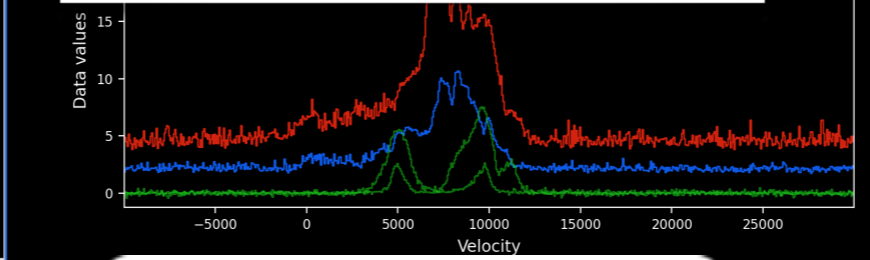
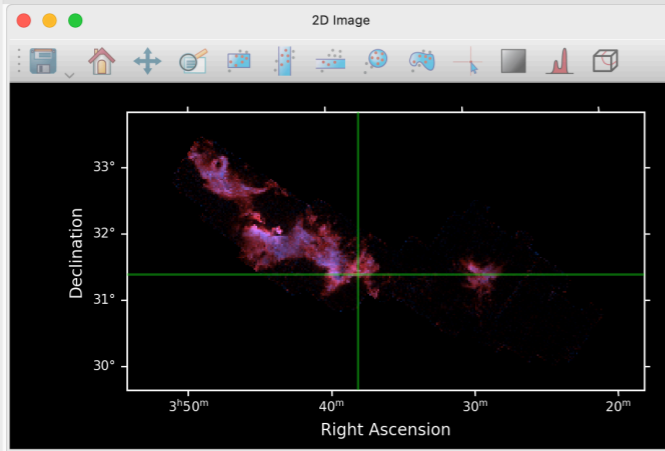
General | Limits | Axes | Legend

function: Maximum

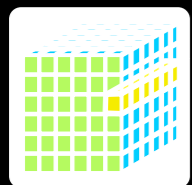
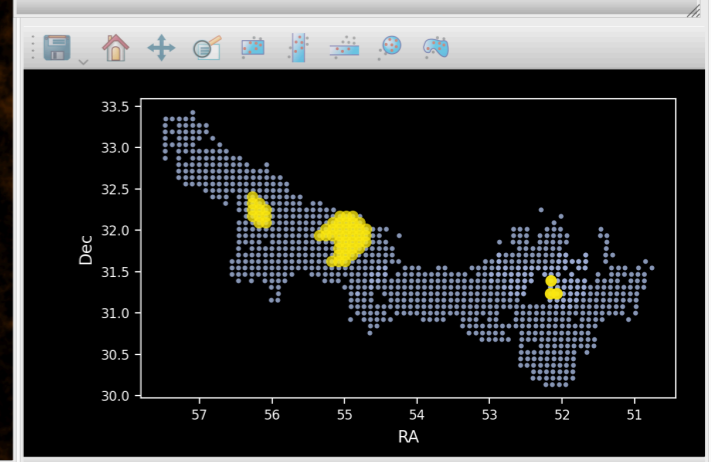
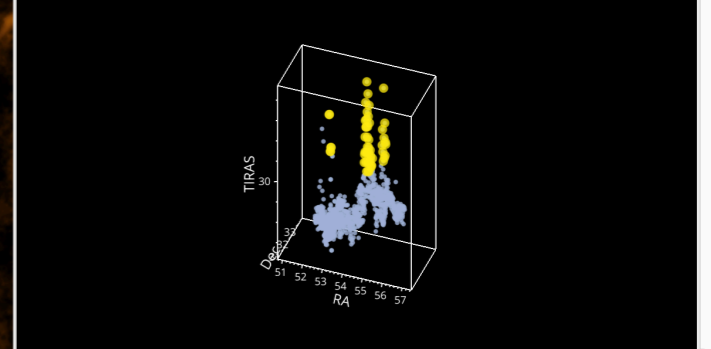
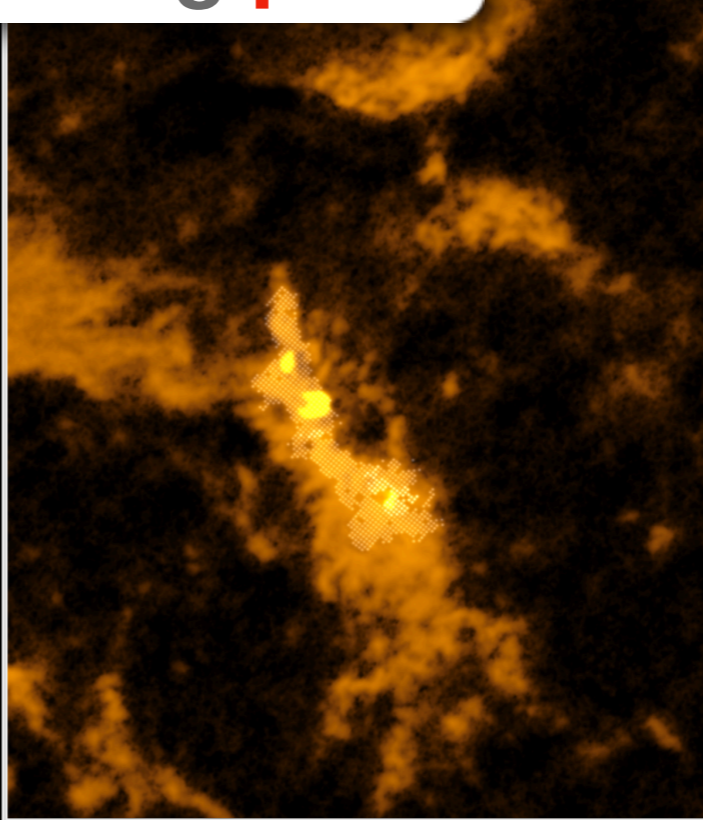
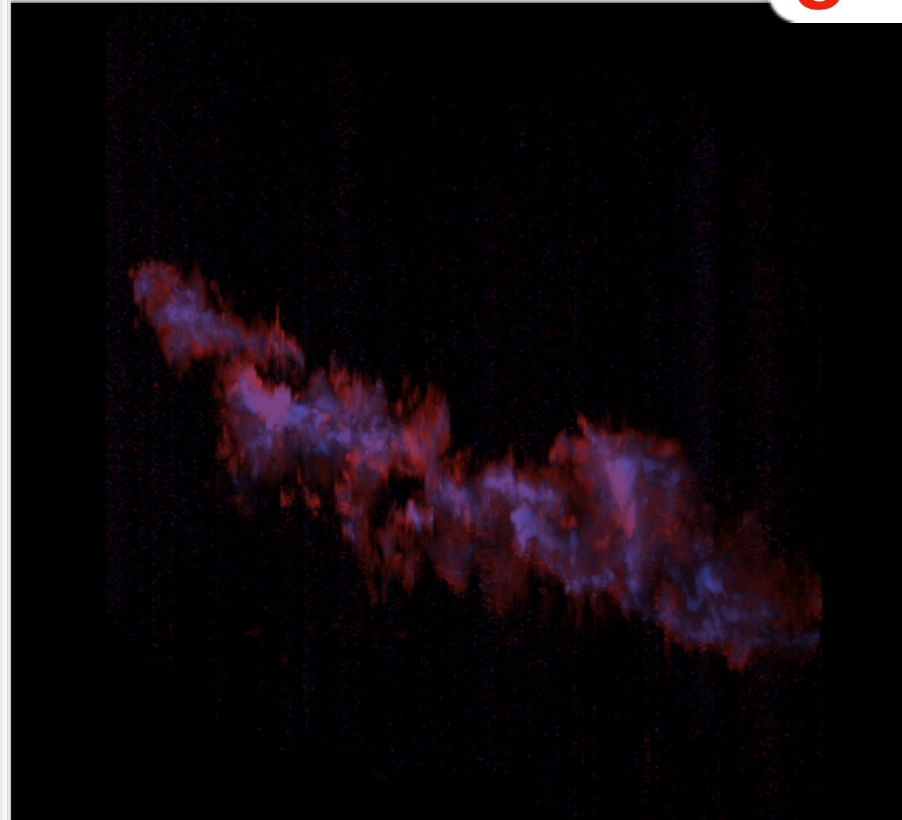
reference: PerA_12coFCRAO_F_xyv

x axis: Velocity

normalize:



glue-ing plots



SEE "DATA, DIMENSIONS, DISPLAY" AND "BIG DATA, WIDE DATA" FOR MORE ON THIS EXAMPLE





glue-ing tools

Glue: multi-dimensional linked-data exploration

[Home](#)

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[Documentation](#)

[Team](#)

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[Plugins](#)

[glue-con events](#)

[Consulting services](#)

Glue Plugins

Glue is designed to make it easy to customize various aspects via plugins, including customized data viewers on top of the standard ones, readers/writers for new file formats, and more. Developers are building glue plugins for a variety of fields from astronomy to medicine. The items below are currently available on the [GitHub](#) repository and most include instructions and sample data on how to install and use.

