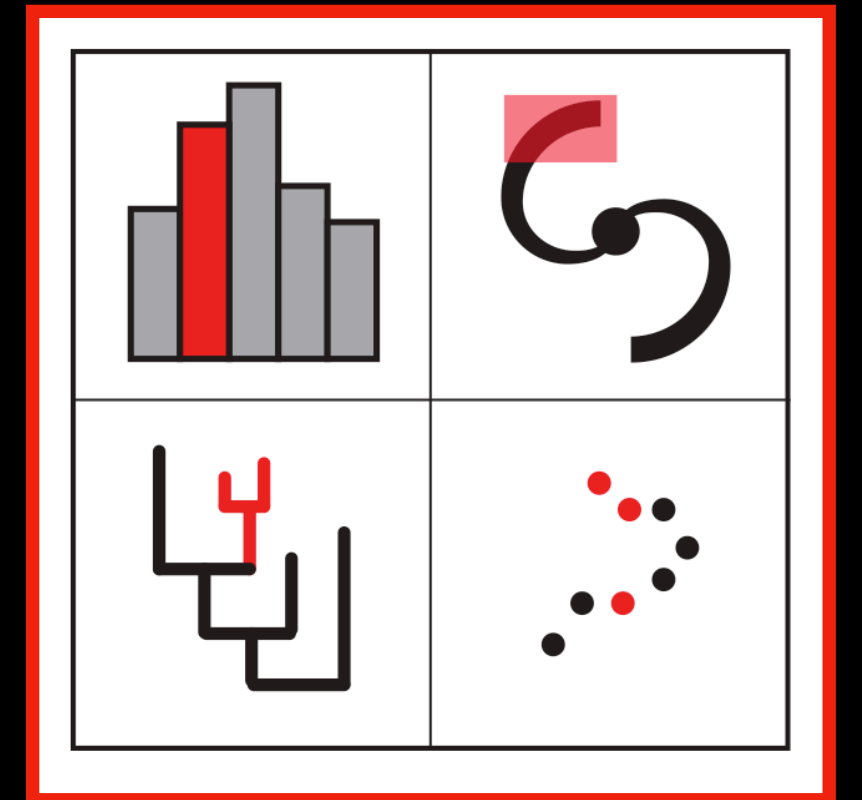


Data Decoupage

with glue



Alyssa Goodman, Center for Astrophysics | Harvard & Smithsonian



GORDON AND BETTY
MOORE
FOUNDATION



glue
solutions
inc.

The Prediction Project

The Past and Present of the Future



f t y i s Search...



HOME ABOUT MATERIALS COURSES TALKS WRITINGS PRESS FORUM

Uncertainty about Uncertainty

by [Alyssa A. Goodman](#), May 18, 2020

This essay accompanies the release of an online [tool for visualization of IHME COVID-19 forecasts](#), evolution over time and a [community discussion](#) of visualizations created with the tool.

Uncertainty about the future has motivated predictions for millennia. Sometimes, we're just curious—but other times, we really need to know. As the present pandemic evolves, our urgent societal need to plan has motivated many scientists to predict the spread and effects of the novel coronavirus.

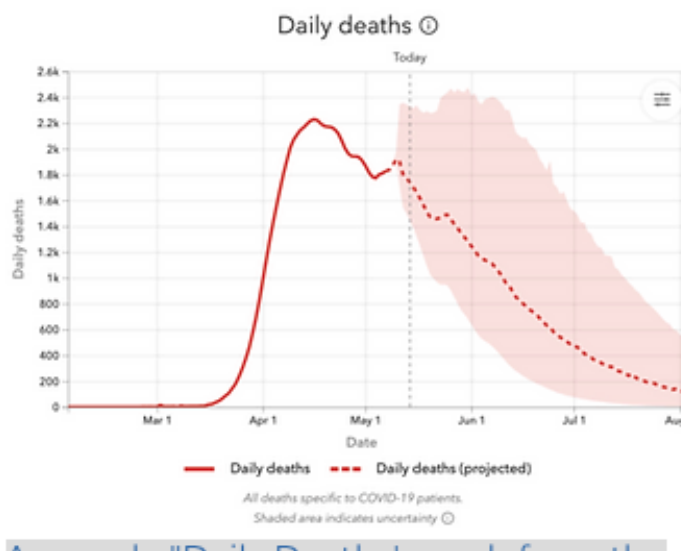
BACKGROUND: TWO BROAD CLASSES OF MODELS

Amongst the many predictions being used by governments to guide policy are two broad classes: infectious disease models based on an understanding of how contagion spreads; and more mechanism-agnostic statistical models informed primarily by data about prior outcomes. To the uninitiated, these approaches, both of which rely on statistical modeling, may sound the same—but they are not.

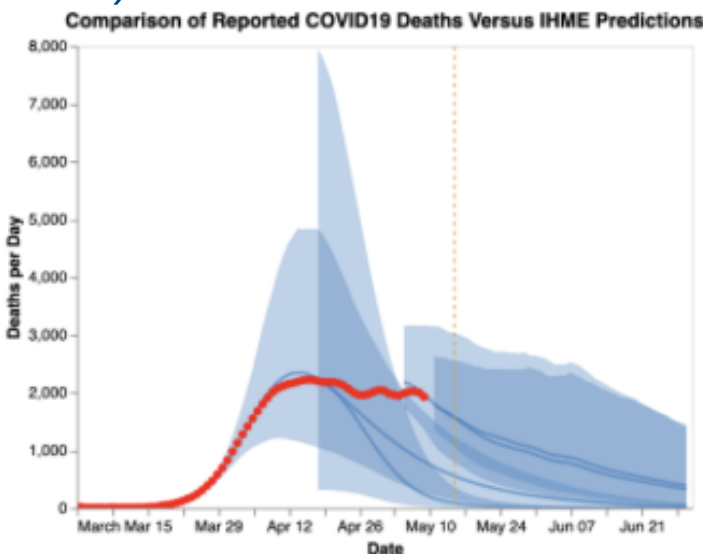
Models of infectious disease take into account, with varying levels of complexity: how many, and importantly why, people are susceptible, infected, immune, or have succumbed to a virus at any given point in time and space. The mathematics of these models moves people between groups called "Susceptible," "Exposed," "Infected," and "Removed," and so are often called "SEIR" models. At the philosophical other end of the modeling spectrum, what we call **"mechanism-agnostic"** approaches use information about cases, testing, hospital admissions, and deaths, to create algorithms that forecast what will happen under various combinations of conditions, given what's happened under similar conditions in the past. Purely mechanism-agnostic approaches do not factor in medically-informed information about how an infectious disease spreads.

At the moment, there are scores of unrefereed articles in scholarly journals, and hundreds of media articles about predictions from infectious disease models, mechanism-agnostic approaches, and various hybrids, available to policy makers. What isn't clear, though, is how much faith to put in any of these analyses or forecasts.

For most of the SEIR-style predictions, one sees a range of scenarios offered in journal articles, from a miraculous end to the pandemic due to summer, to a devastating "second wave" to come in the fall of 2020, and waves beyond. Human factors, including both government regulation and compliance with it, are often the most unpredictable



Thanks to Caroline Buckee for inspiring this "extra" slide!



IHME Models over time, for the United States, for 4 representative dates, made with the interactive tools offered below.

What's this tool for? Using the interactive graphics below, you can re-create the display of deaths/day akin to what would have been visible at [IHME's COVID-19 web site](#) on a range of modeling dates, for any region you select. In addition, you can show more than one model (date) at a time, to make comparisons.

How should I interpret what I see? In each of the panels below: red dots show reported *actual* deaths per day; solid blue lines show forecasts, and light blue shaded regions show uncertainty bands. Those uncertainty bands indicate ranges of possible outcomes, as forecast on the date when the model was made. The ranges should account for 95% of possible outcomes. As one can see by moving the time slider below each graph, the model and its associated uncertainty band change over time. As more and more models are added, regions where shading appears darkest are regions where models agree.

There are four versions of the IHME evolution visualization offered below. They are as follows (with source links):

1. For the United States, showing only 4 representative model dates. [\[source, GitHub\]](#) [\[mobile site\]](#)
2. For the United States, offering a wide range of model dates [\[source, GitHub\]](#)
3. For the World, showing only 4 representative model dates [\[source, GitHub\]](#) [\[mobile site\]](#)
4. For the World, offering a wide range of model dates [\[source, GitHub\]](#)

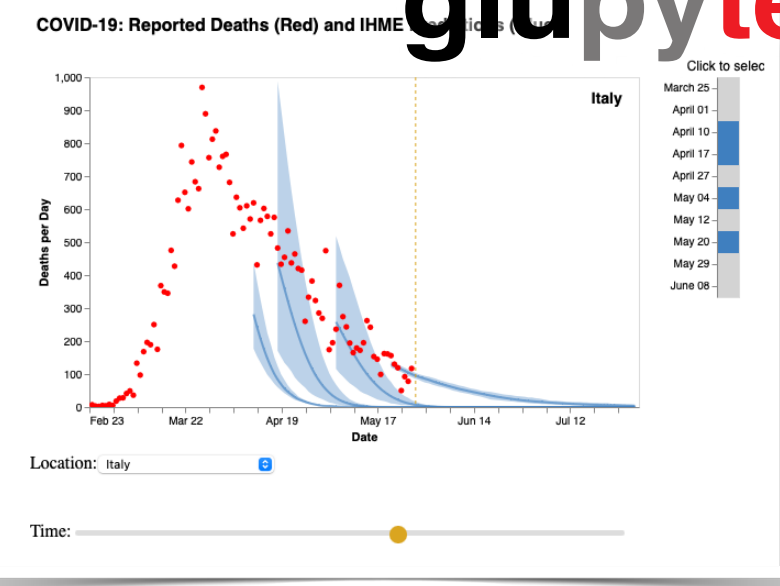
Social Impact

IHME Model Uncertainty, Visualized over Time

The [Institute for Health Metrics and Evaluation \(IHME\)](#) creates, maintains, [updates](#), and publishes an open-source statistical [model](#) of the impact of the COVID-19 pandemic, based on open-data resources. As a public service, [glue solutions, inc.](#) here offers an online tool for visualizing the evolution of the IHME models over time.

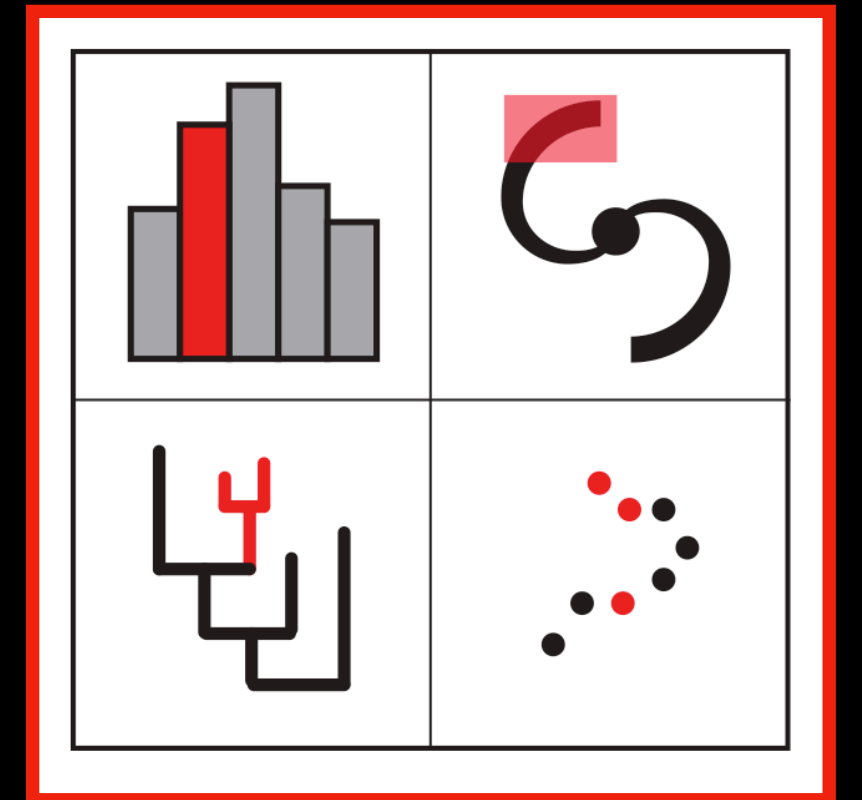
The general public has seen many versions of the IHME "Daily Deaths" plots, including in several White House briefings. Our goal here is to offer a look at how the models change—appropriately, in response to new data and information—over time, and how that affects model updates. In a [companion essay online at the Prediction Project](#) site, we offer more context on why this evolution is so interesting.

(Banner above shows sample IHME "Daily Deaths" [graphic](#), from 14 May 2020.)



Data Decoupage

with glue



Alyssa Goodman, Center for Astrophysics | Harvard & Smithsonian



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glue
solutions
inc.

What is glue?

multidimensional data exploration

It's not an acronym.

It is open-source software that
glues data,
glues graphs &
glues tools.

data



numbers (tables, arrays, spreadsheets)

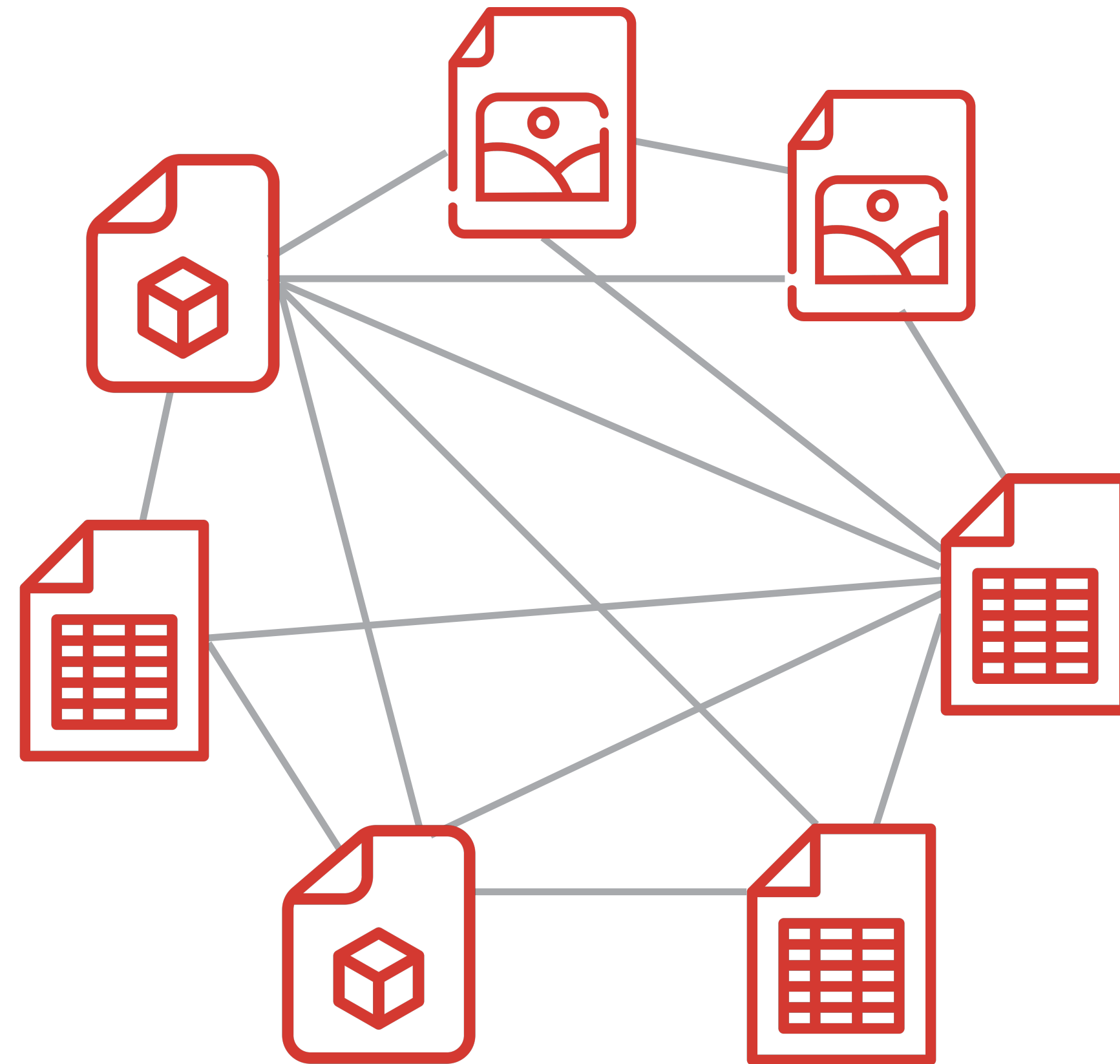


images & maps (FITS, JPEG, GIS and more)



data cubes (3D, 4D, and more)

data files' common attributes are **glued**



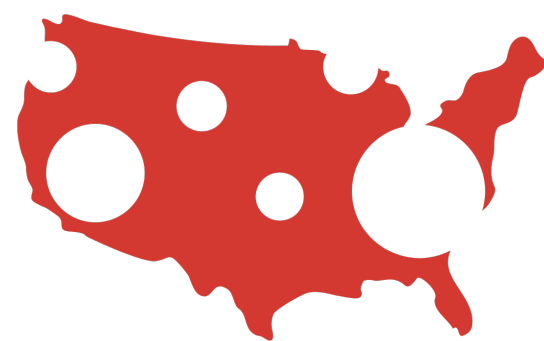
avoiding the need to merge data files

“graphs”



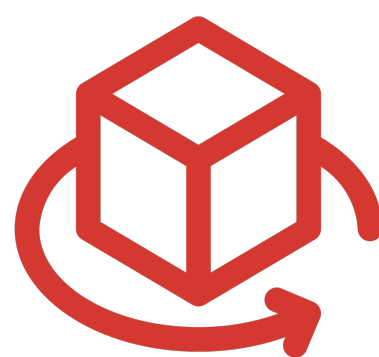
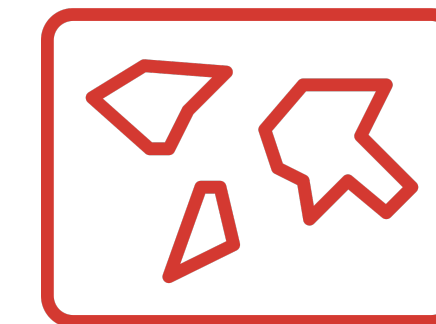
common statistical graphics

(scatterplots, histograms, tables, curves, overlays)



maps & images

(greyscale, color, contours, layer control...)



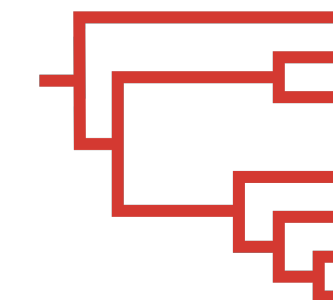
3D displays

(scatter plots, volumetric rendering, sliders...)



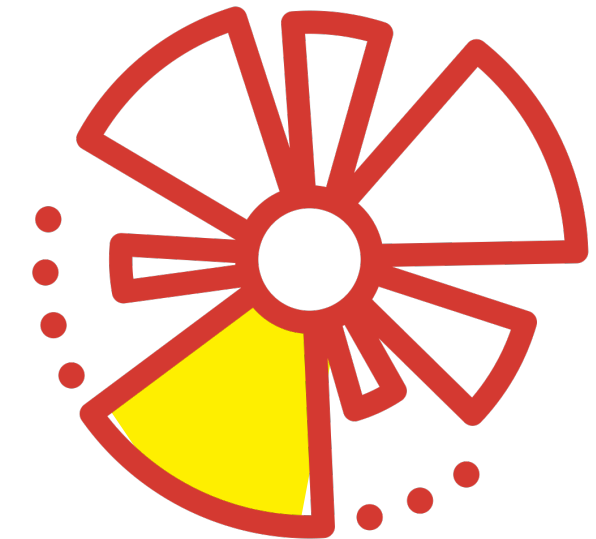
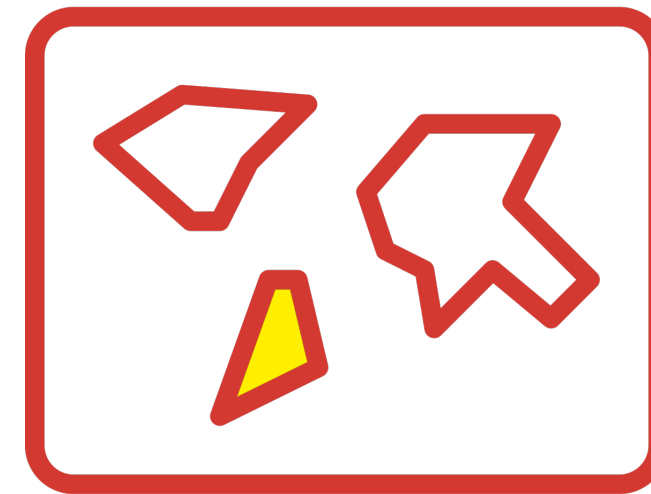
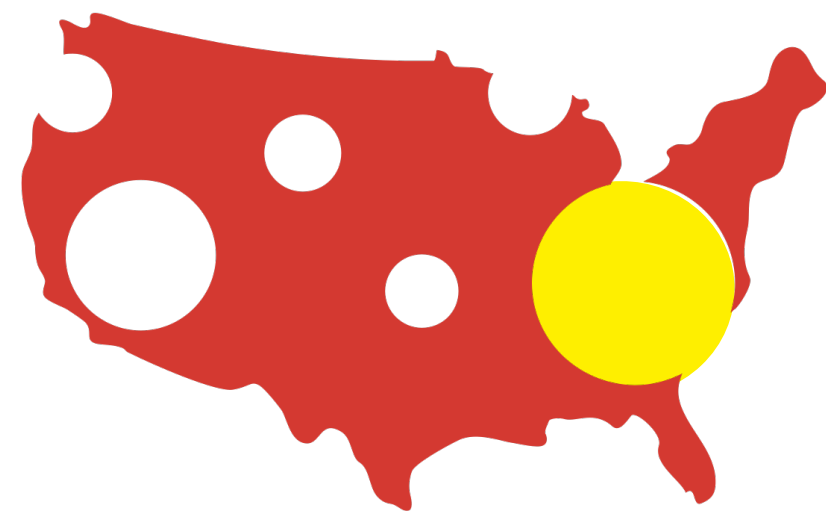
specialized & custom charts

(dendrograms, polar plots, + domain-specific options)





selections propagate across all **graphs**

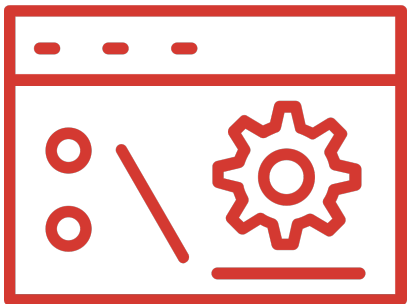


for real-time data exploration & insight

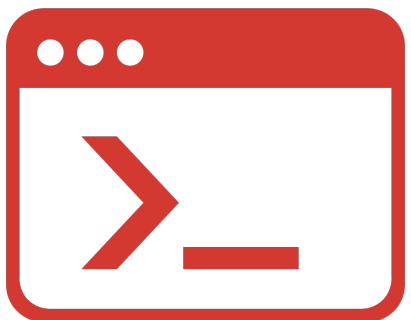
tools



plug-ins (user-defined formats, plots, layouts...)



web services (across domains)



command-line (built-in terminal, scriptable)

for easy customization



glues data,
glues graphs &
glues tools.

glueviz.org

BONUS: **save, share, or publish** what you learn—

save “sessions” to continue where you left off

export graphics

use/export to Jupyter environments

export to plot.ly (javascript)

export to augmented reality

learn how at glueviz.org.



