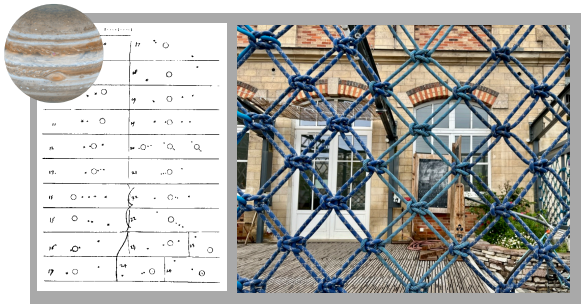
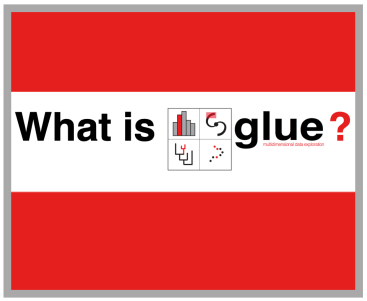
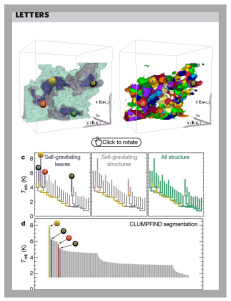
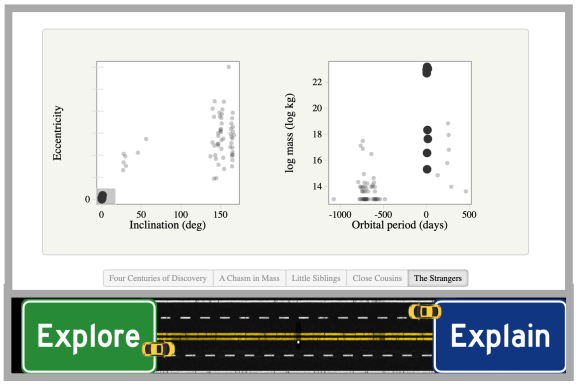
Seeing the universe, more clearly, with glupyter

Alyssa A. Goodman • Center for Astrophysics | Harvard & Smithsonian • glue solutions, inc.
with SO many others working on glue, glupyter, and adjacent efforts!





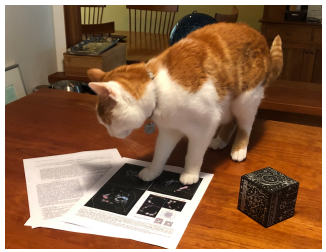




glue

plotly

Seeing the universe, more clearly, with glupyter

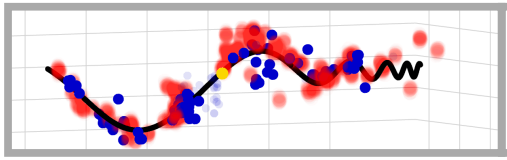


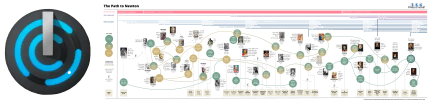
glupyter
multidimensional data exploration

glue genes

CosmicDS

Jdaviz



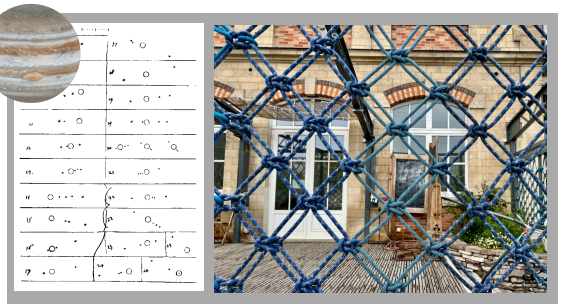


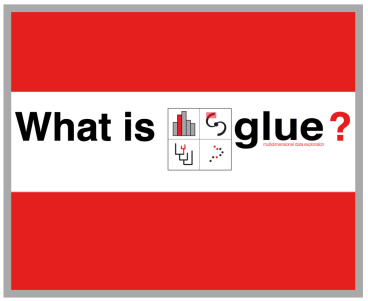
The TIMELINE CONSORTIUM

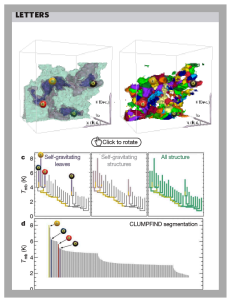
astrophysics data system

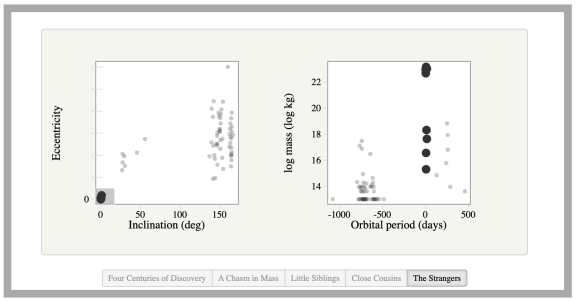
OpenAI

ViZ









glue
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plotly

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glupyter
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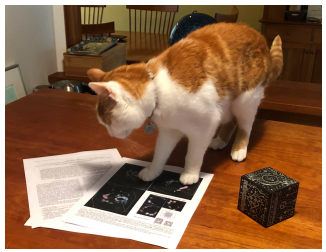
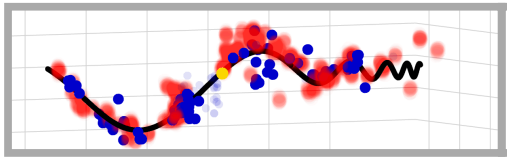
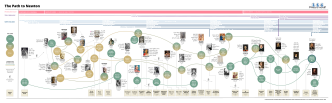


CosmicDS

Jdaviz





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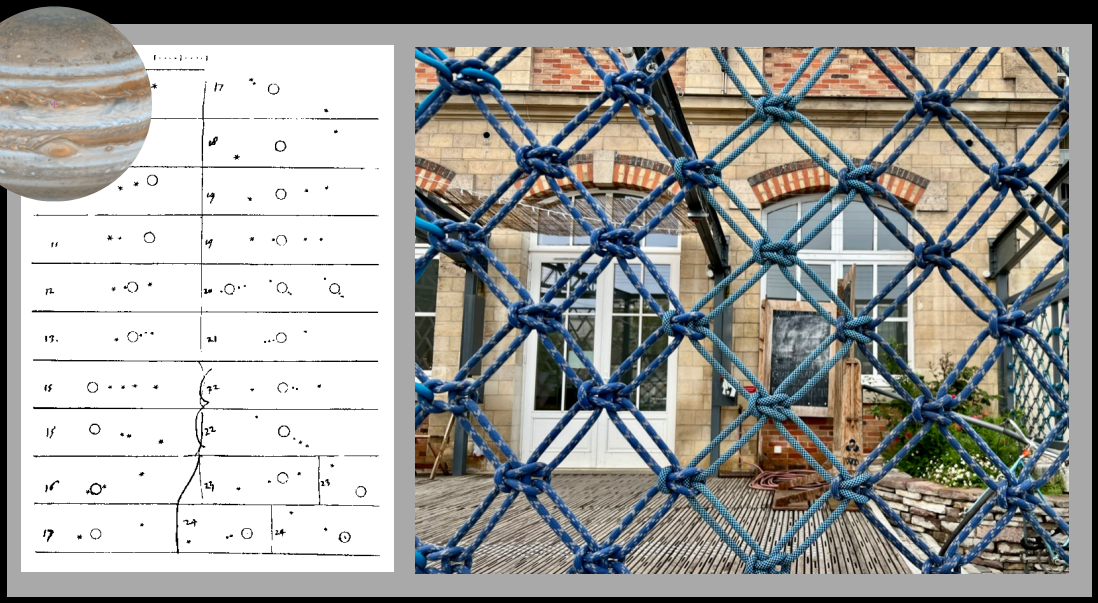
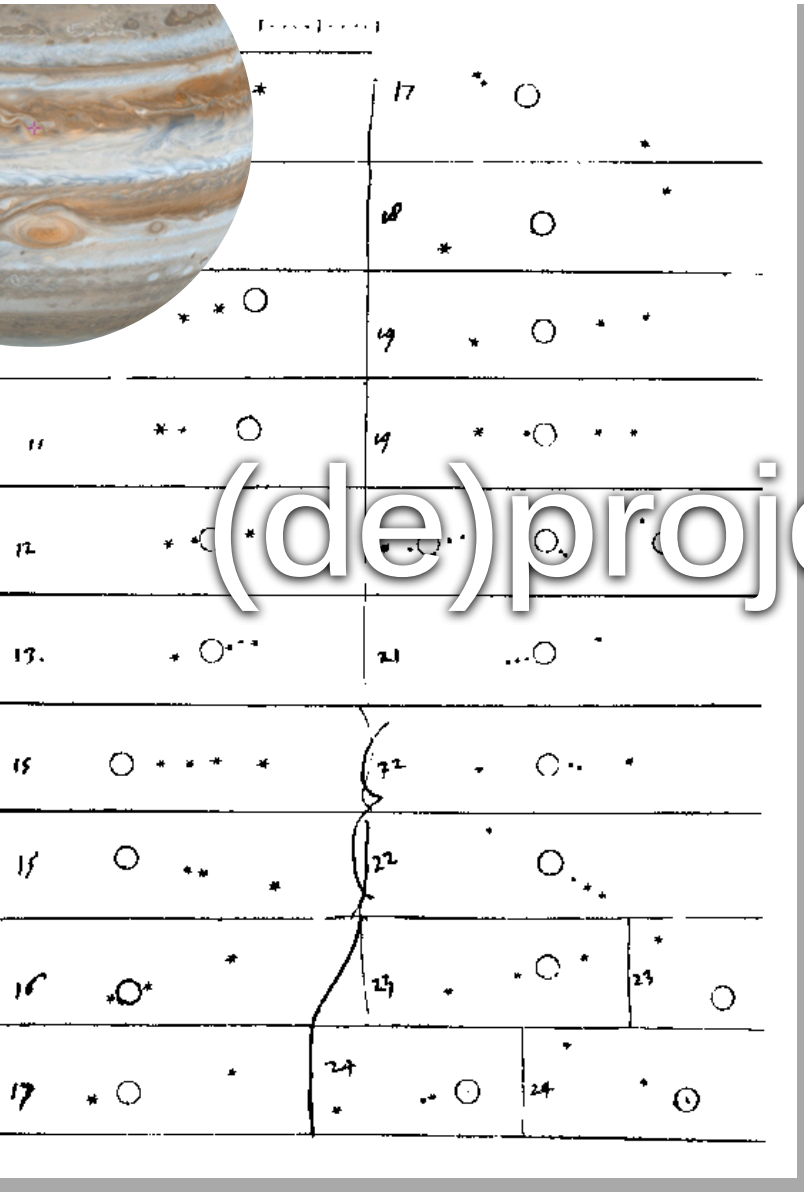
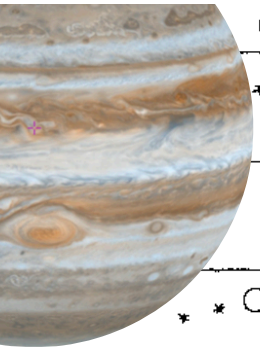
A little bit about astronomy.





(de)projection & color



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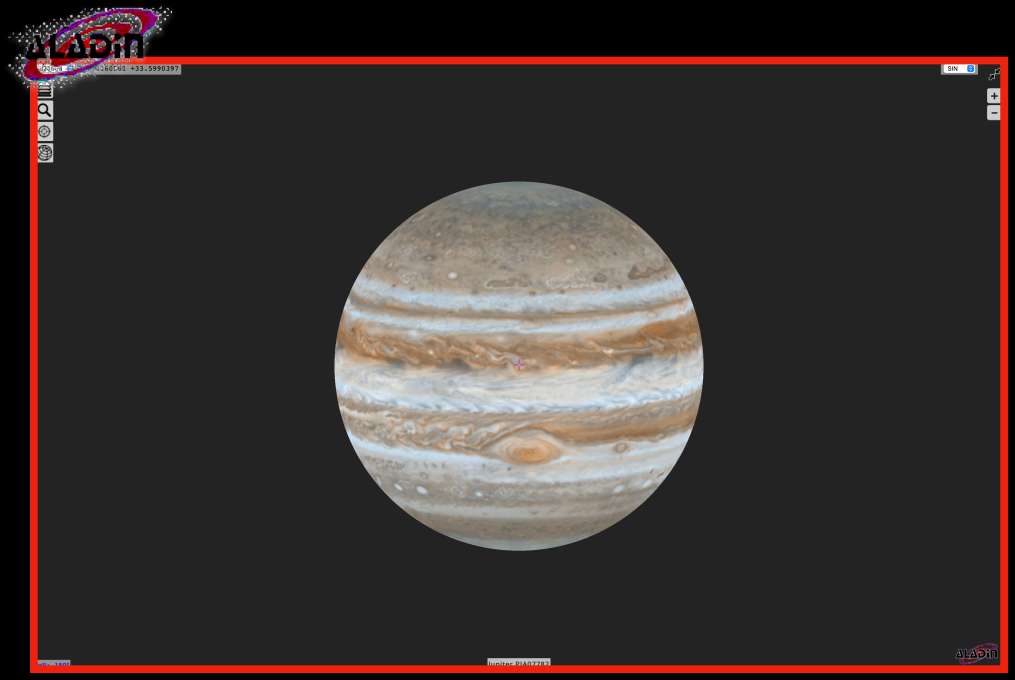
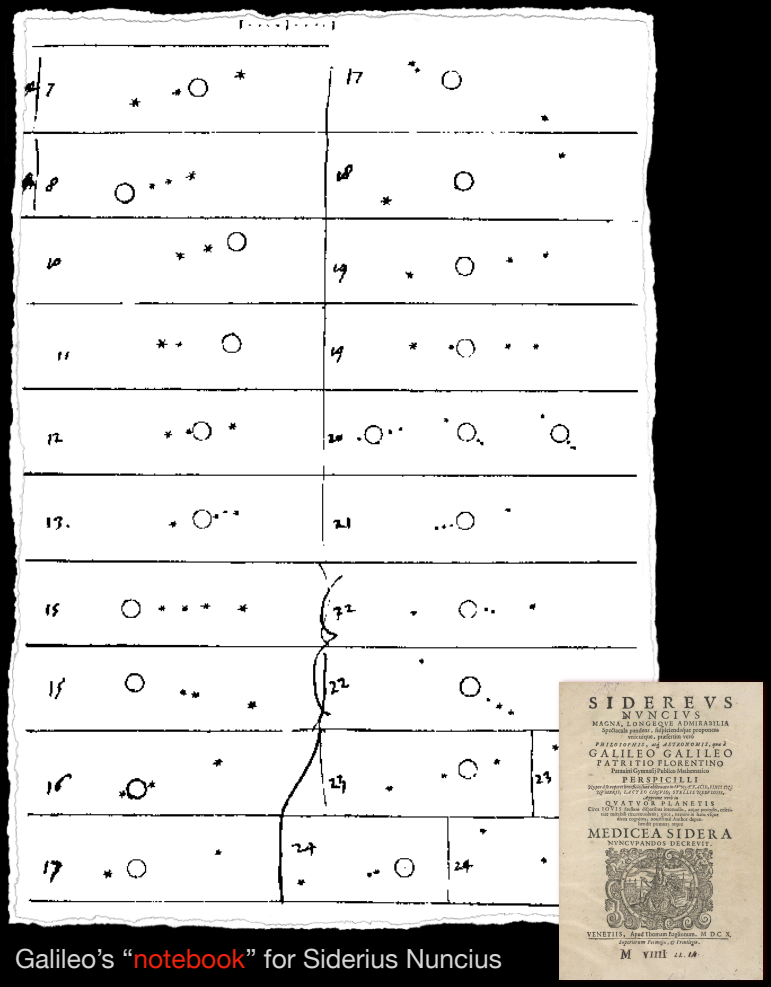
Jupiter



