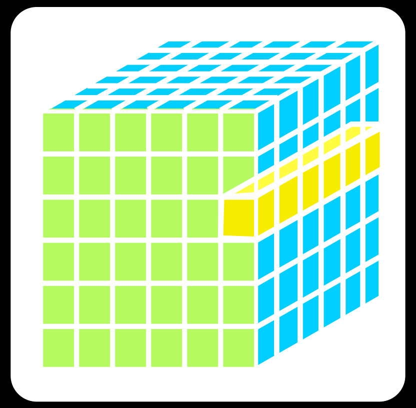
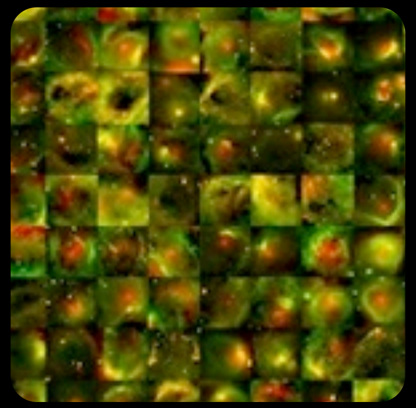
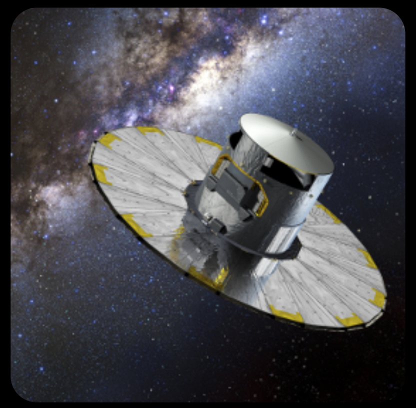