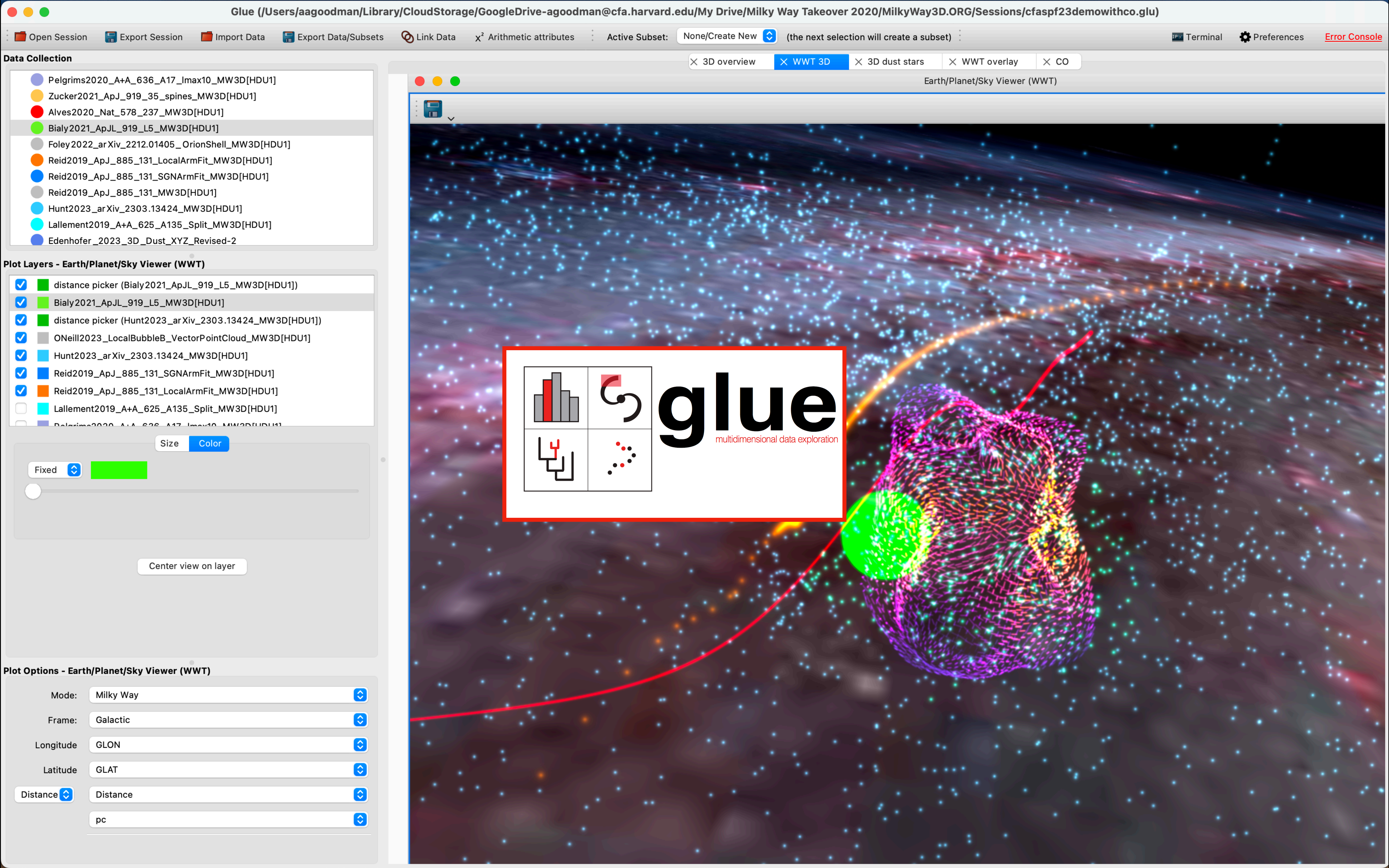
glueviz.org

supported by

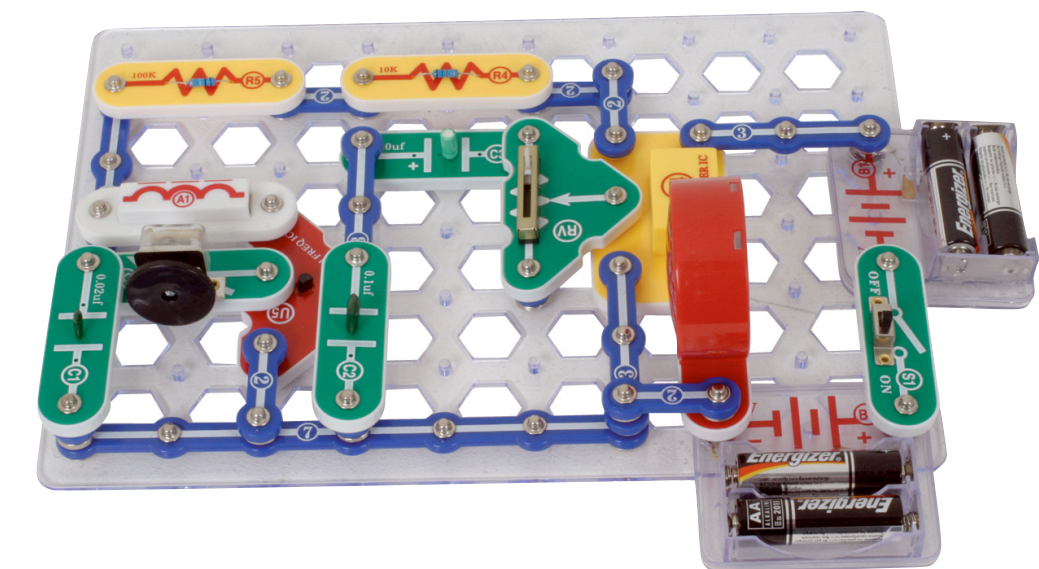


glue
solutions
inc.

GORDON AND BETTY
MOORE
FOUNDATION



“Customizable Complexity”



2009 Customizable Complexity



Visualization in Science and Education
Gordon Research Conference

Revealing Nature, Generating Insight

July 26 - 31, 2009

Chairs

Arthur J. Olson and Shaaron
Ainsworth

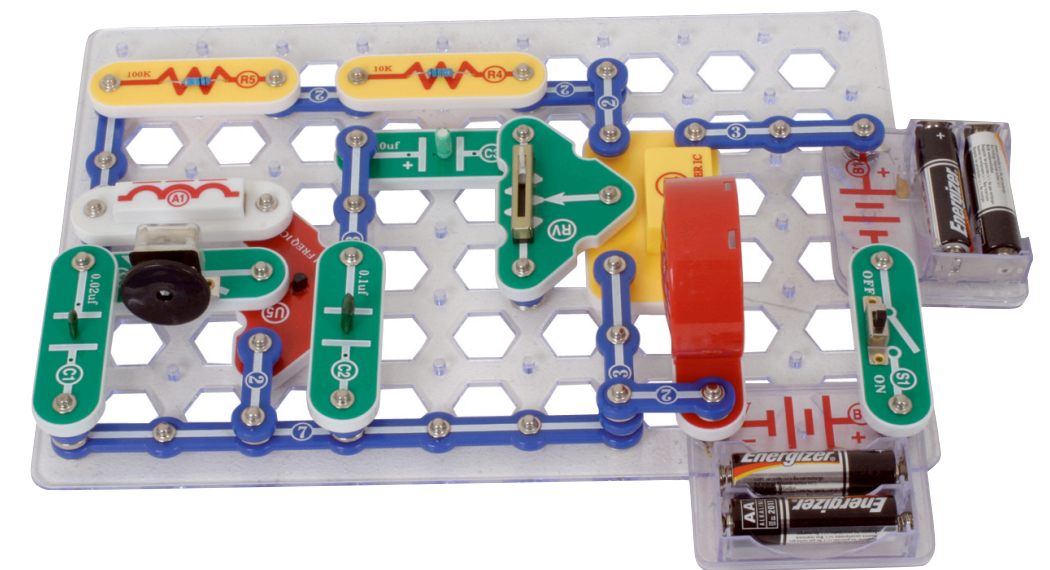
Vice Chairs

Elizabeth M. Dorland and Ghislain Deslongchamps

9:00 am - 9:40 am

Alyssa Goodman (Harvard University, USA)

"From Baby Pictures to Baby Stars: What Scientists /Can/ See"



Discussing:

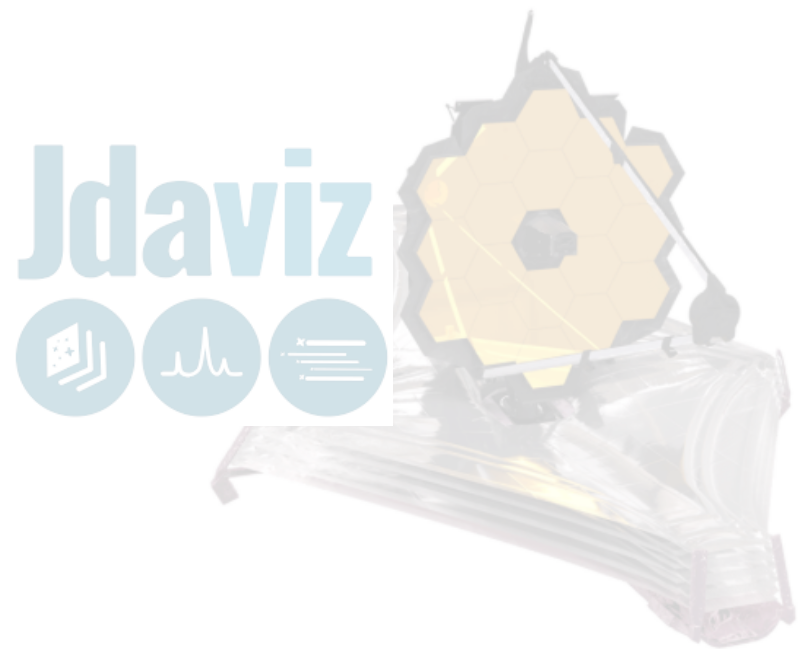
The Modular, Personalizable, Approach we
“Can”, “Could” (& Should!?) Take to *Interactions*

14 years later...

...at Jupytercon 2023

"glupyter" is a union of [glue](#) and [Jupyter](#) software environments. We think it may well be the future of glue, or "glue-qt" as experts sometimes call the desktop app version of glue. This webpage, hosted openly and freely by [glue solutions, inc.](#), serves as a clearinghouse for current information about open-source glupyter-related projects. Some of these projects are funded by government agencies (notably [NSF](#) and [NASA](#)), others by private foundations (e.g. [The Gordon and Betty Moore Foundation](#)), some as part of corporate collaborations (e.g. [Harvard+Google Data+Climate](#)), and some by open-source consulting work carried out by [glue solutions, inc.](#)

The [glue-jupyter GitHub repository](#) is fully open, and more detail can be found on this [Read the Docs page](#).



Quick insights for Images, Spectra

JDAViz

includes: ImViz, CubeViz, SpecViz, MOSViz

Sponsor: NASA, James Webb Space Telescope

[Read more \(blog post at 10QViz.org\)...](#)



Open-Source GIS Data Exploration

SAVE

Search-Analysis-Visualization-Environment

Sponsors: Harvard+Google Data+Climate

[Read more](#) at Data+Climate site...



Data Science Education

Cosmic Data Stories

Sponsor: NASA, Science Activation Program (funded proposal)

[Read more](#) at CosmicDS website...

[GitHub](#)

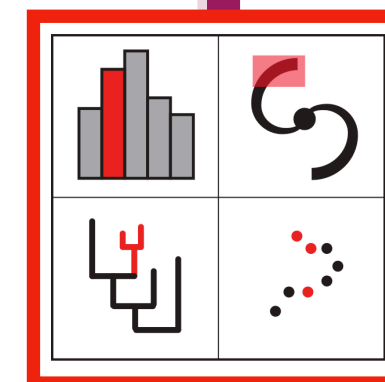


bringing glue to JupyterLab

glupyter prototype

Sponsors: The Gordon and Betty Moore Foundation and the National Science Foundation

Read more in the justification of the GBF [proposal](#), awarded to Harvard, and watch this 2022 demo [video](#)



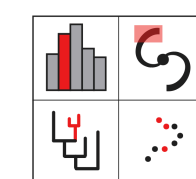
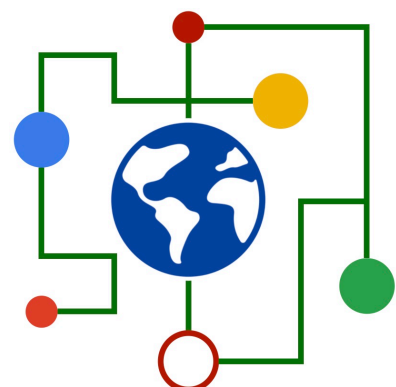
"LEVELS" of interaction/users



guided experience for learners, no coding, only interactive webpages



dashboard-style



glupyter

fully flexible, scriptable, extensible.

tinyurl.com/dimensionsofdiscovery

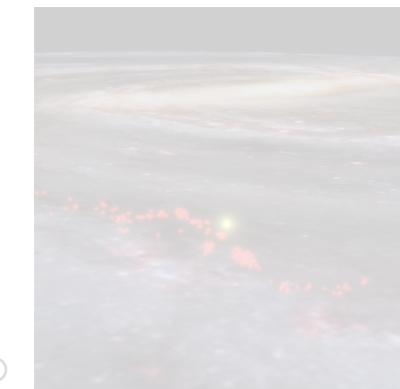
Dimensions of Discovery

Home M83 (secrets) AG-SoFar

DIMENSIONS OF DISCOVERY

A web page created by [Alyssa Goodman](#) to showcase the use of technology in research, education, and communication, of science and more.

What's happening "these days?" A sampler of ongoing and recent projects.



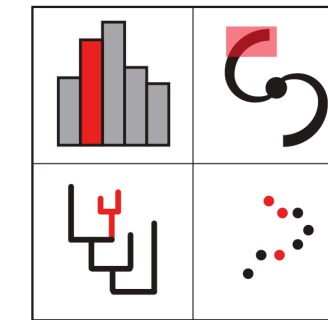
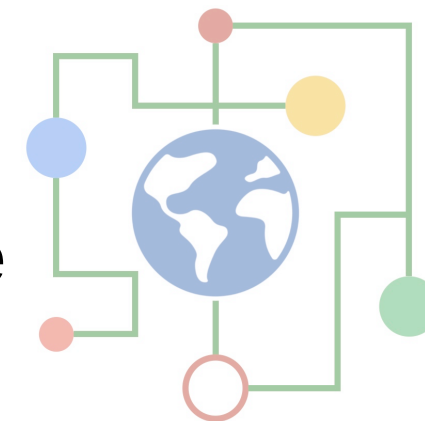
“Customizable Complexity”



guided experience for learners, no coding, only interactive webpages



dashboard-style



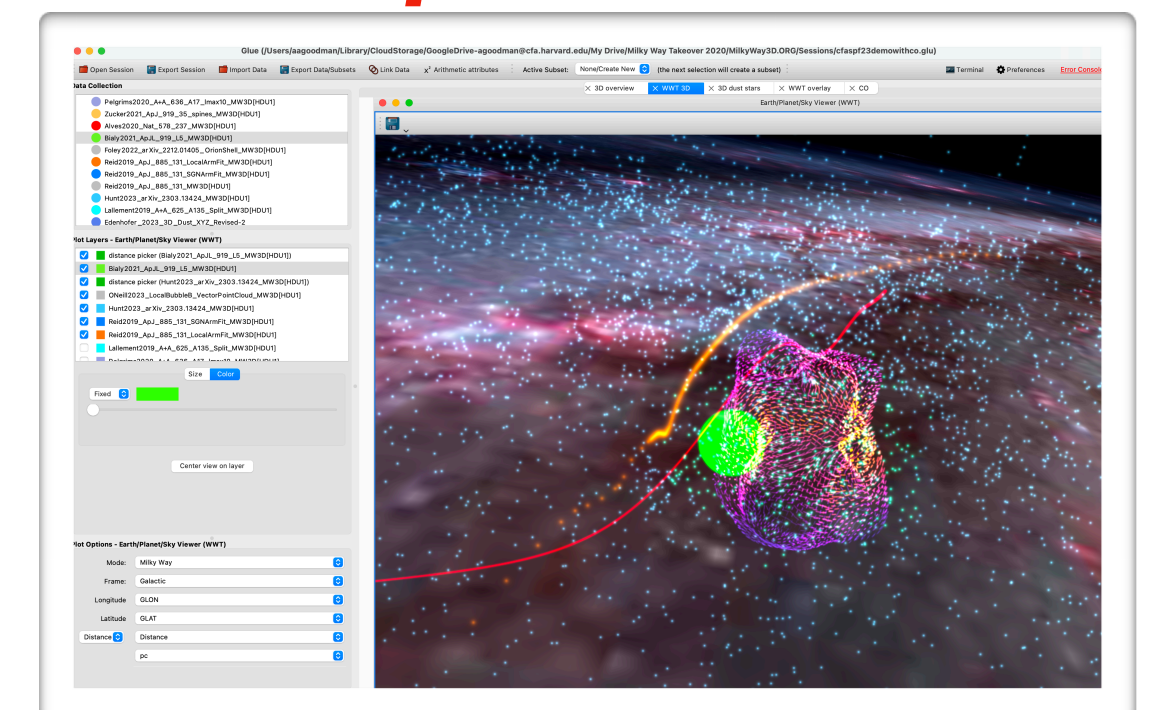
glue
multidimensional data exploration

fully **flexible**,
scriptable,
extensible.

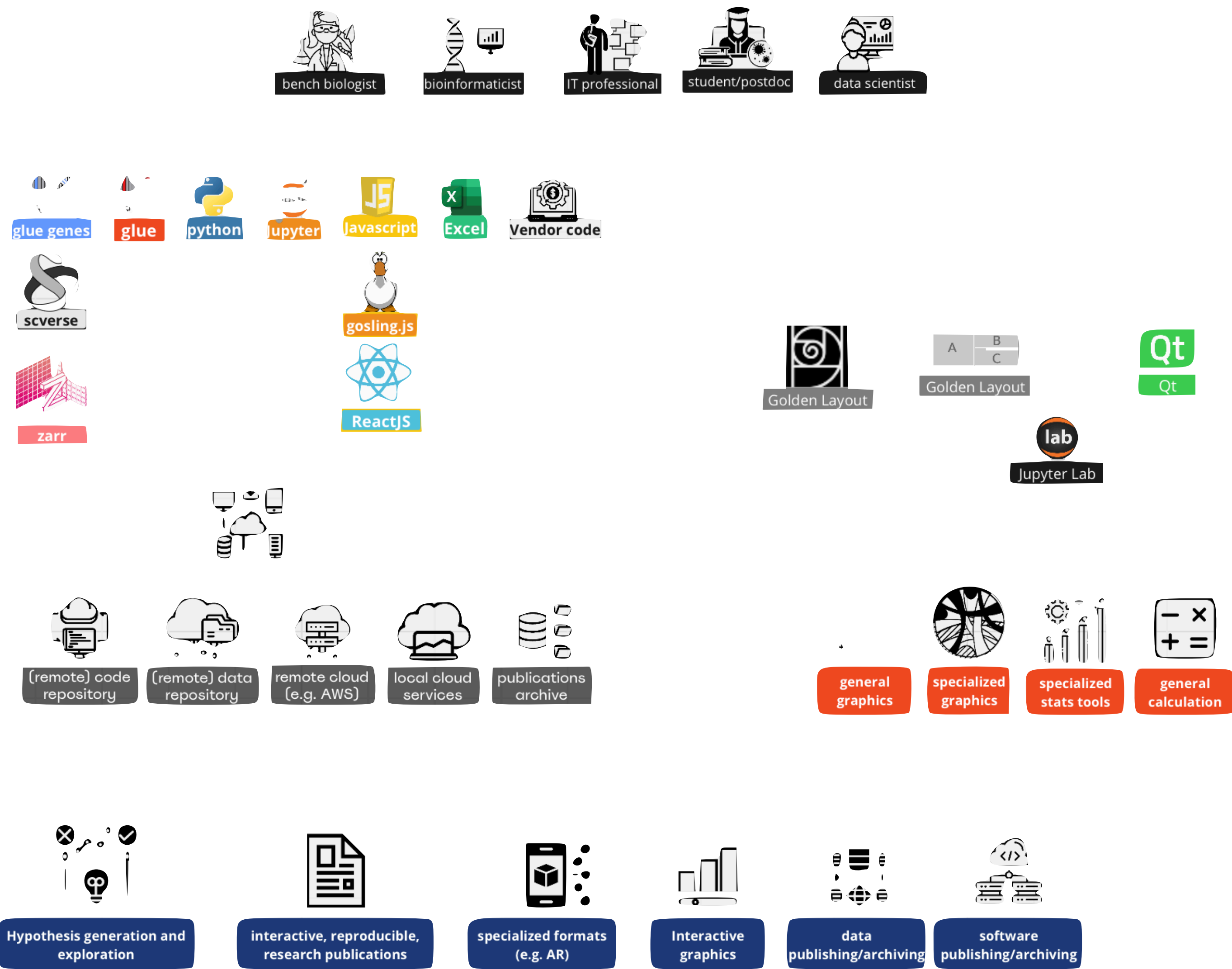
“simple”



“complicated”



“Customizable Complexity”



“Customizable Complexity”

“classic”
(Qt)

augmented
reality
(K plot)

CosmicDS
education +
outreach

dashboards

Something
for
everyone?

glue genes

MILKY WAY 3D.org
research +
edu + outreach
+ planetarium

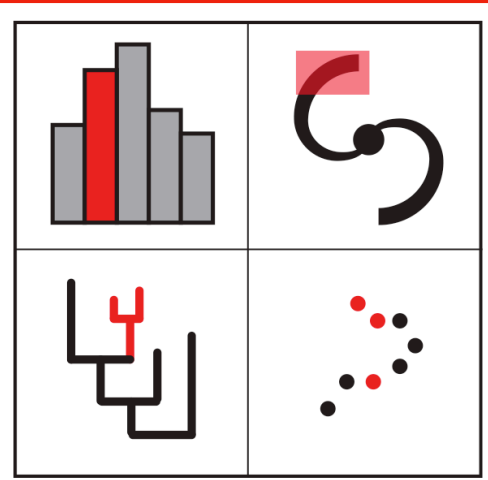
glue genes
What's next?

Data Collection

- Pelgrims2020_A+A_636_A17_lmax10_MW3D[HDU1]
- Zucker2021_ApJ_919_35_spines_MW3D[HDU1]
- Alves2020_Nat_578_237_MW3D[HDU1]
- Bialy2021_ApJL_919_L5_MW3D[HDU1]
- Foley2022_arXiv_2212.01405_OrionShell_MW3D[HDU1]
- Reid2019_ApJ_885_131_LocalArmFit_MW3D[HDU1]
- Reid2019_ApJ_885_131_SGNArmFit_MW3D[HDU1]
- Reid2019_ApJ_885_131_MW3D[HDU1]
- Hunt2023_arXiv_2303.13424_MW3D[HDU1]
- Lallement2019_A+A_625_A135_Split_MW3D[HDU1]
- Edenhofer_2023_3D_Dust_XYZ_Revised-2

Plot Layers - Earth/Planet/Sky Viewer (WWT)

- | | | |
|-------------------------------------|---|--|
| ☒ |  | distance picker (Bialy2021_ApJL_919_L5_MW3D[HDU1]) |
| ☒ |  | Bialy2021_ApJL_919_L5_MW3D[HDU1] |
| ☒ |  | distance picker (Hunt2023_arXiv_2303.13424_MW3D[HDU1]) |
| ☒ |  | ONeill2023_LocalBubbleB_VectorPointCloud_MW3D[HDU1] |
| ☒ |  | Hunt2023_arXiv_2303.13424_MW3D[HDU1] |
| ☒ |  | Reid2019_ApJ_885_131_SGNArmFit_MW3D[HDU1] |
| ☒ |  | Reid2019_ApJ_885_131_SGNArmFit_MW3D[HDU1] |
| ☐ |  | Lallement2019 |
| ☐ |  | Delorme2020 |



Center view on layer

"classic"
(Qt)

Plot Options - Earth/Planet/Sky Viewer (WWT)