aladin.cds.unistra.fr/AladinLite/planets-explorer/

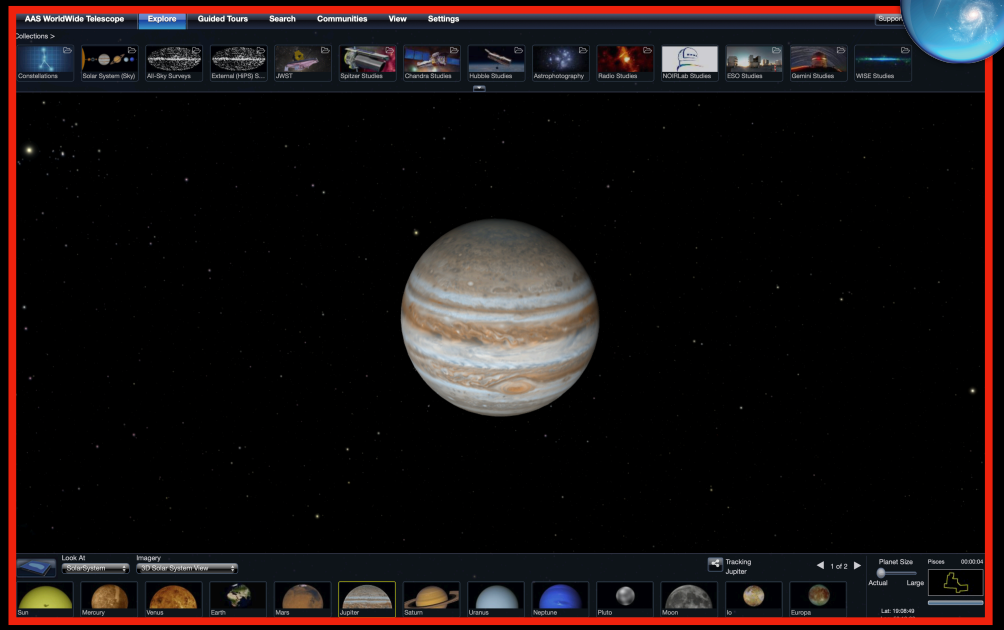
worldwidetelescope.org/webclient/

Galileo, 1610, 2D↔3D caused a revolution

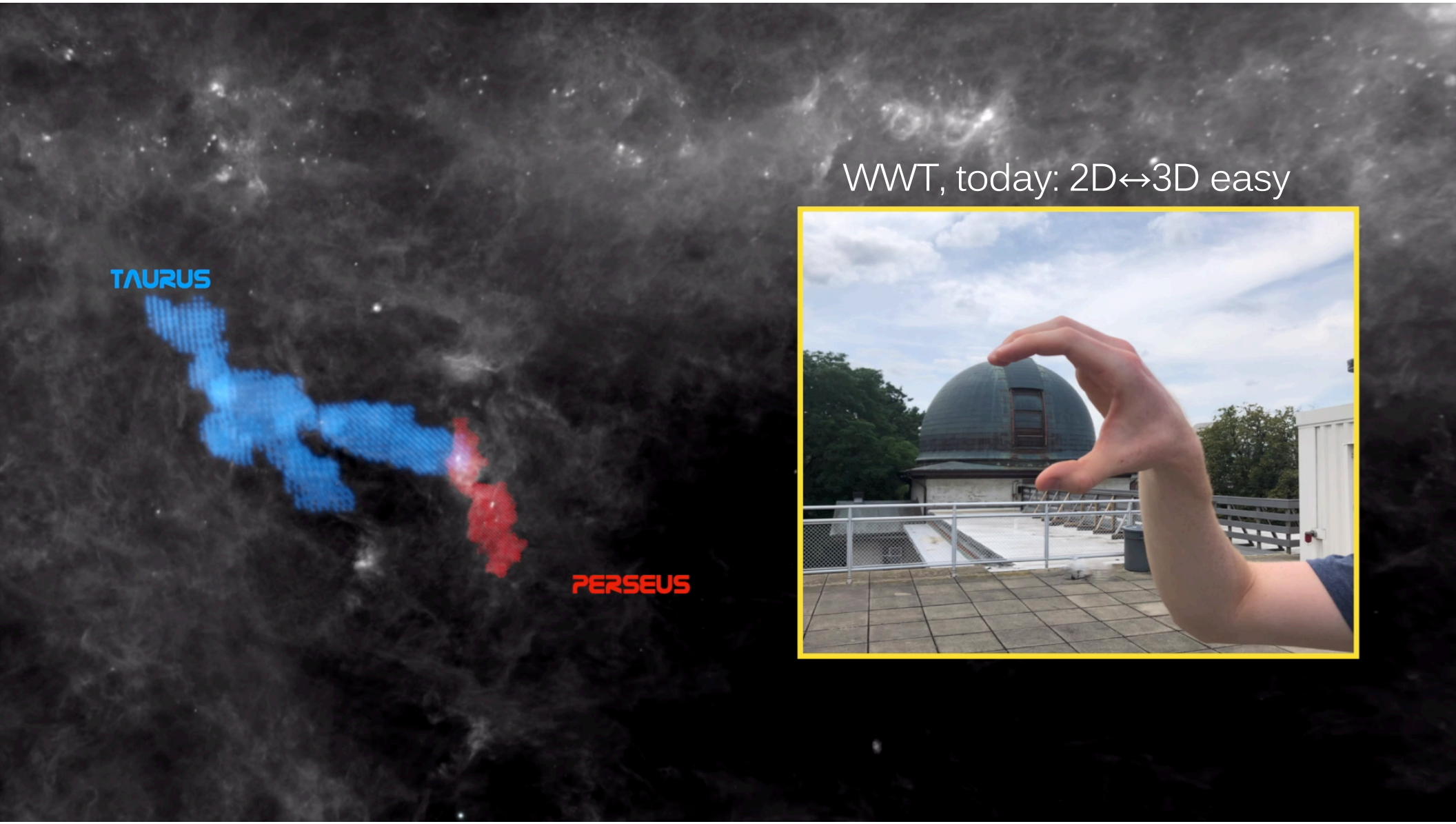


Galileo's "notebook" for Siderius Nuncius

WWT, today: 2D↔3D easy



worldwidetelescope.org/webclient/



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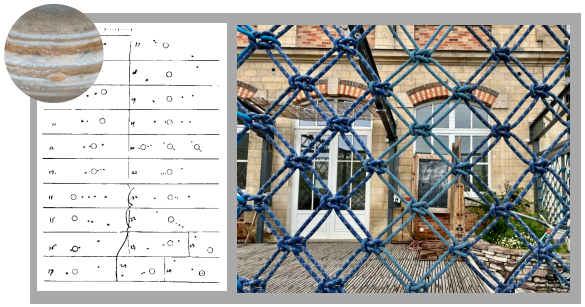

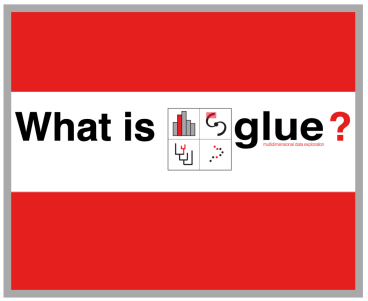

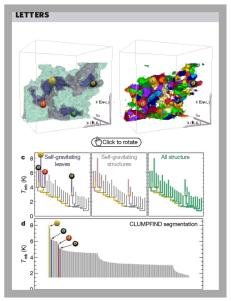

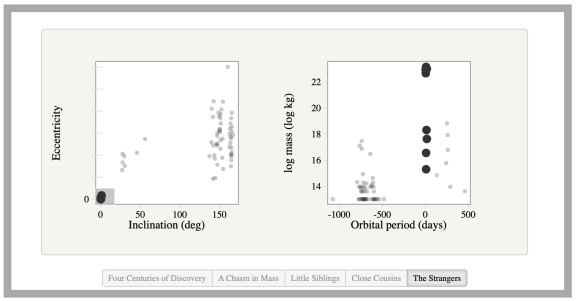

glue
multidimensional data exploration

plotly

CO SPACES

lab
glupyter
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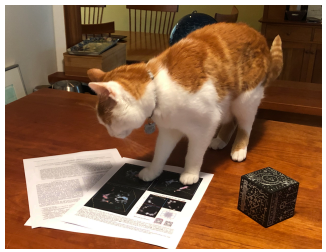
glue genes



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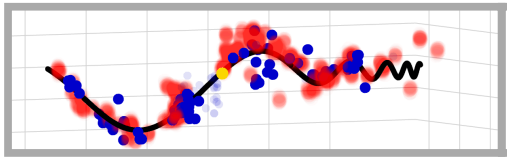
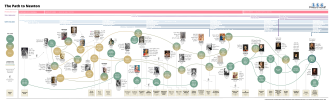
Jdaviz





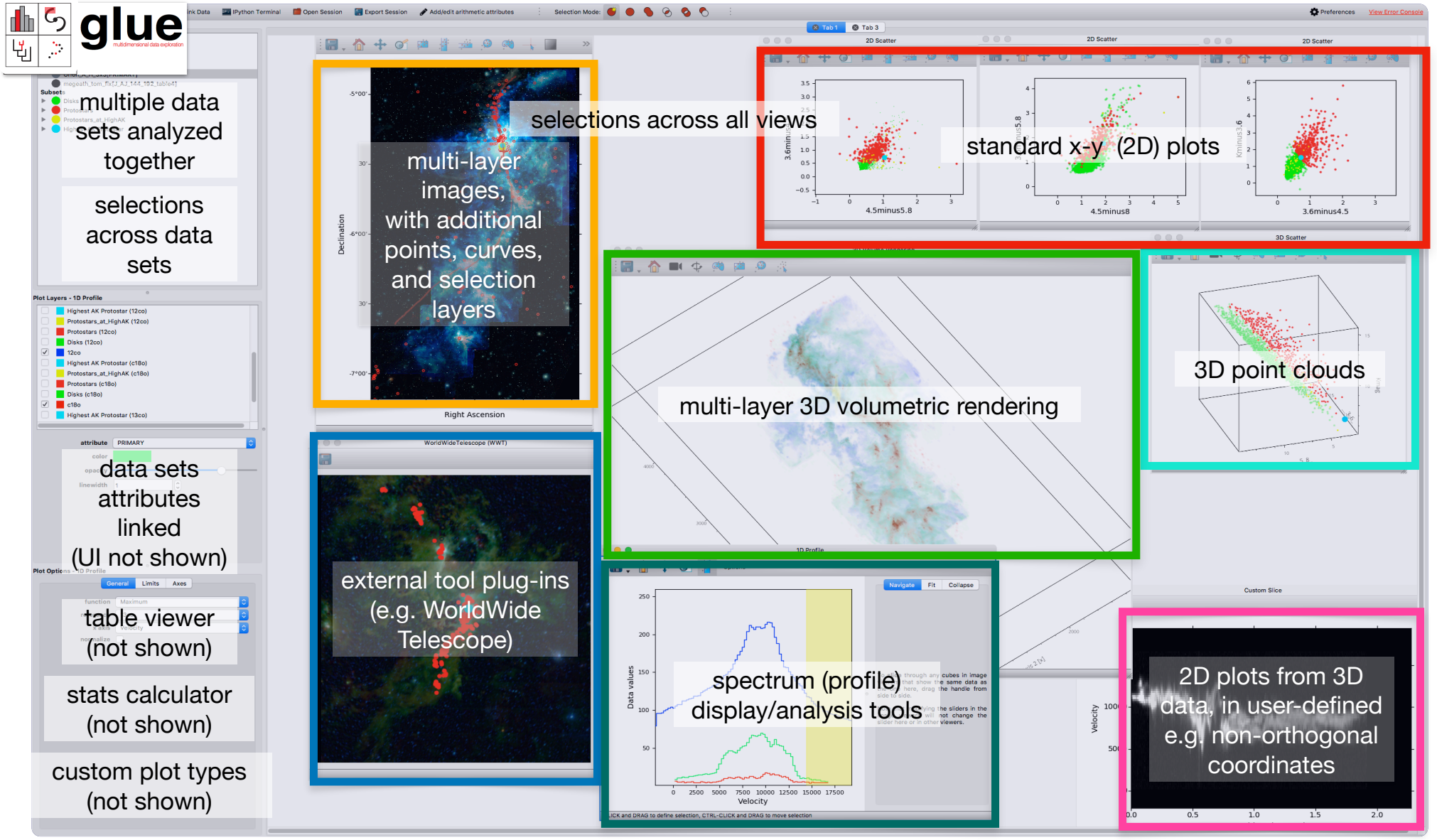
The TIMELINE CONSORTIUM

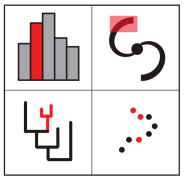
astrophysics data system

OpenAI

ViZ

What is glue?


glue
multidimensional data exploration
multiple data sets analyzed together
selections across data sets
data sets attributes linked (UI not shown)
table viewer (not shown)
stats calculator (not shown)
custom plot types (not shown)
multi-layer images, with additional points, curves, and selection layers
selections across all views
standard x-y (2D) plots
multi-layer 3D volumetric rendering
3D point clouds
external tool plug-ins (e.g. WorldWide Telescope)
spectrum (profile) display/analysis tools
2D plots from 3D data, in user-defined e.g. non-orthogonal coordinates

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)

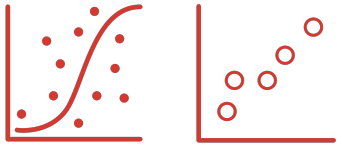
data files' common attributes are glued

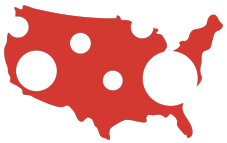
avoiding the need to merge data files

“graphs”

common statistical graphics

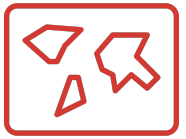
(scatterplots, histograms, tables, curves, overlays)





maps & images

(greyscale, color, contours, layer control…)

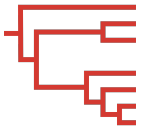


3D displays

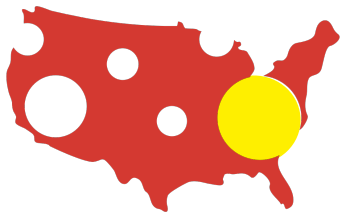
(scatter plots, volumetric rendering, sliders…)

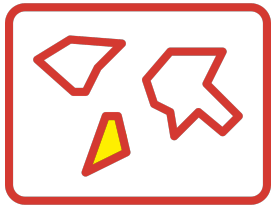
specialized & custom charts

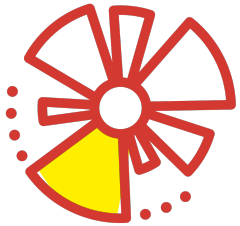
(dendrograms, polar plots, + domain-specific options)



selections propagate across all graphs



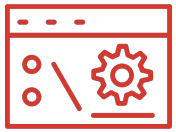




for real-time data exploration & insight

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

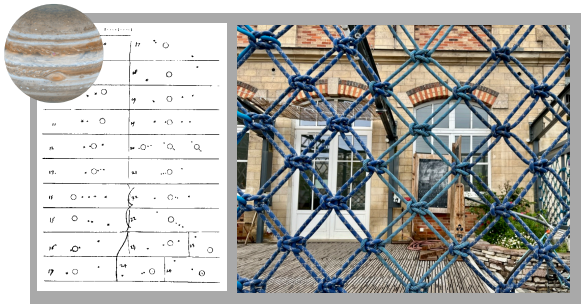
learn how at glueviz.org.

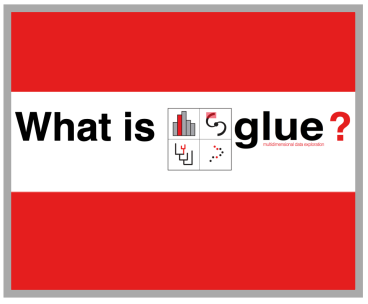
glueviz.org

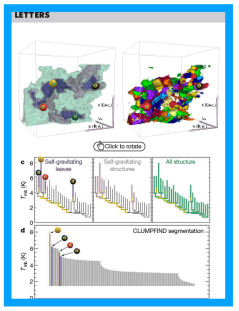
supported by

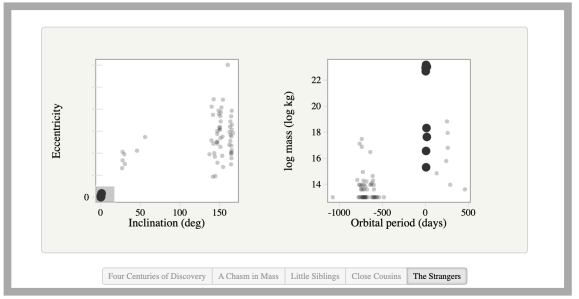
glue solutions inc.