glue-ing together the Universe
from Galileo to Gaia

WorldWide Telescope

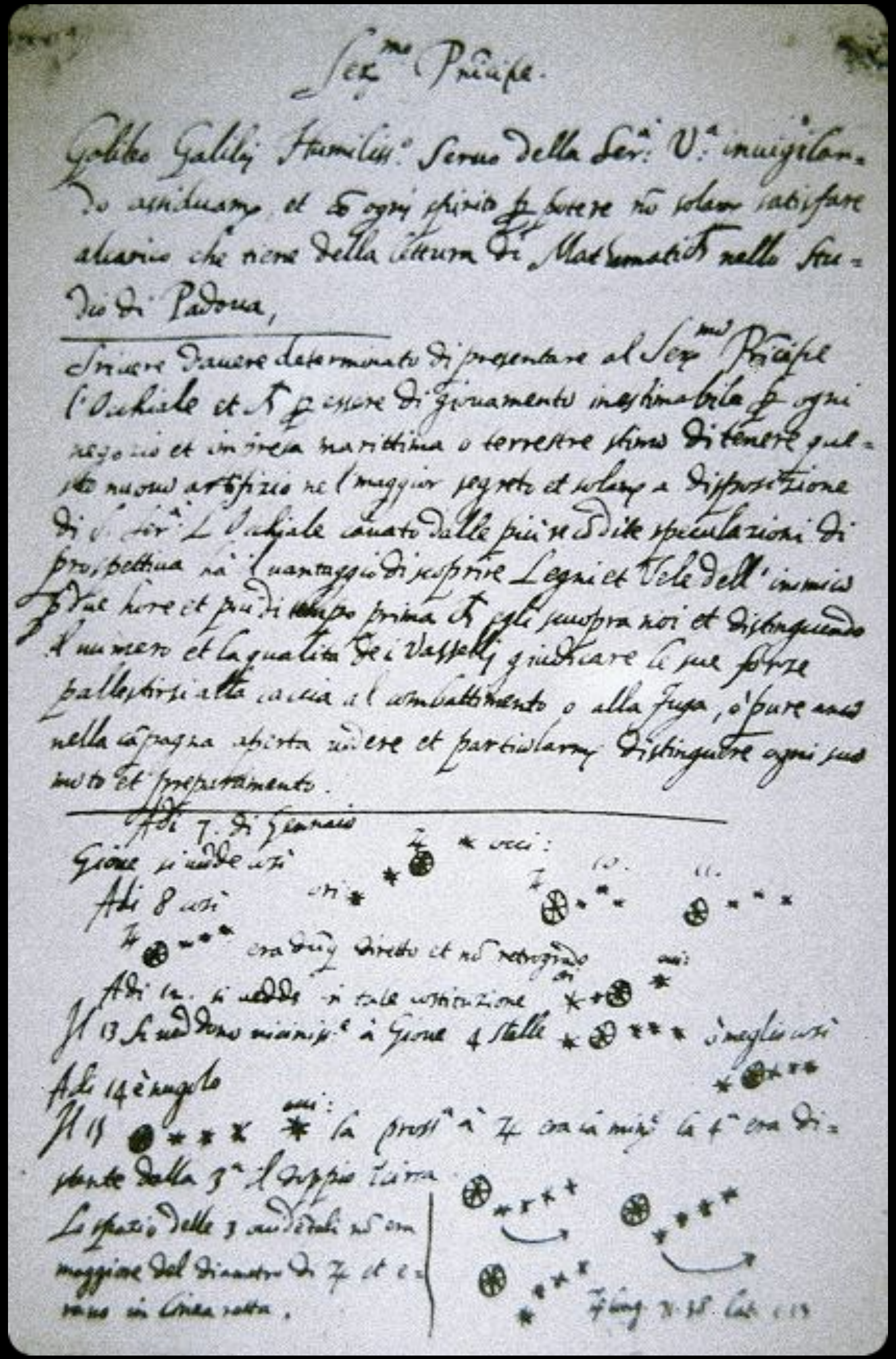
glue

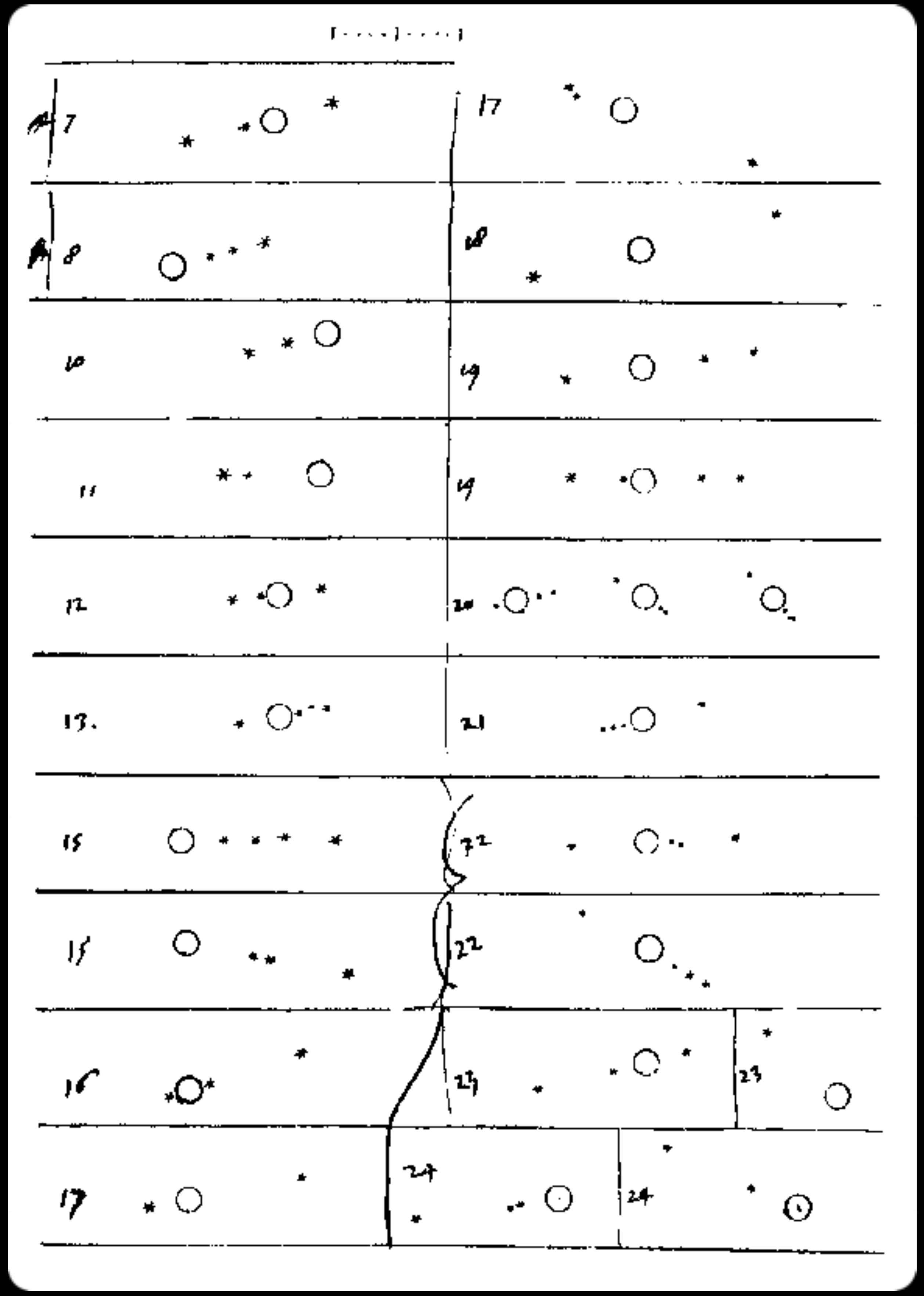
Au Authorea

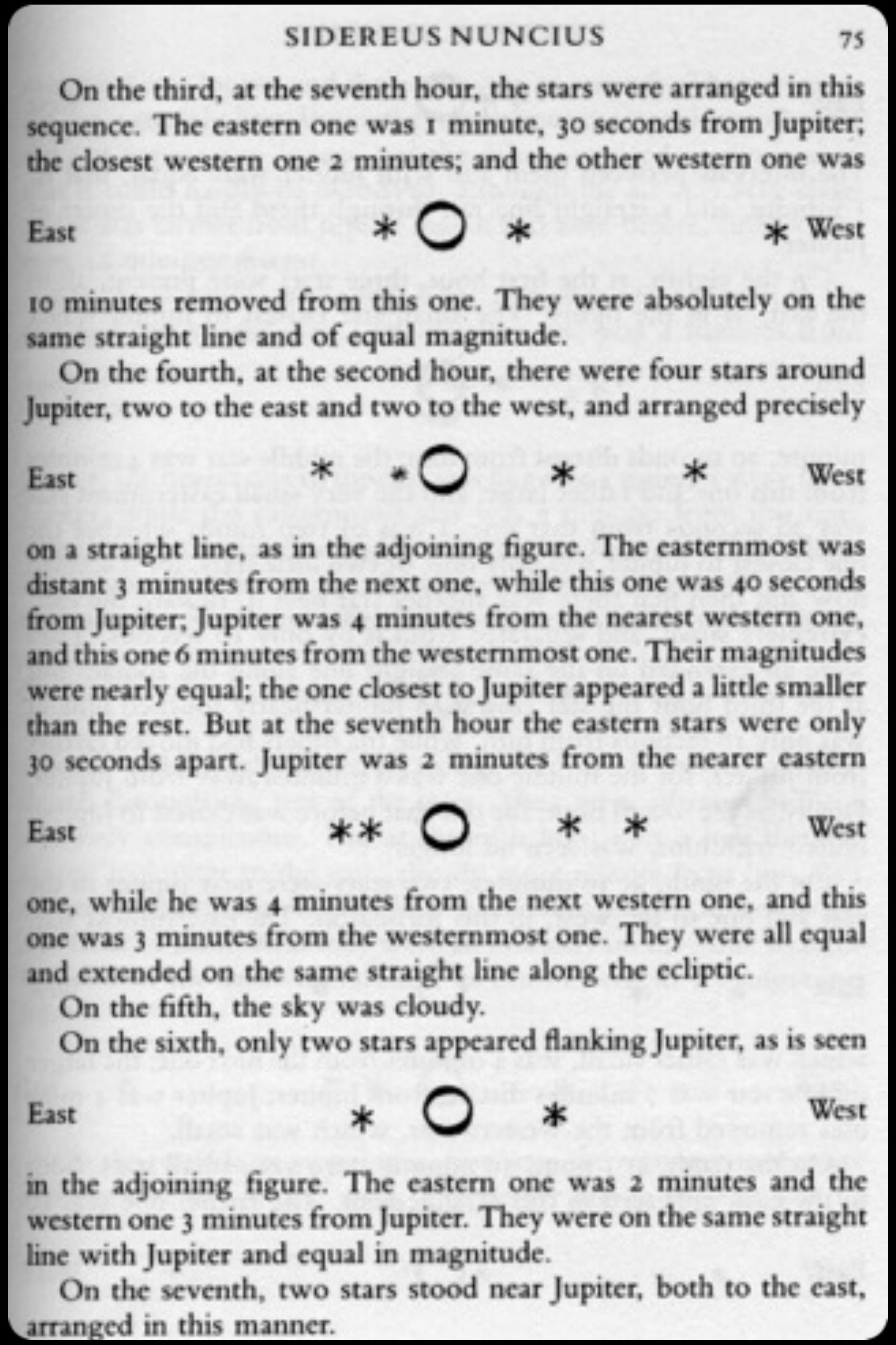
ViZ

Alyssa A. Goodman
Harvard-Smithsonian Center for Astrophysics +Radcliffe Insitute for Advanced Study @AlyssaAGoodman

Galileo, Jupiter's Moons, "3D" thinking







On the third, at the seventh hour, the stars were arranged in this sequence. The eastern one was 1 minute, 30 seconds from Jupiter; the closest western one 2 minutes; and the other western one was

East * O * * West

10 minutes removed from this one. They were absolutely on the same straight line and of equal magnitude.

On the fourth, at the second hour, there were four stars around Jupiter, two to the east and two to the west, and arranged precisely

East * *O * * West

on a straight line, as in the adjoining figure. The easternmost was distant 3 minutes from the next one, while this one was 40 seconds from Jupiter; Jupiter was 4 minutes from the nearest western one, and this one 6 minutes from the westernmost one. Their magnitudes were nearly equal; the one closest to Jupiter appeared a little smaller than the rest. But at the seventh hour the eastern stars were only 30 seconds apart. Jupiter was 2 minutes from the nearer eastern

East ** O * * West

one, while he was 4 minutes from the next western one, and this one was 3 minutes from the westernmost one. They were all equal and extended on the same straight line along the ecliptic.

On the fifth, the sky was cloudy.