Mode: Milky Way

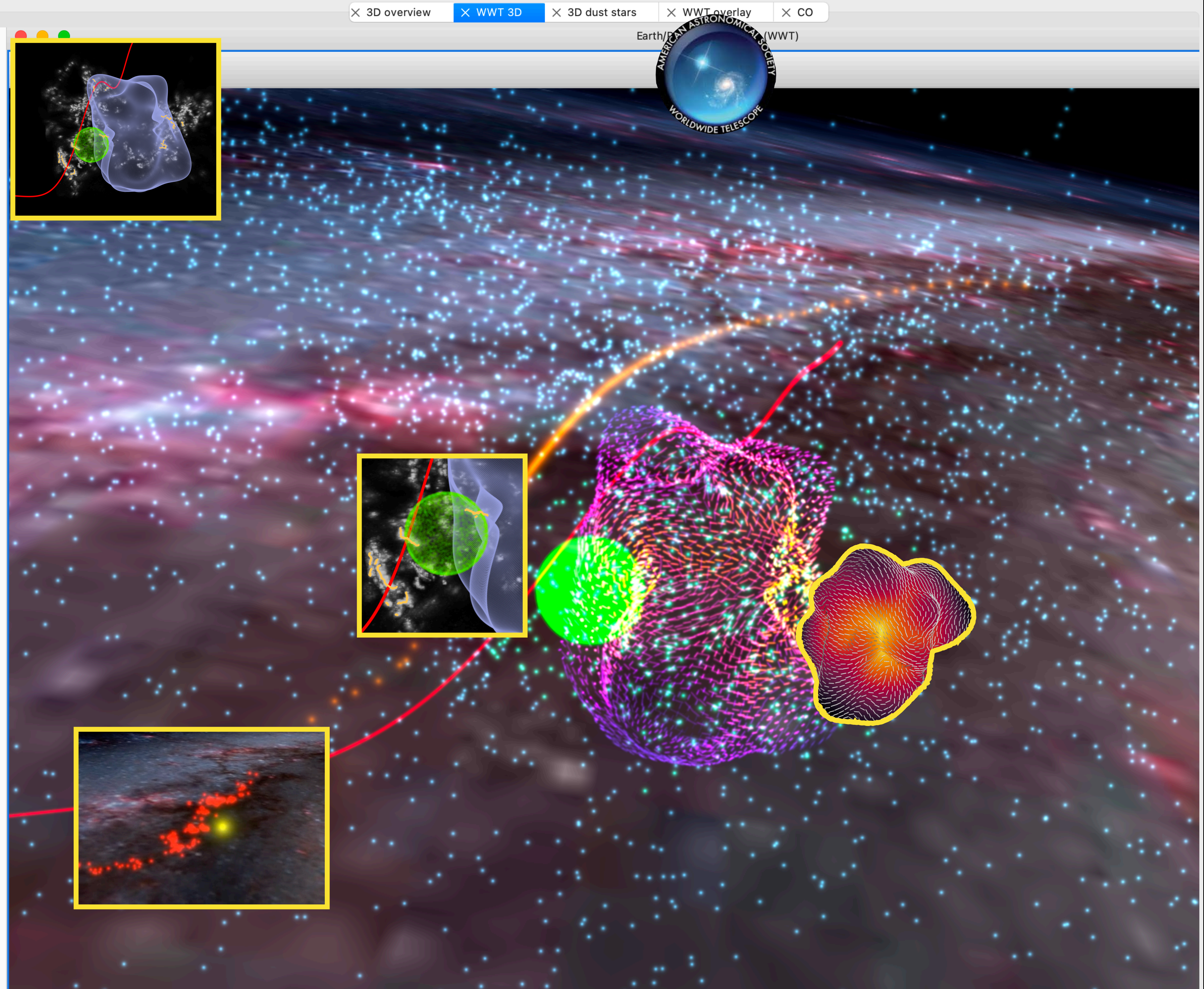
Frame: Galactic

Longitude GLON

Latitude ☒ GLAT

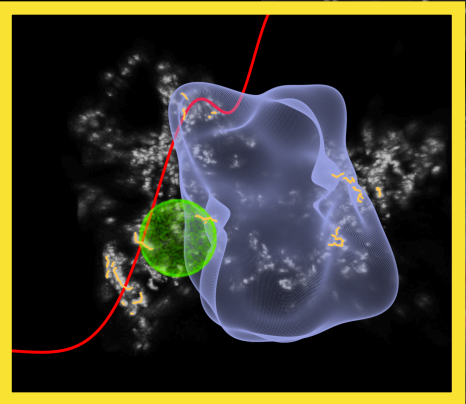
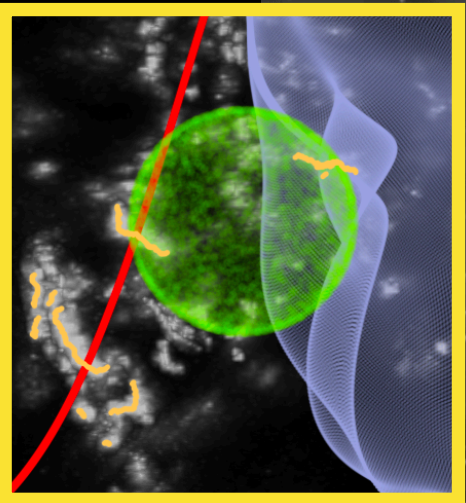
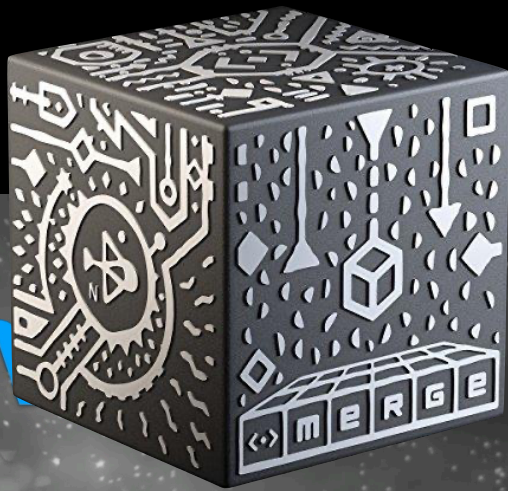
Distance  Distance

pc



The New Milky Way made possible by **glue** (& 3D dust mapping)

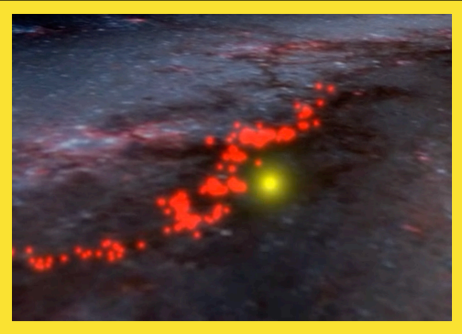
2021



THE **PERSEUS-TAU** SUPERSHELL IN 3D

you in 2021 by an international team of scientists from
Center for Astrophysics | Harvard & Smithsonian, Harvard Radcliffe Institute, University of Vienna, University of
Wisconsin, Max-Planck Institute, Ludwig Maximilian University, and technology from ESA, and Delightex.

Magnetized Local Bubble,



SURF THE RADCLIFFE WAVE

The Radcliffe Wave is a gigantic structure that defines the shape of the Sun's local neighborhood in the Milky Way Galaxy. Its existence was first presented officially in a paper published in *Nature* on January 7, 2020. This website offers scientists, educators, and the interested public much more information about the "RadWave," as we like to call it. Please use this page to find **publications** and **talks**, **visuals** (images, interactives, and videos), **history**, **team** info, **software**, and **data**. And, if we forgot something, just let us know—and we'll try to include it in future updates!

Want to see for yourself? Explore the Wave in 3D in WorldWide Telescope!

Publications & Talks

Visuals

History

Team

Software

Data

2020

Star Formation near the Sun is driven by expansion of the Local Bubble

The discovery that the 1000-light-year-wide "Local Bubble" surrounding the Sun and Earth is responsible for the formation of all nearby, young stars was first presented in a paper published in *Nature* on January 12, 2022. Please use this page to find **news**, **publications** and **talks**, **visuals** (images, interactives, and videos), **team** info, and **data**. And, if we forgot something, just let us know—and we'll try to include it in future updates!

Want to see for yourself? Click [HERE](#) for interactive figure!

Visuals

Team

Software

Data



2022

Jump to...

Publications & Talks

Visuals

Software

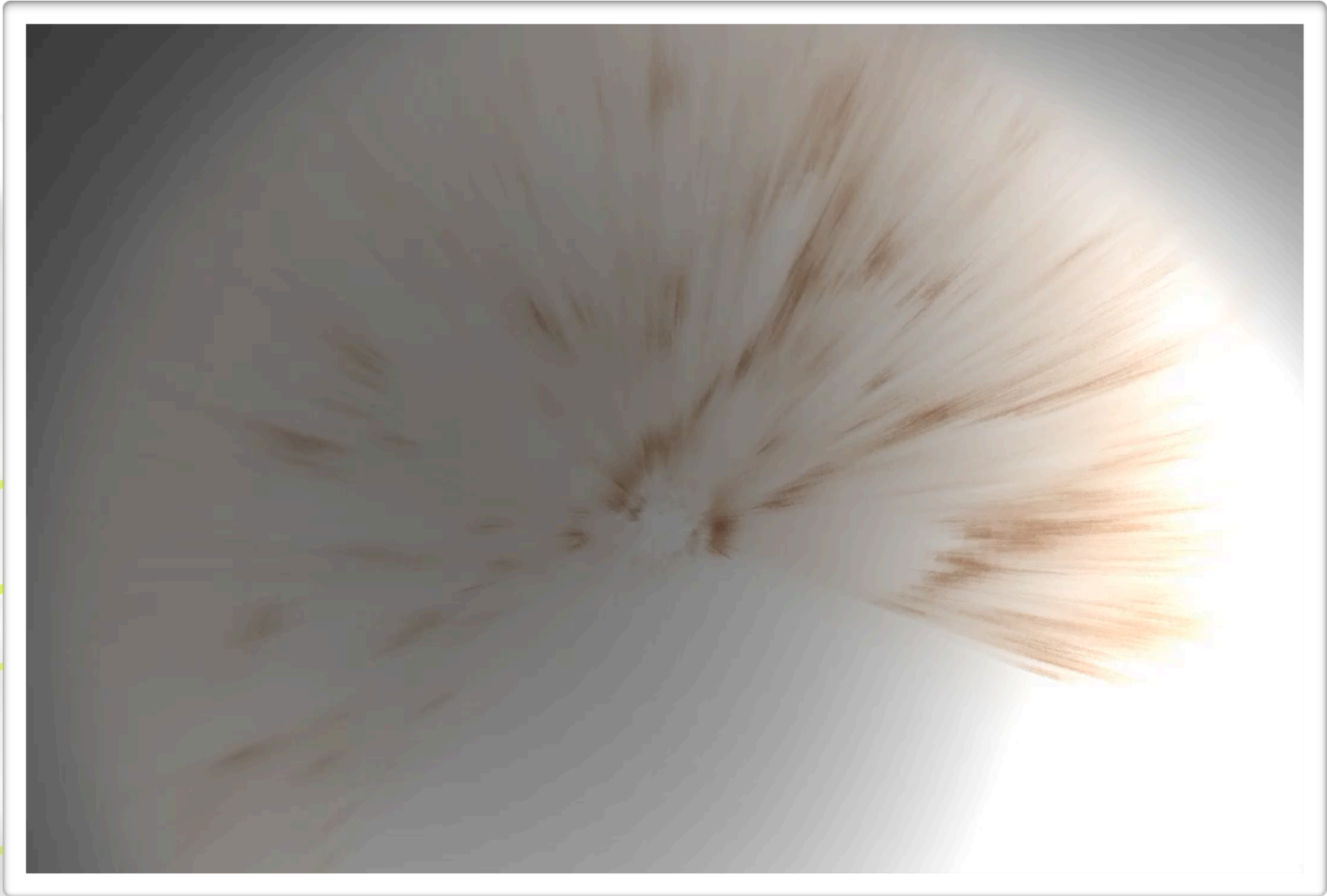
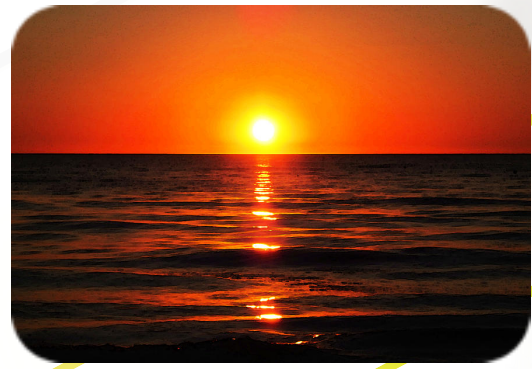
News

Data

2023

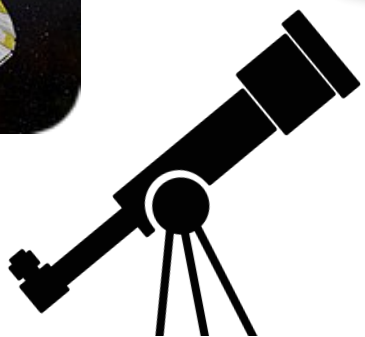
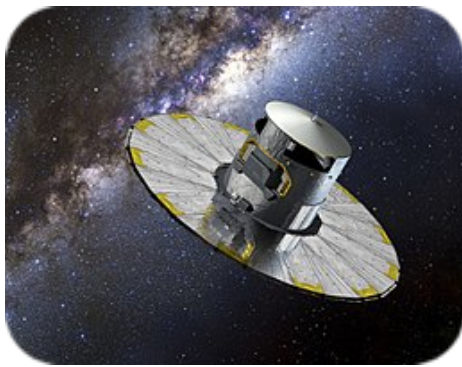
“3D dust Mapping”

extinction & reddening, from color imaging



Green et al. 2019

Can infer matter's distance from dust's effects on stars.



THE **PERSEUS**—**TAURUS**

SUPERSHELL IN SPACE

*brought to you in 2021 by an international team of scientists from
Center for Astrophysics | Harvard & Smithsonian, Harvard Radcliffe Institute, University of Vienna, University of
Wisconsin, Max-Planck Institute, Ludwig Maximilian University, and technology from ESA, NASA, NSF and Delightex.*

animation by Jasen Lux Chambers

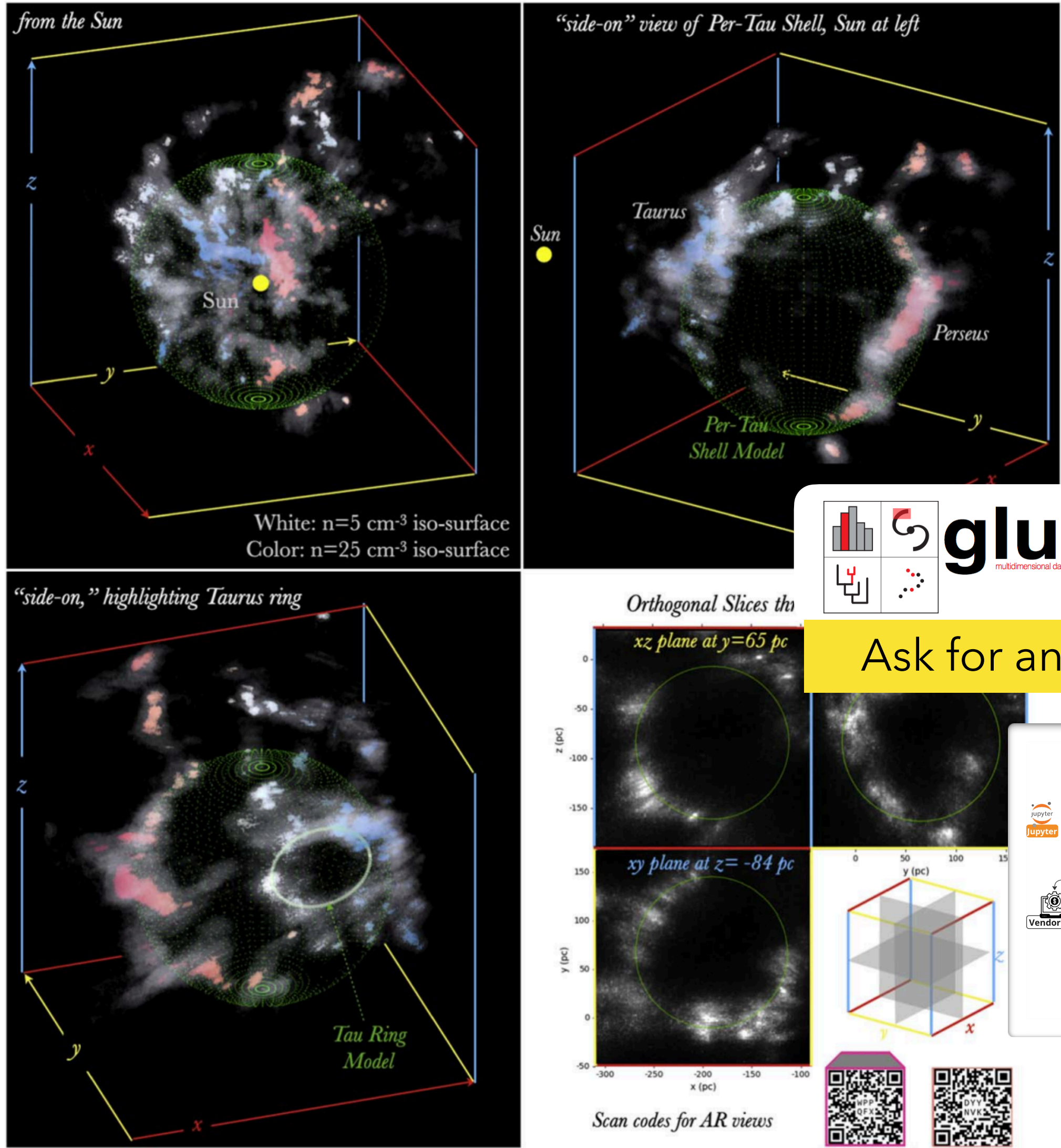
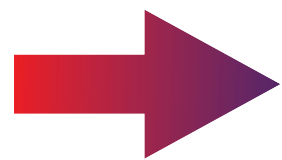
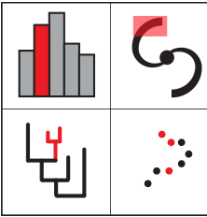
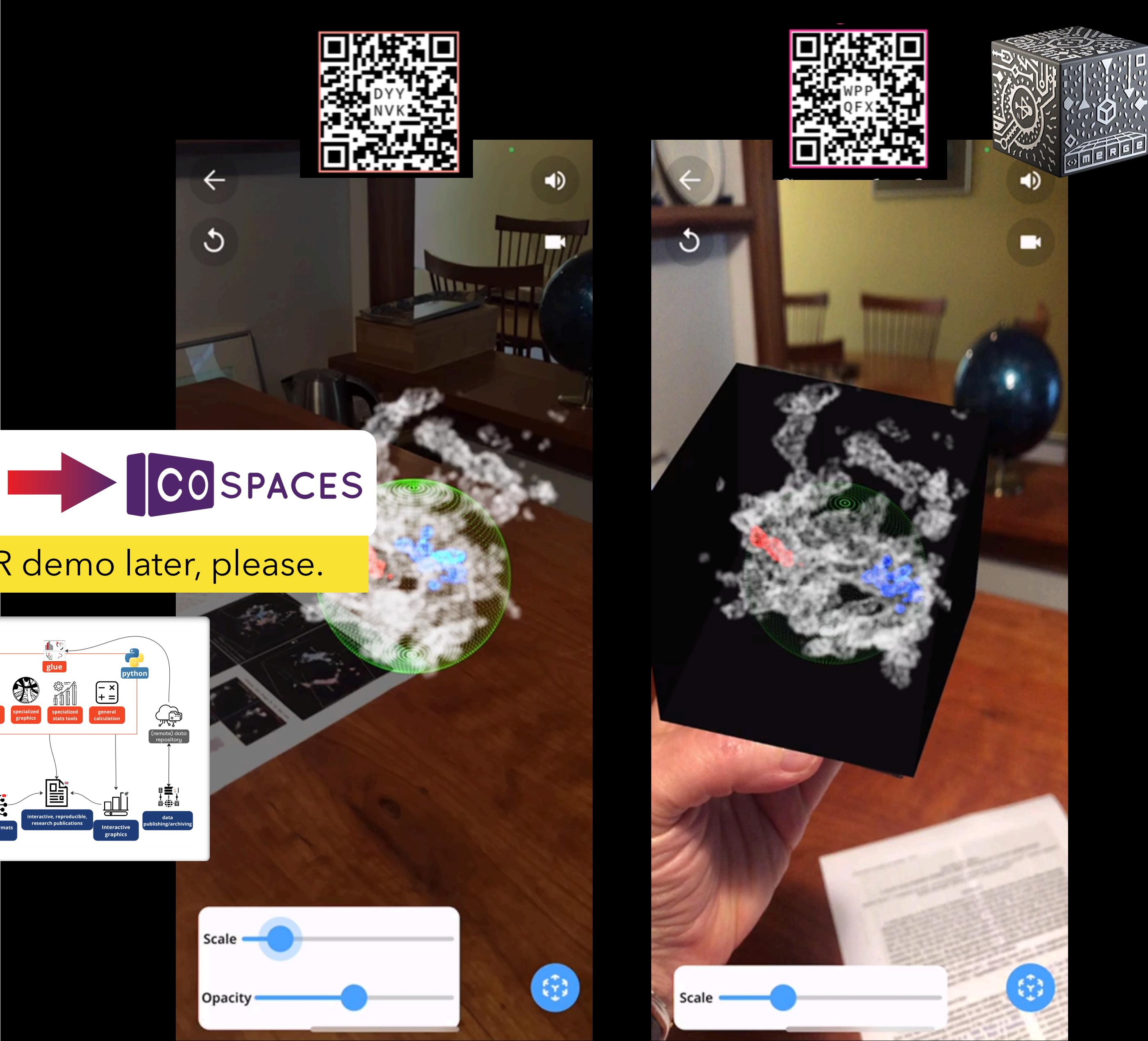
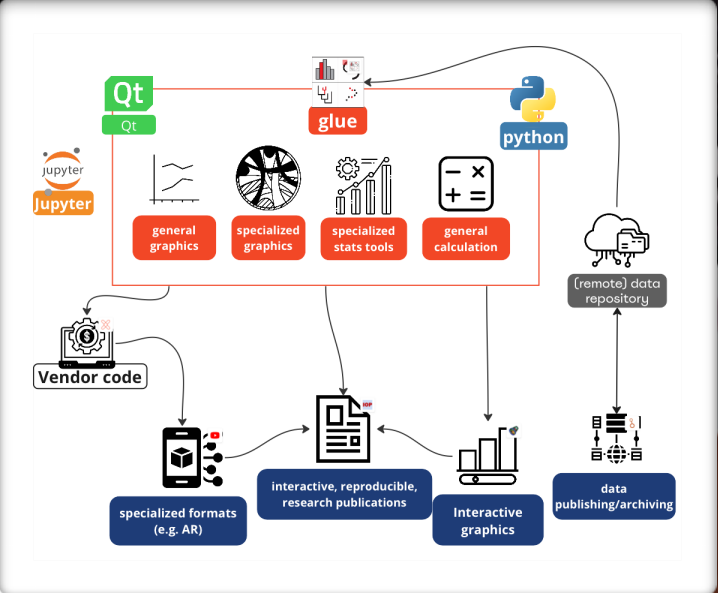


Figure 2. 3D views of the Per-Tau shell (for an interactive version⁸ of this figure click [here](#)⁹; see Figure 5 for more static visualizations). Plotted are density iso-surfaces at levels $n = 5 \text{ cm}^{-3}$ (gray) and $n = 25 \text{ cm}^{-3}$ (color), overlaid with our spherical-shell model, radius $R_s = 78 \text{ pc}$, distance from the Sun $d = 218 \text{ pc}$. The $n = 25 \text{ cm}^{-3}$ surfaces are colored by distance from the Sun (blue-to-red). Top-left panel: view from the Sun (compare with Figure 1). Top-right panel: a side view of the region. Perseus and Taurus and their diffuse envelopes are arranged on two opposing sides of the Per-Tau shell. Bottom-left panel: another side view emphasizing the Tau Ring. The ellipse is the Tau Ring model (Appendix B). Bottom-right panel: 2D density slices along the xy , xz , yz planes. All planes intersect at shell’s center. In all panels xyz are the Heliocentric Cartesian Galactic Coordinates.

2. *Tau Ring*: in a sky projection the Tau Ring is seen almost edge-on. The near side of the Tau Ring connects with the main body of Taurus at $d \approx 150 \text{ pc}$, whereas the farthest part extends to $d \approx 220 \text{ pc}$.
3. *The Fictitious Connection*: A filament seems to connect Taurus to Perseus. This connection is only a coincidental projection effect, where in actuality the filament is located at the distance of Taurus, and does not physically connect



Ask for an AR demo later, please.



THE “MAKING OF” THE PER-TAU EXPLAINER—WHY WE NEED TO DO BETTER...

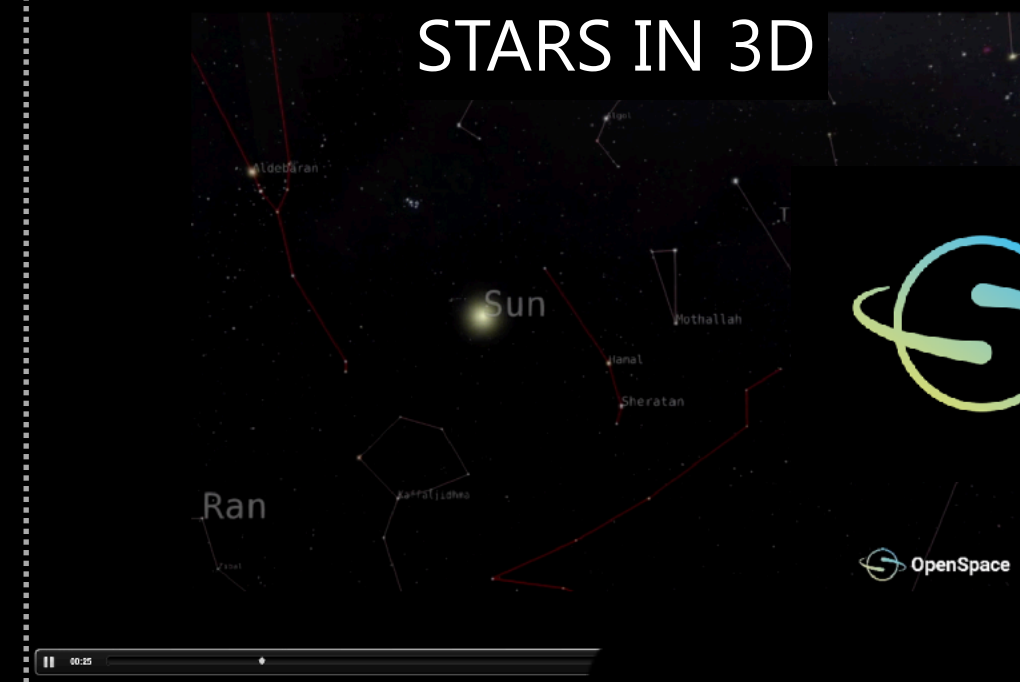


THE “MAKING OF” THE PER-TAU EXPLAINER—WHY WE NEED TO DO BETTER...