GORDON AND BETTY MOORE FOUNDATION









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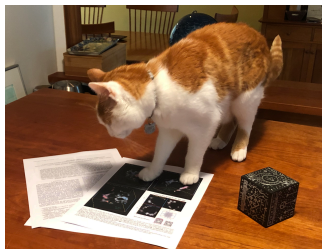
plotly

COSPACES



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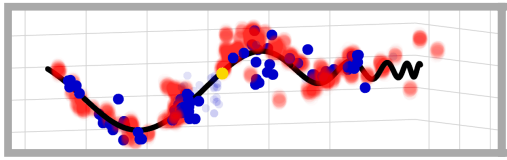

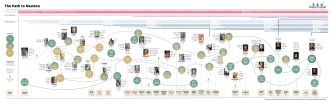

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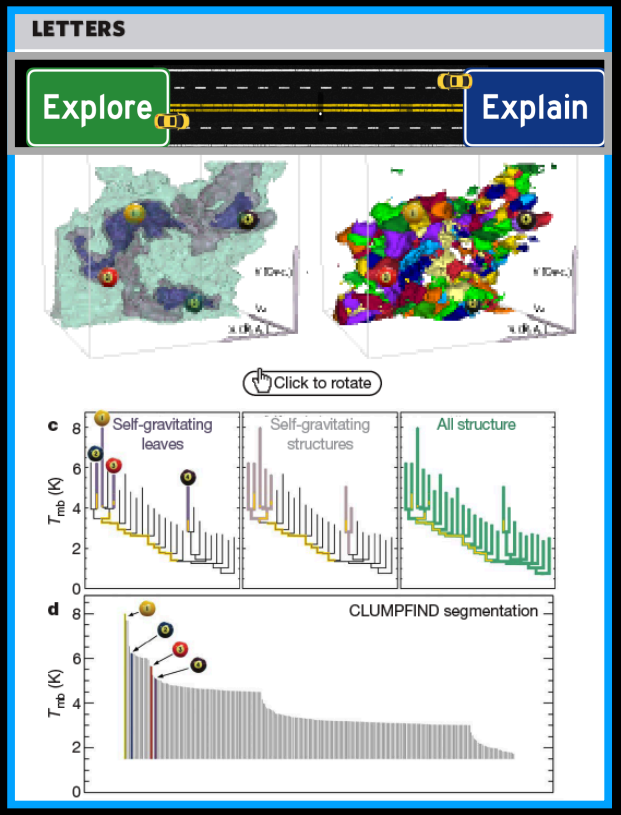
Origins of glue

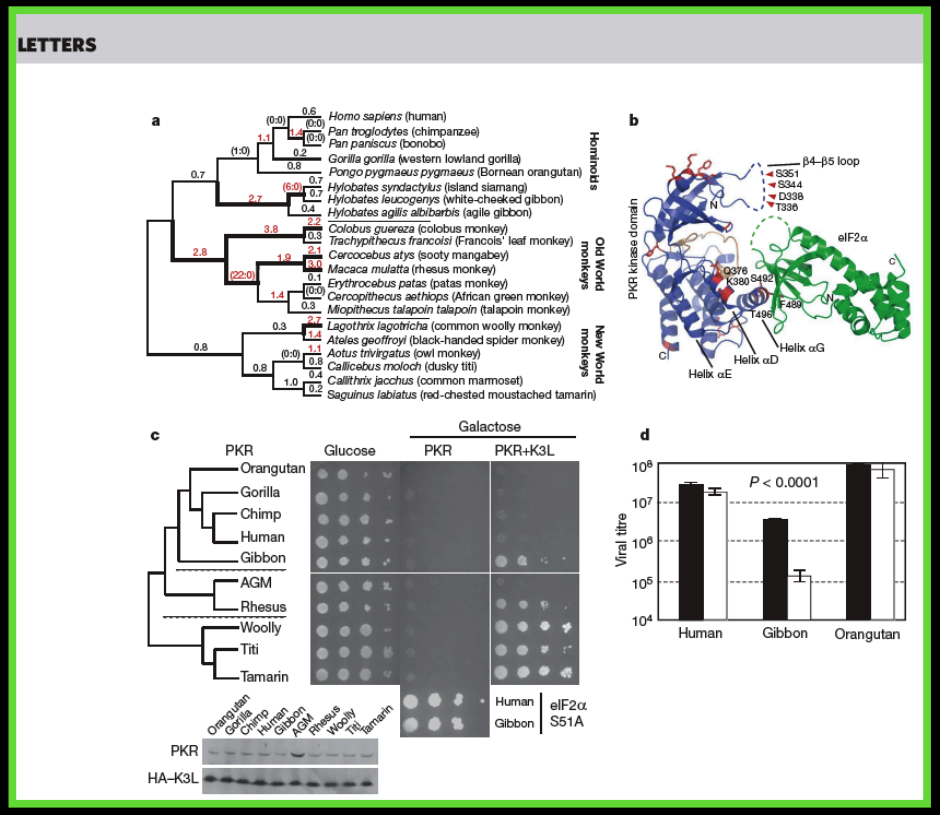
"High-dimensional" or "multivariate" data challenges are similar across astro & bio.

+

we wanted all these plots to talk to each other & be interactive in publications!



Goodman et al. *Nature*, 2009 (IIC)



Elde et al. *Nature*, 2008

AstronomicalMedicine@IIC

Origins of glupyter

2005-8

AstronomicalMedicine@IIG

Microsoft Research
WorldWide Telescope
www.worldwidetelescope.org

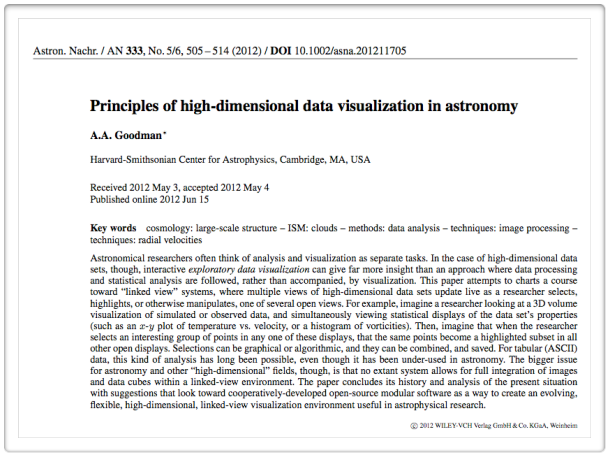
2008

2011

STScI | SPACE TELESCOPE SCIENCE INSTITUTE

WEBB SPACE TELESCOPE

$ 2013, launch 2022



Astron. Nachr. / AN **333**, No. 5/6, 505 – 514 (2012) / **DOI** 10.1002/asna.201211705

Principles of high-dimensional data visualization in astronomy

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Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA

Received 2012 May 3, accepted 2012 May 4
Published online 2012 Jun 15

Key words cosmology: large-scale structure – ISM: clouds – methods: data analysis – techniques: image processing – techniques: radial velocities

Astronomical researchers often think of analysis and visualization as separate tasks. In the case of high-dimensional data sets, though, interactive *exploratory data visualization* can give far more insight than an approach where data processing and statistical analysis are followed, rather than accompanied, by visualization. This paper attempts to charts a course toward "linked view" systems, where multiple views of high-dimensional data sets update live as a researcher selects, highlights, or otherwise manipulates, one of several open views. For example, imagine a researcher looking at a 3D volume visualization of simulated or observed data, and simultaneously viewing statistical displays of the data set's properties (such as an x-y plot of temperature vs. velocity, or a histogram of vorticities). Then, imagine that when the researcher selects an interesting group of points in any one of these displays, that the same points become a highlighted subset in all other open displays. Selections can be graphical or algorithmic, and they can be combined, and saved. For tabular (ASCII) data, this kind of analysis has long been possible, even though it has been under-used in astronomy. The bigger issue for astronomy and other "high-dimensional" fields, though, is that no extant system allows for full integration of images and data cubes within a linked-view environment. The paper concludes its history and analysis of the present situation with suggestions that look toward cooperatively-developed open-source modular software as a way to create an evolving, flexible, high-dimensional, linked-view visualization environment useful in astrophysical research.

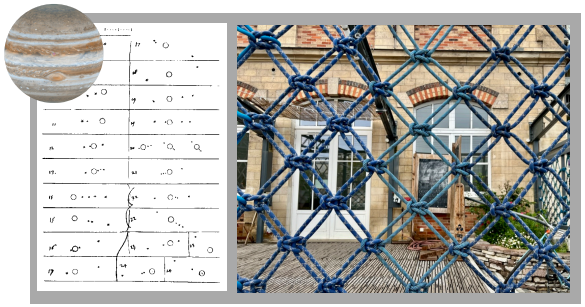
2012

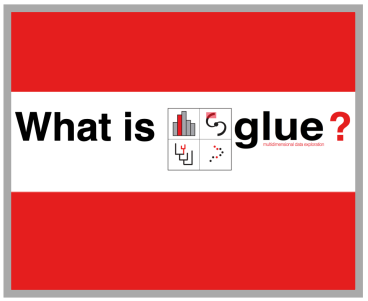
c. 2011

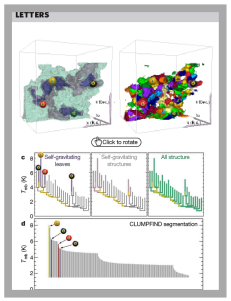
glue
multidimensional data exploration

glupyter
multidimensional data exploration

c. 2019



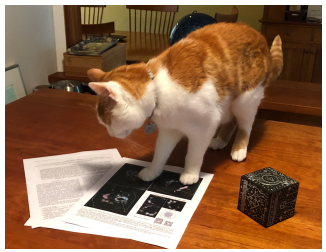




glue
multidimensional data exploration

plotly

COSPACES

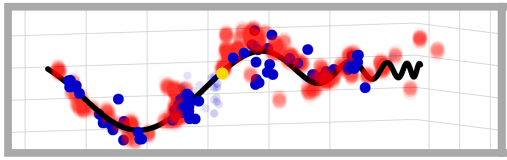


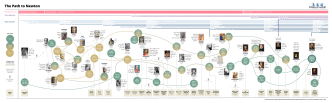
lab
glupyter
multidimensional data exploration

glue genes

CosmicDS

Jdaviz





The TIMELINE CONSORTIUM

astrophysics data system

OpenAI

ViZ

glue

multidimensional data exploration

c. 2017

plotly

enabled by d3.js (javascript) outputs, in 2013

d3po

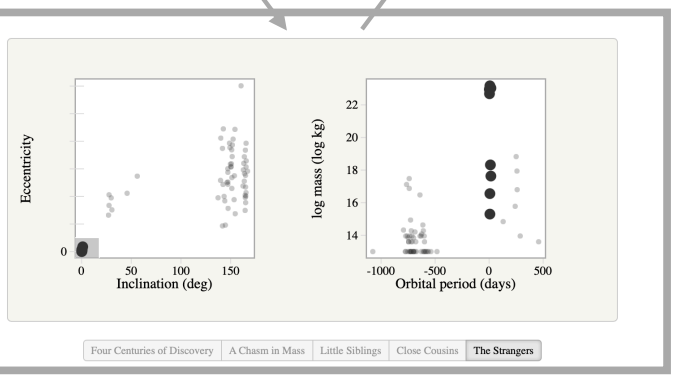
d3po is a project designed to allow an astronomer (or anyone), with no special data visualization skills, to make an interactive, publication-quality figure that has staged builds and linked brushing through scatter plots. Our current version can be previewed at d3po.org, and represents a figure from upcoming work by graduate student Elisabeth Newton. The figure describes how metalicity affects color in cool stars, and represents a nice use case for d3po. Try clicking and dragging in the scatter plots to understand the power of linked brushing in published figures.

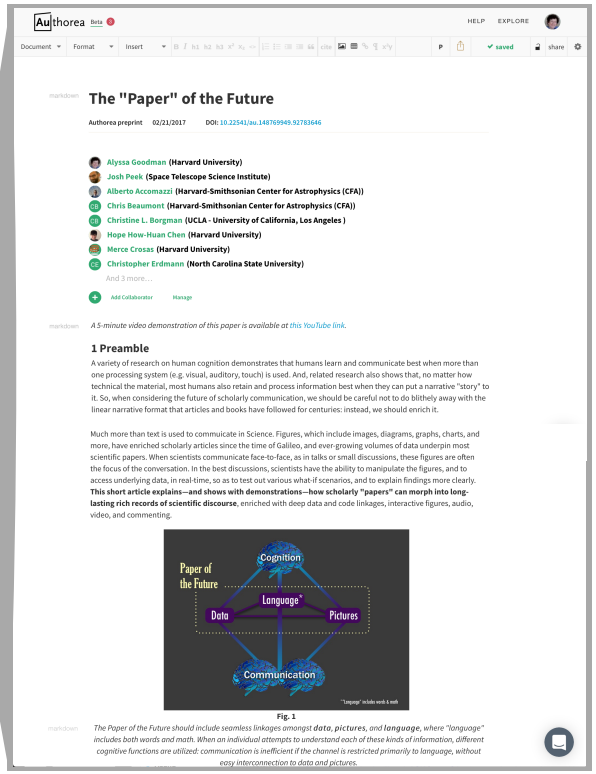
Right now we are in search of alpha testers, who have figures that could be made interactive and who are willing to get their hands a little dirty (No javascript skills needed). In future versions, we plan to link to glue to allow the creation of d3po figures interactively. We are also exploring implementation of d3po within presentations and within authorea. Full 1.0 version expected in January 2014.

Installing your own d3po server

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

Authorea





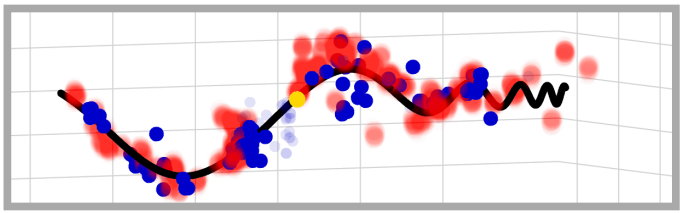
[demo]

Many thanks to Alberto Pepe, Josh Peek, Chris Beaumont, Tom Robitaille, Adrian Price-Whelan, Elizabeth Newton, Michelle Borkin & Matteo Cantiello for making this posible.