Plugins

[glue-aladin](#): Experimental [Aladin Lite](#) viewer plugin

[example_data_viewers](#): A collection of user-defined Glue data viewers including basketball shots, earthquakes, and Mario

[glue-geospatial](#): Experimental plugin to support satellite imagery

[glue-h5part](#): Experimental plugin to deal with h5part data

[glue-jupyter](#): Jupyter interface for Glue

[glue-medical](#): Experimental Glue medical plugin

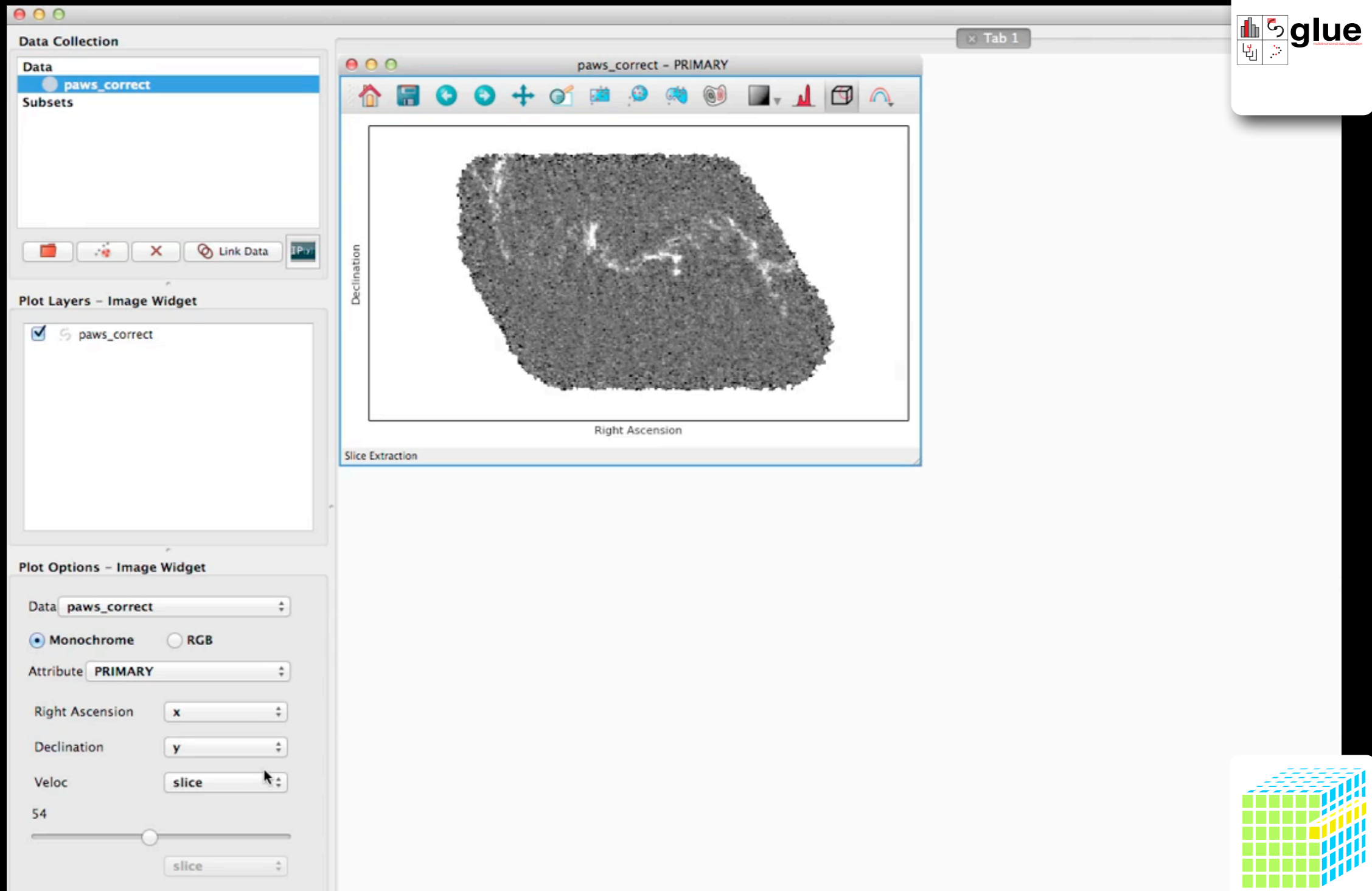
[glue-openspace](#): Experimental [OpenSpace](#) plugin

[glue-samp](#): Experimental [SAMP](#) plugin

[glue-specviz](#): Experimental plugin to wrap [specviz](#) spectroscopy tool

[glue-vispy-viewers](#): Plugin for 3D viewers using [VisPy](#)

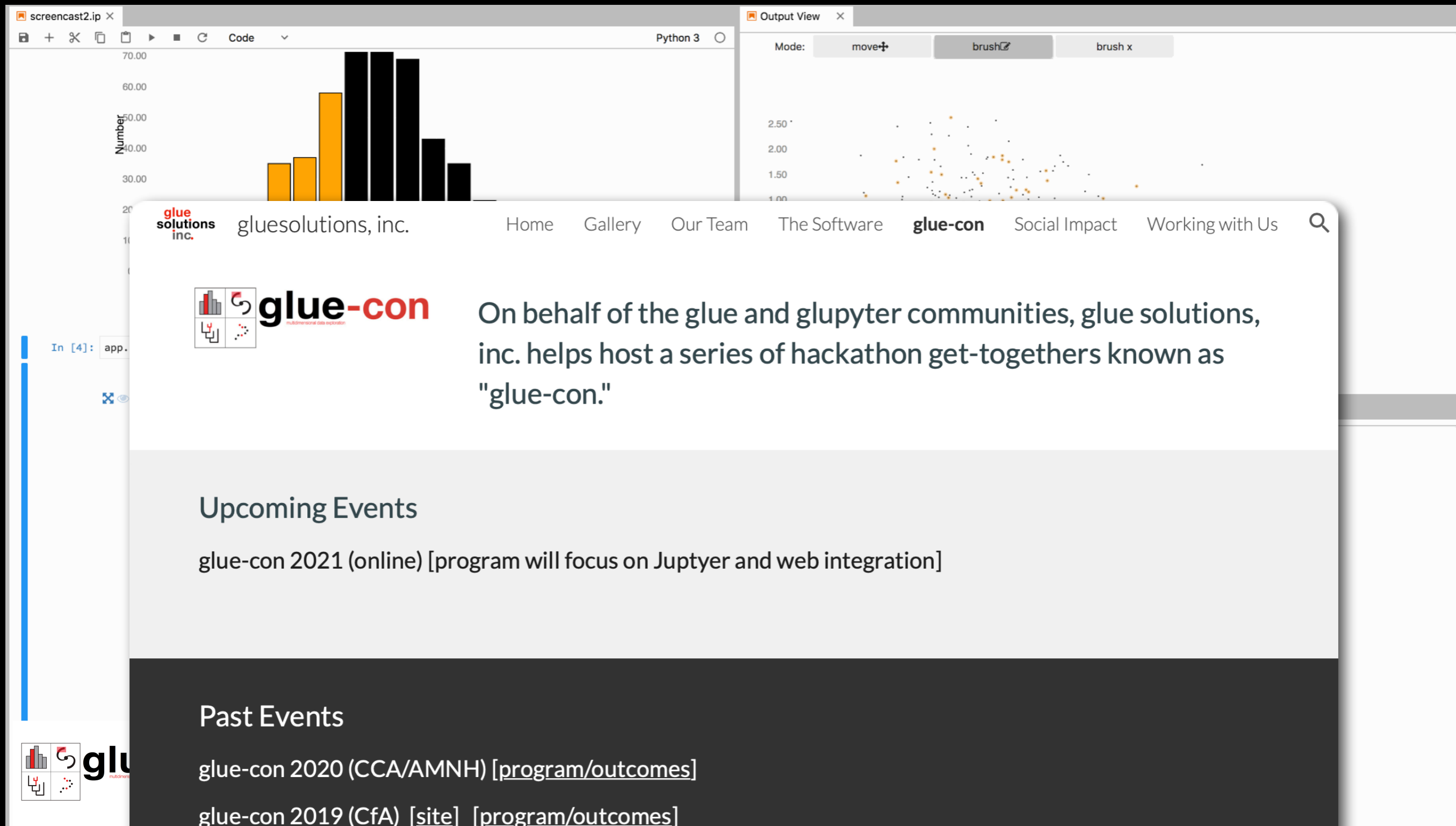
REMEMBER, "DIMENSIONS" NEED NOT BE ORTHOGONAL (OR EVEN SPATIAL)



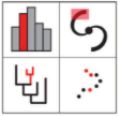
video by Chris Beaumont

glue created by: C. Beaumont, M. Borkin, A. Goodman (PI), T. Robitaille, C. Zucker, et al.