OVERVIEW CARTOON



STARS IN 3D



3D→2D (Sky) view shifting



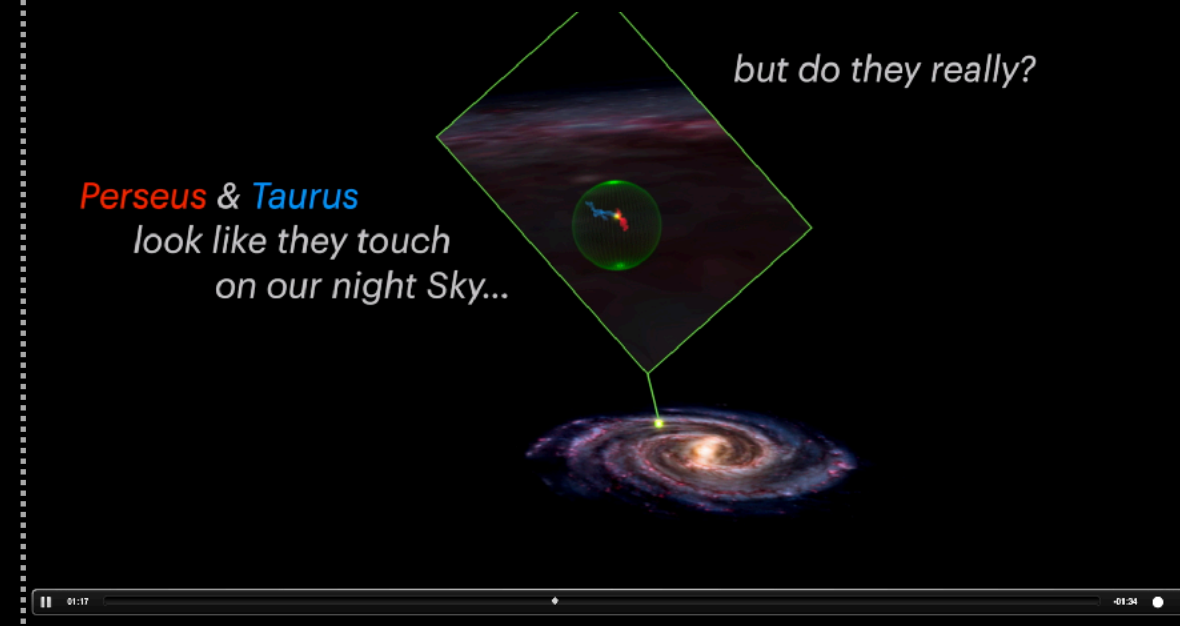
“special” region indications (2D)



pop-outs

but do they really?

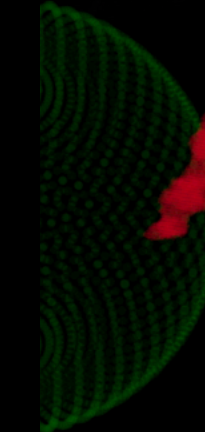
Perseus & Taurus
look like they touch
on our night Sky...



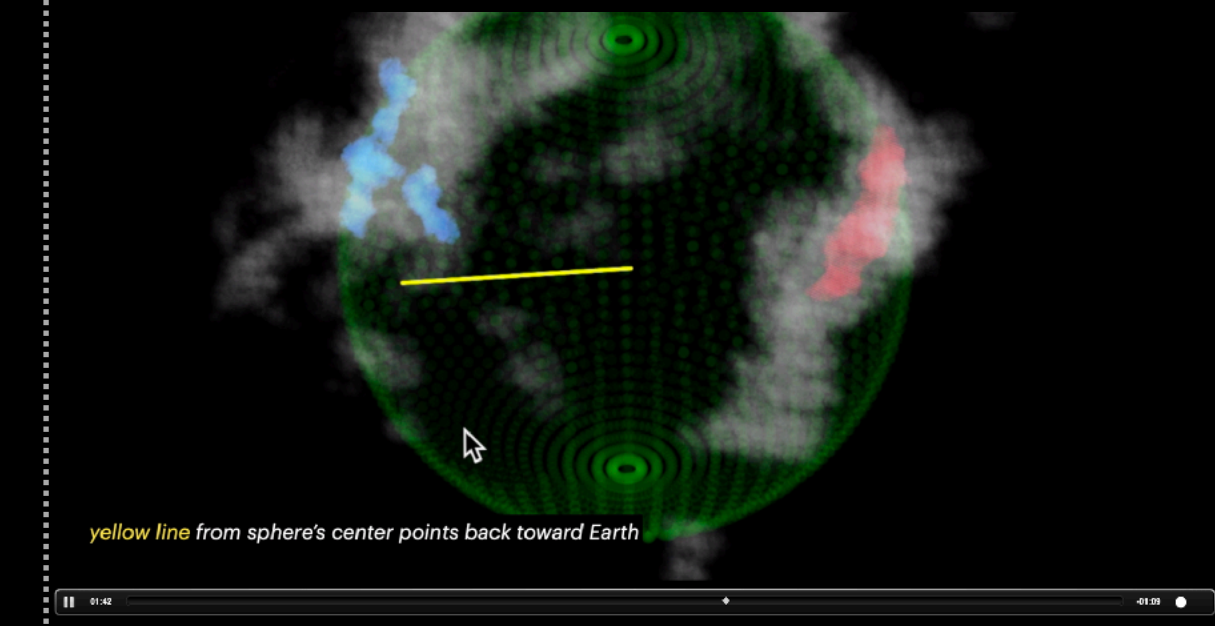
interaction, with



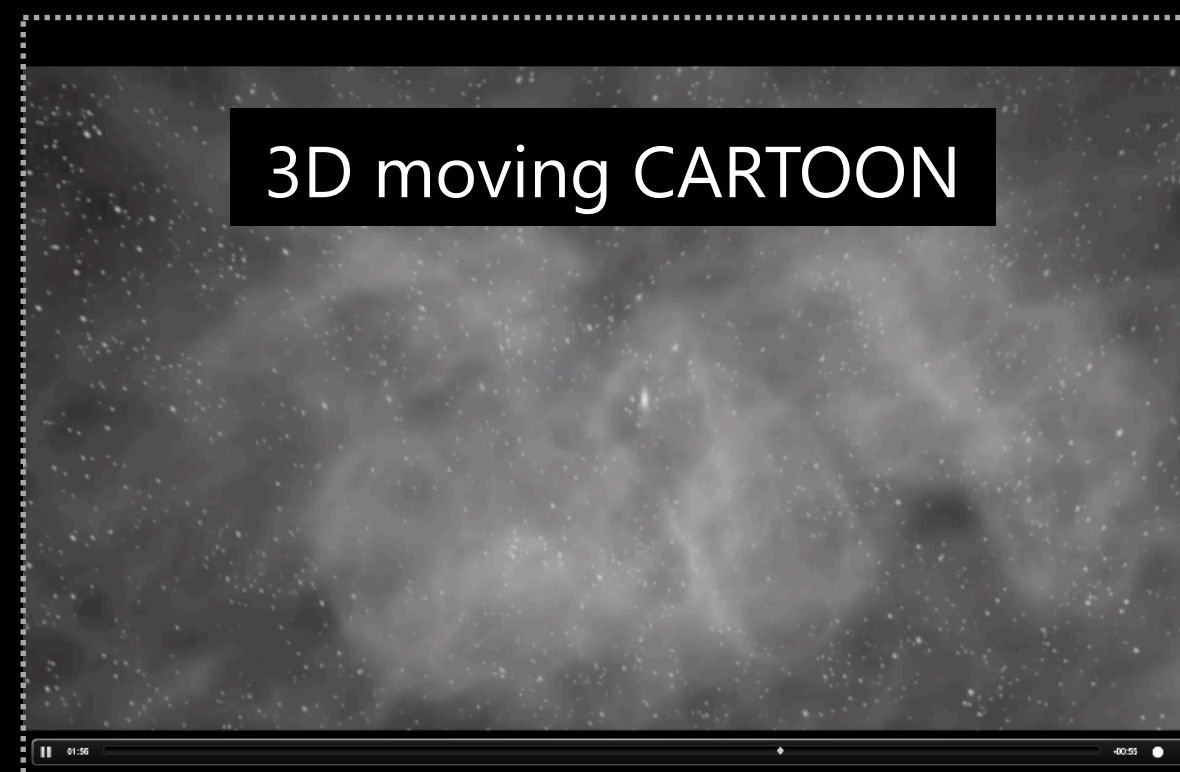
n, scales, grids



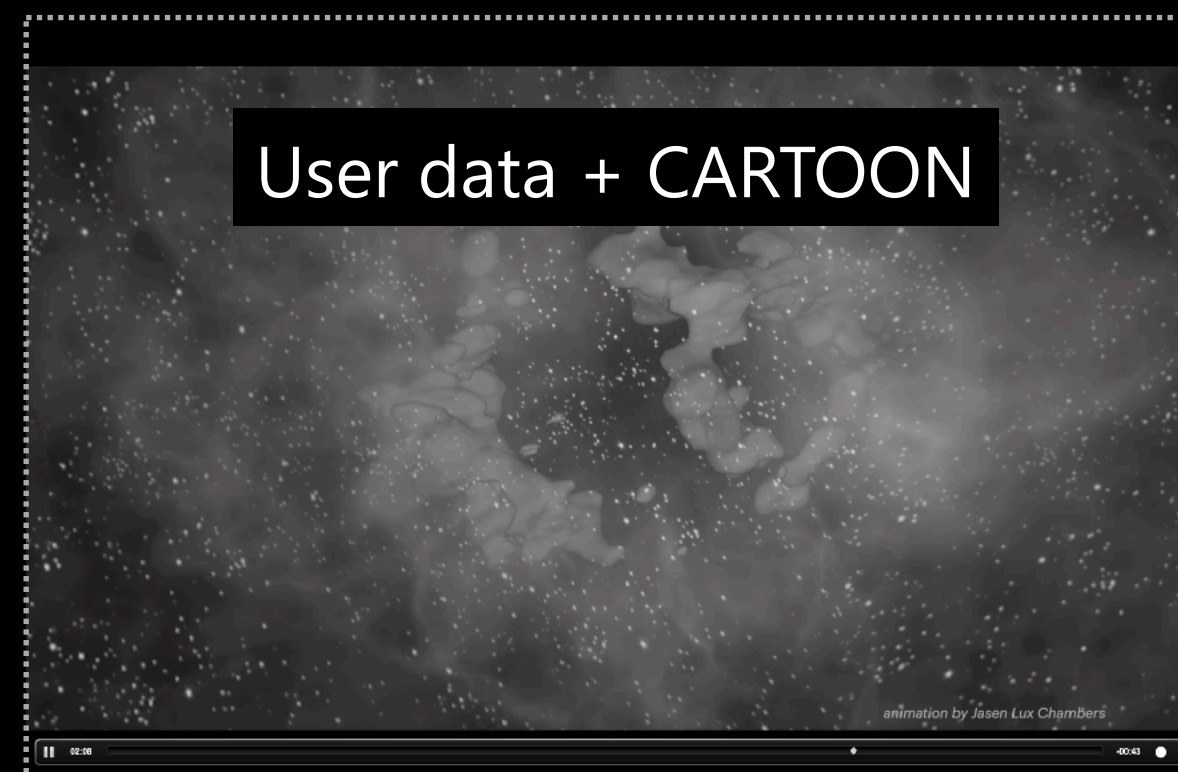
layer control + slicing (not shown)



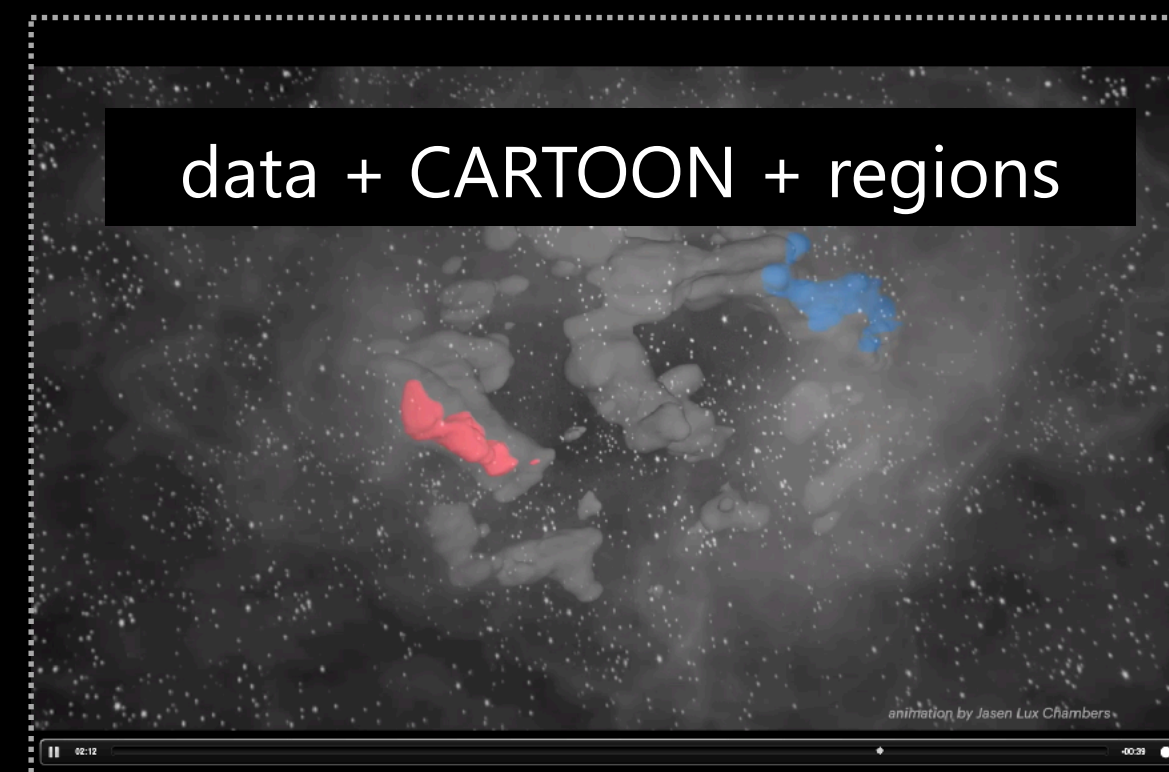
3D moving CARTOON



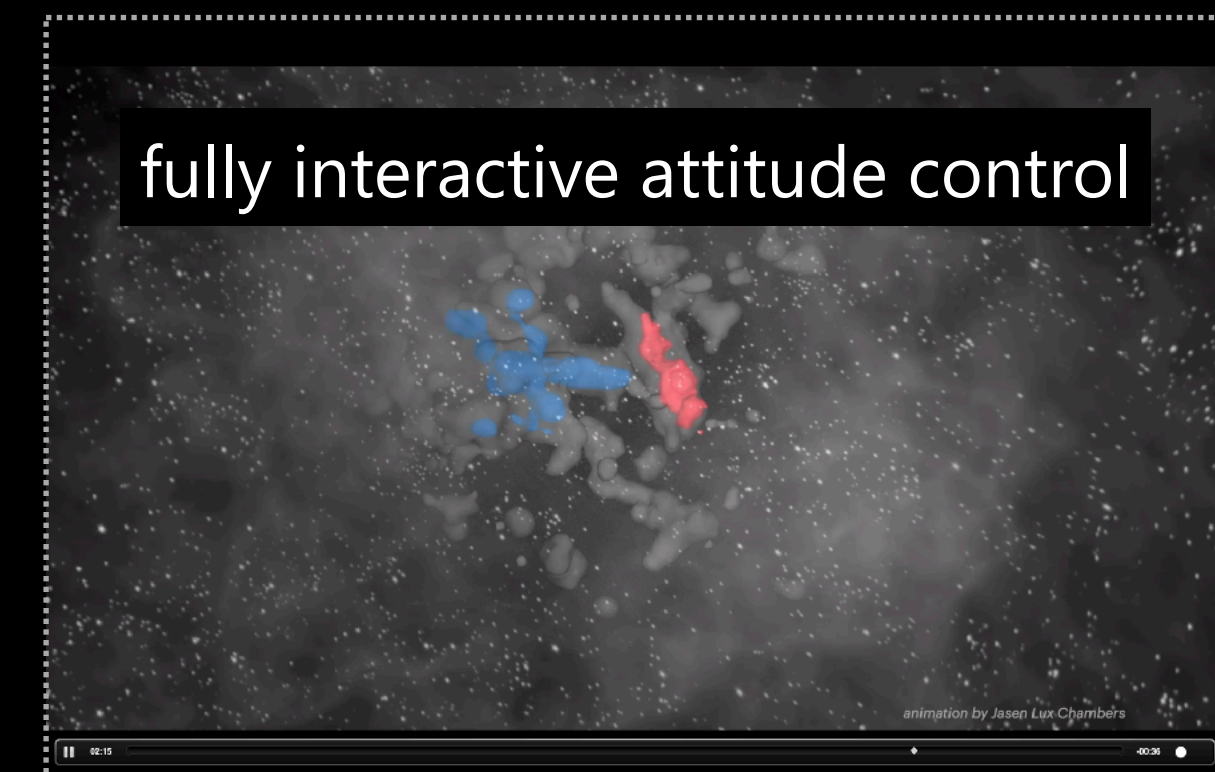
User data + CARTOON



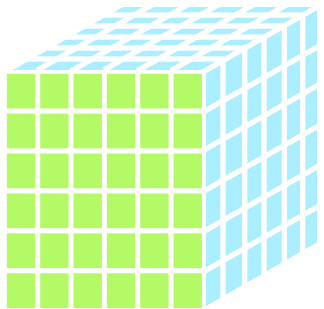
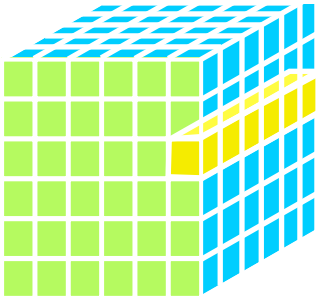
data + CARTOON + regions



fully interactive attitude control



great 1D, 2D and 3D data manipulation,
flexible architecture facilitating plug-ins, data
transfer, and interactive data exploration;
"glupyter" flavor runs in web pages



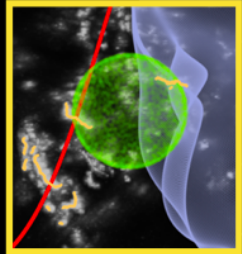
plug-in shows WWT images in
context

great 2D object and all-sky images
limited 3D functionality

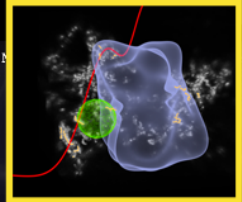
The New Milky Way made possible
by glue (& 3D dust mapping)



SURF



2021
THE PERSEUS-TAURUS
SUPERSHELL



Magnetized Local Bubble,



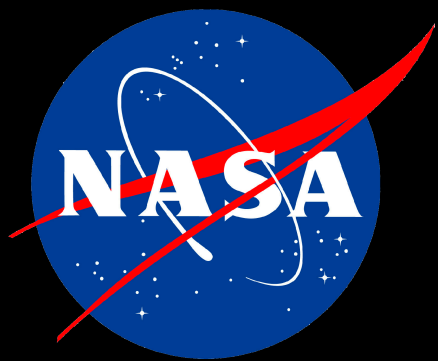
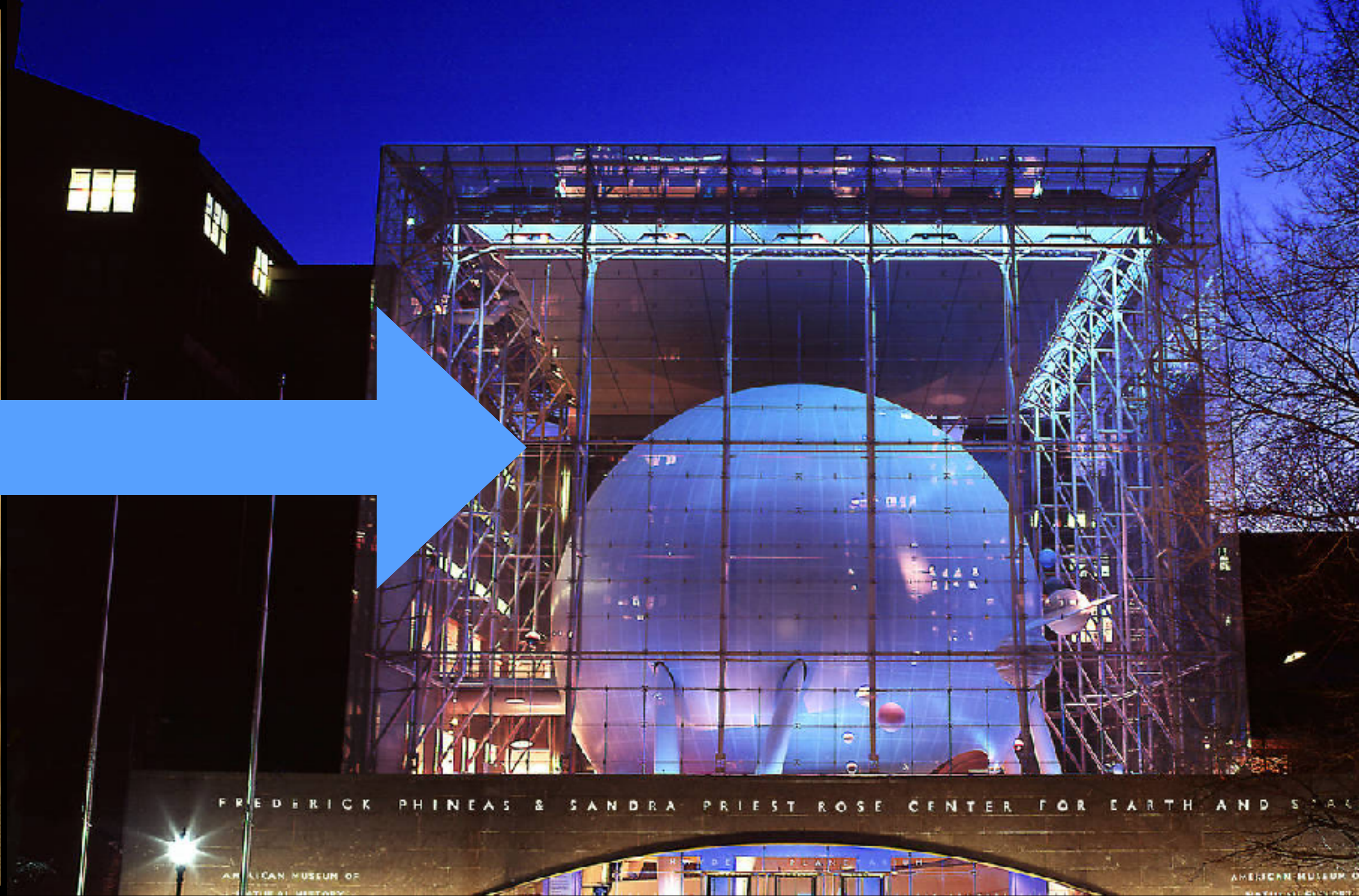
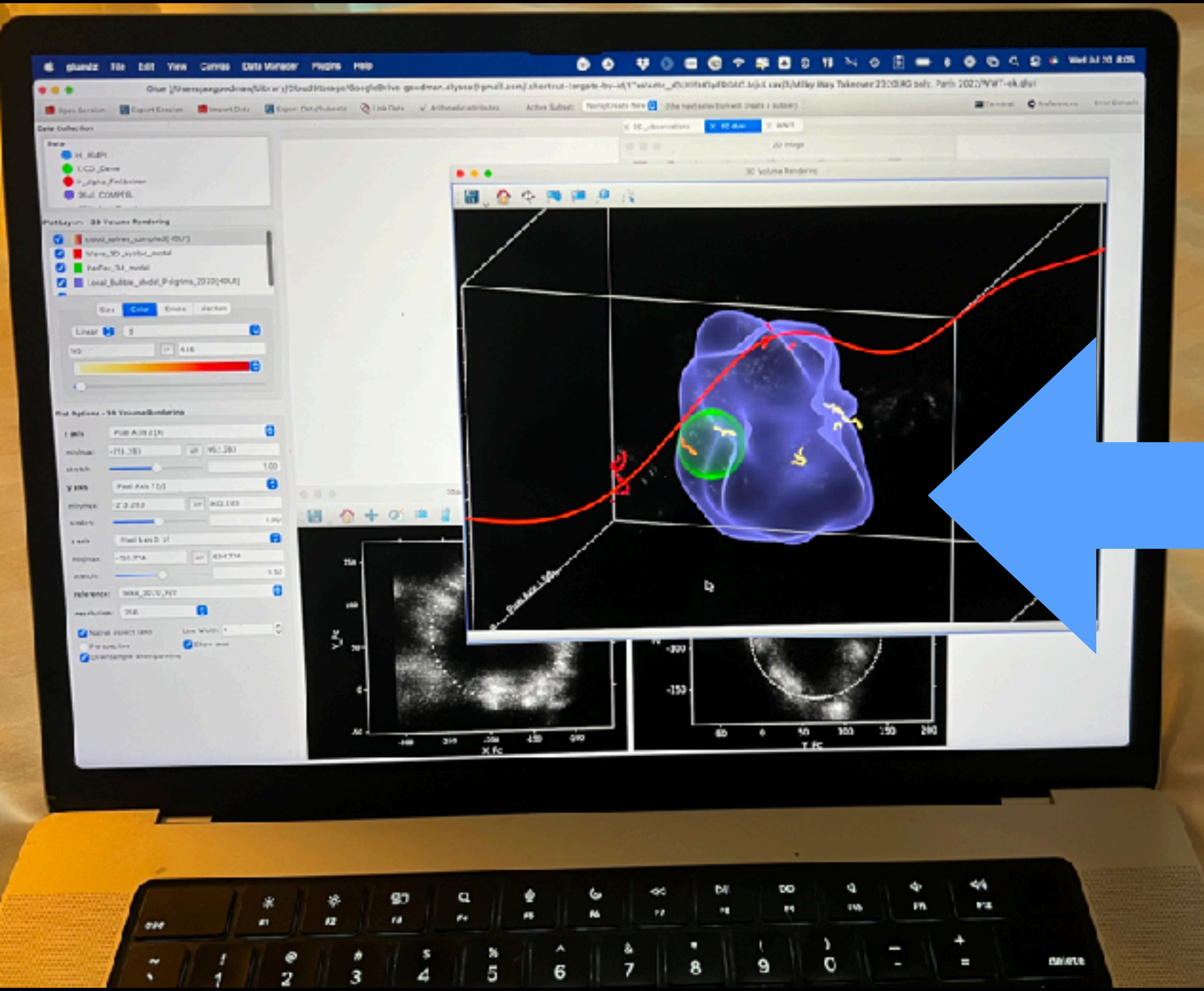
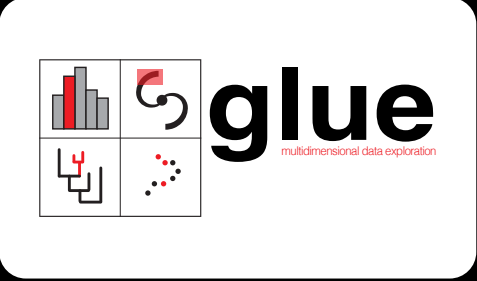
research+
edu+outreach
+planetarium



2022

2023







THE MILKY WAY IN 3D

(V1-THE SUN'S NEIGHBORHOOD)



PEOPLE

Brian Abbott

American Museum of Natural History

Assistant director of the Hayden Planetarium and co-founder of the Digital Universe atlas. I work on collating astrophysical data into a consistent atlas that we explore in OpenSpace. Trained as an astrophysicist, I work more on visualizing science and communicating astrophysics to the public.