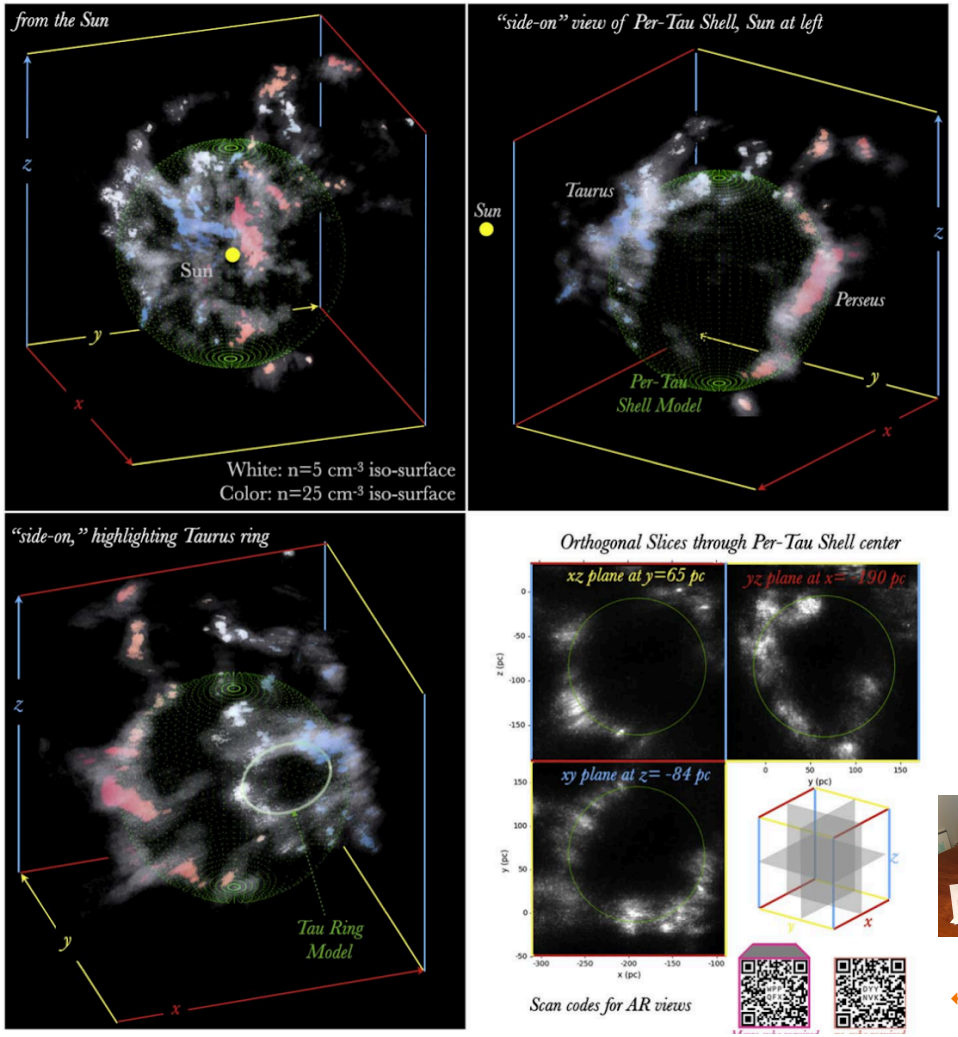
Triumphs of glue (and plot.ly)

Triumphs of glue (and plot.ly) ++

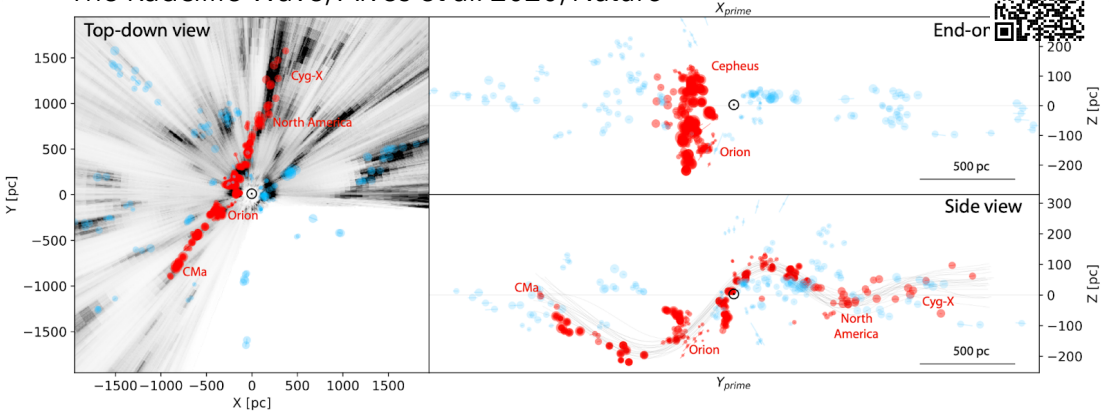
*This one is EMBARGOED—I will show you a demo, but please **do not post it, or share it.***



The Perseus-Taurus Supershell
Bialy et al. 2021, *ApJL*



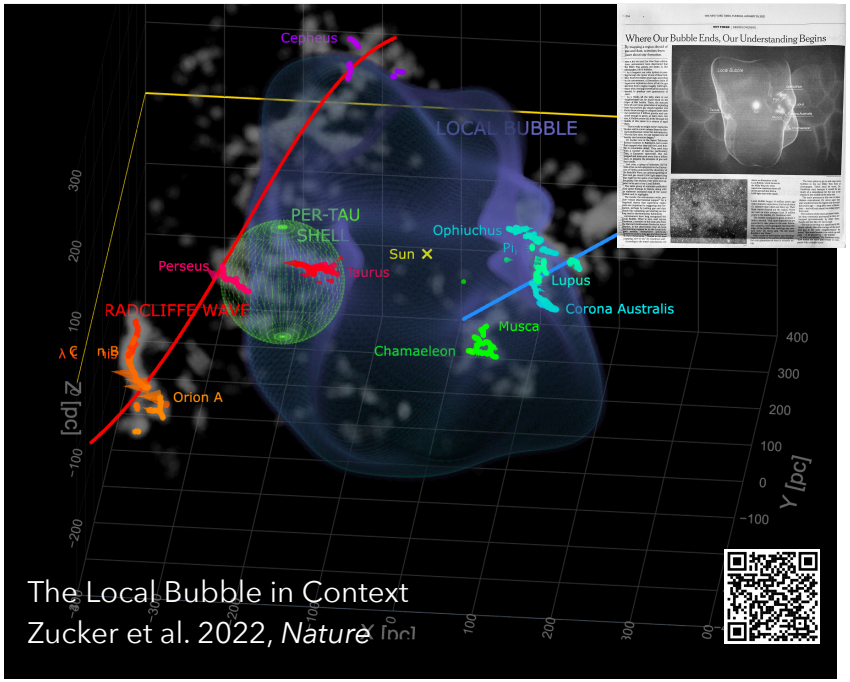
The Radcliffe Wave, Alves et al. 2020, *Nature*



Scan this code for

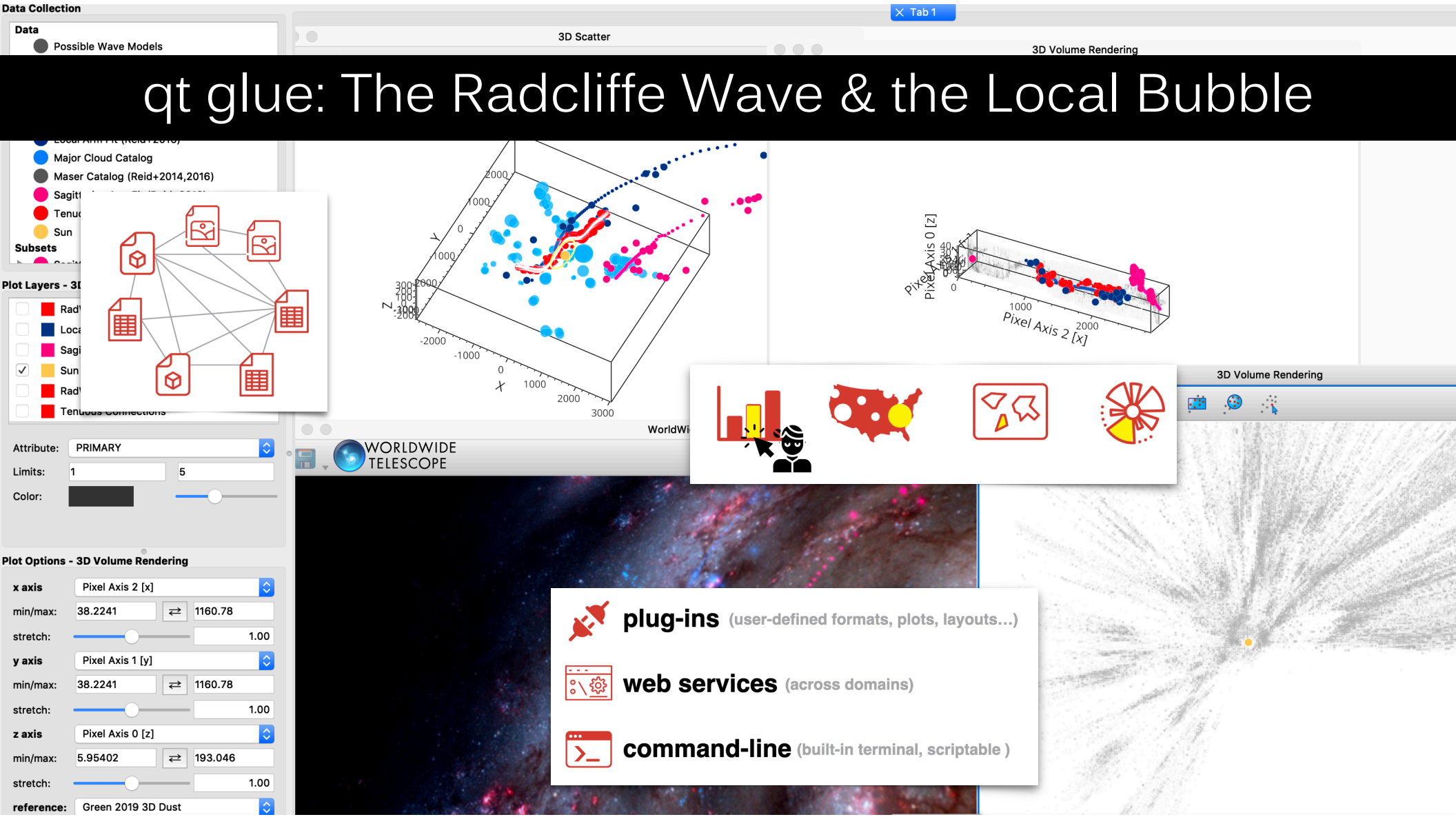
a "handout"

←AR Codes

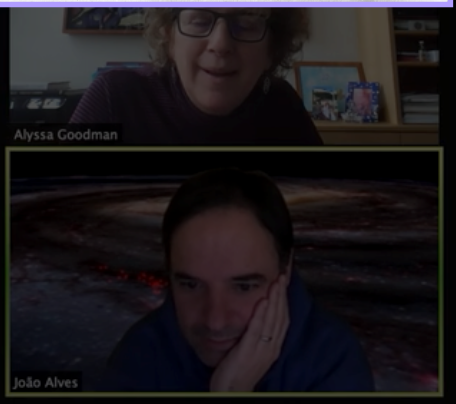


The Local Bubble in Context
Zucker et al. 2022, *Nature*

qt glue: The Radcliffe Wave & the Local Bubble

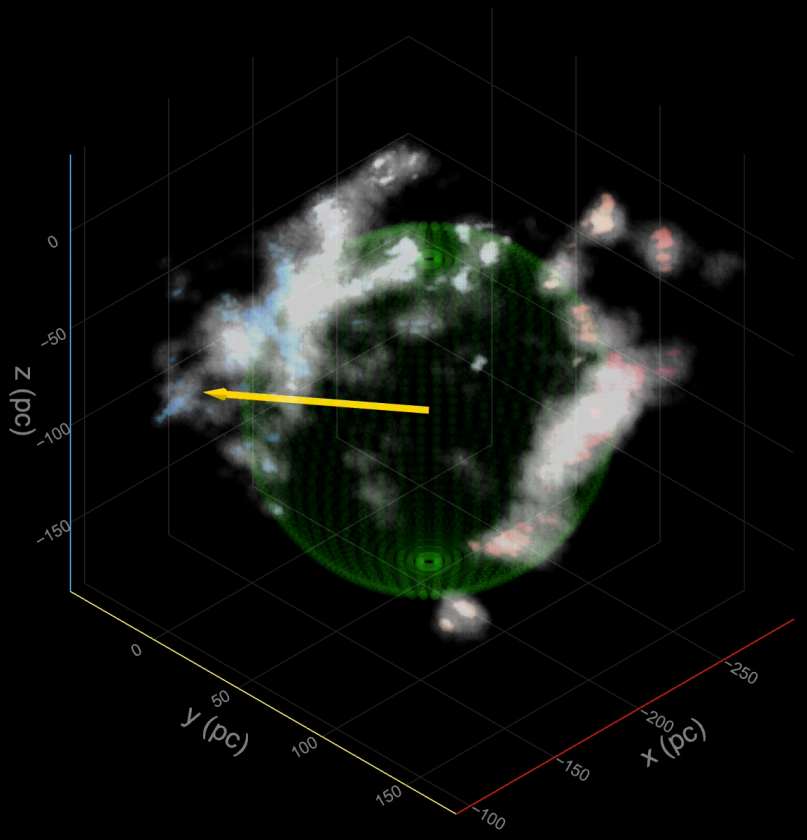


And how easy/hard is it to use?

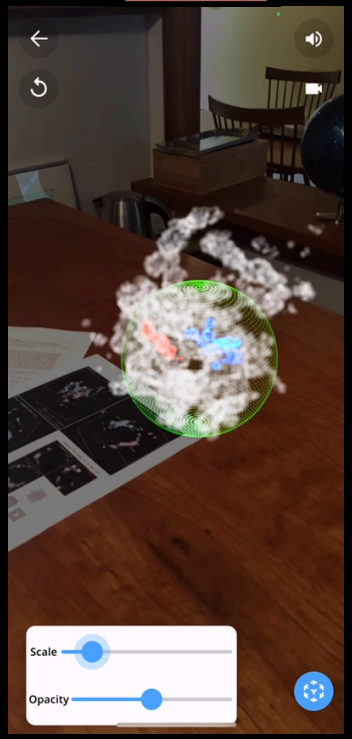


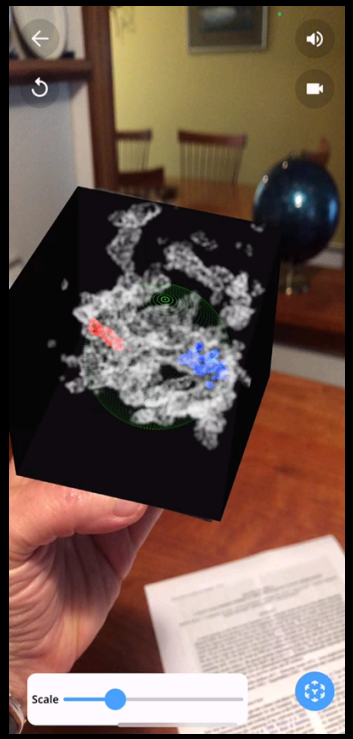
The Future

The Future of Publishing



TINYURL.COM/UNIVERSE-IN-MY-HAND



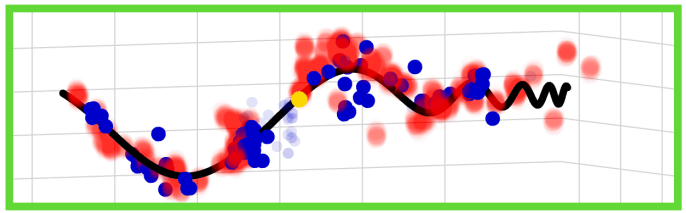


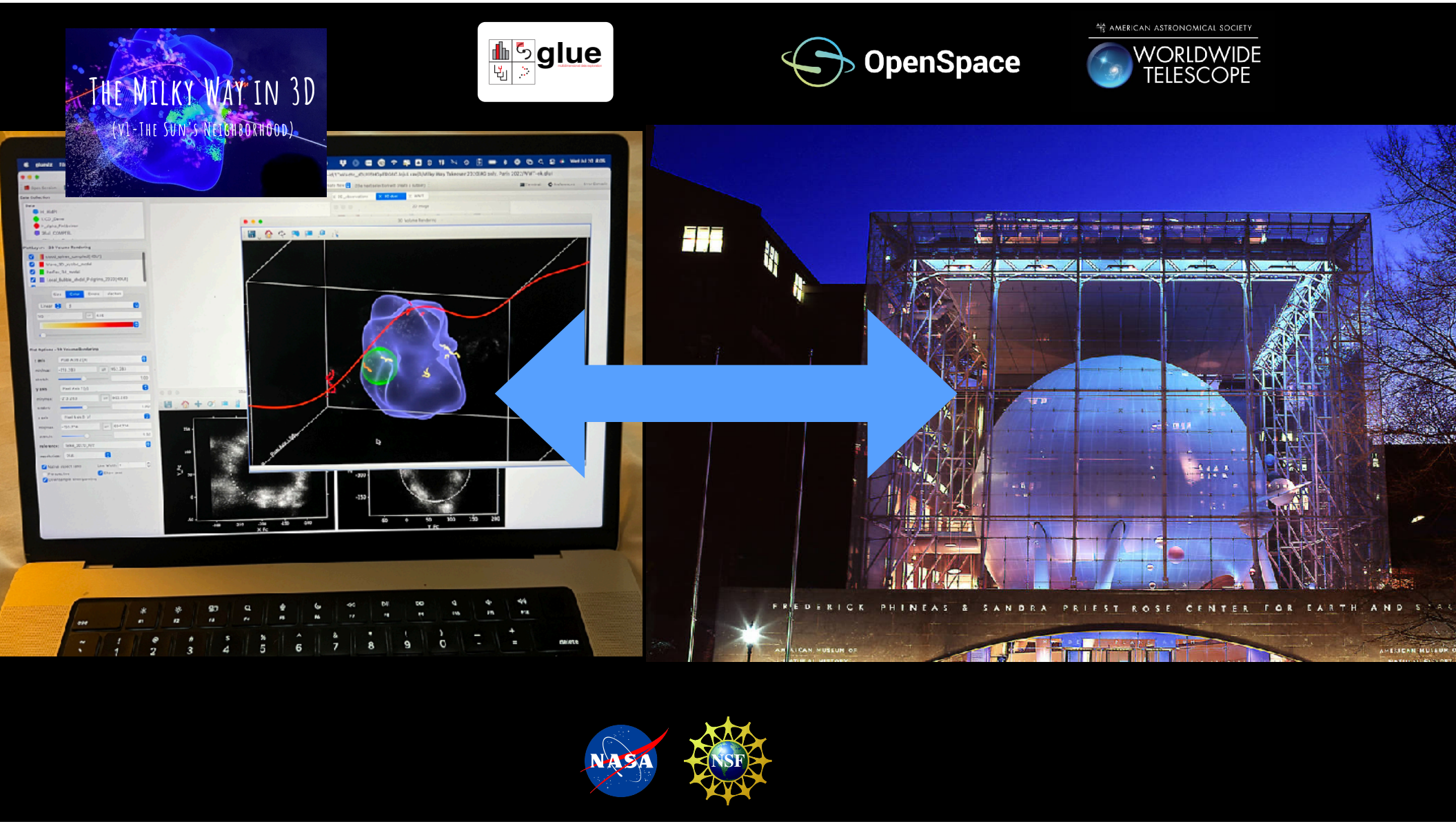
AUGMENTED REALITY

Triumphs of glue (and plot.ly) ++

glue
multidimensional data exploration

*This one is EMBARGOED—I will show you a demo, but please **do not post it, or share it.***