COMING NEXT: GLUE IN THE BROWSER



glue solutions, inc. Home Gallery Our Team The Software **glue-con** Social Impact Working with Us

 **glue-con**

On behalf of the glue and glupyter communities, glue solutions, inc. helps host a series of hackathon get-togethers known as "glue-con."

Upcoming Events

glue-con 2021 (online) [program will focus on Jupyter and web integration]

Past Events

glue-con 2020 (CCA/AMNH) [[program/outcomes](#)]
glue-con 2019 (CfA) [[site](#)] [[program/outcomes](#)]
glue-con 2018 (CfA) [[program/outcomes](#)]



get glue

glueviz.org

Glue

stable

Search docs

- Installing and running glue
- Getting started
- Advanced User Interface Guide
- Using the IPython terminal in Glue
- Working with Data objects
- Starting Glue from Python
- Visualizing Astronomical Dendrograms
- Introduction to customizing/extending glue
- List of available plugins
- Configuring Glue via a startup file
- Customizing your Glue environment
- Distributing your own plugin package
- Customizing the coordinate system of a data object
- Programmatically configuring viewers
- Writing a simple custom data viewer
- Watching data for changes

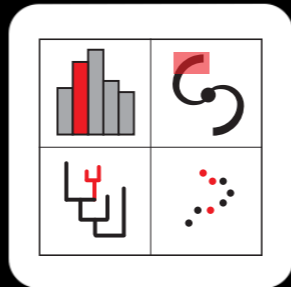
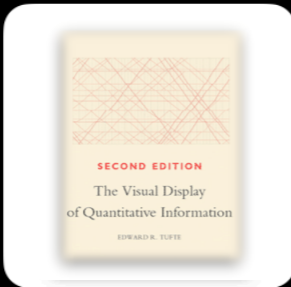
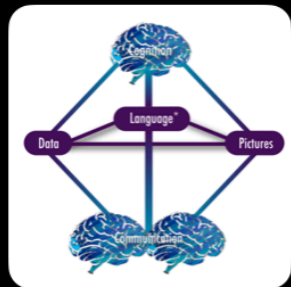
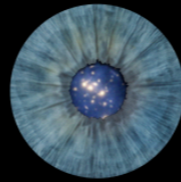
Docs » Glue Documentation [Edit on GitHub](#)

Glue Documentation

Glue is a Python library to explore relationships within and among related datasets. Its main features include:

- **Linked Statistical Graphics.** With Glue, users can create scatter plots, histograms and images (2D and 3D) of their data. Glue is focused on the brushing and linking paradigm, where selections in any graph propagate to all others.
- **Flexible linking across data.** Glue uses the logical links that exist between different data sets to overlay visualizations of different data, and to propagate selections across data sets. These links are specified by the user, and are arbitrarily flexible.
- **Full scripting capability.** Glue is written in Python, and built on top of its standard scientific libraries (i.e., Numpy, Matplotlib, Scipy). Users can easily integrate their own python code for data input, cleaning, and analysis.

SEEING MORE OF THE UNIVERSE



Explore

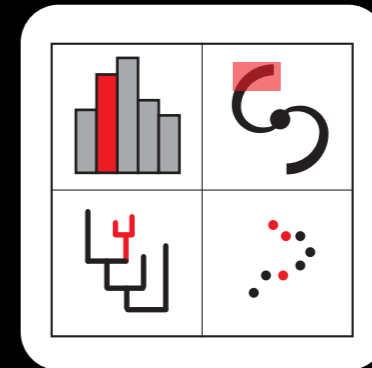
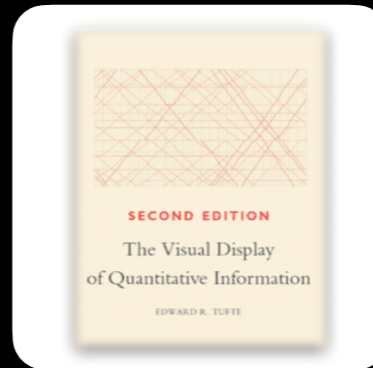
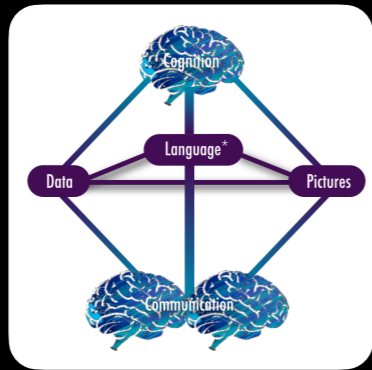
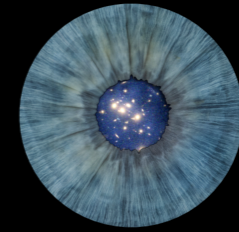
Explain

FIND THE FULL
SERIES ON

You **Tube**

TINYURL.COM/
10QVIZVIDEOS

SEEING MORE OF THE UNIVERSE



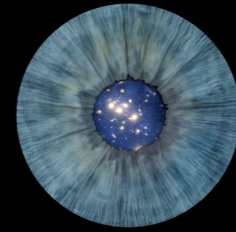
Explore

Explain

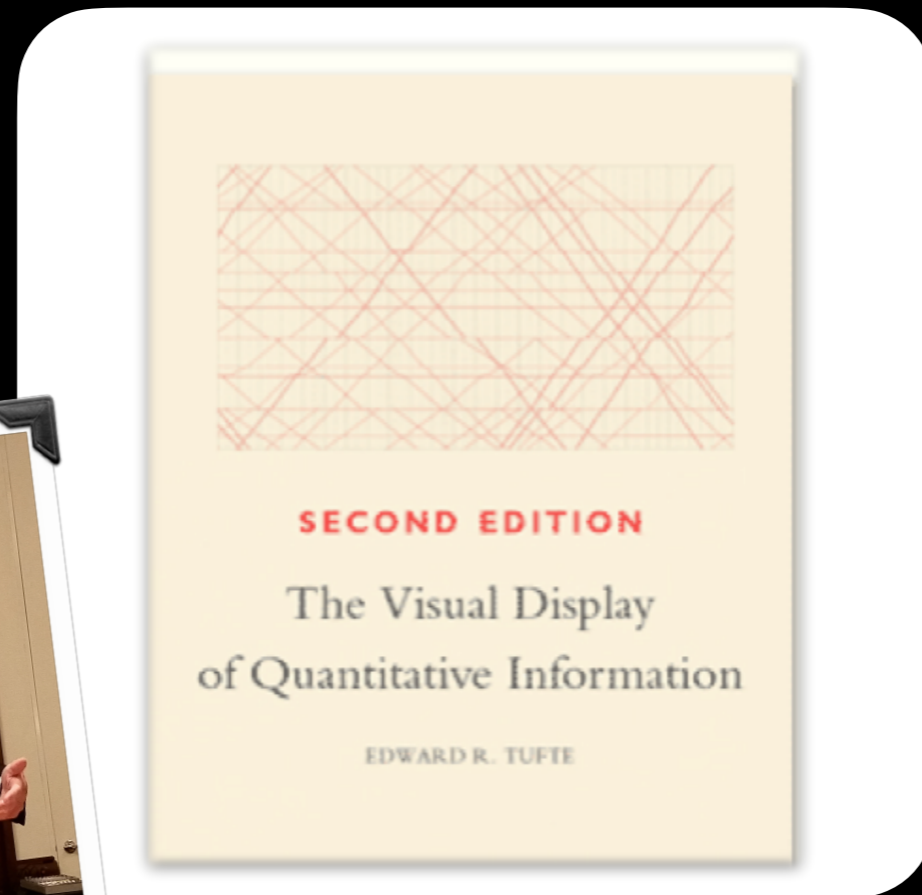
Alyssa A. Goodman

Harvard-Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

SEEING MORE OF THE UNIVERSE



“THE WISE WORDS OF EDWARD TUFTE”