On the sixth, only two stars appeared flanking Jupiter, as is seen

East * O * West

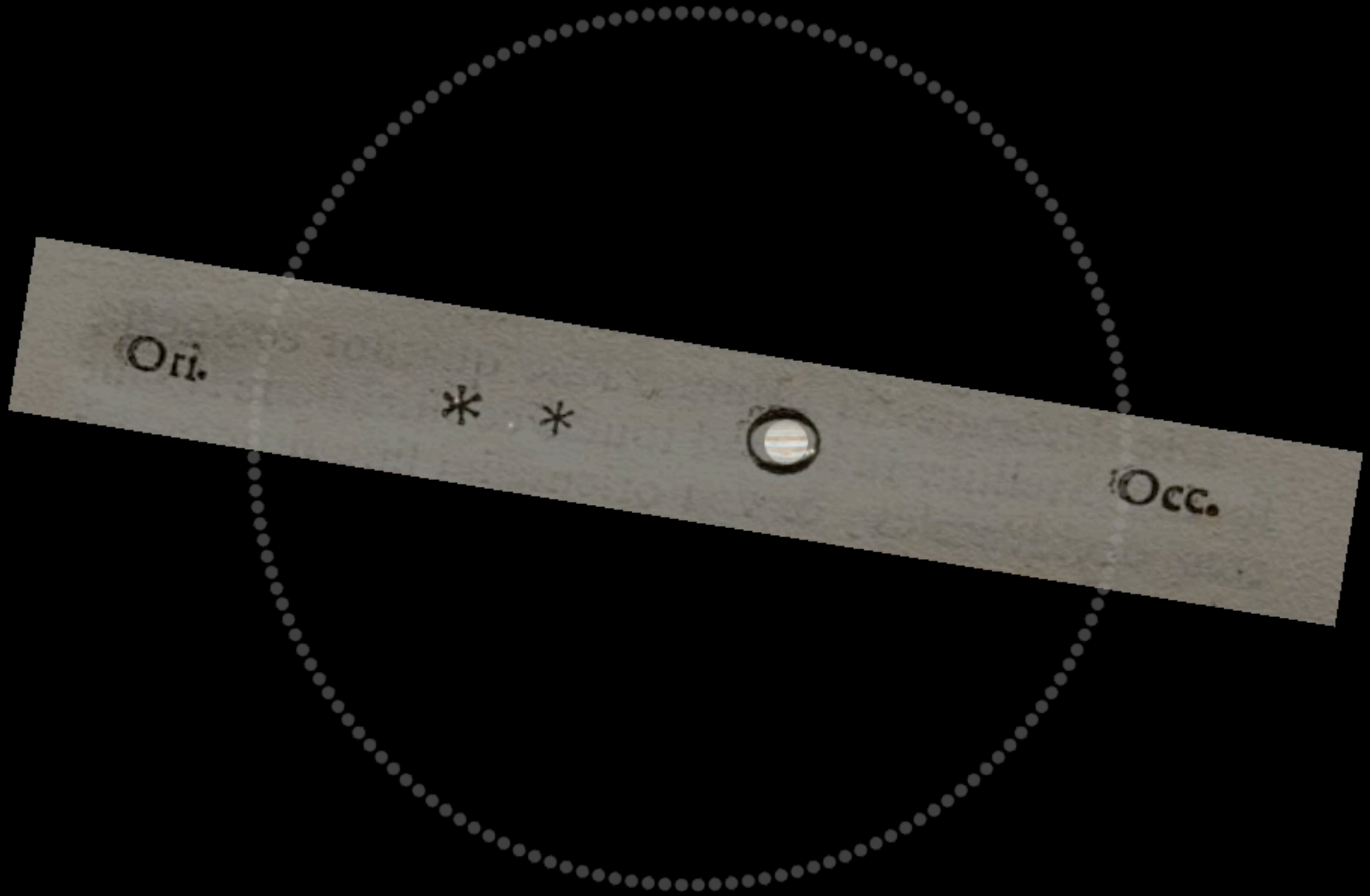
in the adjoining figure. The eastern one was 2 minutes and the western one 3 minutes from Jupiter. They were on the same straight line with Jupiter and equal in magnitude.

On the seventh, two stars stood near Jupiter, both to the east, arranged in this manner.

Notes for & re-productions of Siderius Nuncius

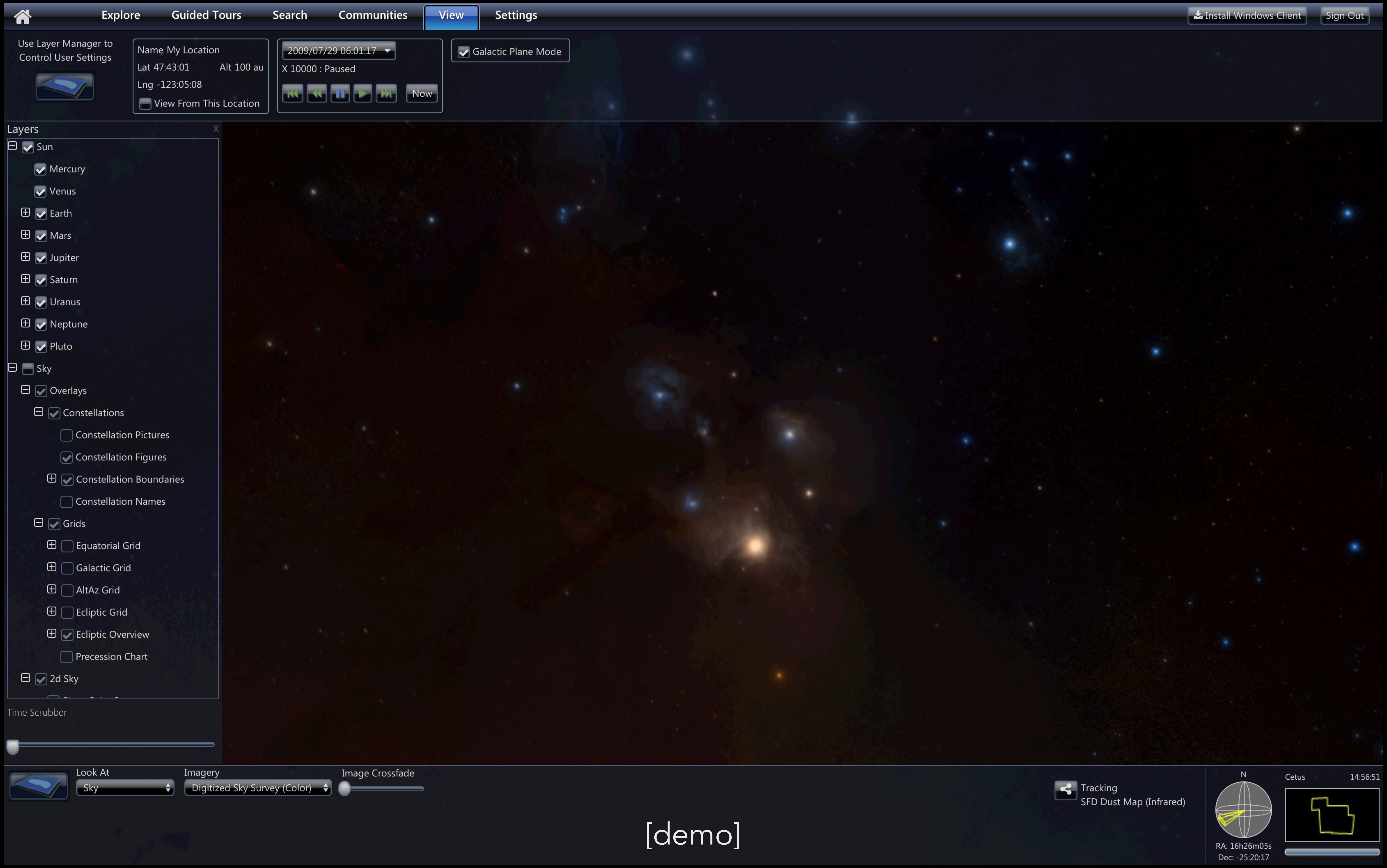
Galileo's 3D thinking, in WorldWide Telescope