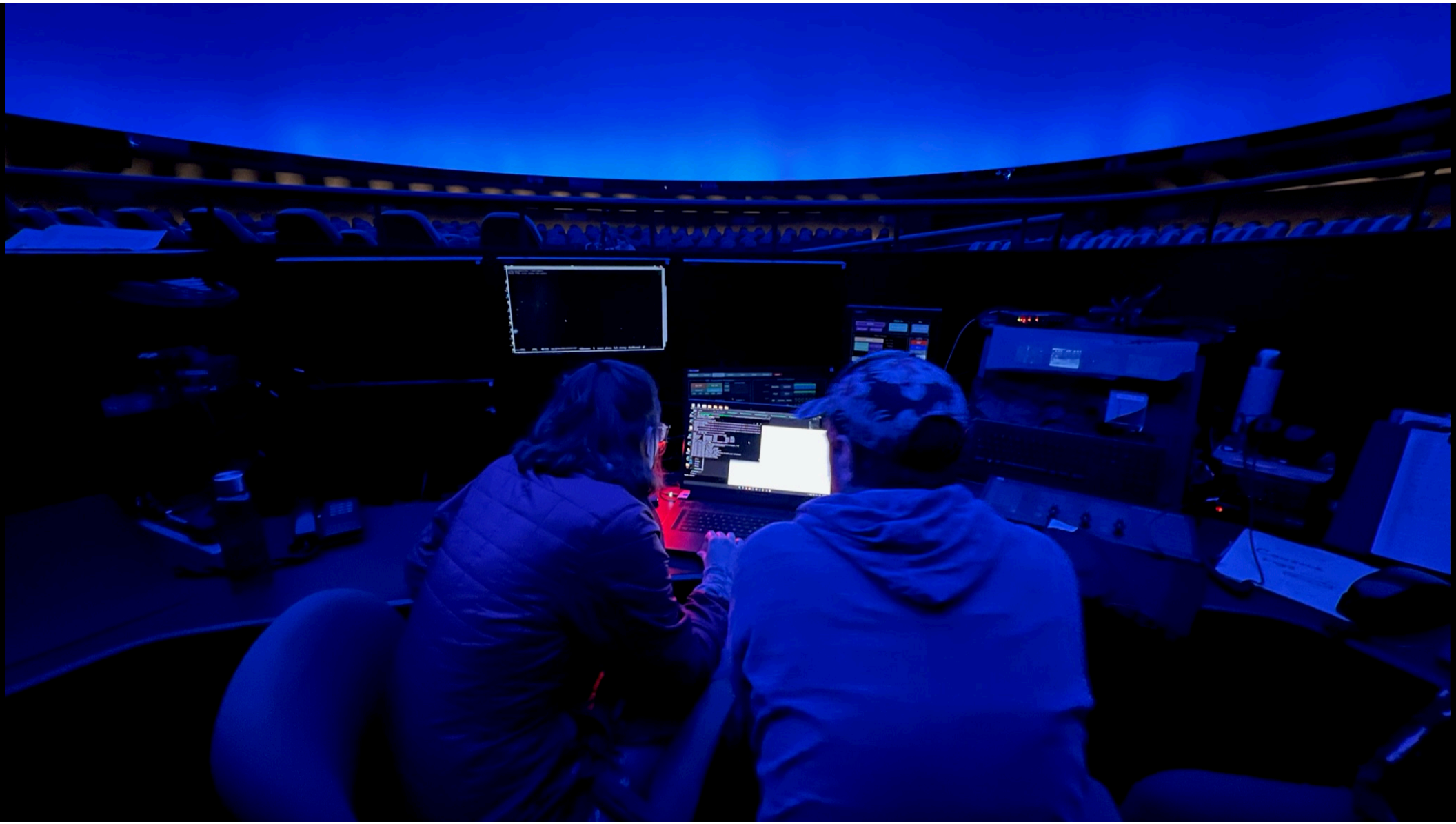

THE MILKY WAY IN 3D
(V1 - THE SUN'S NEIGHBORHOOD)
glue
OpenSpace
AMERICAN ASTRONOMICAL SOCIETY
WORLDWIDE TELESCOPE
FREDERICK PHINEAS & SANDRA PRIEST ROSE CENTER FOR EARTH AND
NASA
NSF

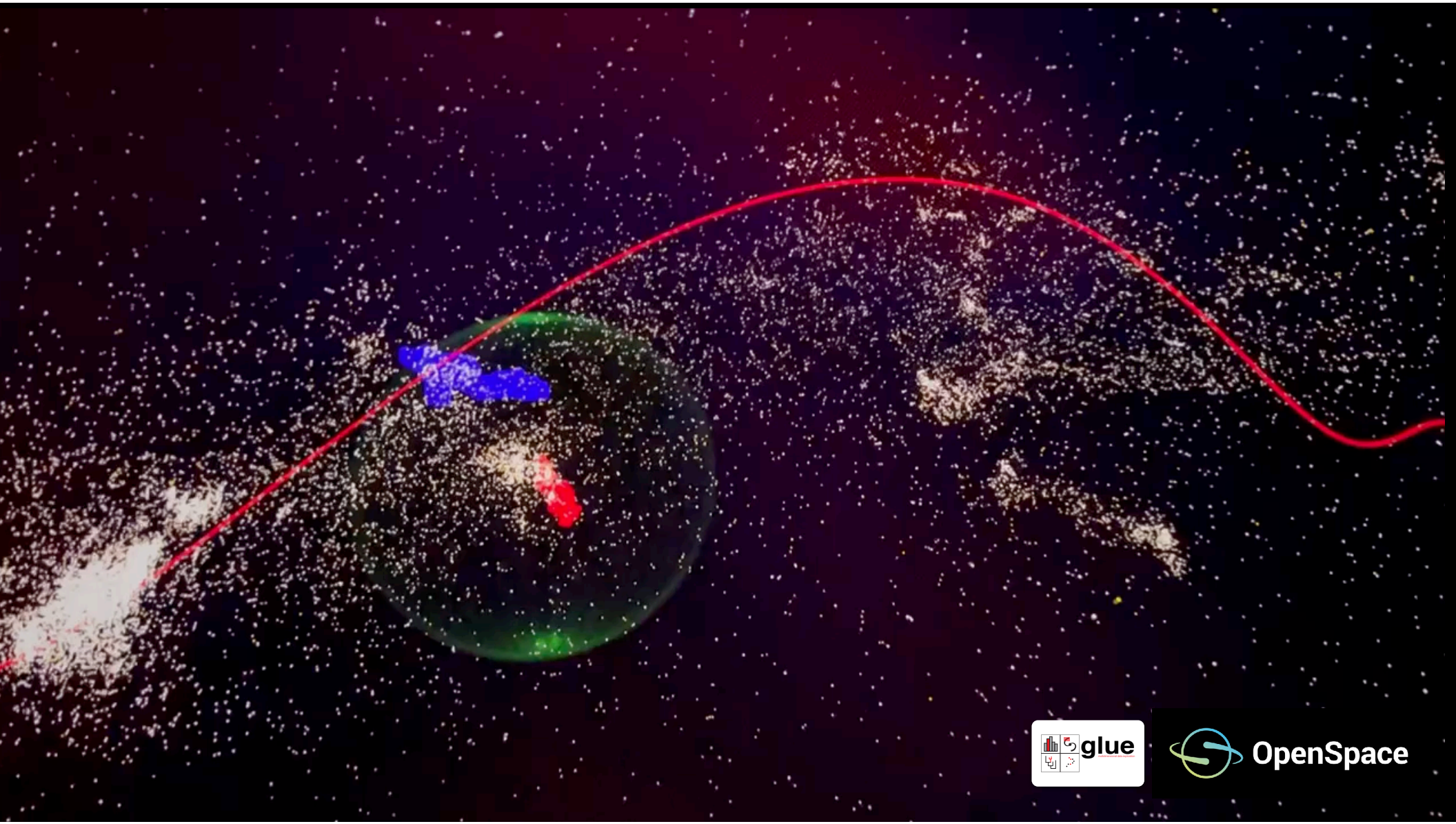
Welcome to a new view of the Milky Way... in 3D!

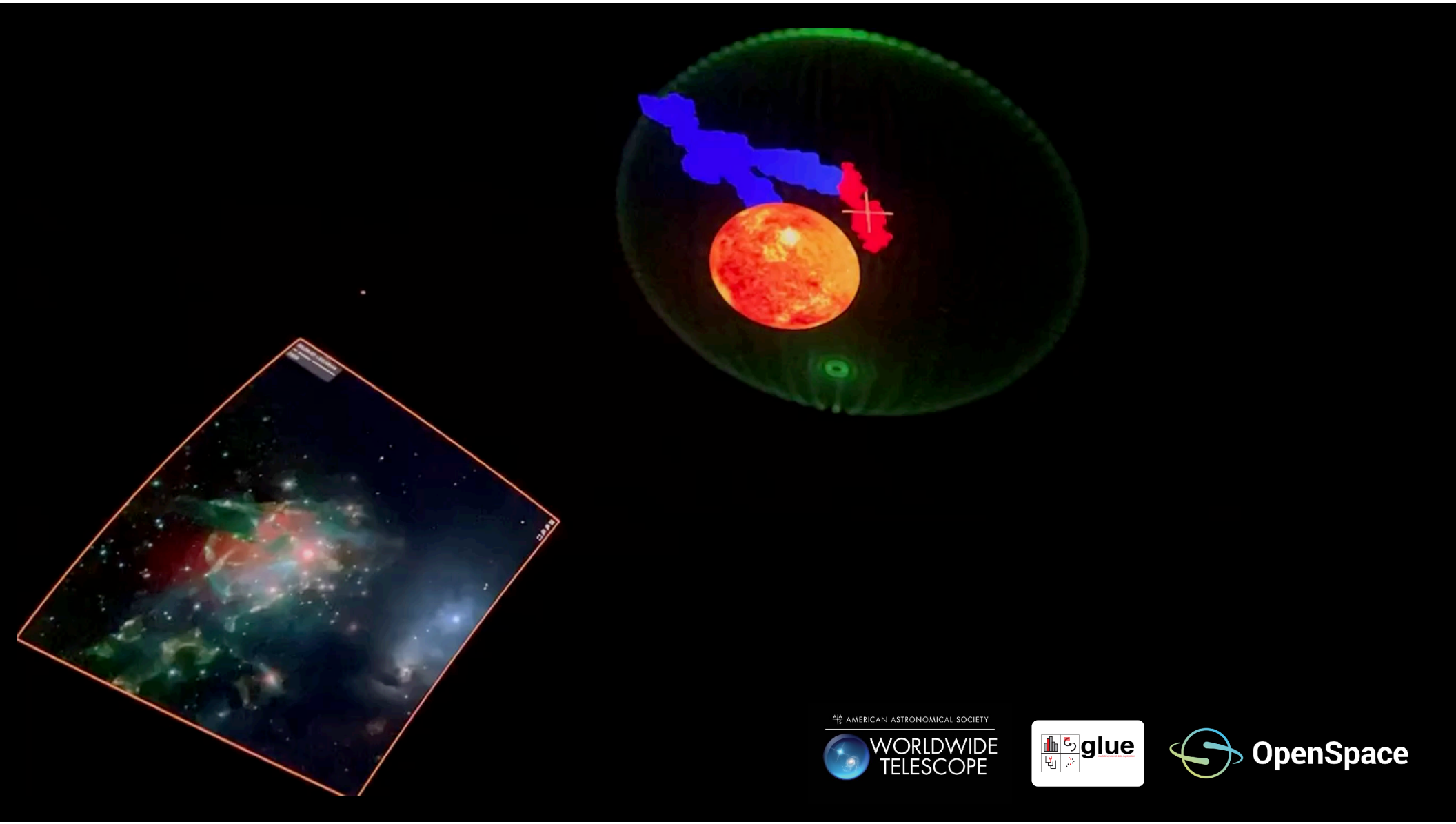
Soon, milkyway3d.org will serve as a hub for the interconnected set of outreach, education, and research resources that will result from the interconnections we're in the process of making.