Micah Acinapura

American Museum of Natural History, OpenSpace

OpenSpace developer, support engineer for OpenSpace users.

João Alves

University of Vienna

Professor of Astronomy with longstanding interests in star formation and data visualizaiton.

Bob Benjamin

Professor, University of Wisconsin, Whitewater

Alex Bock *Linköping University*

Lead developer of OpenSpace; Tailored visualizations.

Jonathan Carifio

Harvard University, Center for Astrophysics | Harvard & Smithsonian

Software developer, glue and WorldWide Telescope

Gordian Edenhofer

Max Planck Institute for Astrophysics, Garching, Germany

PhD Student

Carter Emmart *American Museum of Natural History*

Director of Astro Visualization. Directs AMNH space show and Creative Director for OpenSpace

Jackie Faherty

American Museum of Natural History, Department of Astrophysics & Department of Education

Senior scientist and senior education manager. Scientific interests include the young solar neighborhood (from stars to brown dwarfs and planets). Education interests include immersive visual presentations of cutting edge scientific discoveries.

Alyssa Goodman

Harvard University, Center for Astrophysics | Harvard & Smithsonian

Astronomy Professor with longstanding interest in data visualization. PI of the glue project, President of glue solutions, inc. WorldWide Telescope “pet scientist.” PI of NASA’s Cosmic Storytelling STEM outreach project.

Anna Nolin

Harvard University, Center for Astrophysics | Harvard & Smithsonian

Graphic designer

Theo O'Neill

Harvard University, Center for Astrophysics | Harvard & Smithsonian

Research Assistant & Data Scientist

Sebastian Ratzenböck

University of Vienna

Post-Doc & Data Scientist

Thomas Robitaille

Aperio Software, glue solutions, inc.

Lead software architect of glue, co-developer of pyWWT

Patricia Udomprasert

Harvard University, Center for Astrophysics | Harvard & Smithsonian

Project Director WWT Ambassadors Program; Science PI of Cosmic Storytelling with NASA Data SciAct project

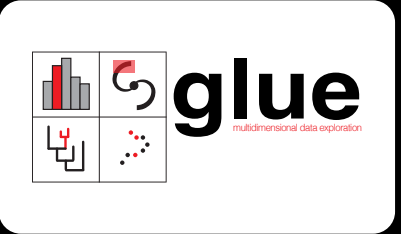
Catherine Zucker

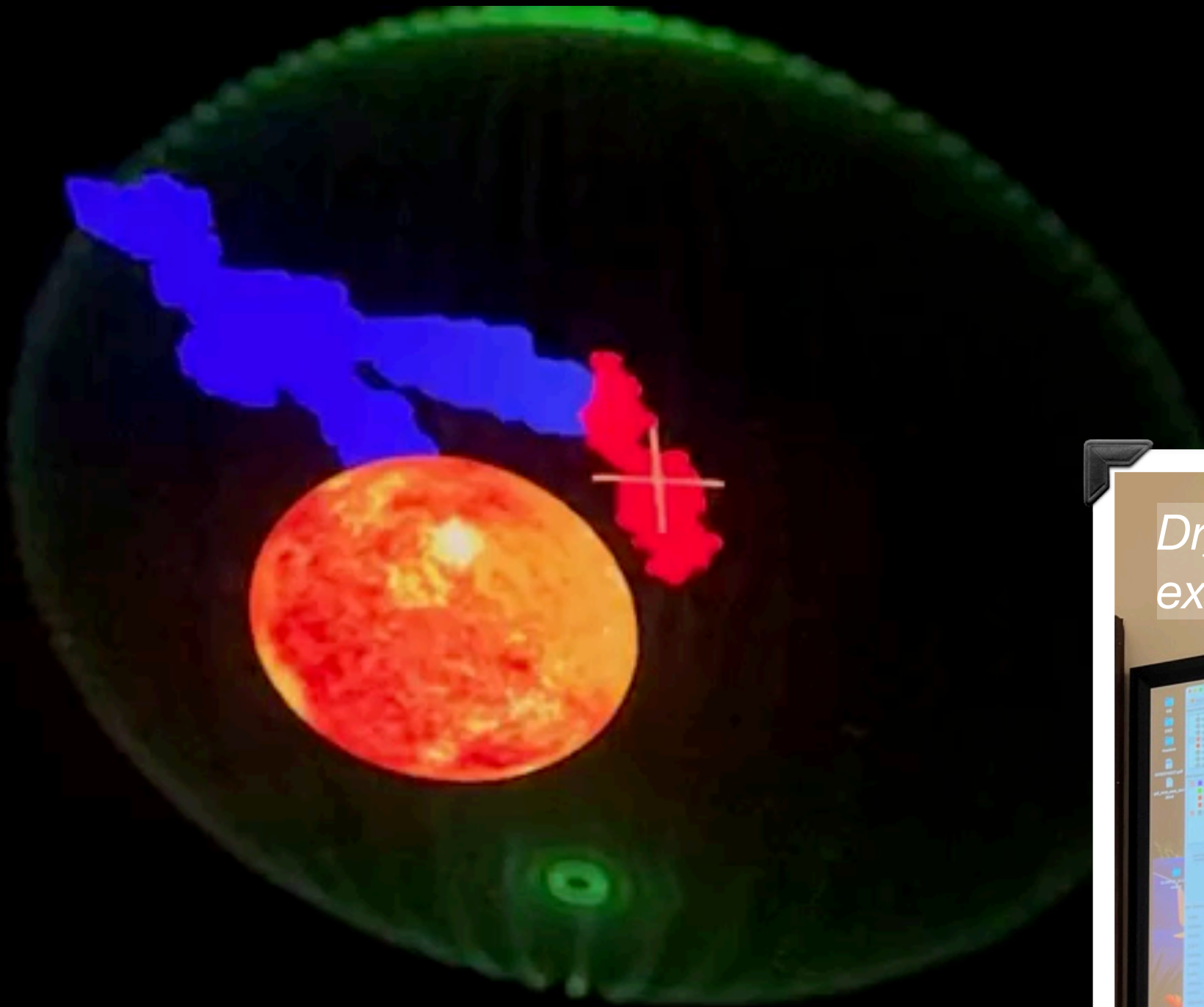
Space Telescope Science Institute

Hubble Fellow with interests in star formation, the interstellar medium, and the structure and dynamics of our Milky Way Galaxy. Loves data visualization, augmented reality, and open data sharing!

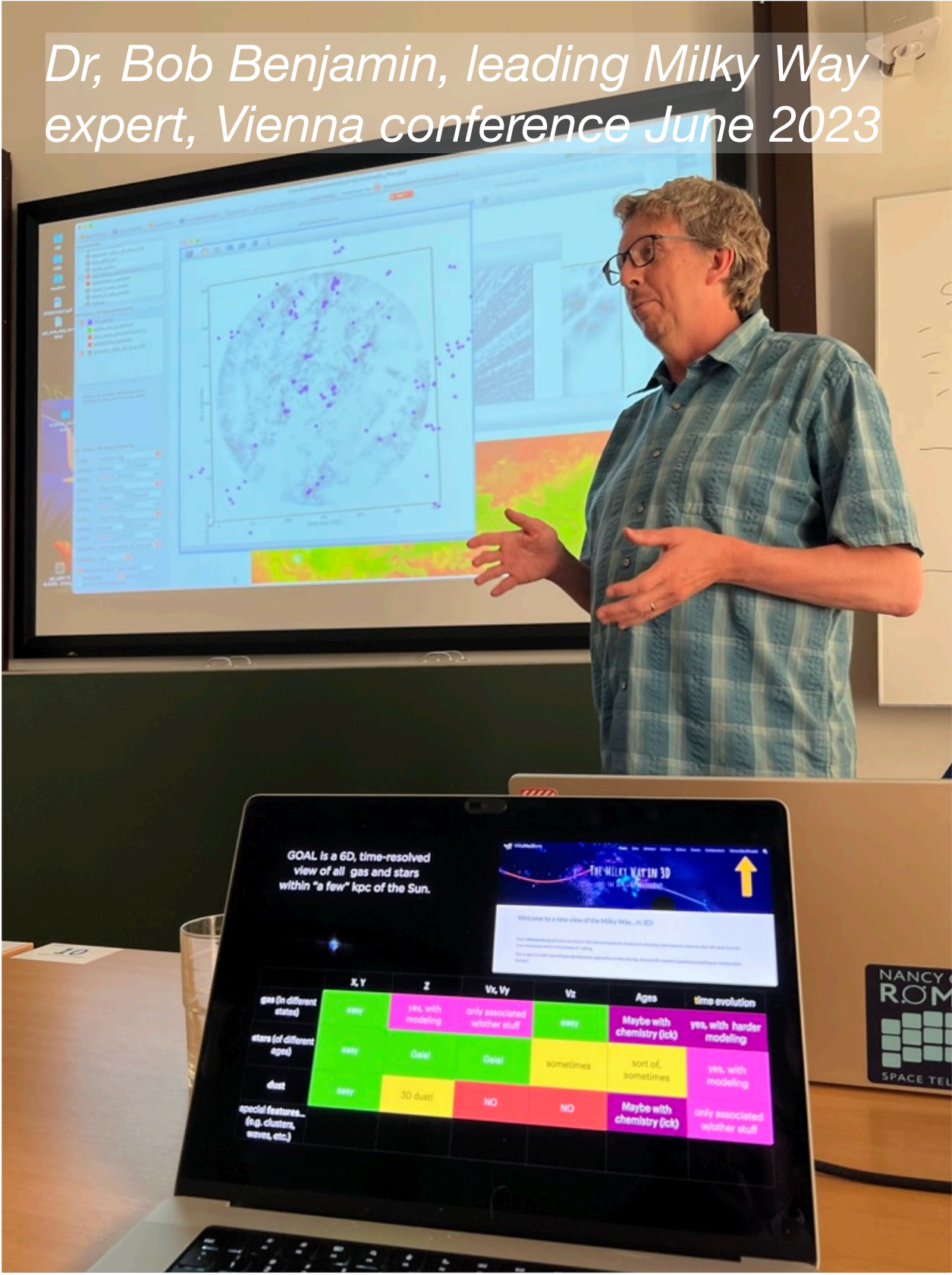
Photo of Dr. Cahterine Zucker & Mlcah Acinapura at the Hayden Planetarium, NYC, Fall 2022

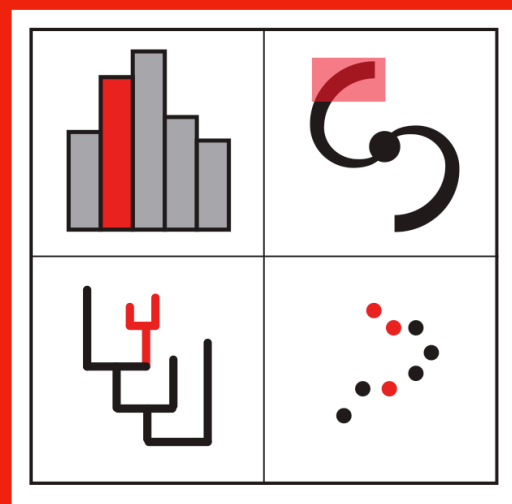






Dr. Bob Benjamin, leading Milky Way expert, Vienna conference June 2023





"classic"
(Qt)

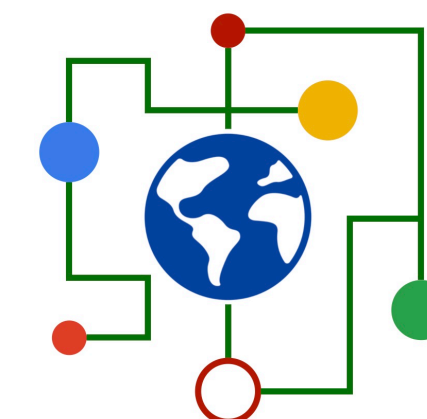


augmented
reality
(& plot.ly)



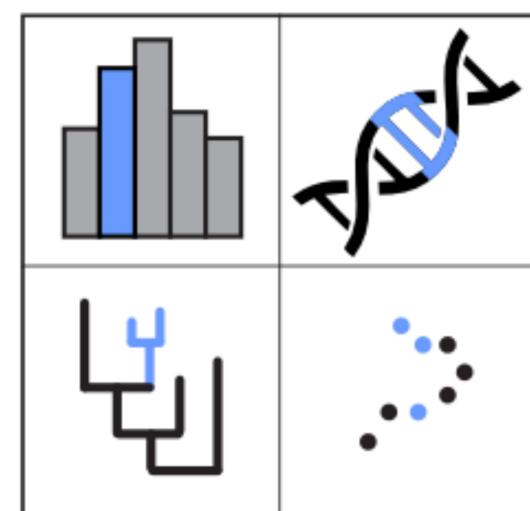
CosmicDS

education+
outreach



dashboards

Something
for
everyone?



glue genes



research+
edu+outreach
+planetarium

glupyter

What's next?

“Customizable Complexity”



guided experience for
learners, no coding, only
interactive webpages



dashboard-style



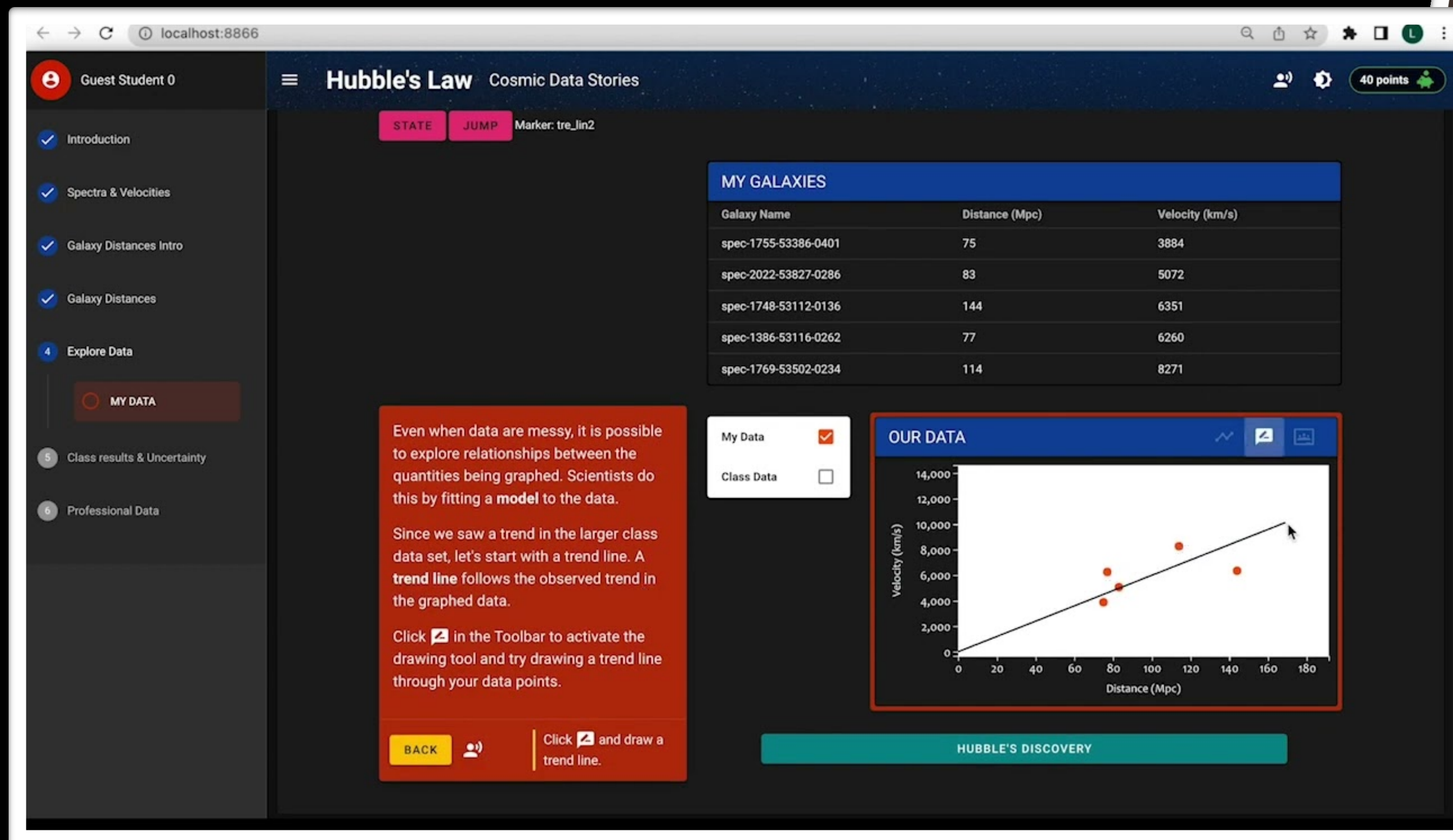
fully **flexible**,
scriptable,
extensible.

“simple” ←  *“complicated”*

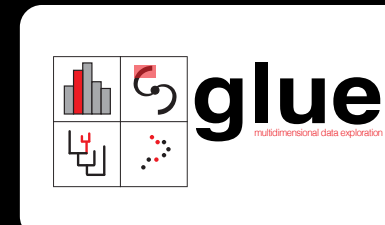


guided experience for learners, no coding, only interactive webpages

“mini” DS



Narrator + Science PI of “Cosmic Data Stories” SciAct Project: Dr. Pat Udomprasert



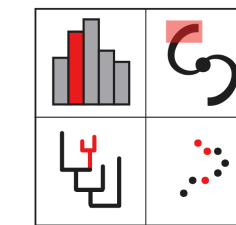
“Customizable Complexity”



guided experience for learners, no coding, only interactive webpages



dashboard-style



glupyter
multidimensional data exploration

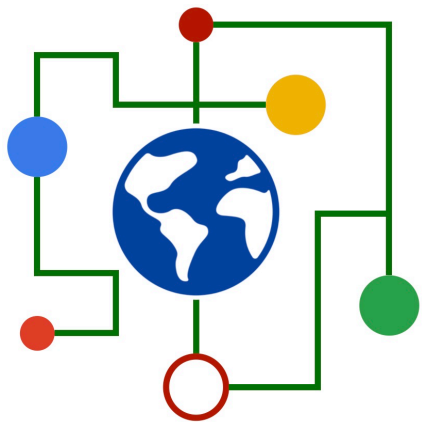
fully **flexible**,
scriptable,
extensible.

“simple”



“complicated”

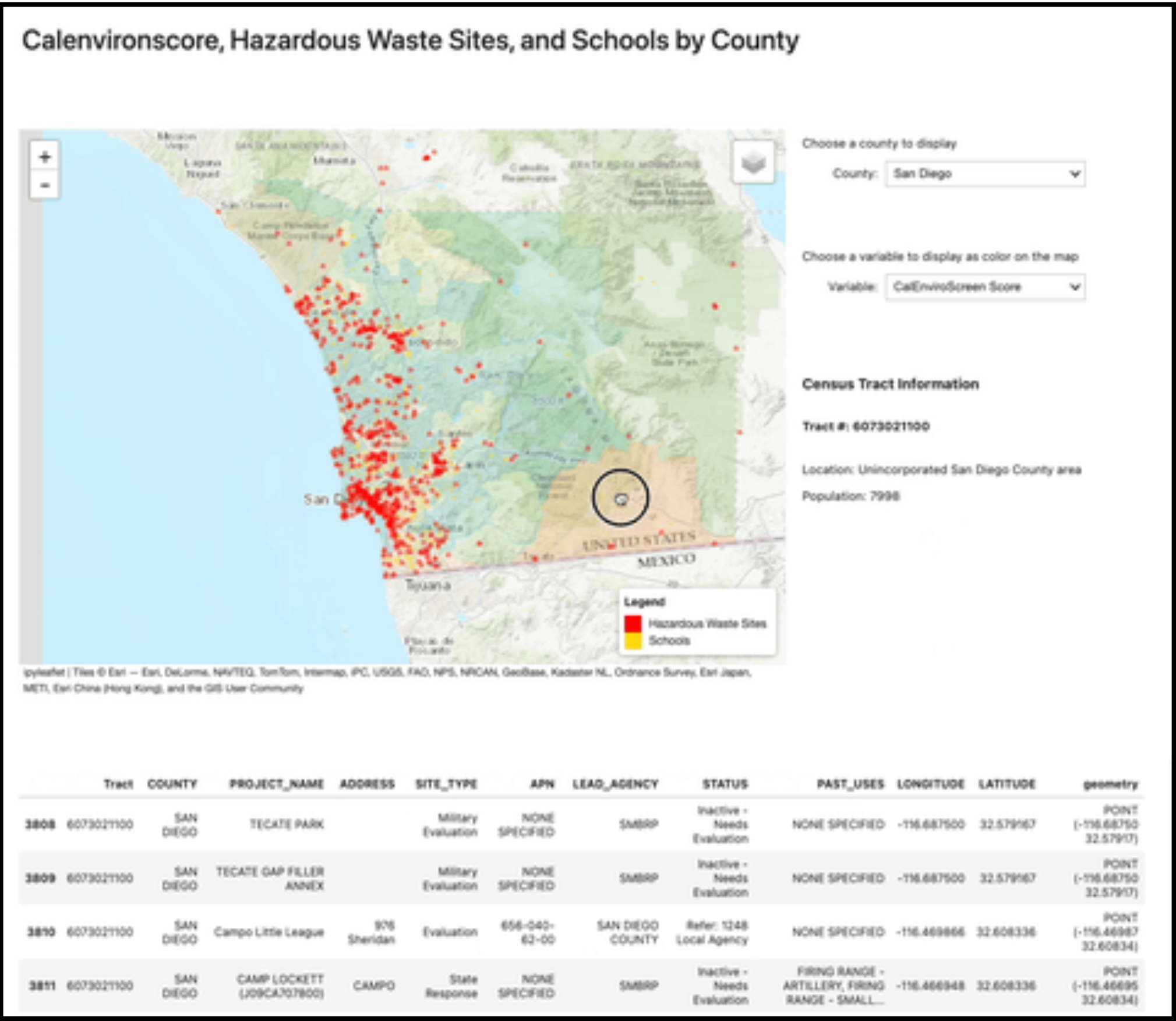
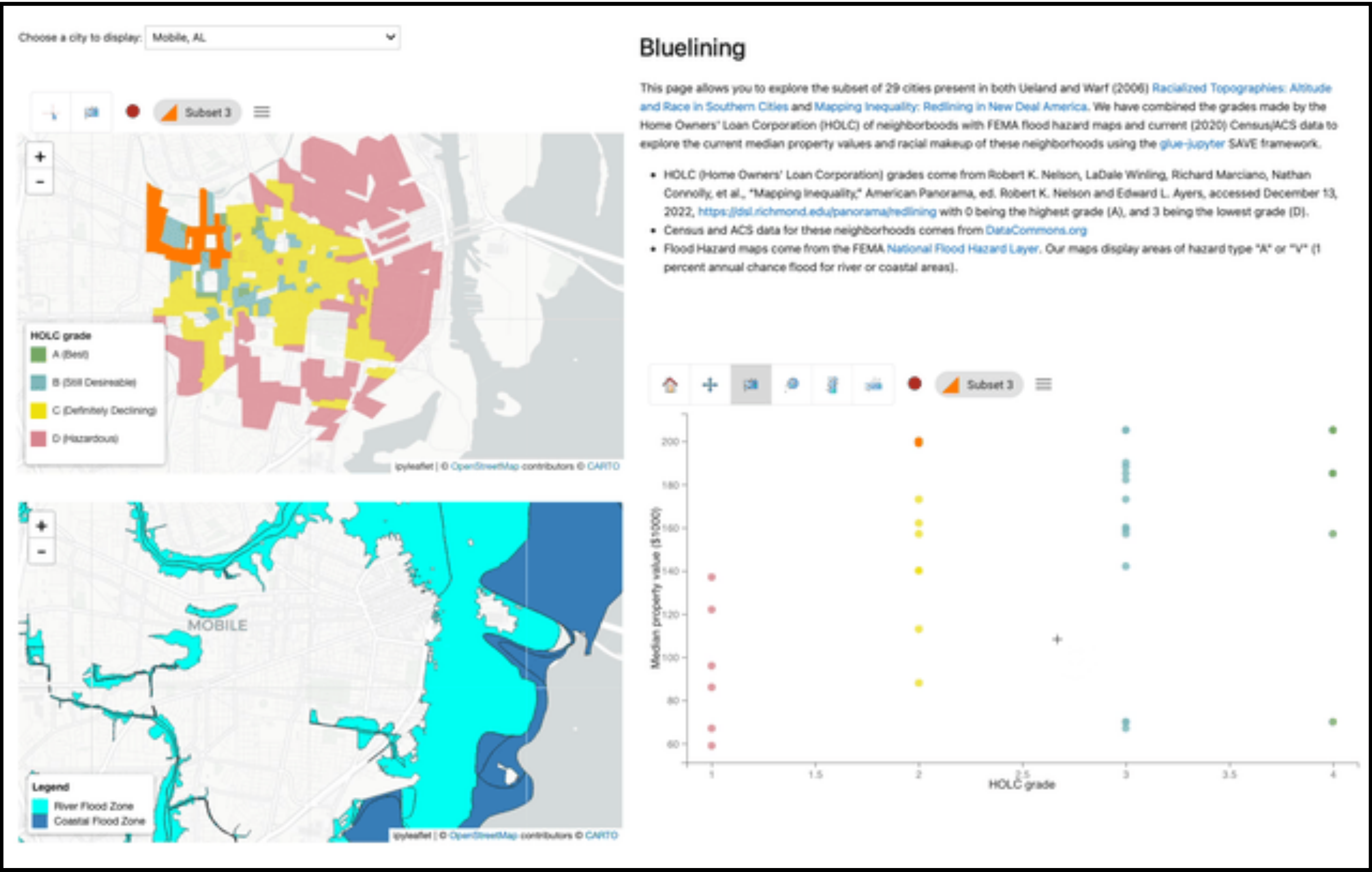
dashboard-style