January 11, 1610



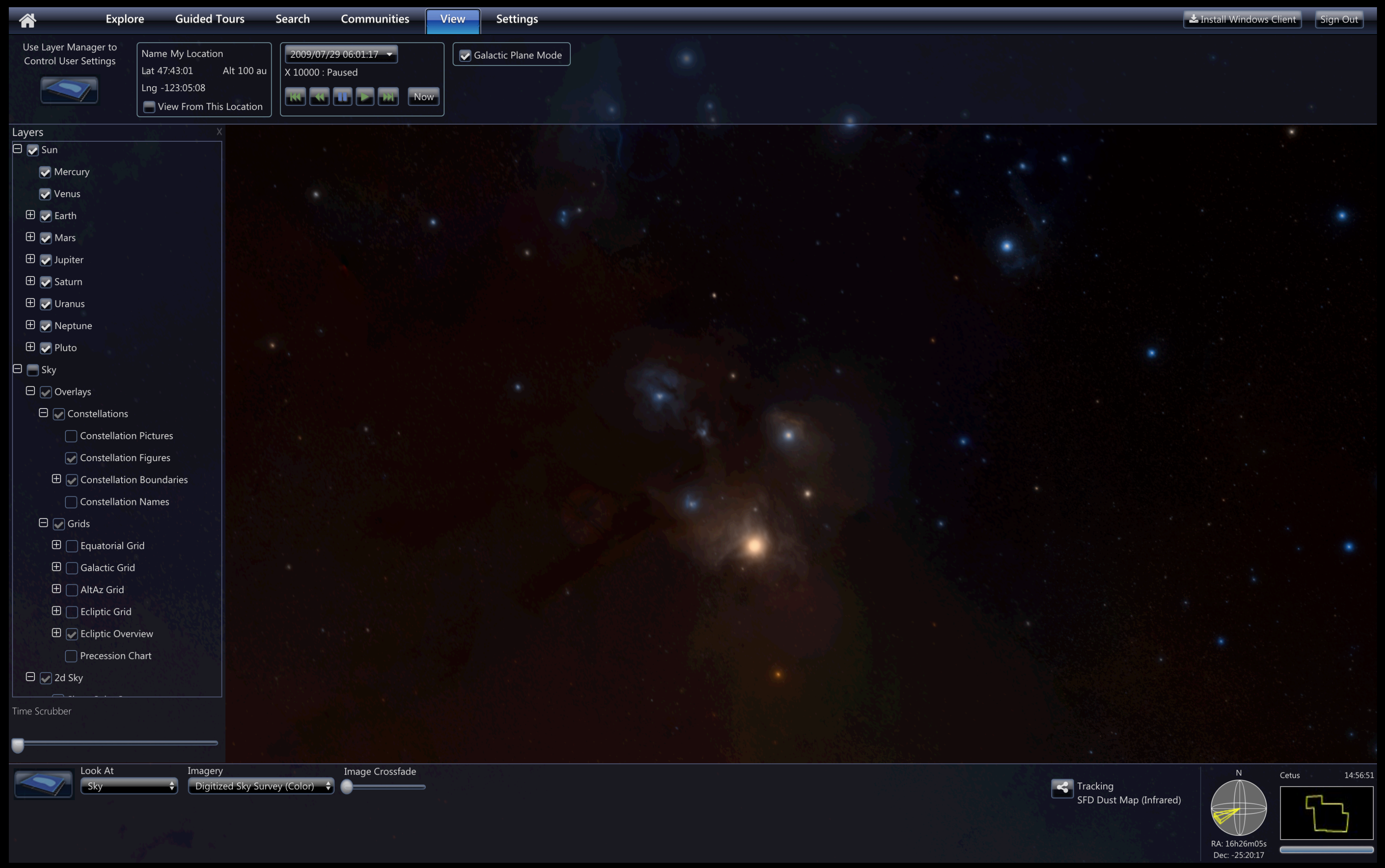
Galileo's New Order, A WorldWide Telescope Tour by Goodman, Wong & Udomprasert 2010
WWT Software Wong (inventor, MS Research), Fay (architect, MS Research), et al., now open source, hosted by AAS
see wwtambassadors.org for more on WWT Outreach