Our project includes new software development; approaches to data sharing; and scientific research questions propelling our collaboration forward.

milkyway3D.org



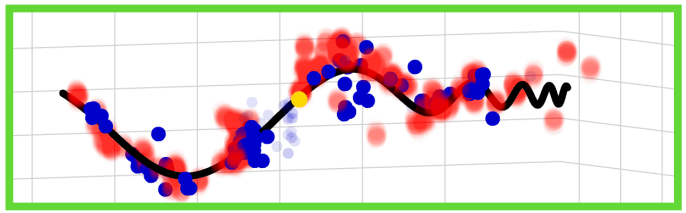

glue
OpenSpace


AMERICAN ASTRONOMICAL SOCIETY
WORLDWIDE TELESCOPE
glue
OpenSpace

Triumphs of glue (and plot.ly) ++

glue
multidimensional data exploration

*This one is EMBARGOED—I will show you a demo, but please **do not post it, or share it.***



Progeny of glue

Progeny of glue

glue
multidimensional data exploration

lab
glupyter
multidimensional data exploration

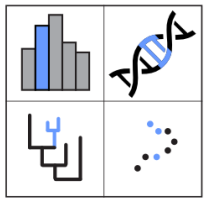
glue genes

CosmicDS

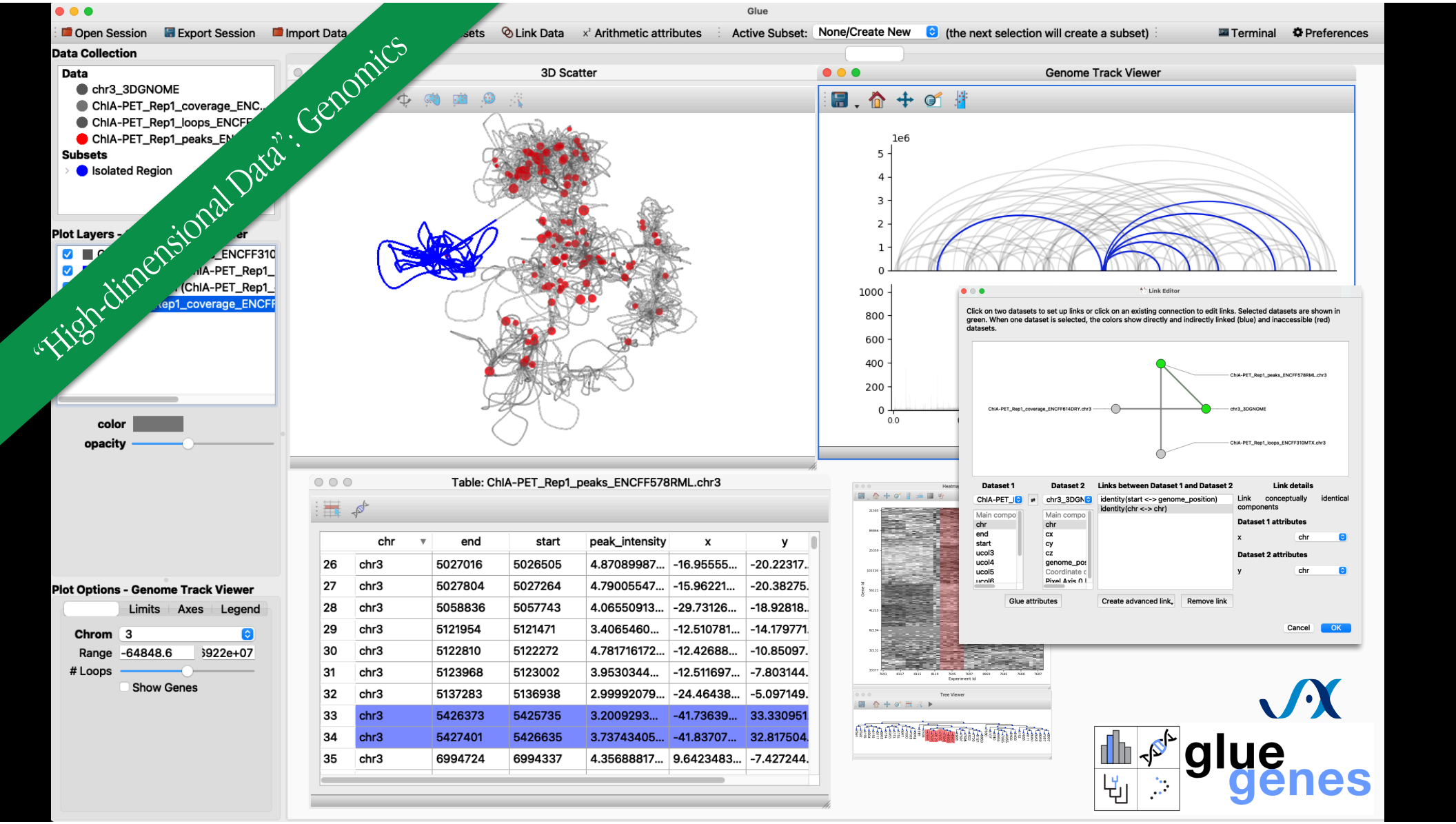
Jdaviz

later...a Google Drive souvenir...
with plenty of notebook samples.

glue
solutions
inc.



glue
genes



	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.

Spatial Transcriptomics

"High-dimensional Data": Genomics

TRANSCRIP

Vi and analysis of gene in tissue sections by transcriptomics

ahl,[1,2*] Fredrik Salmén,[2*] Sanja Vickovic,[2†] Anna Lundmark,[2,3†] nández Navarro,[1,2] Jens Magnusson,[1] Stefania Giacomello,[2] Michaela Asp,[2] O. Westholm,[4] Mikael Huss,[4] Annelie Mollbrink,[2] Sten Linnarsson,[5] mone 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 Frisén[1]

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.

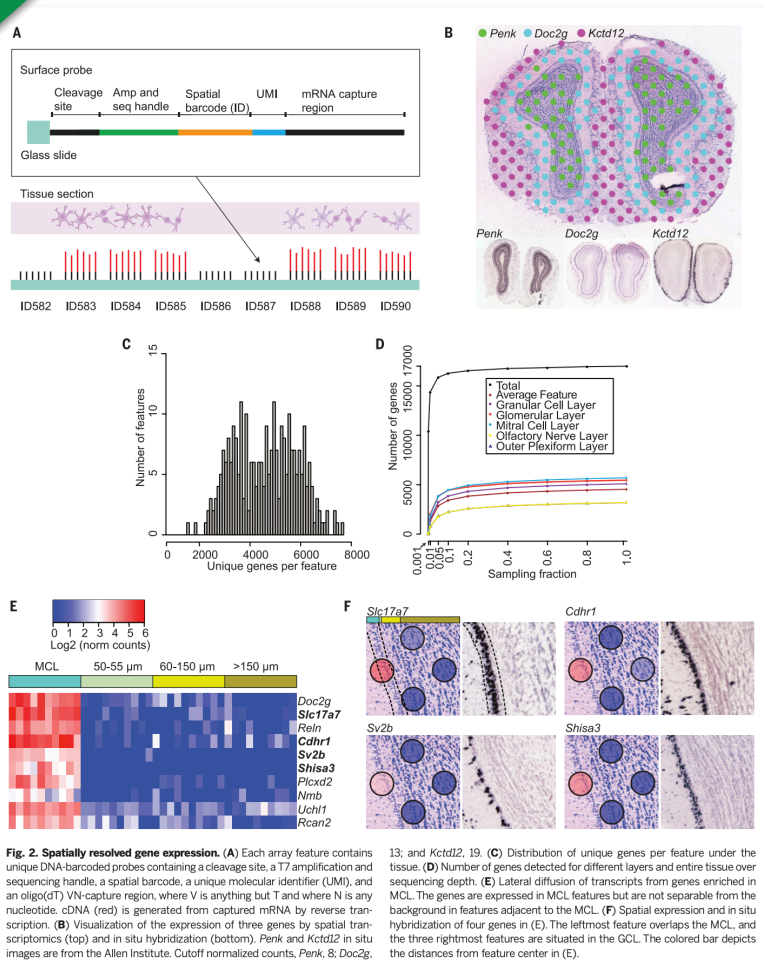


Fig. 2. Spatially resolved gene expression. (**A**) Each array feature contains unique DNA-barcoded probes containing a cleavage site, a T7 amplification and sequencing handle, a spatial barcode, a unique molecular identifier (UMI), and an oligo(dT) VN-capture region, where V is anything but T and where 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).

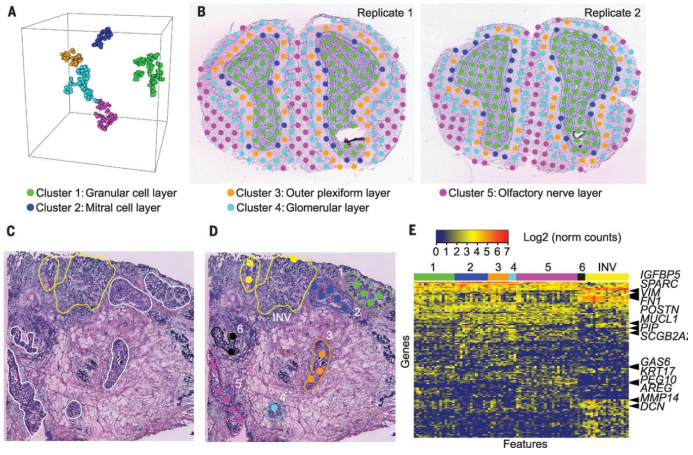
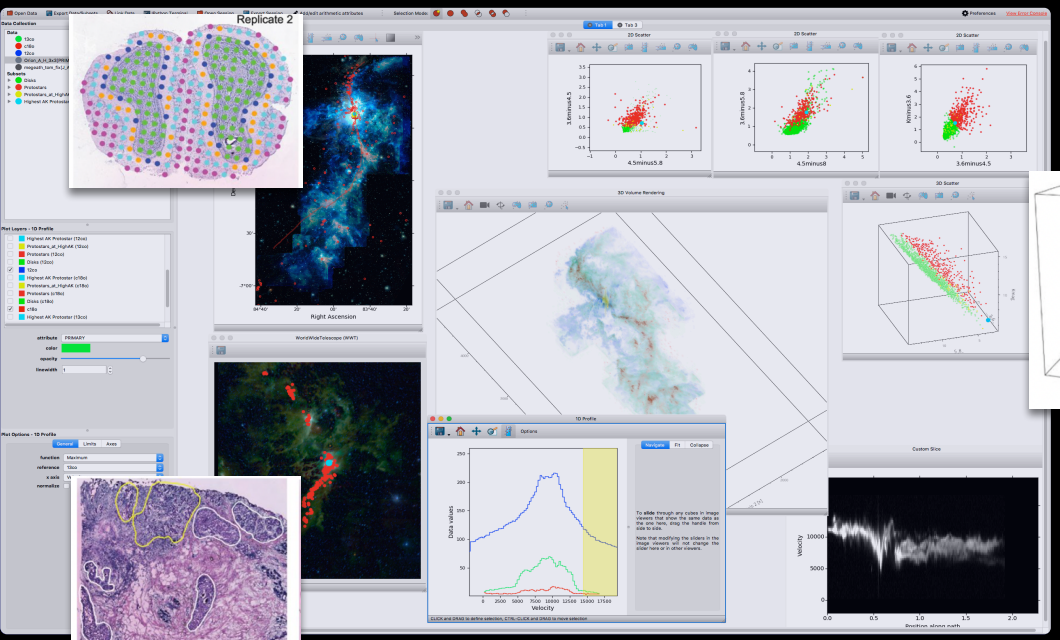


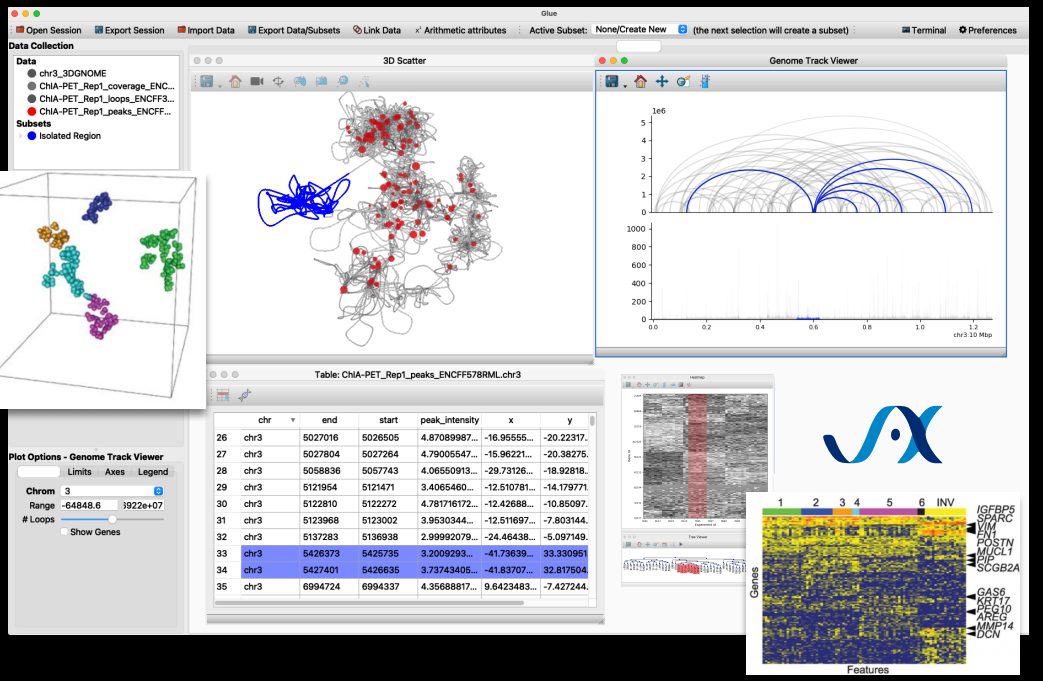
Fig. 4 Comparative analyses of tissue domains. (**A**) t-SNE analysis and hierarchical clustering of 551 features from two replicates creates five distinct clusters. (**B**) The features placed back onto the two tissue images. (**C** and **D**) Histological section of a breast cancer biopsy (C) containing 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).

Ståhl PL, Salmén F, Vickovic S, Lundmark A, Navarro JF, Magnusson J, Giacomello S, Asp M, Westholm JO, Huss M, Mollbrink A, Linnarsson S, Codeluppi S, Borg Å, Pontén F, Costea PI, Sahlén P, Mulder J, Bergmann O, Lundeberg J, Frisén J (2016) Visualization and analysis of gene expression in tissue sections by spatial transcriptomics. *Science*, 353(6294):78–82. https://doi.org/10.1126/science.aaf2403

High-dimensional Data: Astronomy



High-dimensional Data: Genomics++



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

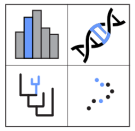
glue genes experimental
Genome Viewer

and next...

glue genes 1.0
Data loaders
cell-to-gene plugins
Core glue changes
Heatmap Viewer
Small Multiples Viewer

glue genes 1.1
glue genes 1.0
glue-spatial-trans

glue genes 1.2



glue genes

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

glue-spatial-trans
OME-NGFF Zarr loader
Display region-like data
Core glue changes

gosling viewer
Improved genome viewer

Progeny of glue

glue
multidimensional data exploration

lab
glupyter
multidimensional data exploration

glue genes

CosmicDS

Jdaviz

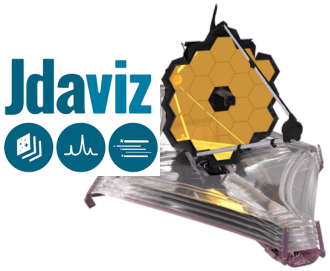
later...a Google Drive souvenir...
with plenty of notebook samples.

glupyter (a.k.a. "glue jupyter")

gluesolutions.io/
the-software/
glupyter

"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)...

GitHub

Open-Source GIS Data Exploration

SAVE

Search-Analysis-Visualization-Environment

Sponsors: Harvard+Google Data+Climate

Read more
at Data+Climate site...

GitHub

CosmicDS

Data Science Education

Cosmic Data Stories

Sponsor: NASA, Science Activation Program (funded proposal)

Read more
at CosmicDS website...