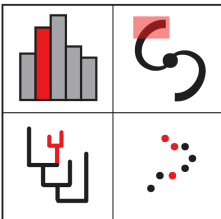
Examples drawn from the



part of **Data+Climate**
a Harvard-Google (Data Commons) Collaboration



The Data+Climate **Search-Analysis-Visualization-Environment** ("SAVE") is maintained by Dr. Jonathan Foster, using **fully flexible, scriptable,**



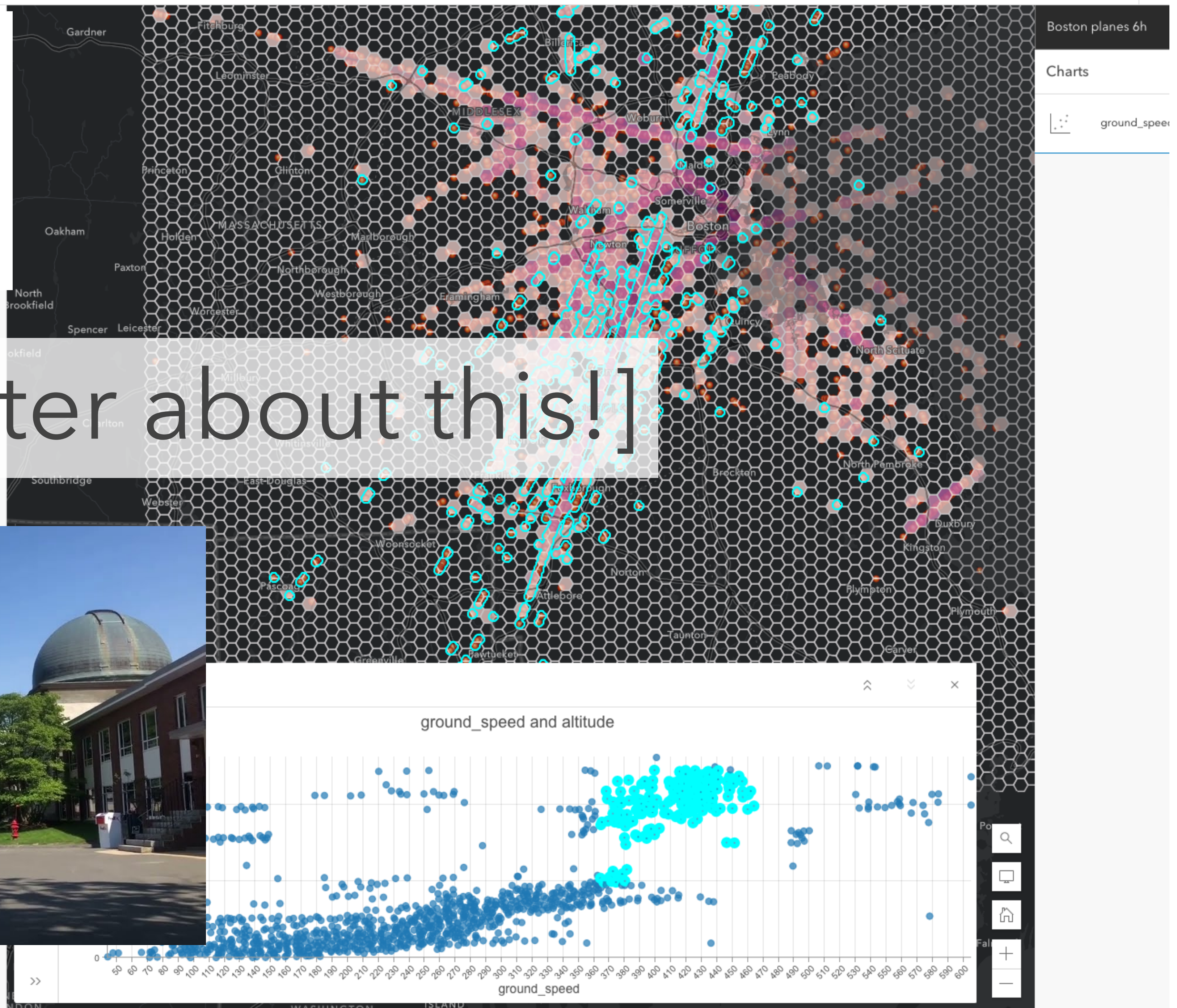
glueviz
multidimensional data exploration

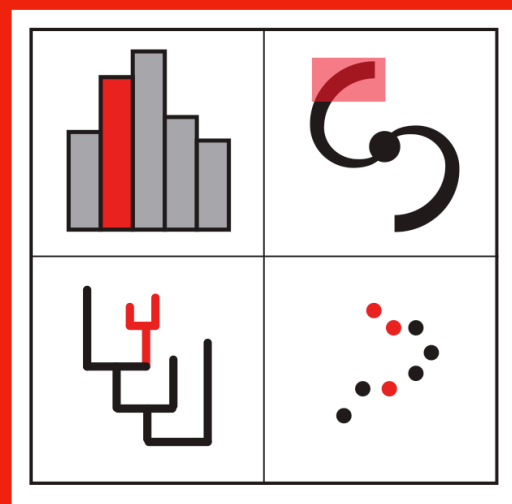
code is open at
github.com/jfoster17/SAVE



Thanks to Dan Pisut, or ESRI, today, for demo where we made this!

[ask later about this!]





"classic"
(Qt)

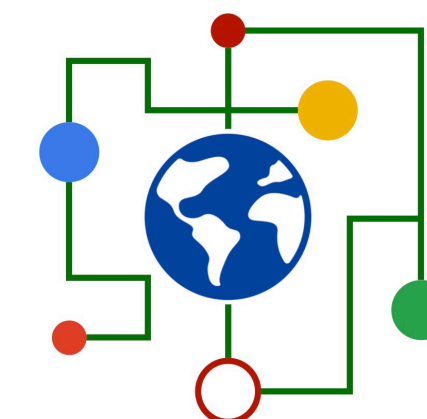


augmented
reality
(& plot.ly)



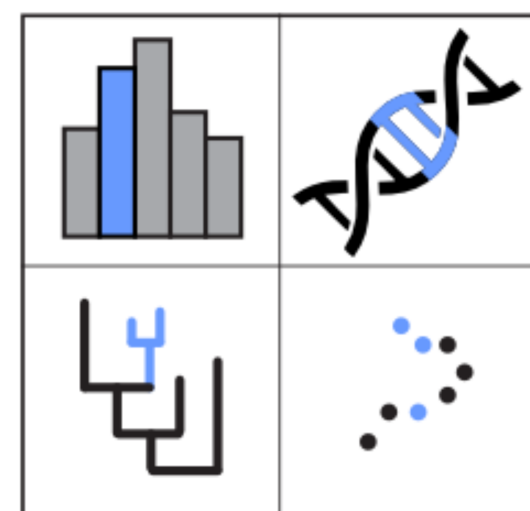
CosmicDS

education+
outreach



dashboards

Something
for
everyone?



glue genes



research+
edu+outreach
+planetarium

glupyter

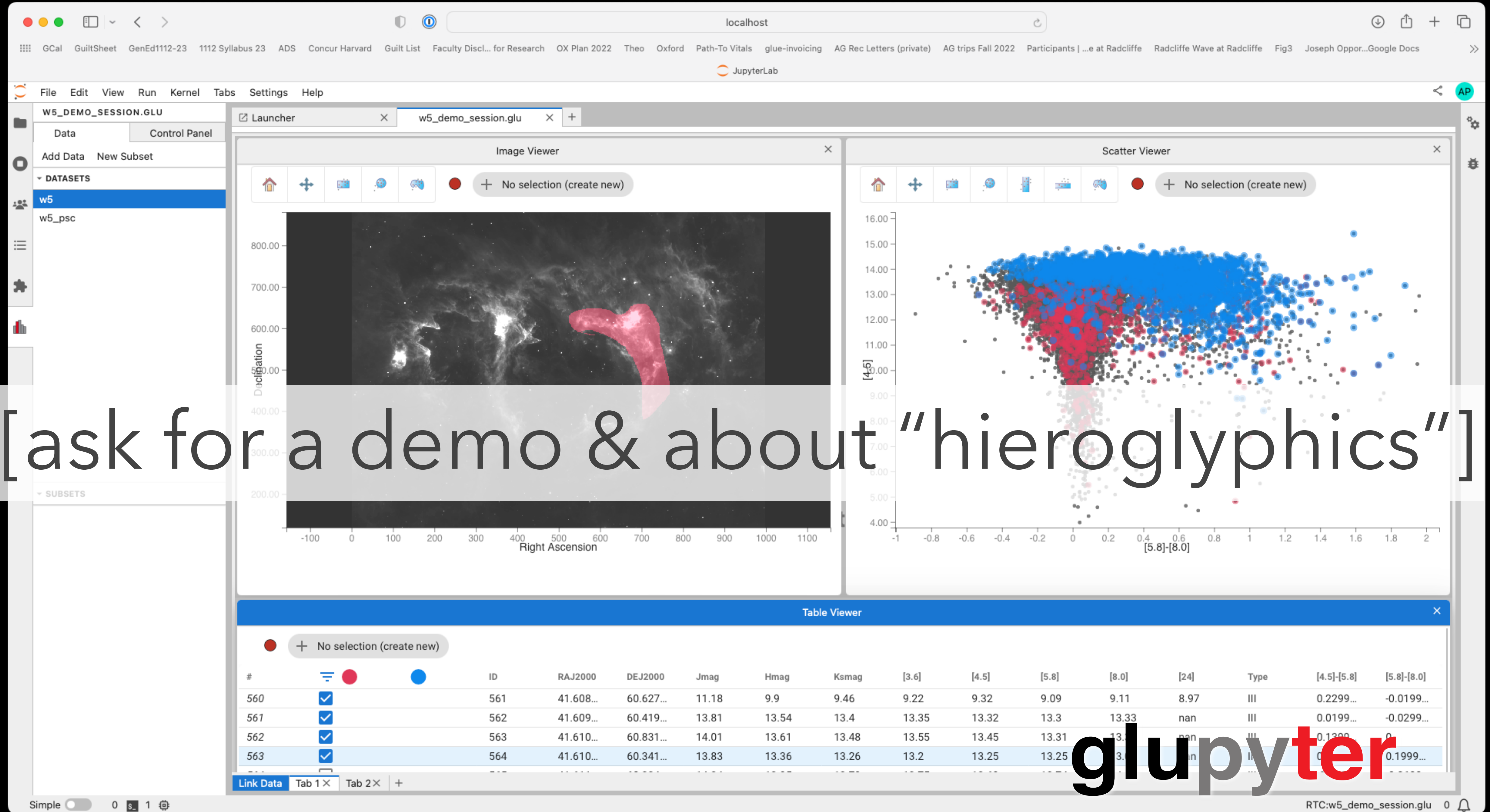
What's next?

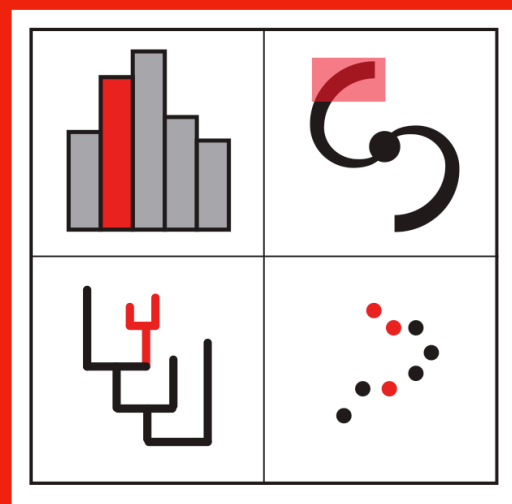
glue now runs in JupyterLab

(in addition to Jupyter Notebook). Web-based glue is a big part of our future plans. Ask me later if you want to connect your work/app/ideas.

glupyter

[ask for a demo & about “hieroglyphics”]





"classic"
(Qt)

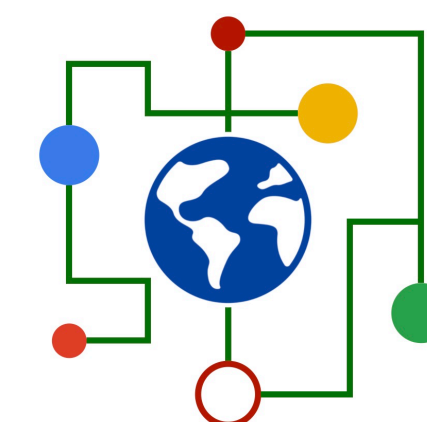


augmented
reality
(& plot.ly)



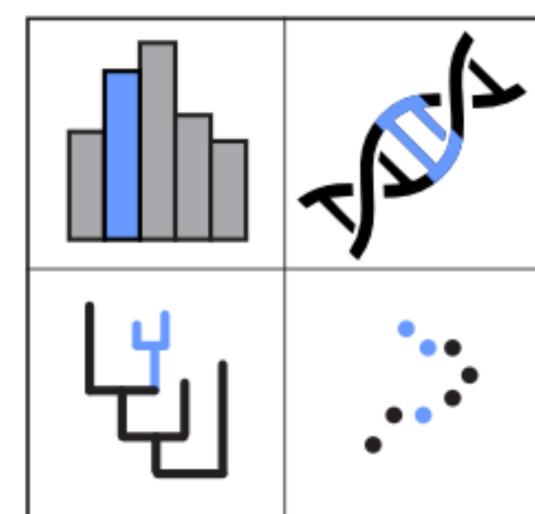
CosmicDS

education+
outreach



dashboards

**Something
for
everyone?**



glue genes



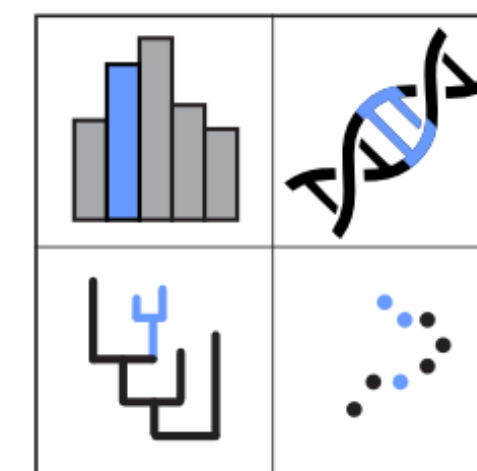
research+
edu+outreach
+planetarium

glupyter

What's next?



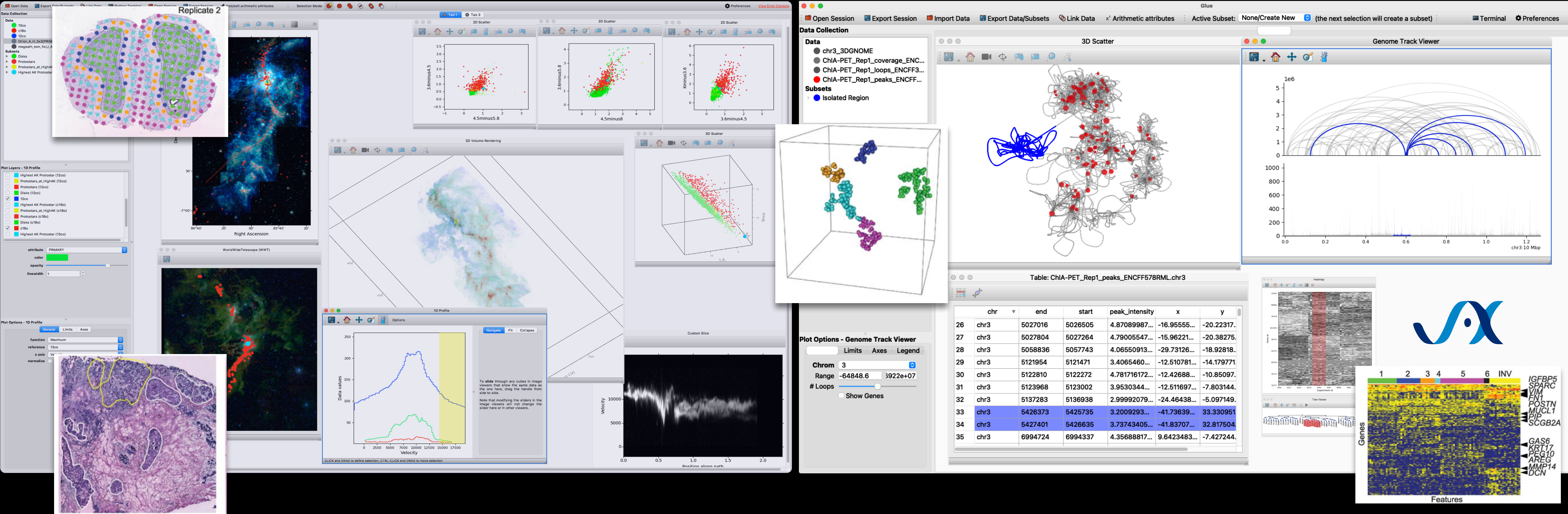
glue
solutions
inc.



glue
genes

High-dimensional Data: Astronomy

High-dimensional Data: Genomics + +



“High-dimensional Data”: Genomics

Data Collection

Data

- chr3_3DGNOME
- ChIA-PET_Rep1_coverage_ENCFF310MTX.chr3
- ChIA-PET_Rep1_loops_ENCFF310MTX.chr3
- ChIA-PET_Rep1_peaks_ENCFF578RML.chr3

Subsets

- > ● Isolated Region

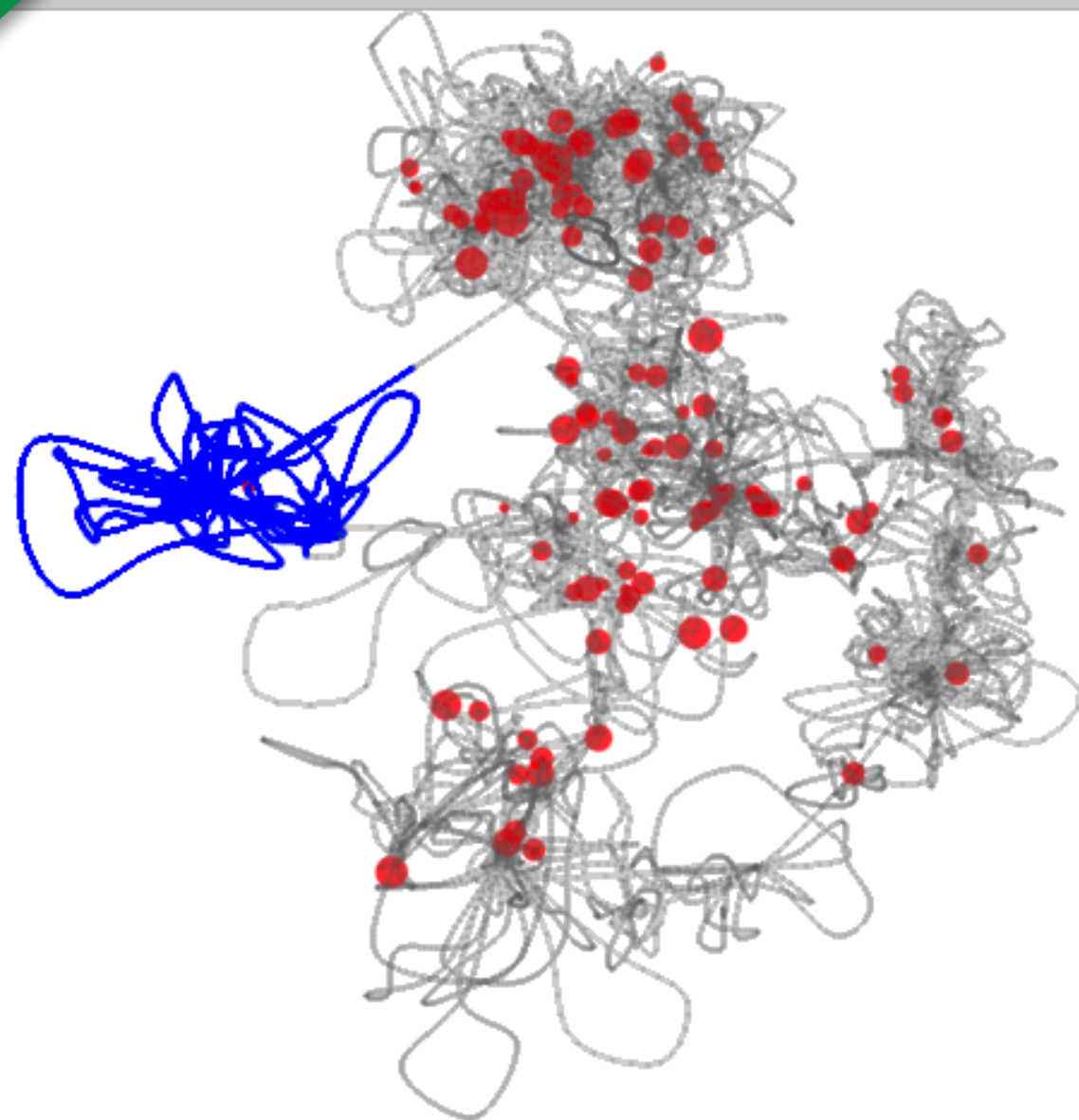
Plot Layers

- ☒ chr3_3DGNOME
- ☒ ChIA-PET_Rep1_loops_ENCFF310MTX.chr3
- ☒ ChIA-PET_Rep1_peaks_ENCFF578RML.chr3
- ☒ ChIA-PET_Rep1_coverage_ENCFF614DRY.chr3