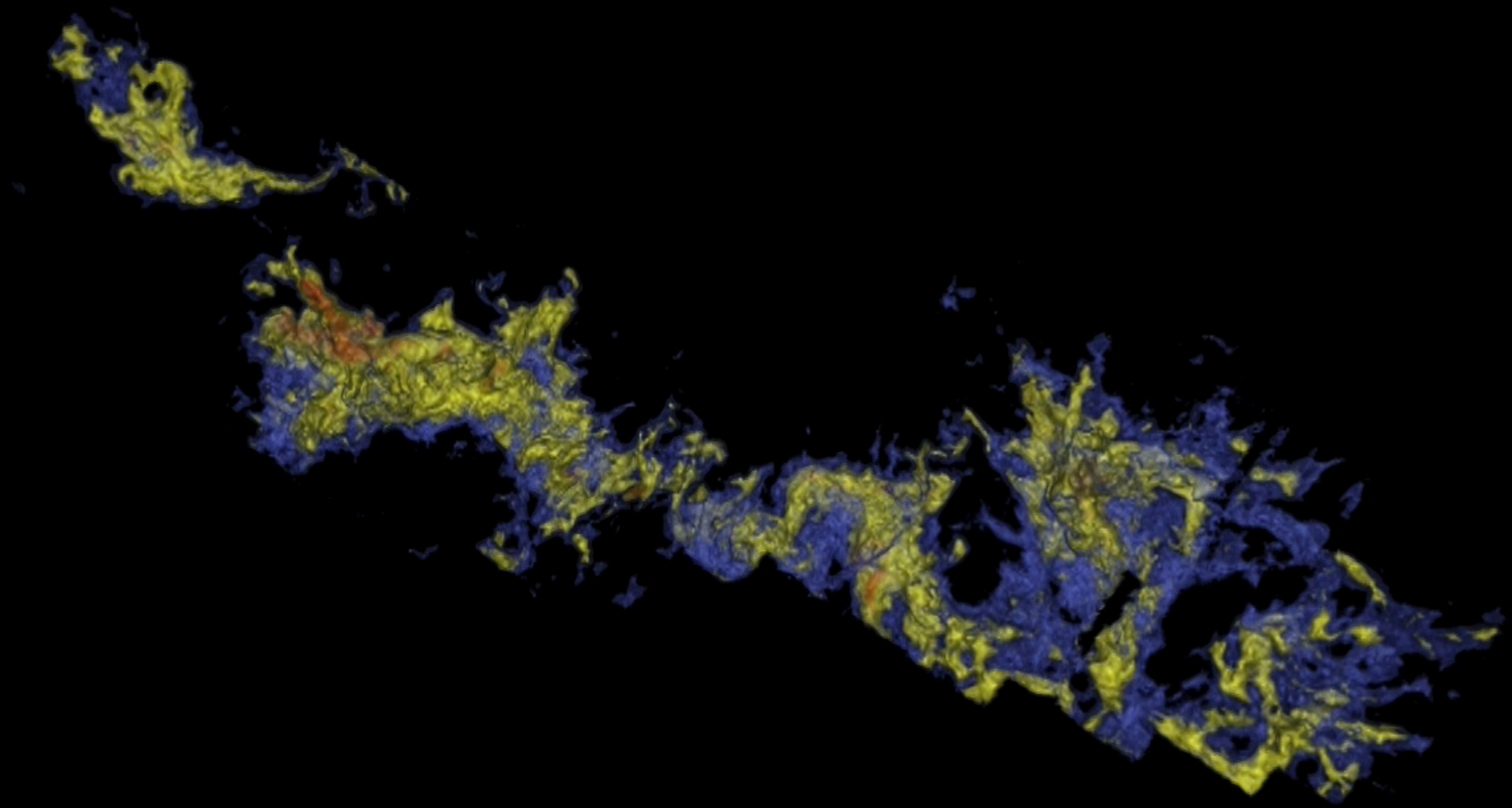
The Sky at Many Wavelengths in a "WorldWide Telescope"