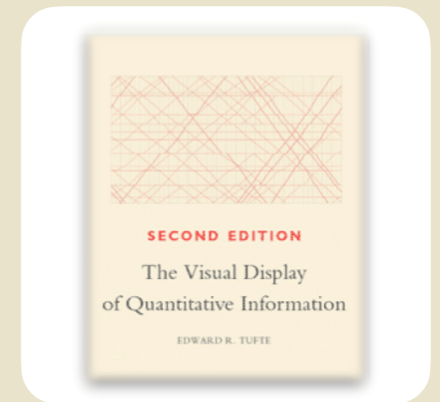
Alyssa A. Goodman

Harvard-Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

The wise words of Edward Tufte

Key concepts from

The Visual Display of Quantitative Information, Tufte 1983



Graphical Excellence

Graphical Integrity
& "The Lie Factor"

Chartjunk
& Subtraction

Data-ink Ratio

Multi-functioning
graphical elements

Data density

Small multiples

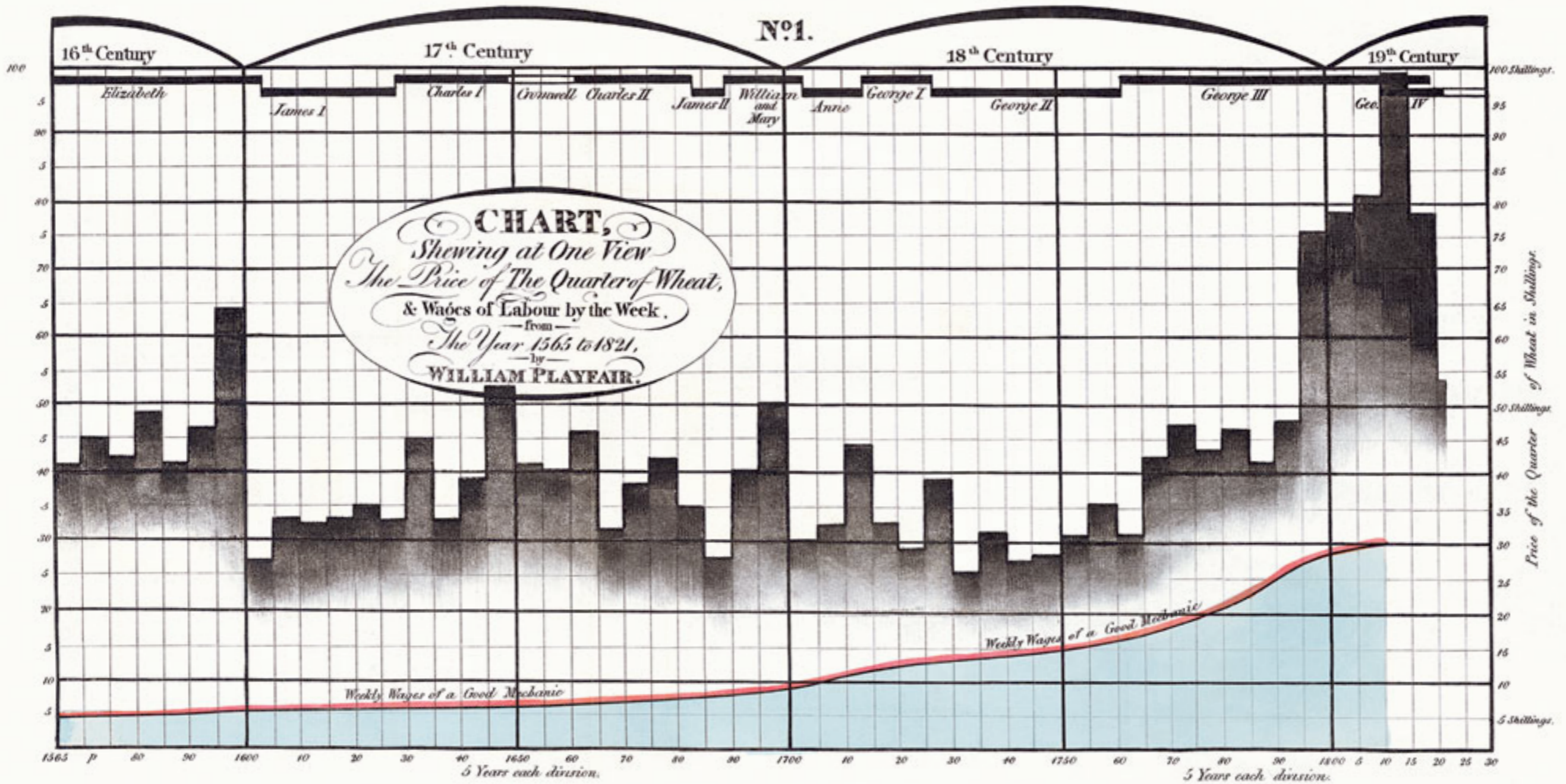
EDWARD TUFTTE'S IDEAS

from *The Visual Display of Quantitative Information*, Tufte 1983

Graphical Excellence – displays should...

- **show** the **data**
- induce the viewer to **think** about the **substance** rather than about methodology, graphic design, the technology of graphic production, or something else
- **avoid distorting** what the data have to say
- present **many numbers** in a small space
- make large data sets **coherent**
- encourage the eye to **compare** different pieces of data
- reveal the data at **several levels of detail**, from a broad overview to the fine structure
- serve a reasonably clear **purpose**: description, exploration, tabulation, or decoration
- be closely **integrated** with the statistical and **verbal descriptions** of a data set

Graphical Excellence



William Playfair (1759-1823)