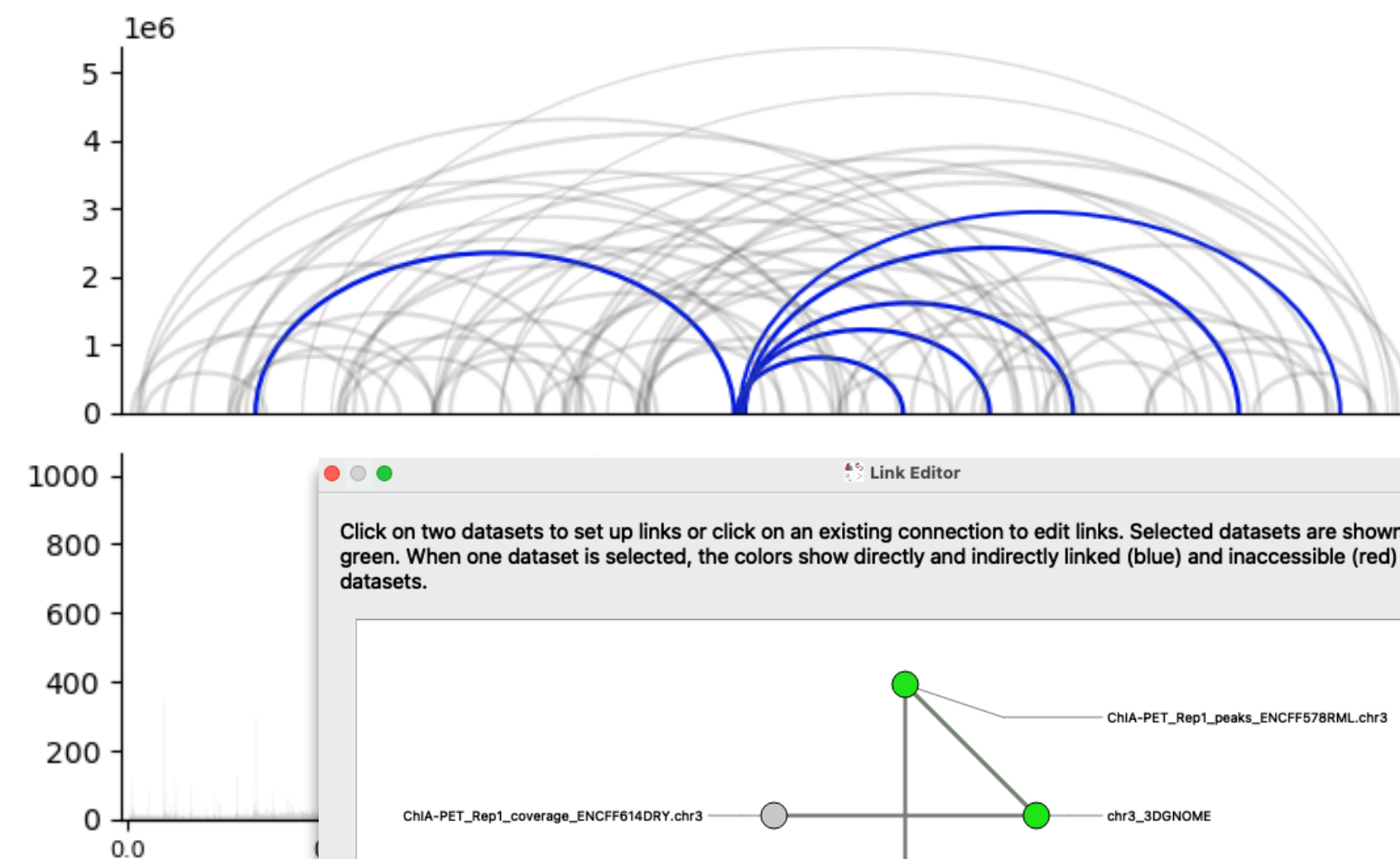
color

opacity

3D Scatter

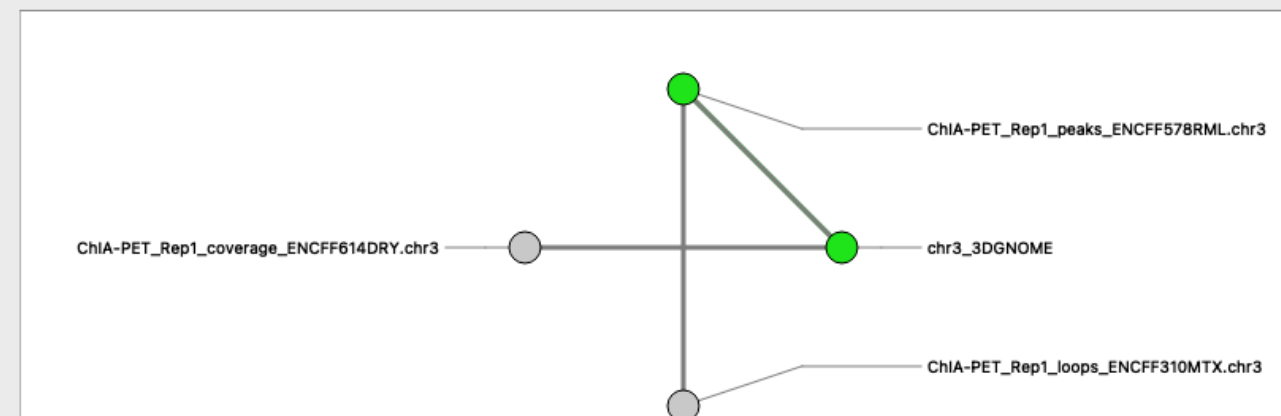


Genome Track Viewer



Link Editor

Click on two datasets to set up links or click on an existing connection to edit links. Selected datasets are shown in green. When one dataset is selected, the colors show directly and indirectly linked (blue) and inaccessible (red) datasets.



Dataset 1

ChIA-PET_Rep1_loops_ENCFF310MTX.chr3

Dataset 2

chr3_3DGNOME

Links between Dataset 1 and Dataset 2

identity(start <-> genome_position)
identity(chr <-> chr)

Link details

Link conceptually identical components

Dataset 1 attributes

x

chr

Dataset 2 attributes

y

chr

Glue attributes

Create advanced link

Remove link

Cancel

OK

Table: ChIA-PET_Rep1_peaks_ENCFF578RML.chr3

	chr	end	start	peak_intensity	x	y
26	chr3	5027016	5026505	4.87089987...	-16.95555...	-20.22317..
27	chr3	5027804	5027264	4.79005547...	-15.96221...	-20.38275.
28	chr3	5058836	5057743	4.06550913...	-29.73126...	-18.92818..
29	chr3	5121954	5121471	3.4065460...	-12.510781...	-14.179771.
30	chr3	5122810	5122272	4.781716172...	-12.42688...	-10.85097.
31	chr3	5123968	5123002	3.9530344...	-12.511697...	-7.803144.
32	chr3	5137283	5136938	2.99992079...	-24.46438...	-5.097149.
33	chr3	5426373	5425735	3.2009293...	-41.73639...	33.330951.
34	chr3	5427401	5426635	3.73743405...	-41.83707...	32.817504.
35	chr3	6994724	6994337	4.35688817...	9.6423483...	-7.427244.

Plot Options - Genome Track Viewer

Limits Axes Legend

Chrom

3

Range

-64848.6 922e+07

Loops

Show Genes



Spatial Transcriptomics

“High-dimensional Data”: Genomics

TRANSCRIPTOMICS

Visualization and analysis of gene expression in tissue sections by spatial transcriptomics

Ståhl, P.^{1,2,*} Fredrik Salmén,^{2,*} Sanja Vickovic,^{2,†} Anna Lundmark,^{2,3,†} J. F. Navarro,^{1,2} Jens Magnusson,¹ Stefania Giacomello,² Michaela Asp,² J. O. Westholm,⁴ Mikael Huss,⁴ Annelie Mollbrink,² Sten Linnarsson,⁵ Simone Codeluppi,^{5,6} Åke Borg,⁷ Fredrik Pontén,⁸ Paul Igor Costea,² Pelin Sahlén,² Jan Mulder,⁹ Olaf Bergmann,¹ Joakim Lundeberg,^{2,†} Jonas Frisén¹

Analysis of the pattern of proteins or messenger RNAs (mRNAs) in histological tissue sections is a cornerstone in biomedical research and diagnostics. This typically involves the visualization of a few proteins or expressed genes at a time. We have devised a strategy, which we call “spatial transcriptomics,” that allows visualization and quantitative analysis of the transcriptome with spatial resolution in individual tissue sections. By positioning histological sections on arrayed reverse transcription primers with unique positional barcodes, we demonstrate high-quality RNA-sequencing data with maintained two-dimensional positional information from the mouse brain and human breast cancer. Spatial transcriptomics provides quantitative gene expression data and visualization of the distribution of mRNAs within tissue sections and enables novel types of bioinformatics analyses, valuable in research and diagnostics.

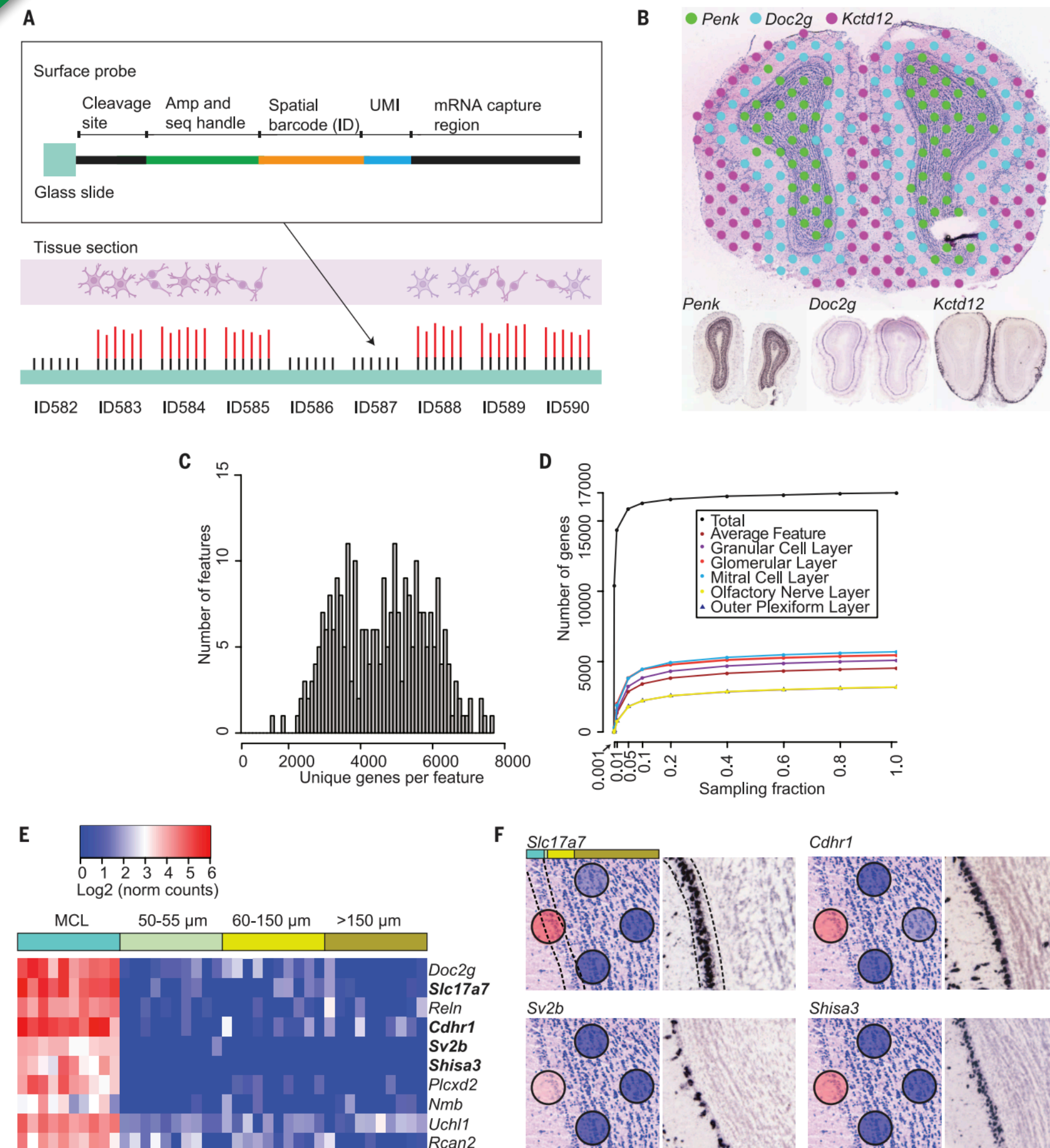


Fig. 2. Spatially resolved gene expression. (A) Each array feature contains unique DNA-barcoded probes containing a cleavage site, a T7 amplification and sequencing handle, a spatial barcode, a unique molecular identifier (UMI), and an oligo(dT) VN-capture region, where V is anything but T and where N is any nucleotide. cDNA (red) is generated from captured mRNA by reverse transcription. (B) Visualization of the expression of three genes by spatial transcriptomics (top) and in situ hybridization (bottom). *Penk* and *Kctd12* in situ images are from the Allen Institute. Cutoff normalized counts, *Penk*, 8; *Doc2g*, 13; and *Kctd12*, 19. (C) Distribution of unique genes per feature under the tissue. (D) Number of genes detected for different layers and entire tissue over sequencing depth. (E) Lateral diffusion of transcripts from genes enriched in MCL. The genes are expressed in MCL features but are not separable from the background in features adjacent to the MCL. (F) Spatial expression and in situ hybridization of four genes in (E). The leftmost feature overlaps the MCL, and the three rightmost features are situated in the GCL. The colored bar depicts the distances from feature center in (E).

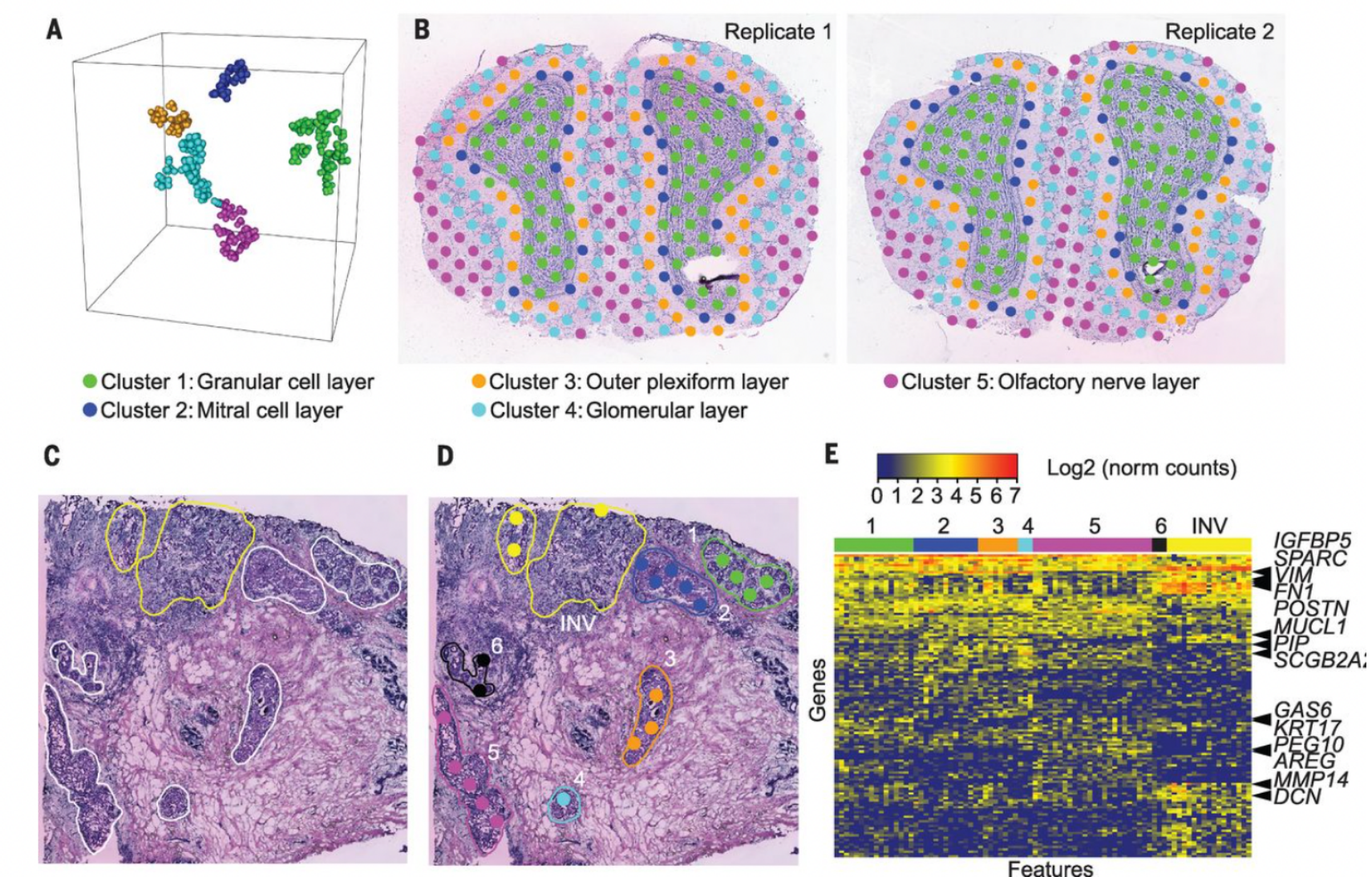
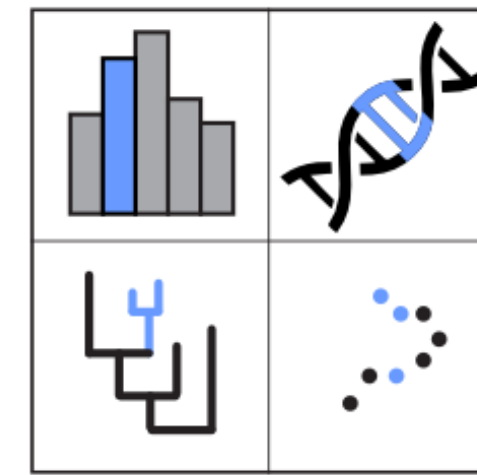


Fig. 4 Comparative analyses of tissue domains. (A) t-SNE analysis and hierarchical clustering of 551 features from two replicates creates five distinct clusters. (B) The features placed back onto the two tissue images. (C and D) Histological section of a breast cancer biopsy (C) containing invasive ductal cancer (INV) and six separate areas of ductal cancer in situ (1 to 6), with analyzed spatial transcriptomics features in (D). INV areas without, or with minimal, stromal infiltration were selected. (E) Gene expression heat map over the different areas in four adjacent sections (D) and (fig. S11).

2023 features of



glue
genes

Reads **Genomic** Data

Bed
Bedgraph

Bedpe
BigWig

RNA-seq and ATAC-seq data
matrices

3D models from 3D-GNOME
Single-cell data (AnnData)

CSV

Excel

Numpy Savefile

HDF5

Images

Standard and **Custom** Viewers

1D histogram

2D scatterplot

2D images

3D scatter

3D volume

2D heatmap

QTL viewer

Small multiples viewer

Analysis plug-ins

Get differentially expressed genes from
two subsets of cells

Measure/display expression of gene
subsets over cells

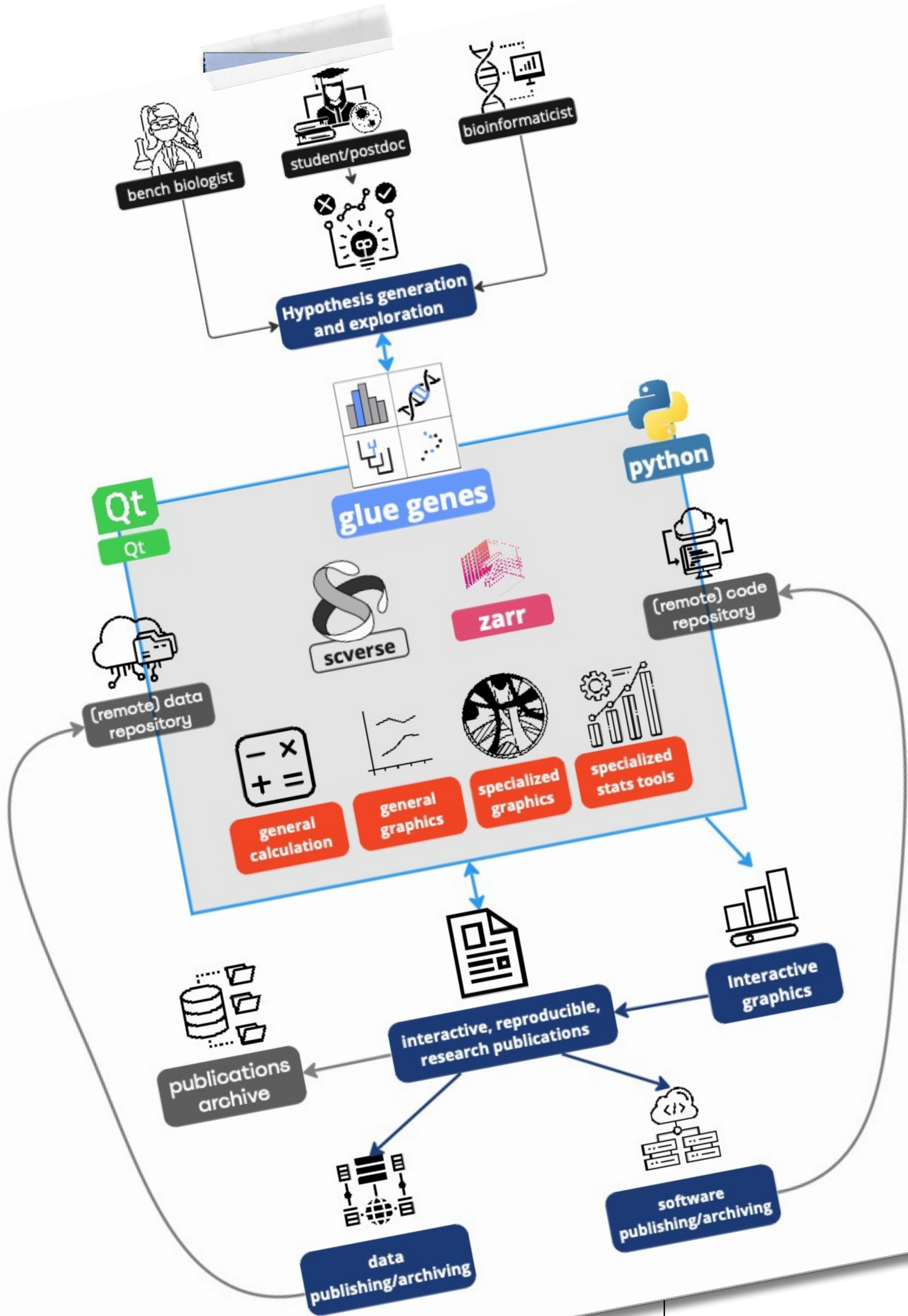
Get KEGG pathways for gene subsets



Customized for Genomics

glue genes alpha
Data loaders
Genome Viewer
Heatmap Viewer
Core glue changes
3D model Viewer

glue-single-cell
Small Multiples Viewer
AnnData loader
cells-to-genes plugins
Enrichr plugins



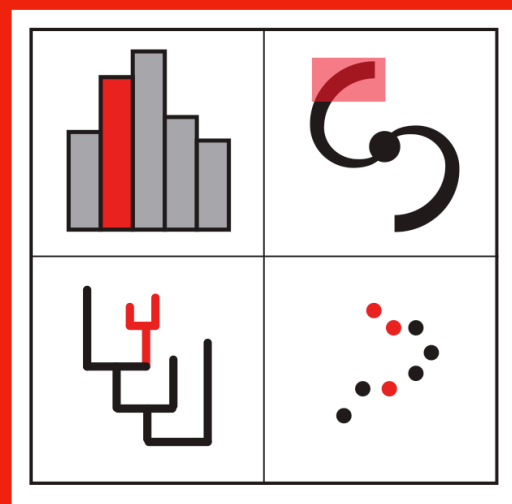
d next...

1.1
.0
ans

glue genes 1.2



ing viewer
genome viewer



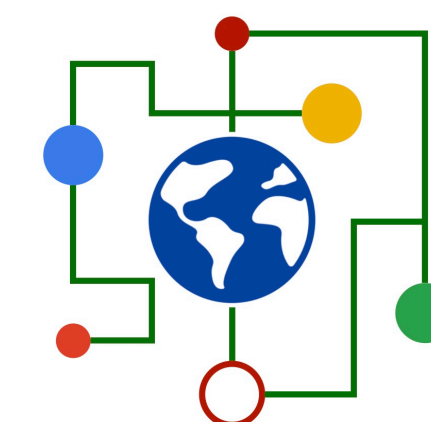
"classic"
(Qt)



augmented
reality
(& plot.ly)



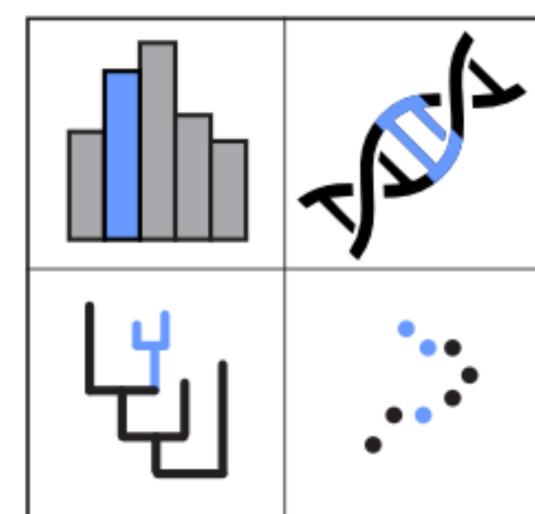
education+
outreach



dashboards



glueviz.org



glue genes



research+
edu+outreach
+planetarium

glupyter

What's next?