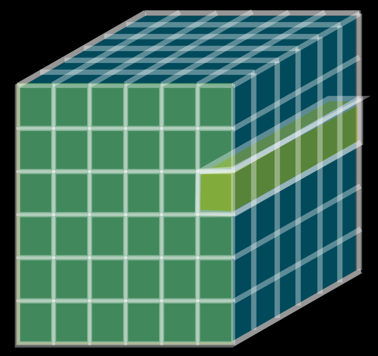


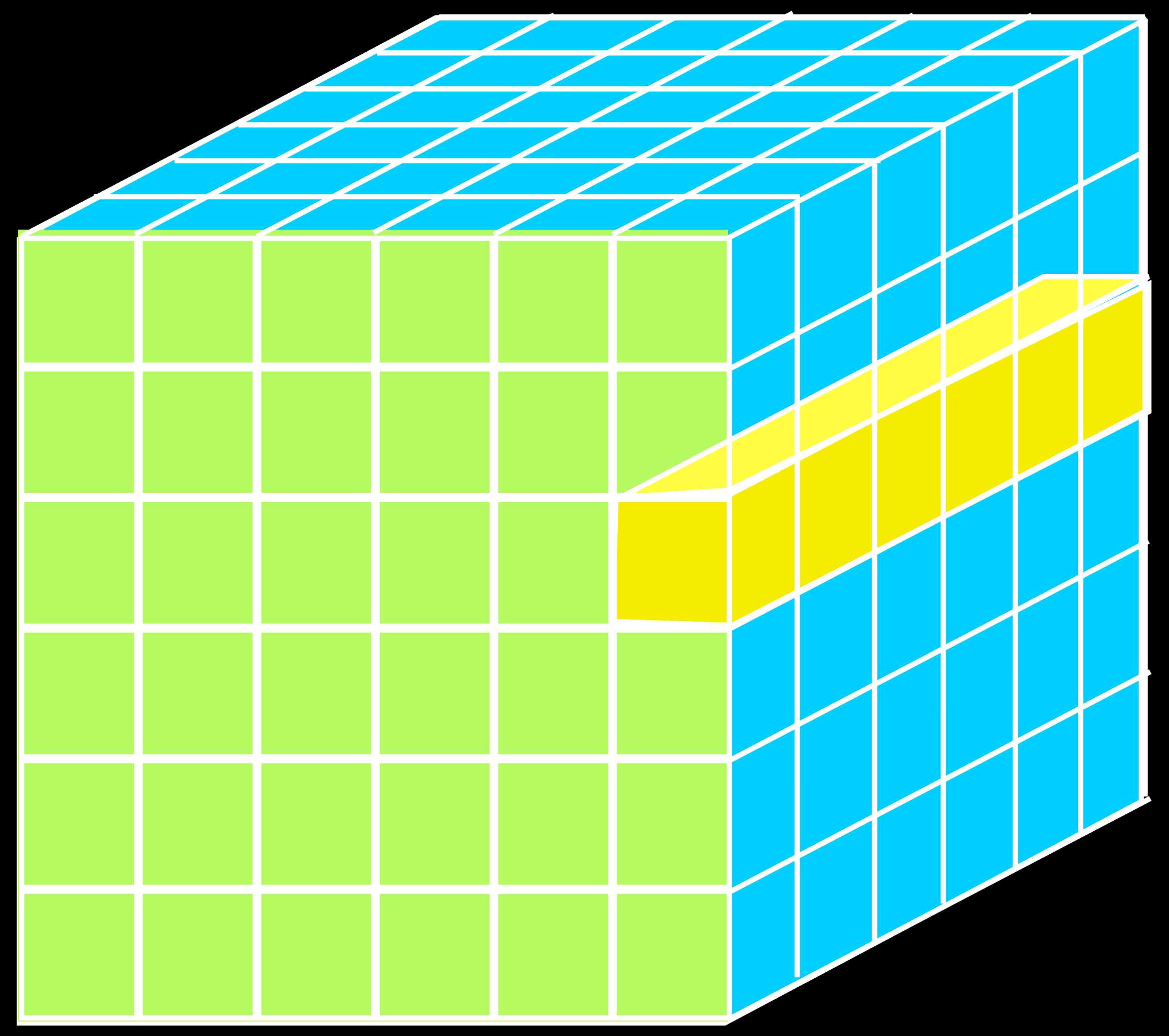
[demo]

Dimensions' many meanings









"Data, Dimensions, Display"

1D: Columns = "Spectra", "SEDs" or "Time Series"
2D: Faces or Slices = "Images"
3D: Volumes = "3D Renderings", "2D Movies"
4D: Time Series of Volumes = "3D Movies"

“3D PDF” (Nature, 2009)