GitHub

glupyter

bringing glue to JupyterLab

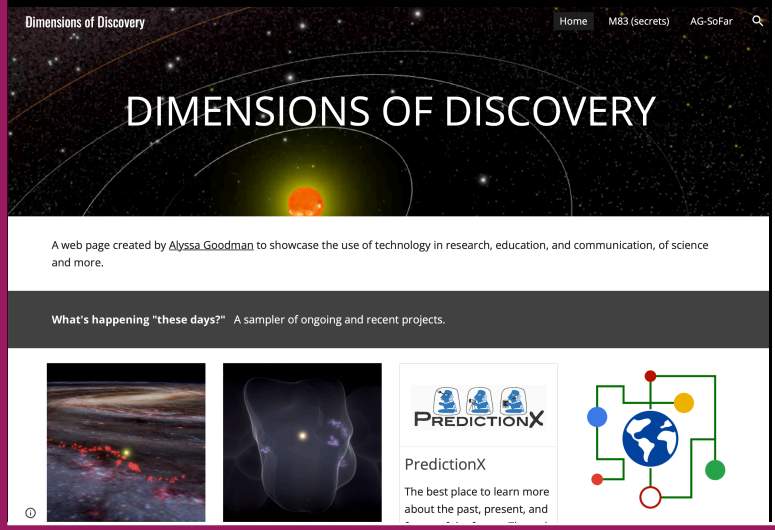
glupyter prototype

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

Read more in the justificaiton of the GBF proposal, awarded to Harvard, and watch this 2022 demo video

GORDON AND BETTY MOORE FOUNDATION

tinyurl.com/dimensionsofdiscovery



"LEVELS" of interaction/users

CosmicDS — Guided experience for learners, no coding, only interactive webpages

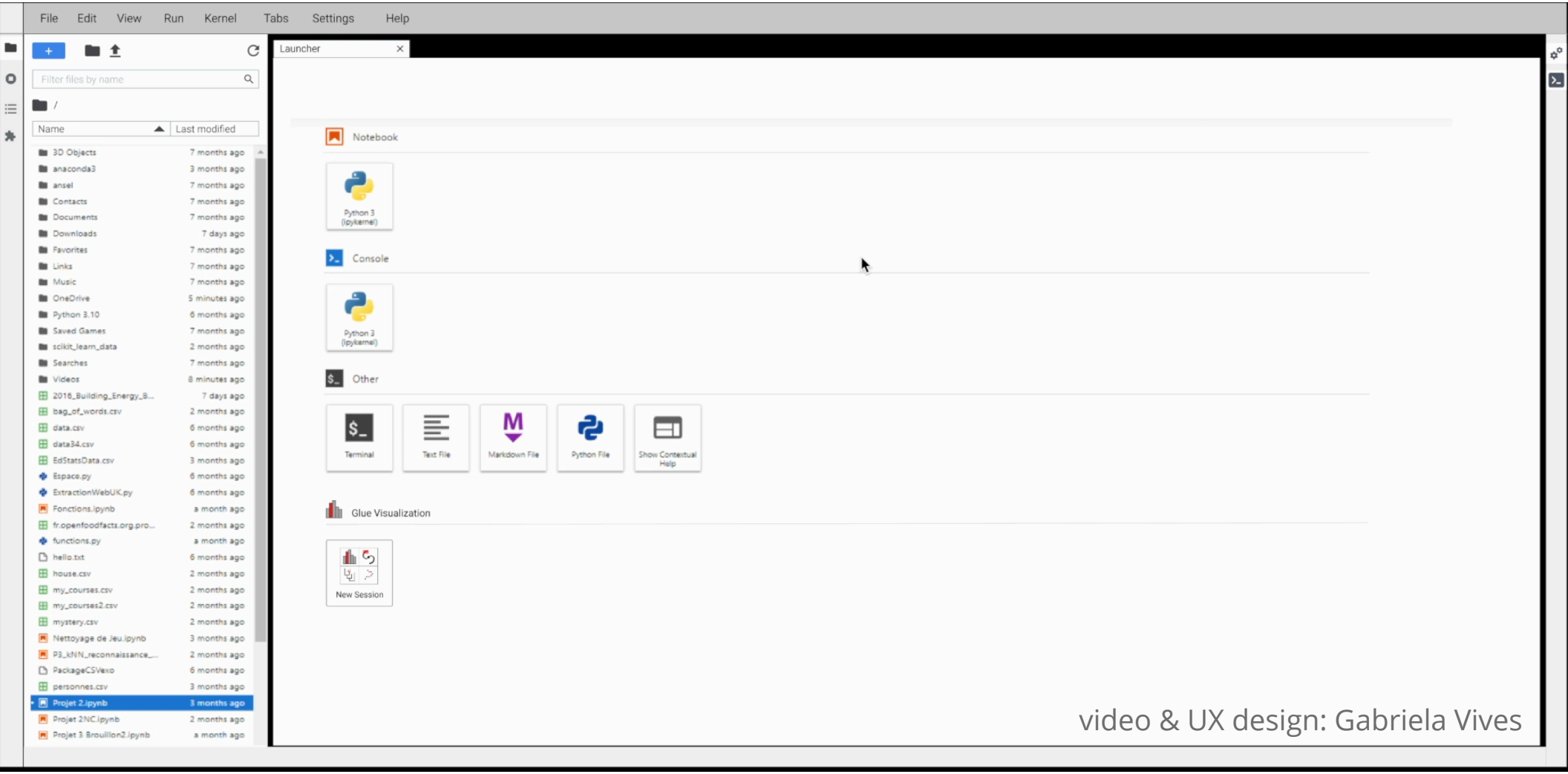
Jdaviz — dashboard-style

glupyter — Fully flexible, scriptable, exensible.

Coming in 2023, glue in jupyter lab v.0.1

glupyter

grant to: glue (A. Goodman), Jupyter (F. Perez) developed in collaboration with S. Corlay et al at QuantStack

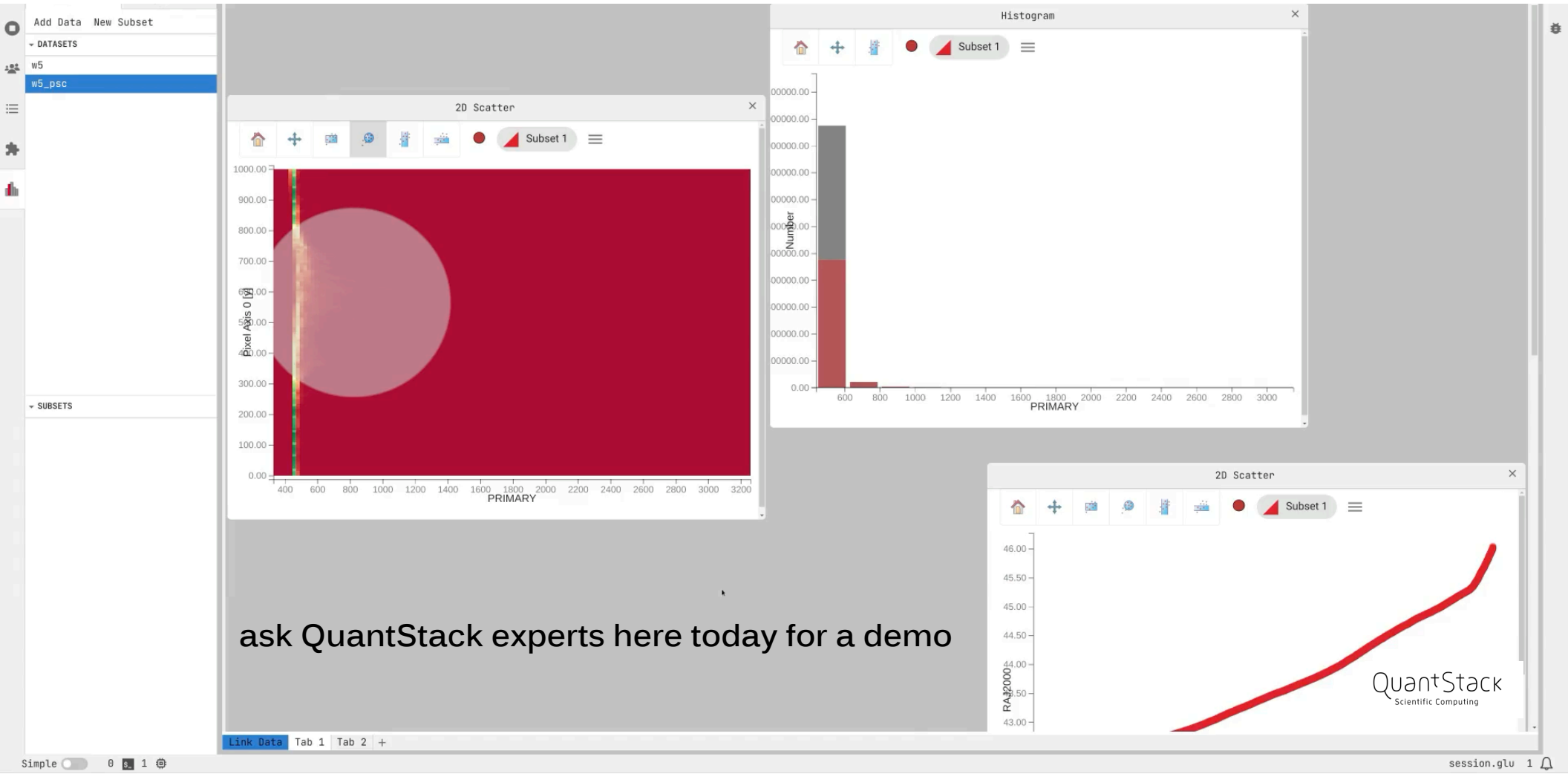


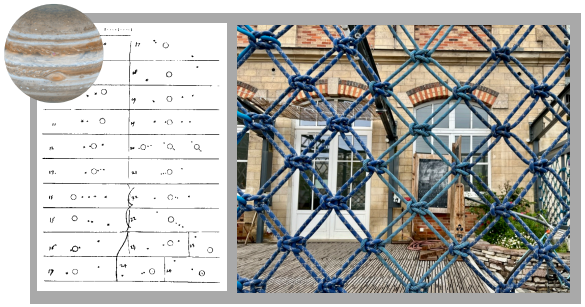
video & UX design: Gabriela Vives

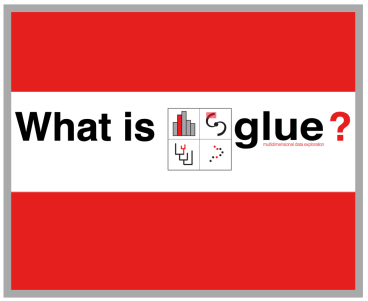
Coming in 2023, glue in jupyter lab v.0.1

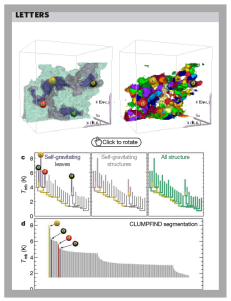
glupyter

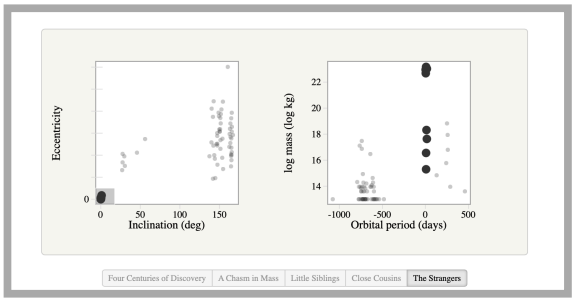
grant to: glue (A. Goodman), Jupyter (F. Perez) developed in collaboration with S. Corlay et al at QuantStack Scientific Computing











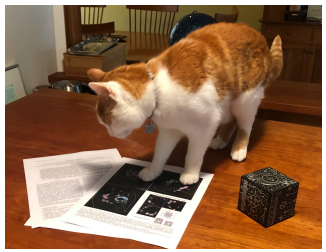
glue
multidimensional data exploration

plotly

CO SPACES

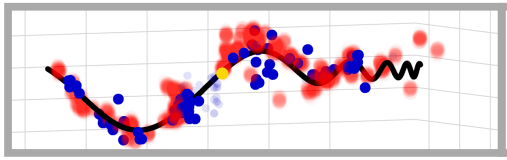
lab
glupyter
multidimensional data exploration

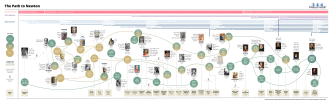
glue genes



CosmicDS

Jdaviz





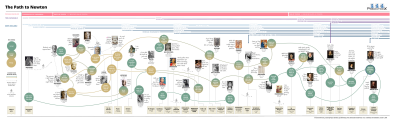
The TIMELINE CONSORTIUM

astrophysics data system

OpenAI

ViZ

Seeds for discussion...



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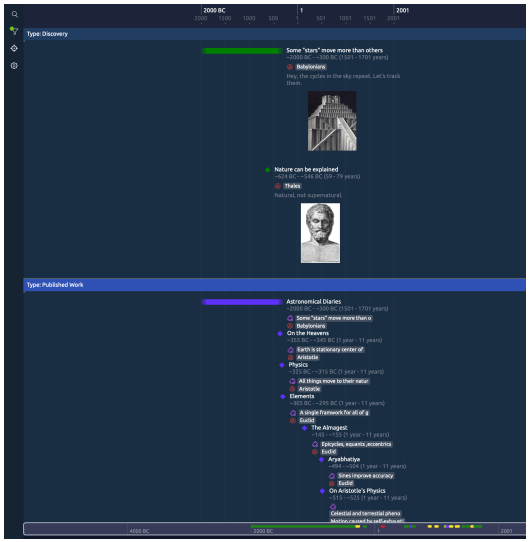


Forging New Horizons in Astronomy Research with Foundation Models
(a proposal SELECTED by Microsoft, April 26, 2023)

Principal Investigator
Alyssa Goodman (Center for Astrophysics | Harvard & Smithsonian)
Co-Investigators
Ioana (Jo) Ciucă & Yuan-Sen Ting (Australian National University)
Alberto Accomazzi (NASA ADS & Center for Astrophysics | Harvard & Smithsonian)
Josh Peek (Space Telescope Science Institute)

Introduction
Dating back nearly five thousand years, Astronomy has aimed to unravel the mysteries of the Universe and push the boundaries of theoretical understanding. The advent of the Internet has allowed astronomers to archive our corpus of knowledge, with NASA's"Astrophysics Data System" (ui.adsabs.harvard.edu) hosting over 15 million resources, representing essentially *all* of the astronomical literature used by researchers (Accommazzi et al. 2015, Borgman & Wofford 2021). Recent breakthroughs in large language models (LLMs, e.g., Vaswani et al. 2017; Devlin et al. 2018; Brown et al. 2020) are now empowering researchers to draw insights from the expansive and intricate body of astronomy literature. For example, the LLMs can help researchers navigate the various scientific interpretations of research findings, which may disagree in non-trivial ways. Moreover, the multidisciplinary aspect of Astronomy enables the utilisation of LLMs to reveal hidden relationships within our knowledge corpus, thereby opening the possibility of formulating novel scientific hypotheses.

Goals
The primary goal of this project is to improve human interaction with astronomy literature by leveraging the capabilities of foundation models such as the SoTA GPT-4 LLM (OpenAI 2023) in a focused manner. To this end, we will collaborate closely with NASA ADS to define a set of astronomy-specific downstream tasks (ADTs) such as extracting questions, answering with references, comparative analyses between different research papers, creating mind maps, scientific summarization, and generating new scientific ideas. We will then *curate an evaluation dataset* representative of a domain in Astrophysics *(e.g., Galaxy Evolution, Galactic Astronomy)* on which to evaluate the LLMs' performance.

The project aims to: a) develop a targeted approach for engaging GPT-4 with complex astronomy literature using in-context prompting; b) evaluate the performance of GPT-4 across astronomy-specific tasks (ADTs); c) create input-output pairs to cover the domain tasks; d) use the GPT-4 generated input-output pairs to fine-tune LLMs available through the Azure OpenAI Service; e) explore the potential of foundation models for generating new scientific hypotheses.

Scope of the research
1. In-Context Prompting Optimization for GPT-4.
   - Employ in-context prompting techniques using tools such as LangChain (Chase 2023) to develop a practical approach for providing GPT-4 with a broad context of astronomy literature, expanding on the approach proposed in Ciucă & Ting 2023.

≡ MENU

TEN QUESTIONS TO ASK WHEN CREATING A VISUALIZATION

The 10 Questions

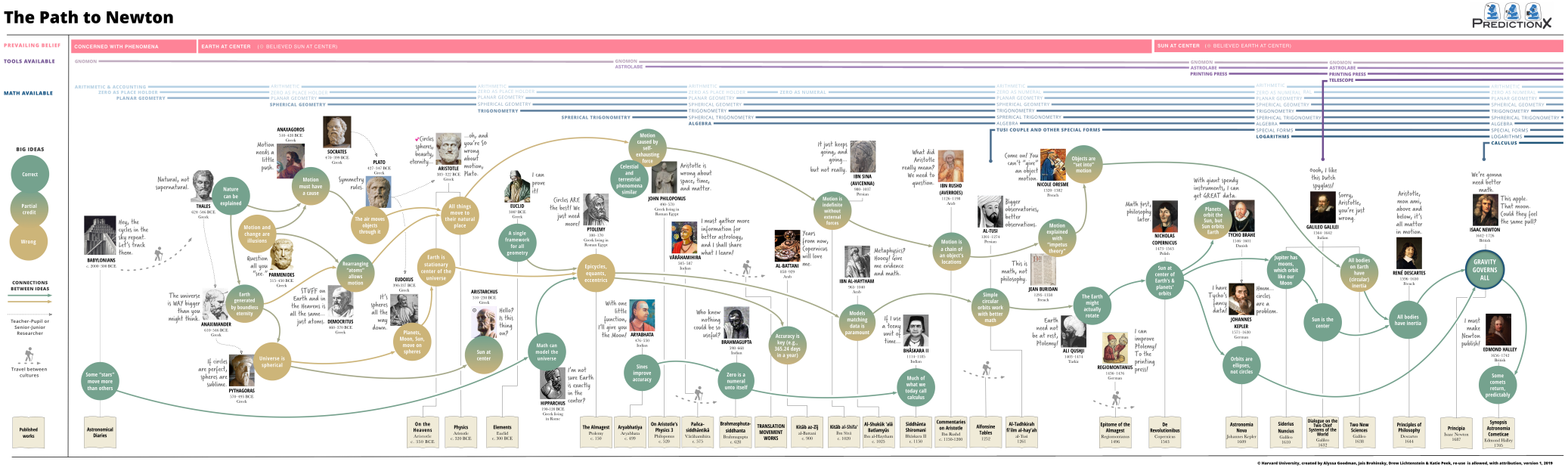
1. **Who** | Who is your audience? How expert will they be about the subject and/or display conventions?
2. **Explore-Explain** | Is your goal to explore, document, or explain your data or ideas, or a combination of these?
3. **Categories** | Do you want to show or explore pre-existing, known, human-interpretable, 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.