EDWARD TUFTE'S IDEAS

from *The Visual Display of Quantitative Information*, Tufte 1983

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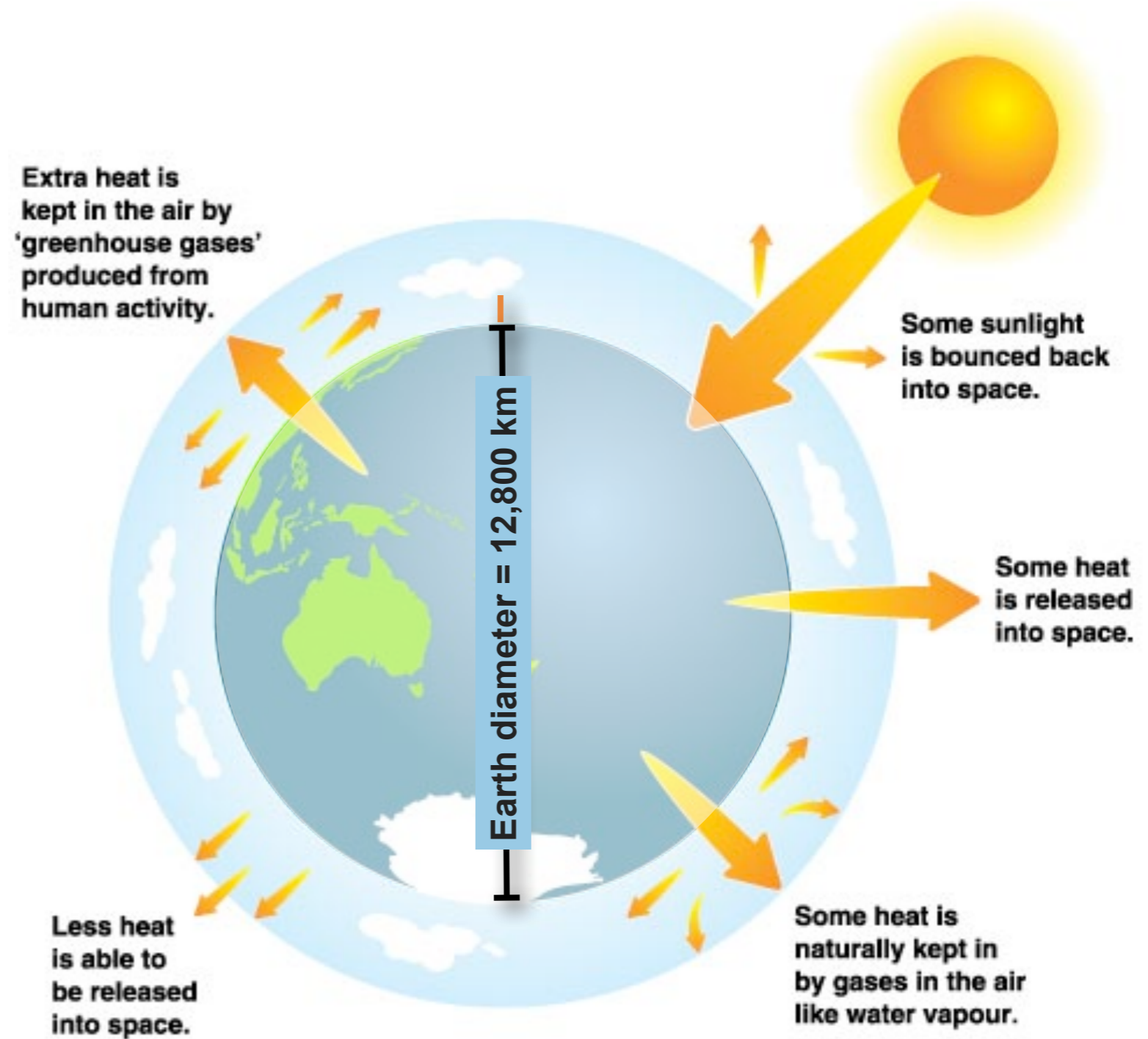
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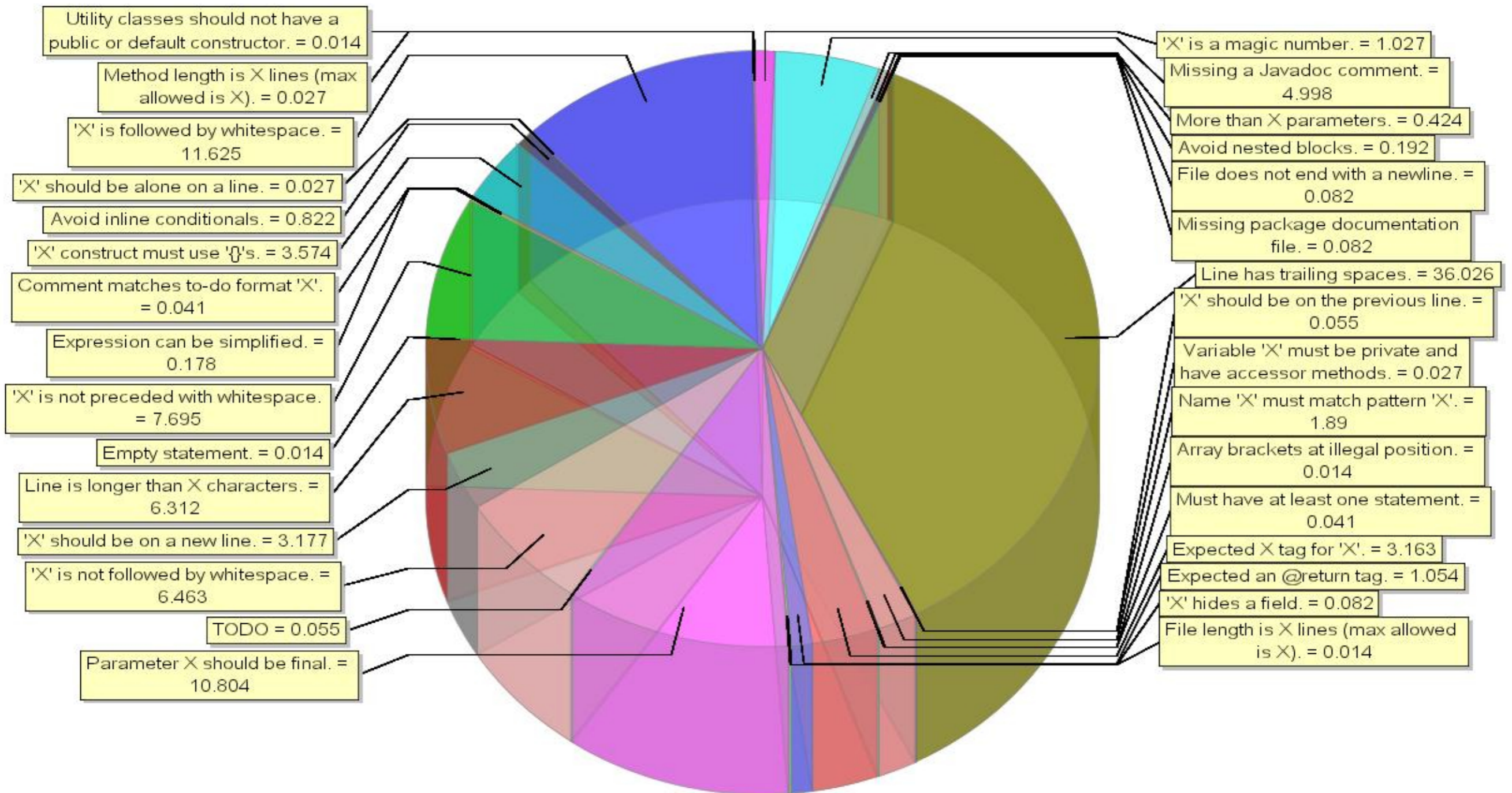
Data-ink Ratio

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Chartjunk & Subtraction



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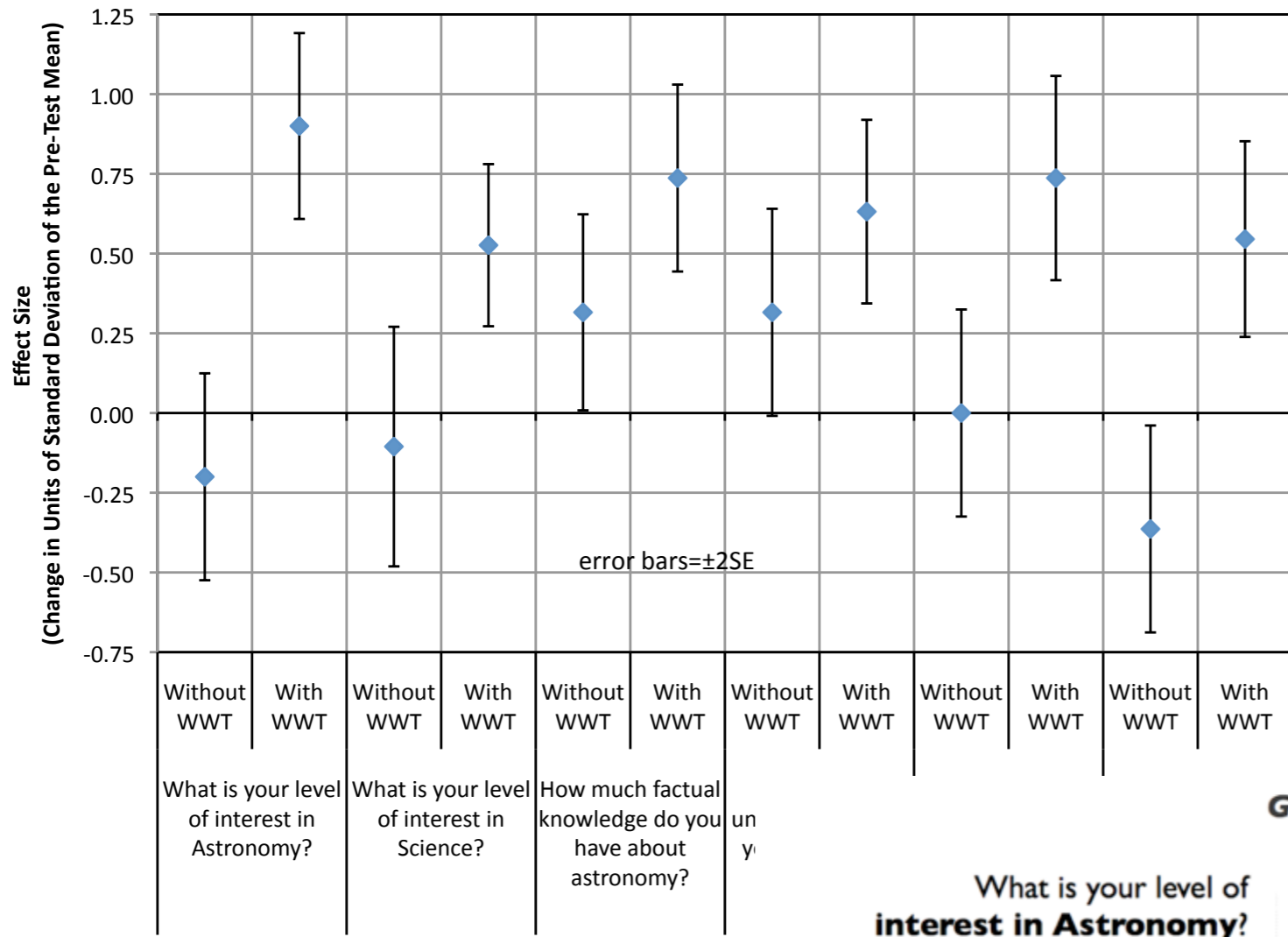
Chartjunk
& Subtraction