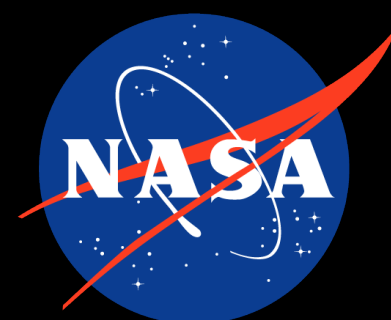


glueviz.org

Data Decoupage

with glue

Alyssa Goodman, Center for Astrophysics | Harvard & Smithsonian



GORDON AND BETTY
MOORE
FOUNDATION



glue
solutions
inc.



Collage and **decoupage** are both paper crafts involving cutting and gluing. They both take **images, photos** and **materials from one source and turn them into something completely different**. However, they are not one and the same. **Collage** is considered a formal **art**, while **decoupage** is considered a **craft**.

Collage has been around for hundreds, if not thousands, of years, with some believing its earliest forms were found in 200 B.C. China. The art form was not always referred to as collage, in fact coinage of the term is attributed to Pablo Picasso in the early 20th century. **The word collage comes from the French word coller, which means to glue**. The fine art community agrees that collage as an art form began in the early 20th century as part of modernism. A mixed-media or photo collage is a work of art, meant to be framed and admired.

Decoupage, on the other hand, comes from the French word decouper, which means to cut out. In this craft, a surface is covered with glued paper cut-outs.

Due to its decorative nature, **the decoupage crafter must take extra steps to protect** the surface once the decorations have been applied and **glued**.

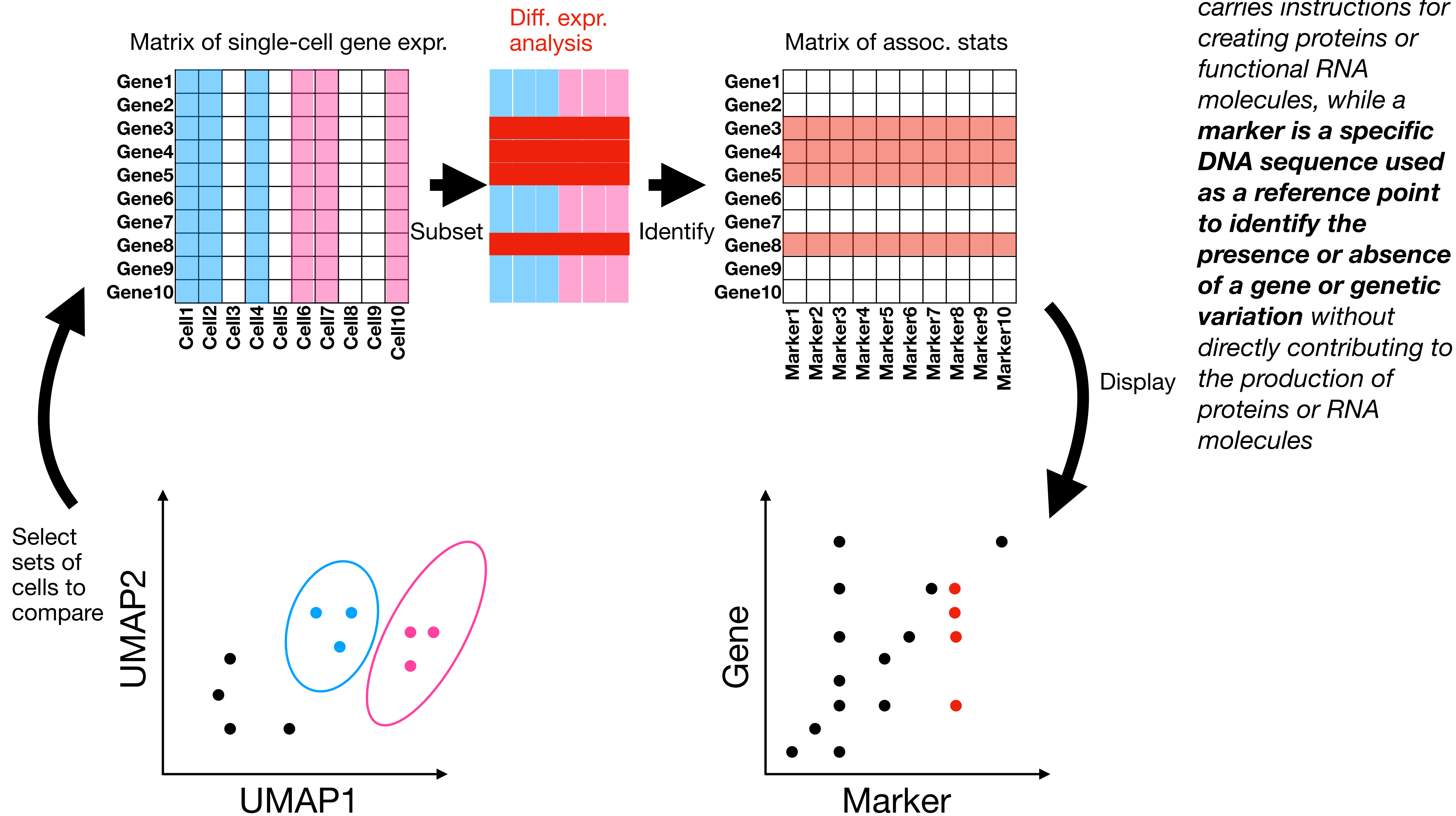
Cells to Genes and Back Again

Using **glue genes** for single cell exploratory data analysis

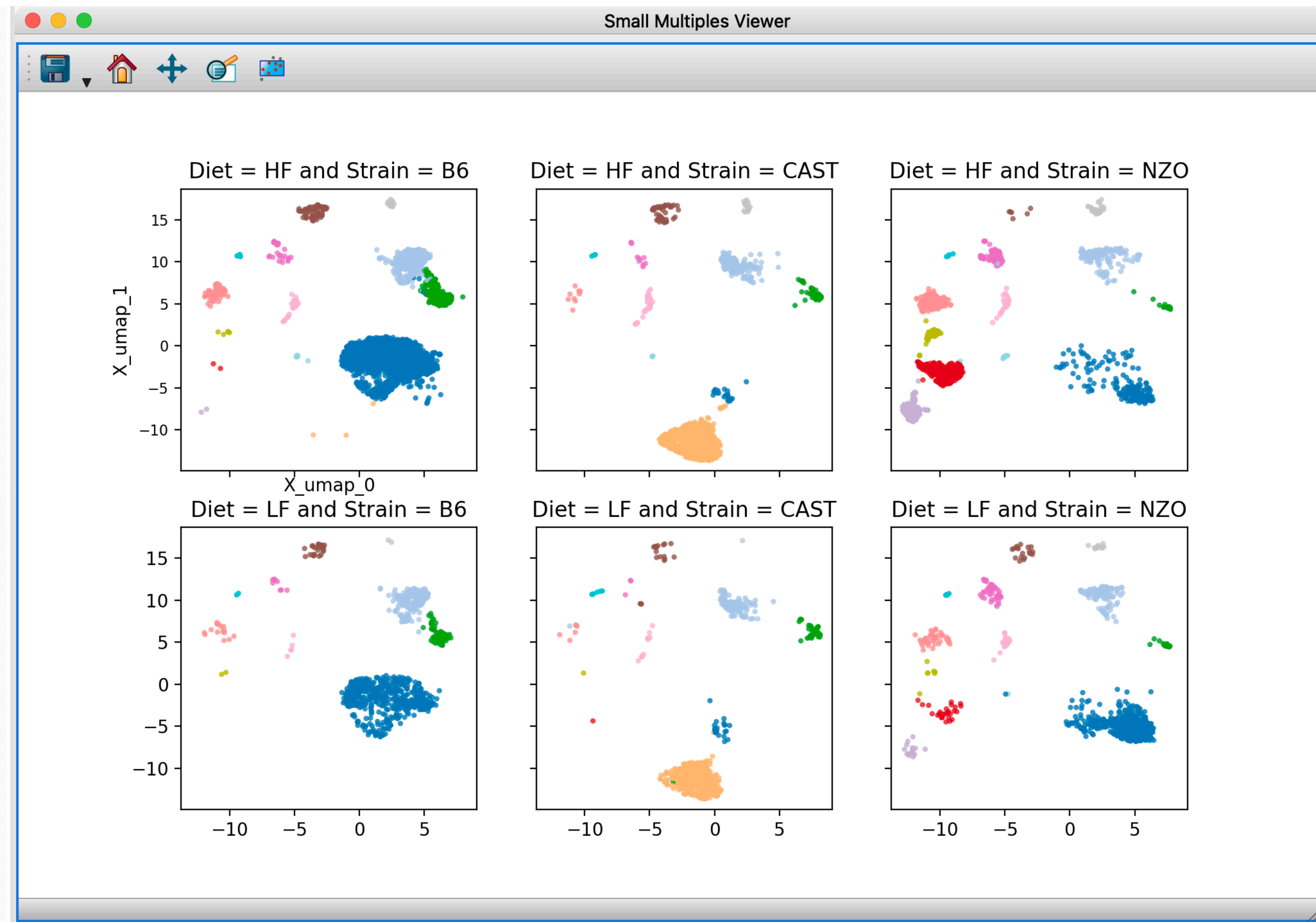
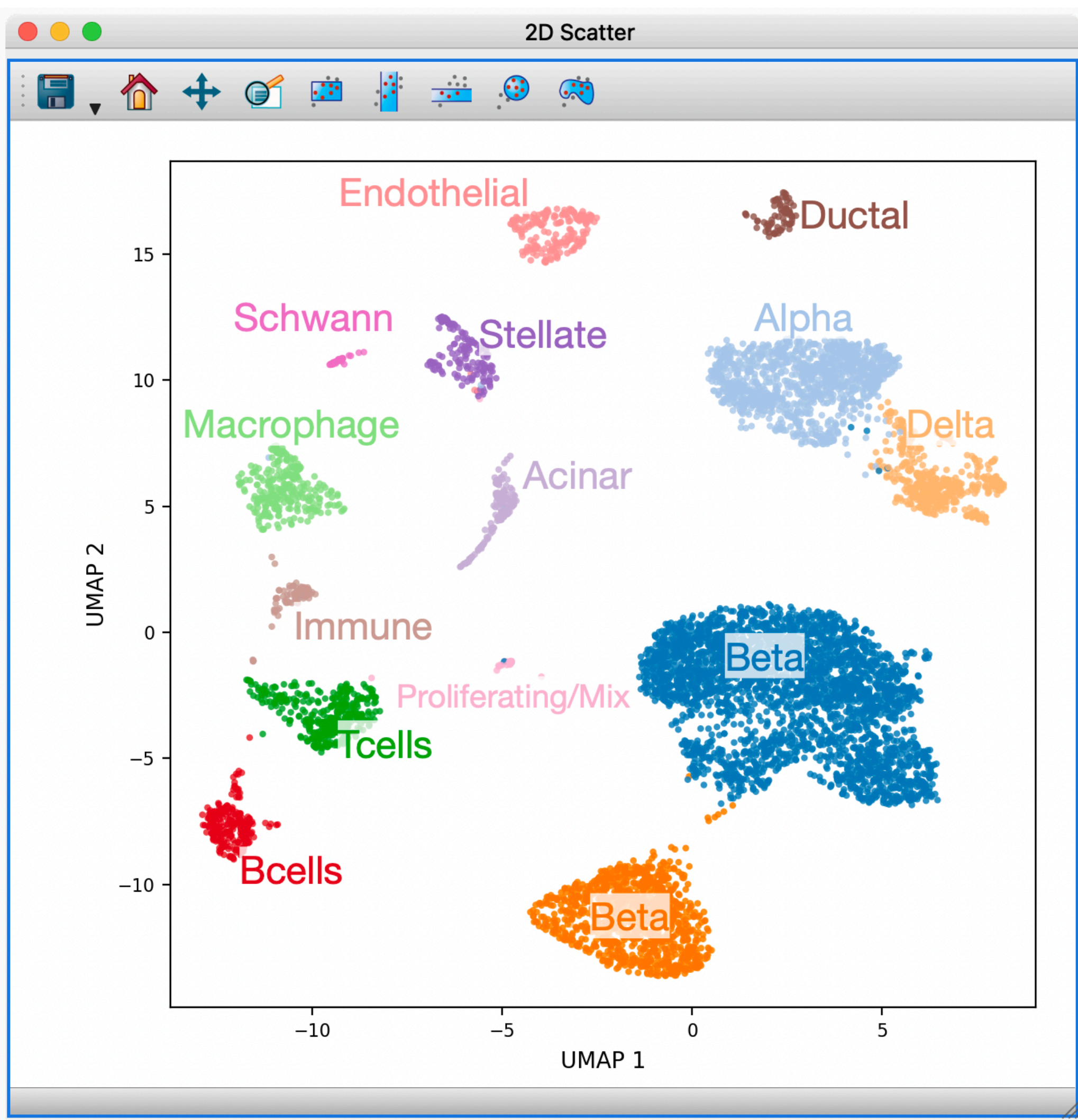


(slides from) Jonathan Foster, CTO, glue solutions, inc.

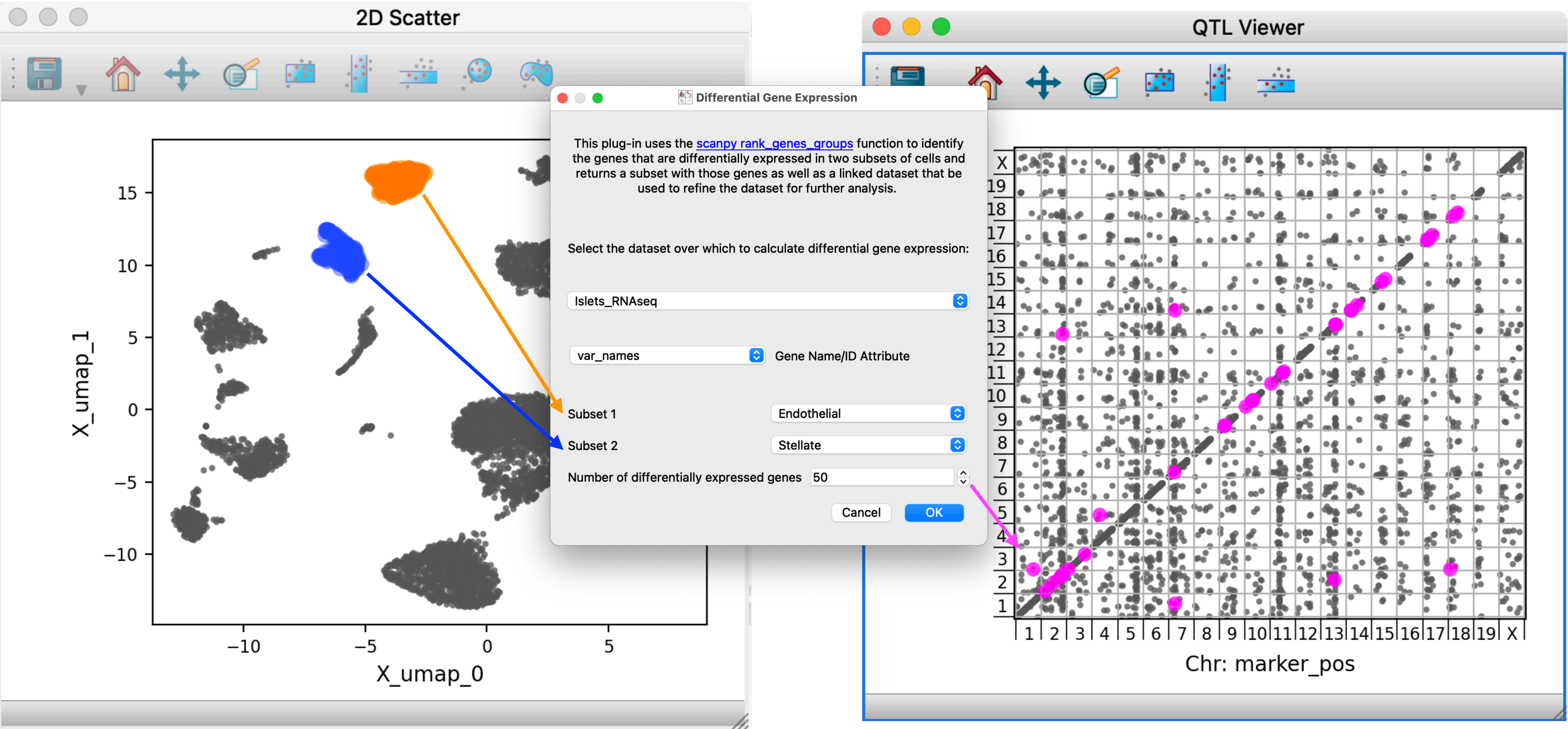
Cells to Genes



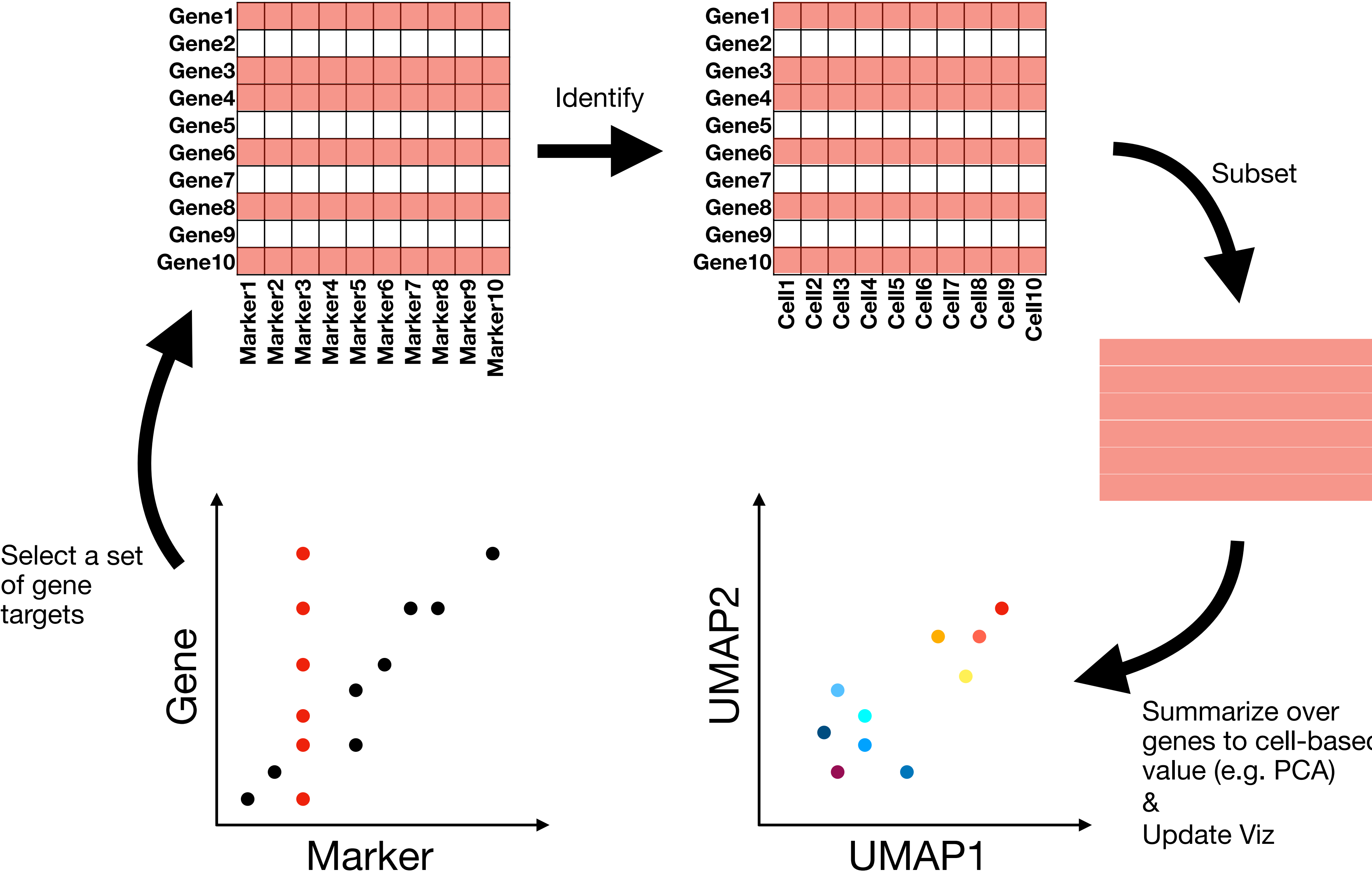
Display cell properties over experimental factors



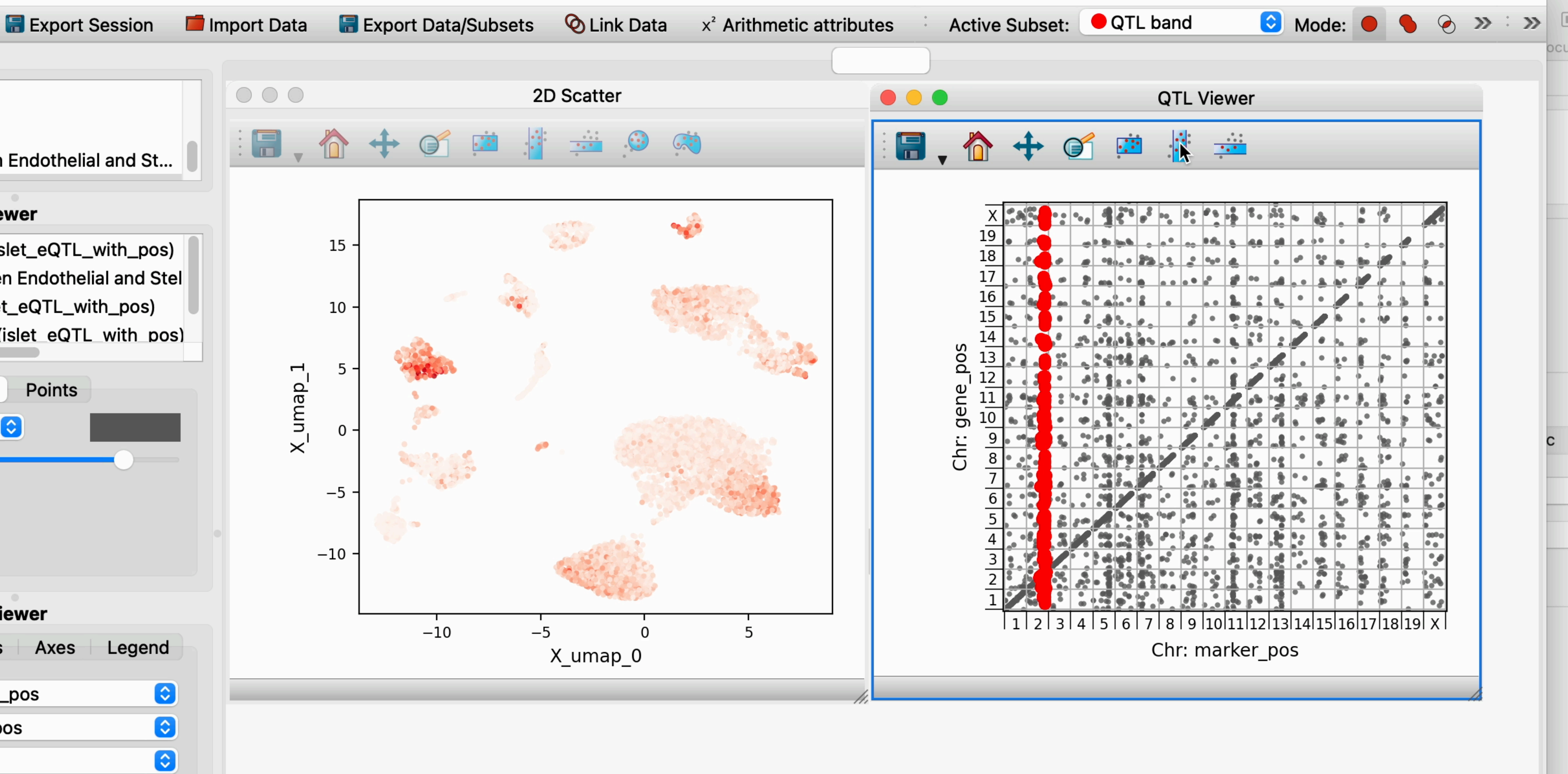
Get differentially expressed genes from subsets



Genes to Cells



Select genes to see which cells express them



[demo]