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?
And, there's more at our **YouTube channel!**
Write to ask for a draft of our research paper, Coltekin & Goodman 2019.

The Path to Newton

PREDICTIONX
predictionx.org



demo: path-to.org or LabXchange™ Science and learning-connected.

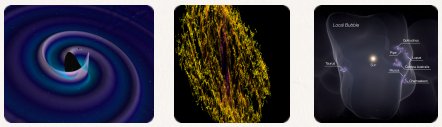
Opinion

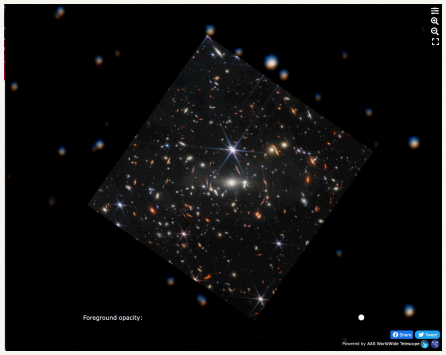
The New Universe

MEMPHIS, SUNDAY OCTOBER 23, 2022

WHAT DO EXPENSIVE NEW TELESCOPES DO FOR HUMANITY TODAY?

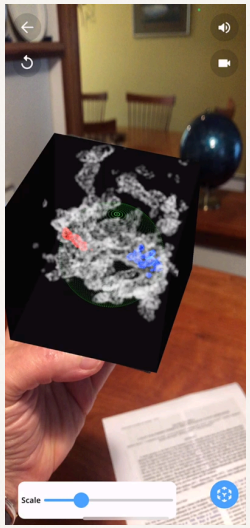
Are mega-projects like ALMA, LIGO, JWST, and Gaia worth the billions?





ARE COMPUTERS THE NEW TELESCOPES?

New galaxies in-silico, the early Universe without physics, and new stars forming in your hand.

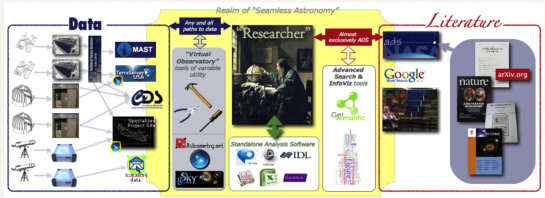


IS ASTROPHYSICS BEING (RE)ORGANIZED?

Lone stargazers are a rarer and rarer breed in professional astronomy. Teams and data scientists seem the way of the future, and tools that talk to each other are essential.

SEAMLESS ASTRONOMY

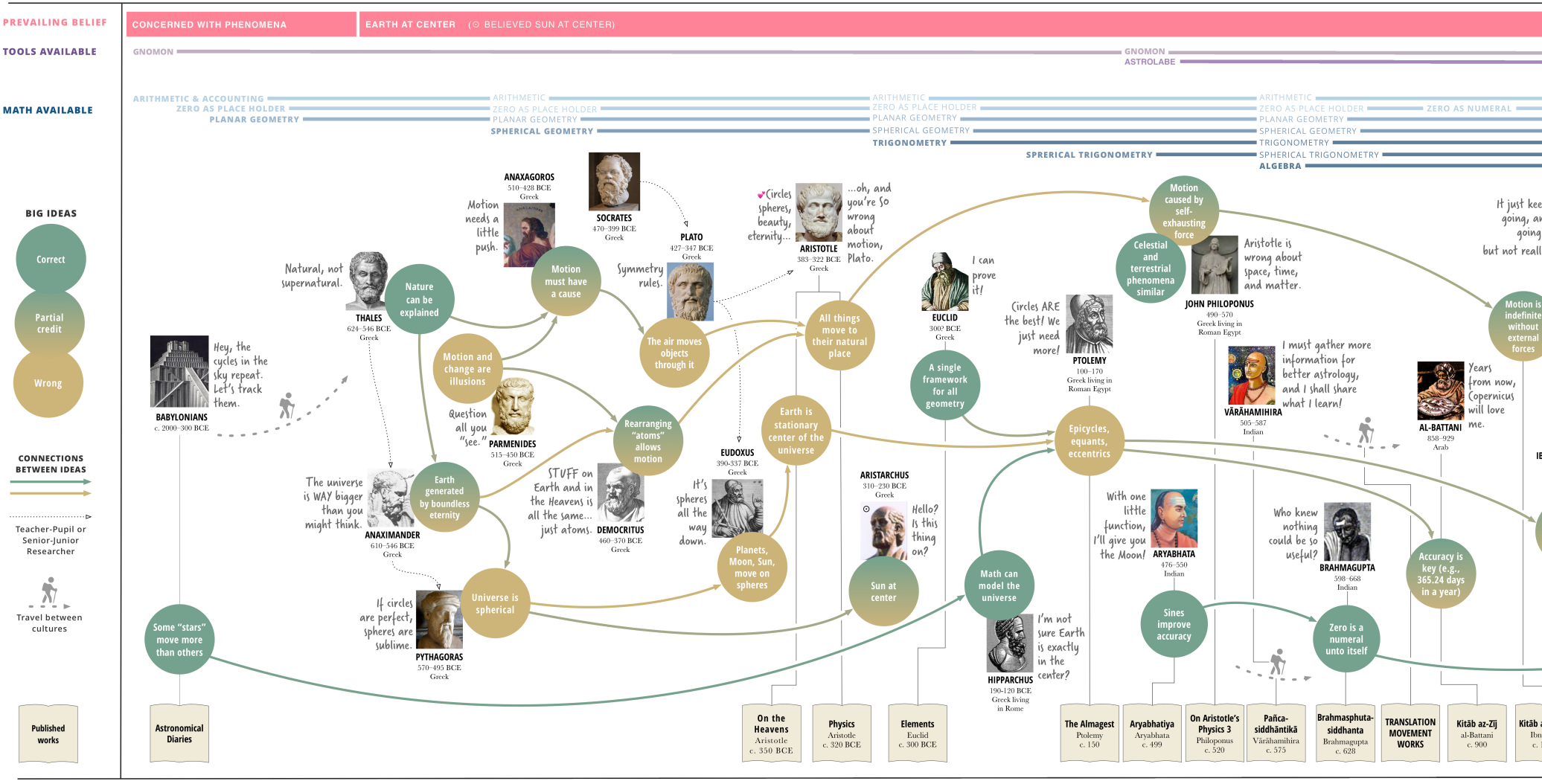
Linking scientific data, publications, and communities

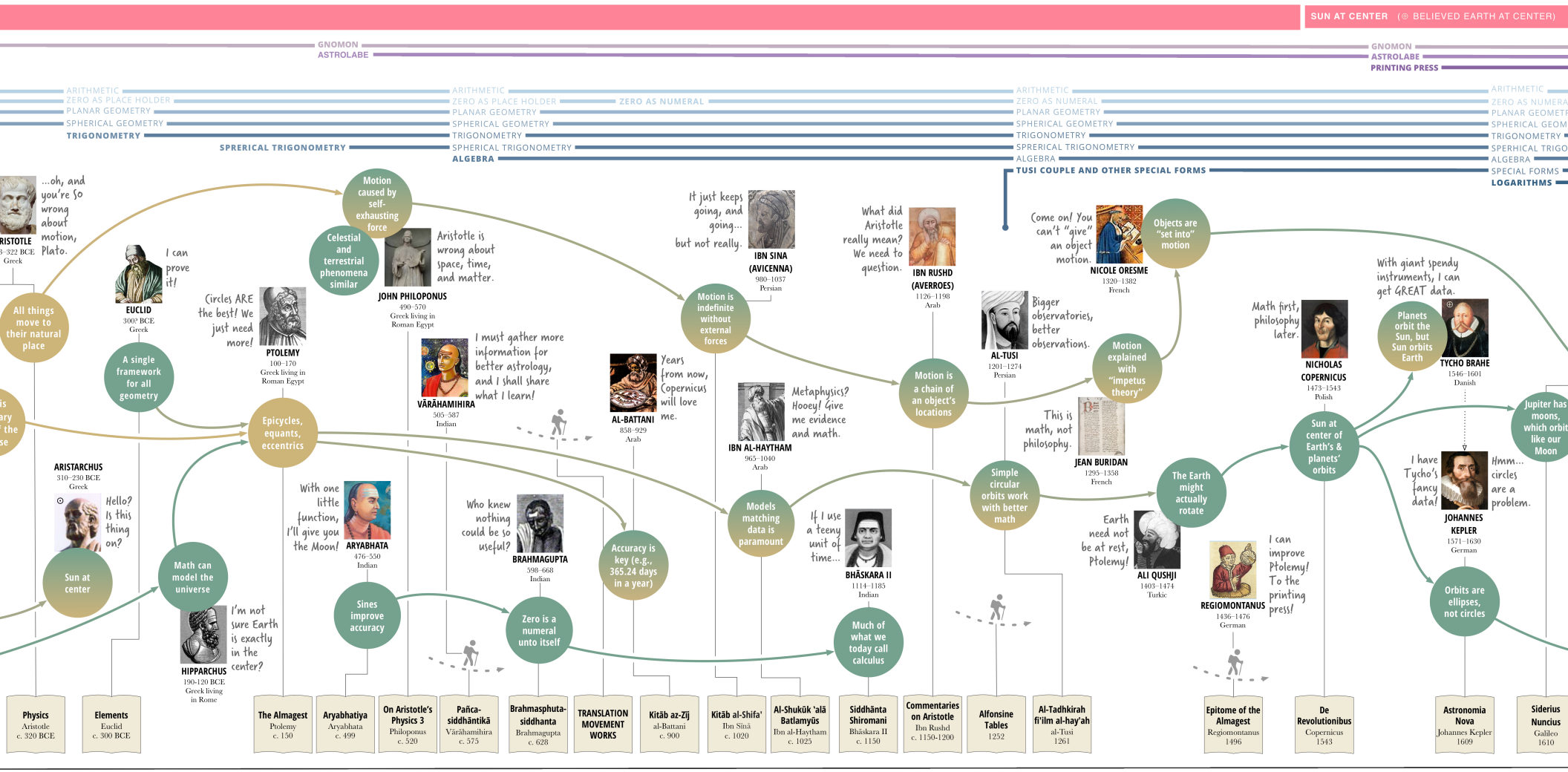


Editor: Alyssa Goodman, Center for Astrophysics | Harvard & Smithsonian, @AlyssaAGoodman

ARE COMPUTERS THE NEW TELESCOPES?

The Path to Newton





PREDICTIONX

SUN AT CENTER (⊕ BELIEVED EARTH AT CENTER)

GNOMON
ASTROLABE
PRINTING PRESS
TELESCOPE

ARITHMETIC
ZERO AS NUMERAL
PLANAR GEOMETRY
SPHERICAL GEOMETRY
TRIGONOMETRY
SPHERICAL TRIGONOMETRY
ALGEBRA
SPECIAL FORMS
LOGARITHMS
CALCULUS

TUSI COUPLE AND OTHER SPECIAL FORMS

Zero is a numeral unto itself

Accuracy is key (e.g., 365.24 days in a year)

Models matching data is paramount

Much of what we today call calculus

Motion is indefinite without external forces

Motion is a chain of an object's locations

Simple circular orbits work with better math

Motion explained with "impetus theory"

Objects are "set into" motion

The Earth might actually rotate

Sun at center of Earth's & planets' orbits

Planets orbit the Sun, but Sun orbits Earth

Jupiter has moons, which orbit like our Moon

Orbits are ellipses, not circles

Sun is the center

All bodies on Earth have (circular) inertia

All bodies have inertia

GRAVITY GOVERNS ALL

Some comets return, predictably

BRAHMAGUPTA
598–668
Indian

AL-BATTANI
858–929
Arab

IBN AL-HAYTHAM
965–1040
Arab

BHĀSKARA II
1114–1185
Indian

IBN SINA (AVICENNA)
980–1037
Persian

IBN RUSHD (AVERROES)
1126–1198
Arab

AL-TUSI
1201–1274
Persian

NICOLE ORESME
1320–1382
French

JEAN BURIDAN
1295–1358
French

ALI QUSHJI
1403–1474
Turkic

REGIOMONTANUS
1436–1476
German

NICHOLAS COPERNICUS
1473–1543
Polish

TYCHO BRAHE
1546–1601
Danish

JOHANNES KEPLER
1571–1630
German

GALILEO GALILEI
1564–1642
Italian

RENÉ DESCARTES
1596–1650
French

ISAAC NEWTON
1642–1726
British

EDMOND HALLEY
1656–1742
British

Years from now, Copernicus will love me.

Metaphysics? Hooey! Give me evidence and math.

If I use a teeny unit of time...

It just keeps going, and going... but not really.

What did Aristotle really mean? We need to question.

Bigger observatories, better observations.

Come on! You can't "give" an object motion.

This is math, not philosophy.

Earth need not be at rest, Ptolemy!

I can improve Ptolemy! To the printing press!

Math first, philosophy later.

With giant spendy instruments, I can get GREAT data.

I have Tycho's fancy data!

Hmm... circles are a problem.

oooh, I like this Dutch spyglass!

Sorry, Aristotle, you're just wrong.

Aristotle, mon ami, above and below, it's all matter in motion.

We're gonna need better math.

This apple. That moon. Could they feel the same pull?

I must make Newton publish!

Brahmasphuta-siddhanta
Brahmagupta
c. 628

TRANSLATION MOVEMENT WORKS

Kitāb az-Zīj
al-Battani
c. 900

Kitāb al-Shifa'
Ibn Sīnā
c. 1020

Al-Shukūk 'alā Batlamyūs
Ibn al-Haytham
c. 1025

Siddhānta Shiromani
Bhāskara II
c. 1150

Commentaries on Aristotle
Ibn Rushd
c. 1150-1200

Alfonsine Tables
1252

Al-Tadhkirah fi'ilm al-hay'ah
al-Tusi
1261

Epitome of the Almagest
Regiomontanus
1496

De Revolutionibus
Copernicus
1543

Astronomia Nova
Johannes Kepler
1609

Siderius Nuncius
Galileo
1610

Dialogue on the Two Chief Systems of the World
Galileo
1632

Two New Sciences
Galileo
1638

Principles of Philosophy
Descartes
1644

Principia
Isaac Newton
1687

Synopsis Astronomia Cometicae
Edmond Halley
1705

PREDICTIONX

GNOMON
ASTROLABE
PRINTING PRESS
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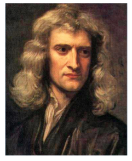

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"ARE COMPUTERS THE NEW TELESCOPES?"

ELECTRONIC COMPUTERS

NUMERICAL SIMULATION
BAYESIAN STATISTICS
INTERACTIVE DATA VISUALIZATION
AI/MACHINE LEARNING

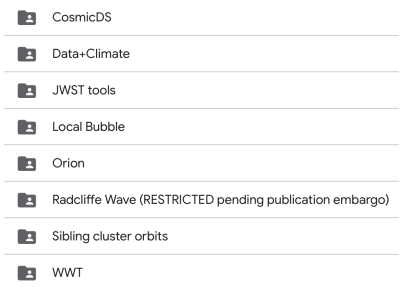
get glue

Seeing the universe, more clearly, with glue & glupyter

glueviz.org

These slides, along with a link to the Google Drive with all the demos/notebooks, will be posted to my website and to the JupyterCon 2023 Slack.

NOTEBOOKS!



MANY thanks to Pat Udomprasert, Jon Carifio, Jonathan Foster, Cami Pacifici, Theo O'Neill, Catherine Zucker, Mike Foley, Ralf Konietzka, Cameren Swiggum, and Peter Williams for providing the ipynb examples!