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Multi-functioning
graphical elements

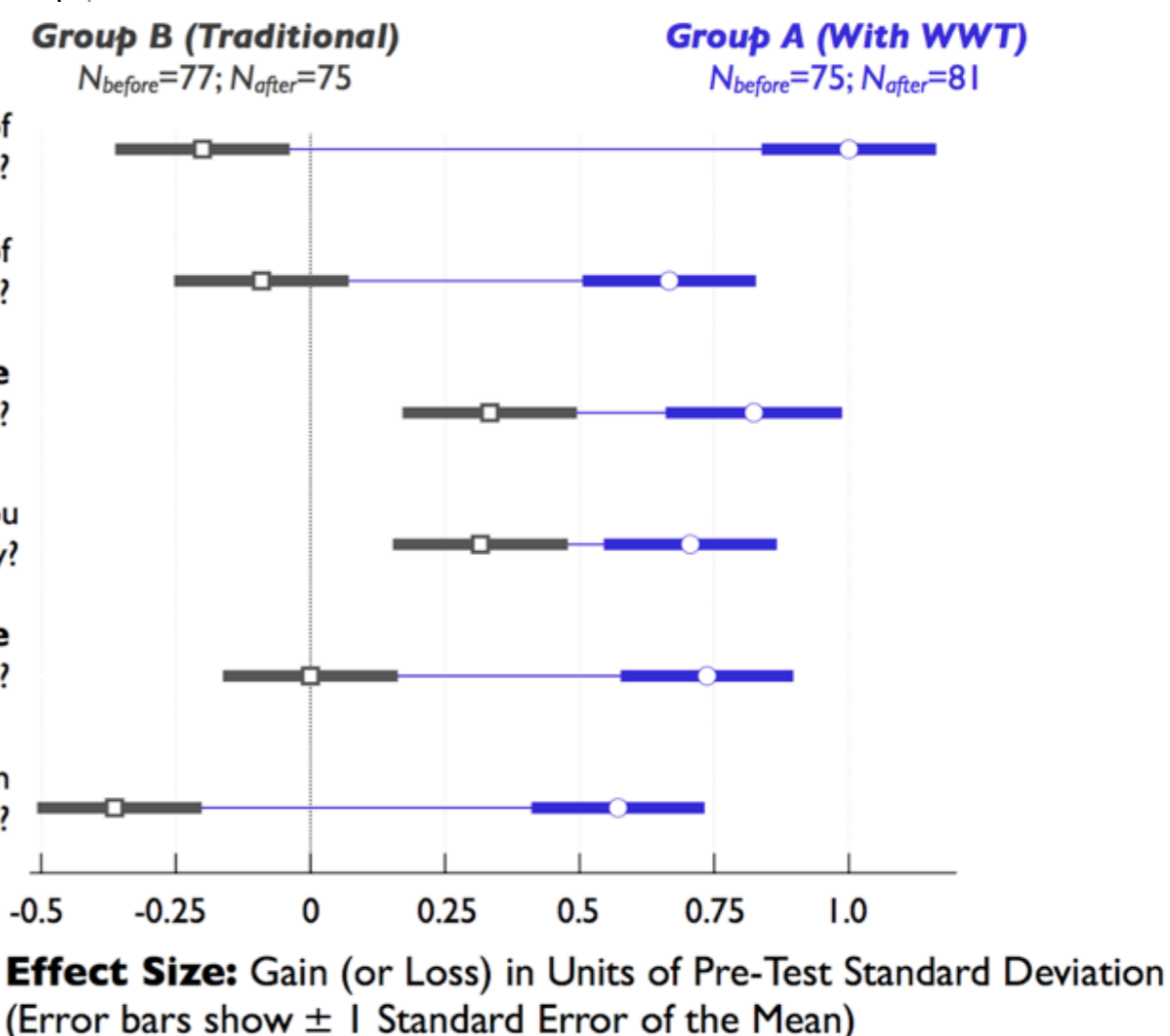
Data density

Small multiples



Data-ink Ratio

- What is your level of **interest in Astronomy?**
- What is your level of **interest in Science?**
- How much **factual knowledge** do you have about astronomy?
- How much **understanding** do you have about topics in astronomy?
- How well can you **visualize** Sun-Earth-Moon relationships?
- How interested are you in using a real **telescope?**



from AG example used in



EDWARD TUFTE'S IDEAS

from *The Visual Display of Quantitative Information*, Tufte 1983

Graphical Excellence

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& Subtraction

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graphical elements

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Small multiples

Multi-functioning graphical elements

Live Scoreboard | Celtics.com

SCOREBOARD

DEN 116	WAS 72	POR 97	PHI 46	MIL 34	DAL 26-11	LAL 25-11
CHA 119	BOS 79	NJN 70	SAS 52	UTA 34	SAC 14-21	SEA 9-27
FINAL	2:34	4th	0:50	4th	Halftime 5:36	2nd 10:00

COURTSIDE LIVE

19-16 STANDINGS

Fouls Full :20
1 4 0

02:46

1	2	3	4	OT	T
18	17	24	13		72
18	19	26	16		79

Fouls Full :20
1 3 1

30-5 STANDINGS

COURTSIDE LIVE **BOX SCORE** **PLAY-BY-PLAY** Highlights Watch the Game Listen to the Game

WAS SELECT: ALL ACTIVE 5

PLAYER NAME	PTS	REB	AST	F
<input type="checkbox"/> Daniels, Antonio	7	2	8	0
<input checked="" type="checkbox"/> Stevenson, DeSha	11	3	4	2
<input checked="" type="checkbox"/> Jamison, Antawn	18	10	0	3
<input checked="" type="checkbox"/> Butler, Caron	14	3	1	3
<input checked="" type="checkbox"/> Haywood, Brenda	12	5	0	3
<input type="checkbox"/> Blatche, Andray	3	5	0	3
<input checked="" type="checkbox"/> Mason, Roger	3	1	1	5
<input type="checkbox"/> Songaila, Darius	2	1	1	2
<input type="checkbox"/> Young, Nick	2	0	0	0
<input type="checkbox"/> Pecherou, Oleksiy	0	1	0	0
<input type="checkbox"/> Arenas, Gilbert				
<input type="checkbox"/> McGuire, Dominic				

BOS SELECT: ALL ACTIVE 5

PLAYER NAME	PTS	REB	AST	F
<input type="checkbox"/> Rondo, Rajon	4	2	2	2
<input checked="" type="checkbox"/> Allen, Ray	16	6	3	2
<input checked="" type="checkbox"/> Garnett, Kevin	21	6	6	3
<input checked="" type="checkbox"/> Pierce, Paul	16	4	2	3
<input type="checkbox"/> Perkins, Kendrick	9	3	1	3
<input checked="" type="checkbox"/> House, Eddie	5	6	3	1
<input type="checkbox"/> Allen, Tony	4	4	0	0
<input type="checkbox"/> Davis, Glen	1	0	0	2
<input checked="" type="checkbox"/> Posey, James	3	2	0	2
<input type="checkbox"/> Pollard, Sot				
<input type="checkbox"/> Scalabrine, Brian				
<input type="checkbox"/> Powe, Leon				

TD Banknorth GARDEN

WIZARDS **CELTICS**

WAS show: made shots missed shots **BOS** show: made shots missed shots

EDWARD TUFTE'S IDEAS

from *The Visual Display of Quantitative Information*, Tufte 1983

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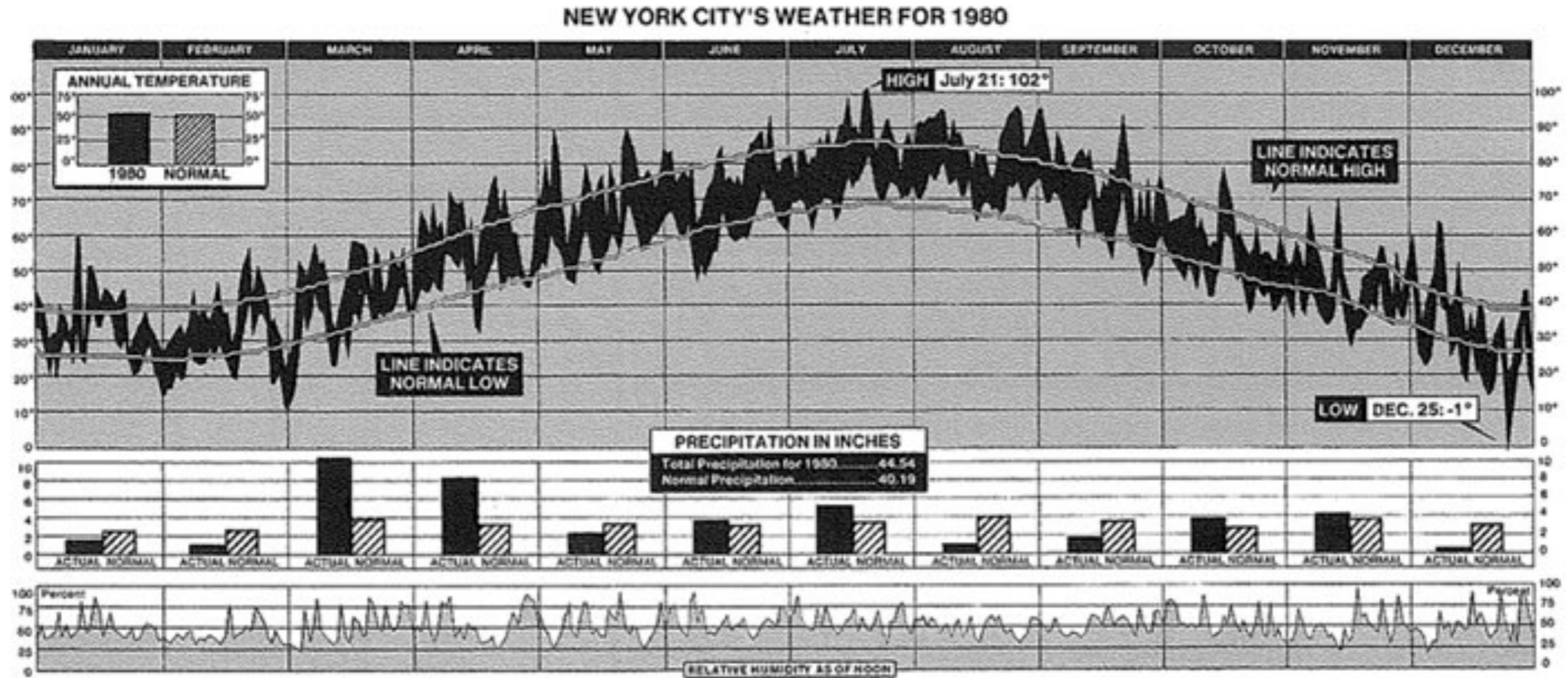
Data-ink Ratio

Multi-functioning
graphical elements

Data density

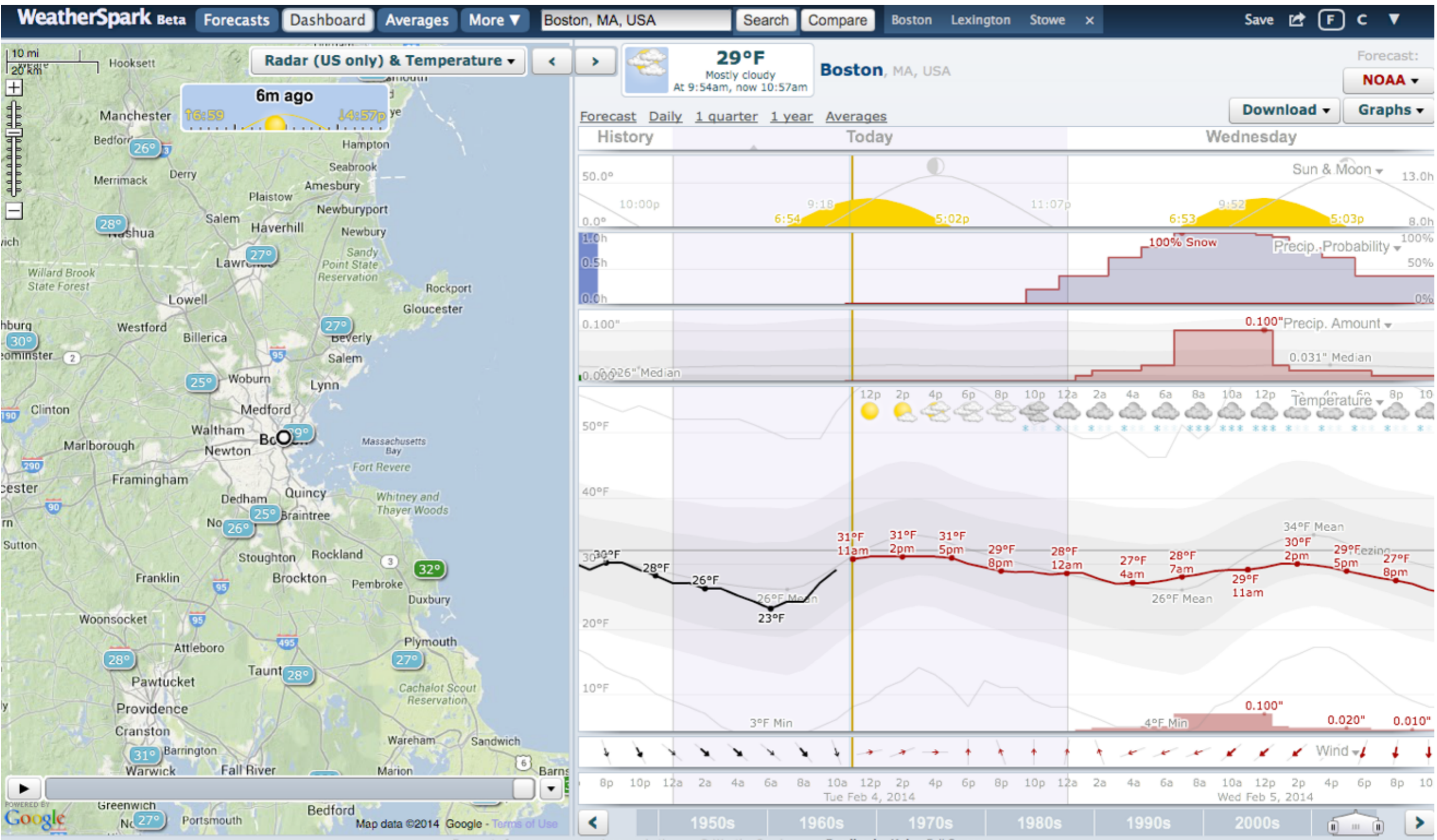
Small multiples

Data density



New York Times, January 11, 1981, p. 32.

Data (over?) density



<http://weatherspark.com/#!dashboard;a=USA/MA/Boston>

EDWARD TUFTE'S IDEAS

from *The Visual Display of Quantitative Information*, Tufte 1983

Graphical Excellence

Graphical Integrity
& "The Lie Factor"

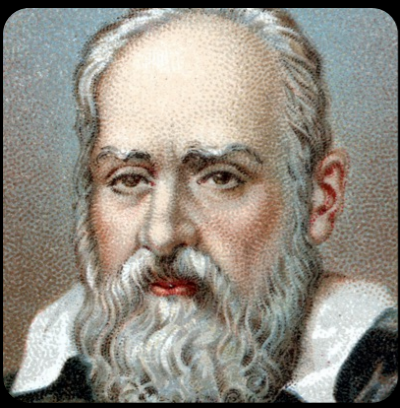
Chartjunk
& Subtraction

Data-ink Ratio

Multi-functioning
graphical elements

Data density

Small multiples



GALILEO GALILEI

(1564-1642)

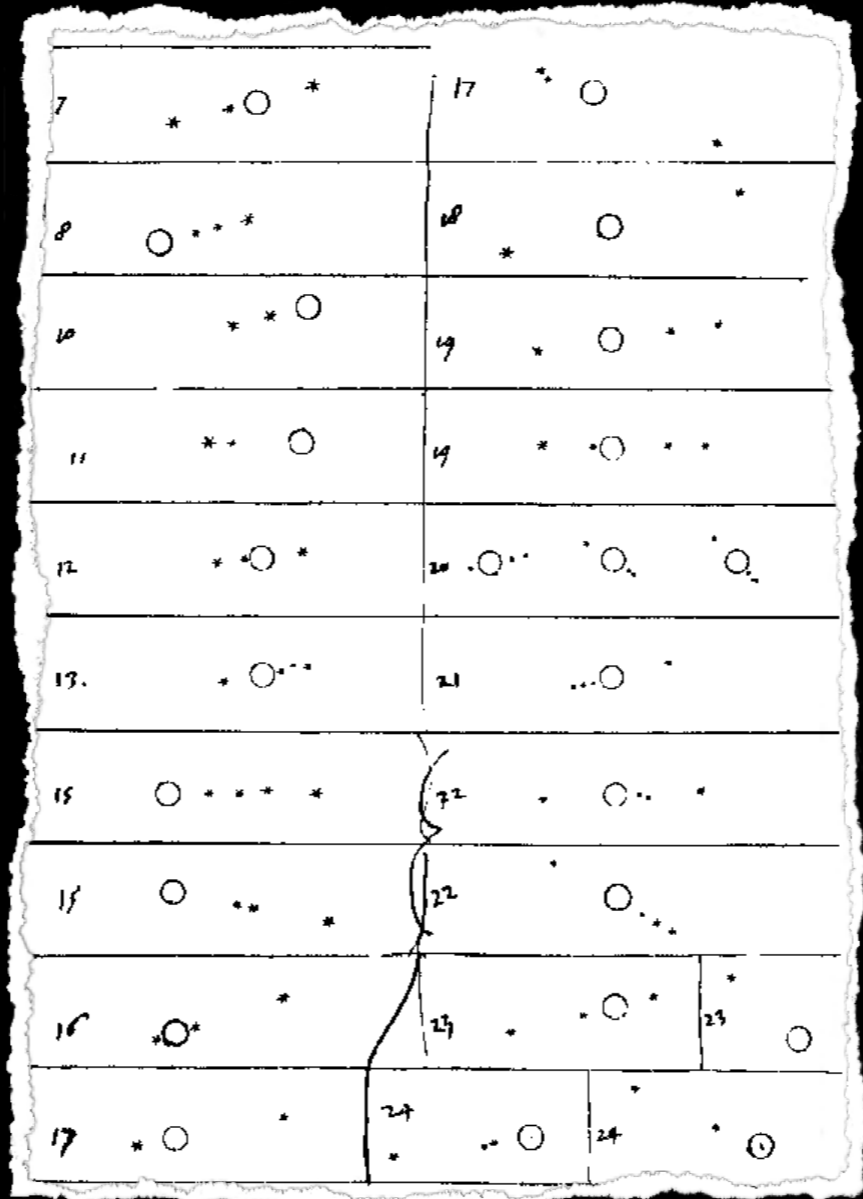
Small multiples

Sc. Principale.

Galileo Galilei, Familiari. Seruo della Ser. V. inuigilato
 do assiduo, et lo ogni spirito di bene no solo satisfas
 aluano che non della lettera di Madonati nelle Ser.
 Dio di Padova,

Inuere d'auere determinato di presentare al Sc. Principe
 l'occhio et il piacere di giuamenti inestimabile di ogni
 negozio et in breua marittima o terrestre stimo di tenere que
 sto nuovo artificio nel maggior segreto et solap a disposizione
 di V. Ser. L. Galileo conato dalle piu uide speculationi di
 prospectua in l'uantaggio di scoprire Legni et Vele dell' inimici
 di due hore et piu di tempo prima di gli scopra noi et distinguend
 il numero et la qualita de i Vasselli, giudicare le sue forze
 ballottarsi alla caccia et combattimento o alla fuga, o pure una
 nella campagna aperta vedere et particolarly distinguere ogni sua
 posto et propriamento.

Feb. 7. di gennaio
 Giove si vede a 7 * uici:
 Feb. 8. uici * * * * *
 Feb. 10. uici * * * * *
 Feb. 11. uici * * * * *
 Feb. 12. uici * * * * *
 Feb. 13. uici * * * * *
 Feb. 14. uici * * * * *
 Feb. 15. uici * * * * *



On the third, at the seventh hour, the stars were arranged in this
 sequence. The eastern one was 1 minute, 30 seconds from Jupiter
 the closest western one 2 minutes; and the other western one was
 3 minutes removed from this one. They were absolutely on the same
 straight line and of equal magnitude.

On the fourth, at the second hour, there were four stars around
 Jupiter, two to the east and two to the west, and arranged precisely
 in a straight line, as in the adjoining figure. The easternmost was
 distant 3 minutes from the next one, while this one was 40 seconds
 from Jupiter; Jupiter was 4 minutes from the nearest western one
 and this one 6 minutes from the westernmost one. Their magnitude
 were nearly equal; the one closest to Jupiter appeared a little smaller
 than the rest. But at the seventh hour the eastern stars were only
 30 seconds apart. Jupiter was 2 minutes from the nearer eastern
 one, while he was 4 minutes from the next western one, and this
 one was 3 minutes from the westernmost one. They were all equal
 and extended on the same straight line along the ecliptic.

On the fifth, the sky was cloudy.

On the sixth, only two stars appeared flanking Jupiter, as is seen
 in the adjoining figure. The eastern one was 2 minutes and the
 western one 3 minutes from Jupiter. They were on the same straight
 line with Jupiter and equal in magnitude.

On the seventh, two stars stood near Jupiter to the east




















COMPOSITE TABLE*

*how AG met ET, 1995





from left: Jonathan Corum, Edward Tufte,
Alyssa Goodman, Mike Bostock (2015)

Table 1: Summary of VLA NH₃ Observations in Low-Mass Dense Cores as of 1994
(double-boxed sources to be observed in this proposal)

Source	Central Source	Outflow	Year of Obsv'n.	Relationship of VLA NH ₃ to Central Source	Comments (all observations are by the current proposers, unless otherwise indicated)
L1172	★		1984		
L1551	★		1989		Torrelles et al. 1985.
L1152	★		1988		improve sensitivity and extend map with proposed observations
TMC-1A (≡ L1534)	★		1988		improve sensitivity with proposed observations
B335	★		1990		Keene, Menten & Masson, in prep.
L1689N	NO	NO	1985		Wooten and Loren 1987. Star shown at left (w/outflow) not within primary beam of observation.
AQ13	NO	?	1988		noise higher in on-line channels, suggestive of signal
B217	NO	NO	1983		relatively poor sensitivity
L1582	★	?	1984		
L1498	NO	NO	1984		
B5	★		1985		relatively poor sensitivity
B1	★		1988		relatively poor sensitivity

New Sources to be Observed in this Proposal

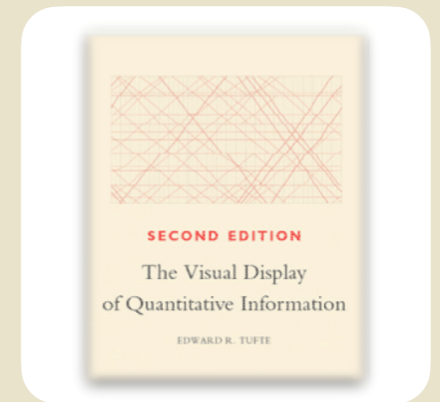
L1527	★		1995		infall candidate
L483	★		1995		infall candidate
B133	NO	NO	1995		strong extended sub-mm continuum, no known point source

*determination is unclear from existing data

The wise words of Edward Tufte

Key concepts from

The Visual Display of Quantitative Information, Tufte 1983



Graphical Excellence

Graphical Integrity
& "The Lie Factor"

Chartjunk
& Subtraction

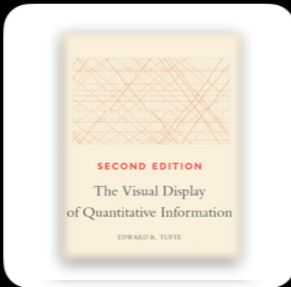
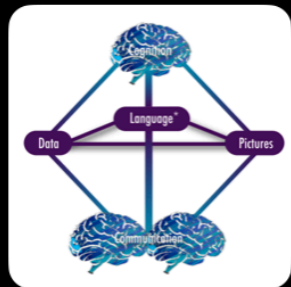
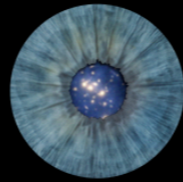
Data-ink Ratio

Multi-functioning
graphical elements

Data density

Small multiples

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