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

nature

LETTERS

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

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

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

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

2009

3D PDF

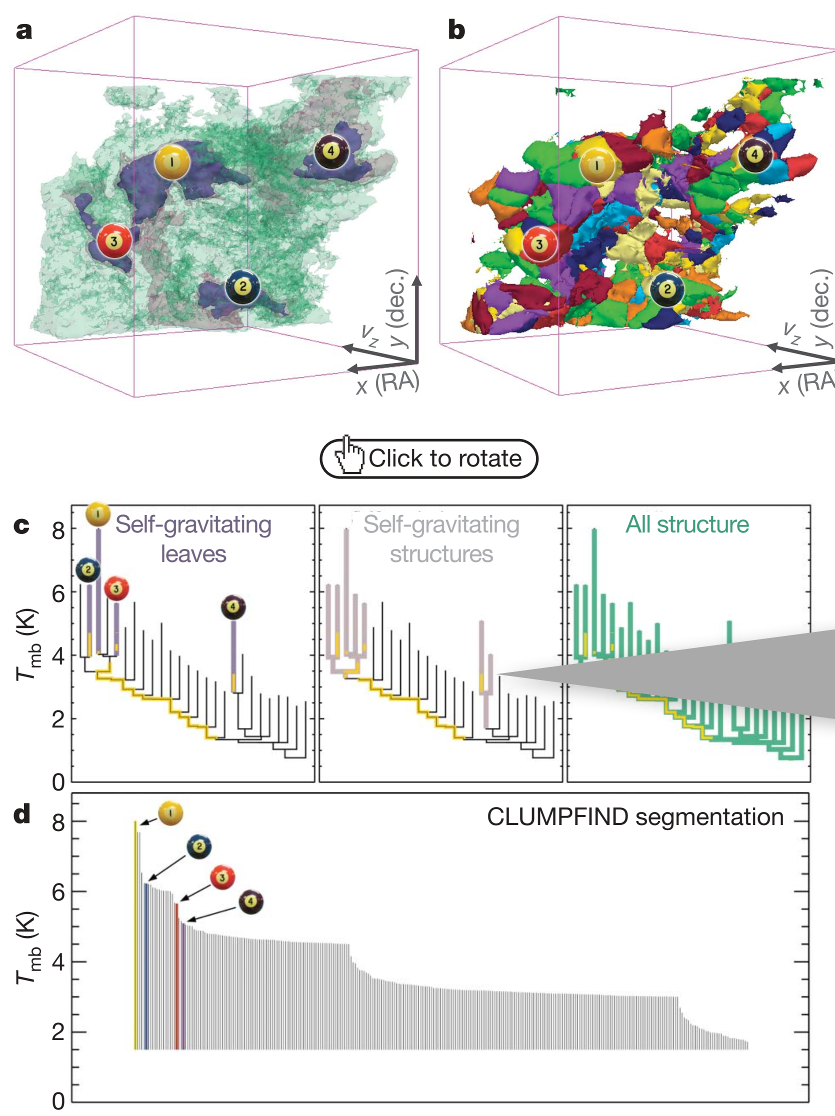


Figure 2 | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. a, 3D visualization of the surfaces indicated by colours in the dendrogram shown in **c**. Purple illustrates the smallest scale self-gravitating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

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

Four years before the advent of CLUMPFIND, 'structure trees'[9] were proposed as a way to characterize clouds' hierarchical structure

using 2D maps of column density. With th
rly 2D work as inspira-
tion, we have developed a structure-id
rithm that
abstracts the hierarchical structure of a
an easily visualized representation calle
well developed in other data-intensive
application of tree methodologies so fa
and almost exclusively within the a
'merger trees' are being used with in
Figure 3 and its legend explain t

These are "dead" panels! That's not good enough.

mass,
K^{-1} km^{-1} s
ary Fig. 2).
can then be
used to estimate the role of self-gravity at each point in the hierarchy, via calculation of an 'observed' virial parameter, $\alpha_{obs} = 5\sigma_v^2 R/GM_{lum}$. In principle, extended portions of the tree (Fig. 2, yellow highlighting) where $\alpha_{obs} < 2$ (where gravitational energy is comparable to or larger than kinetic energy) correspond to regions of p–p–v space where self-gravity is significant. As α_{obs} only represents the ratio of kinetic energy to gravitational energy at one point in time, and does not explicitly capture external over-pressure and/or magnetic fields[16], its measured value should only be used as a guide to the longevity (boundedness) of any particular feature.

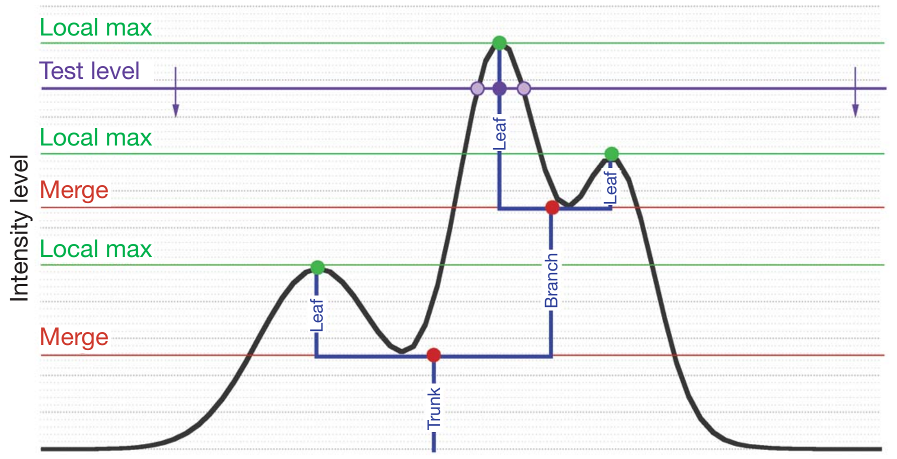
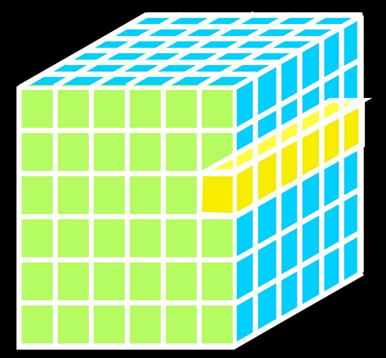
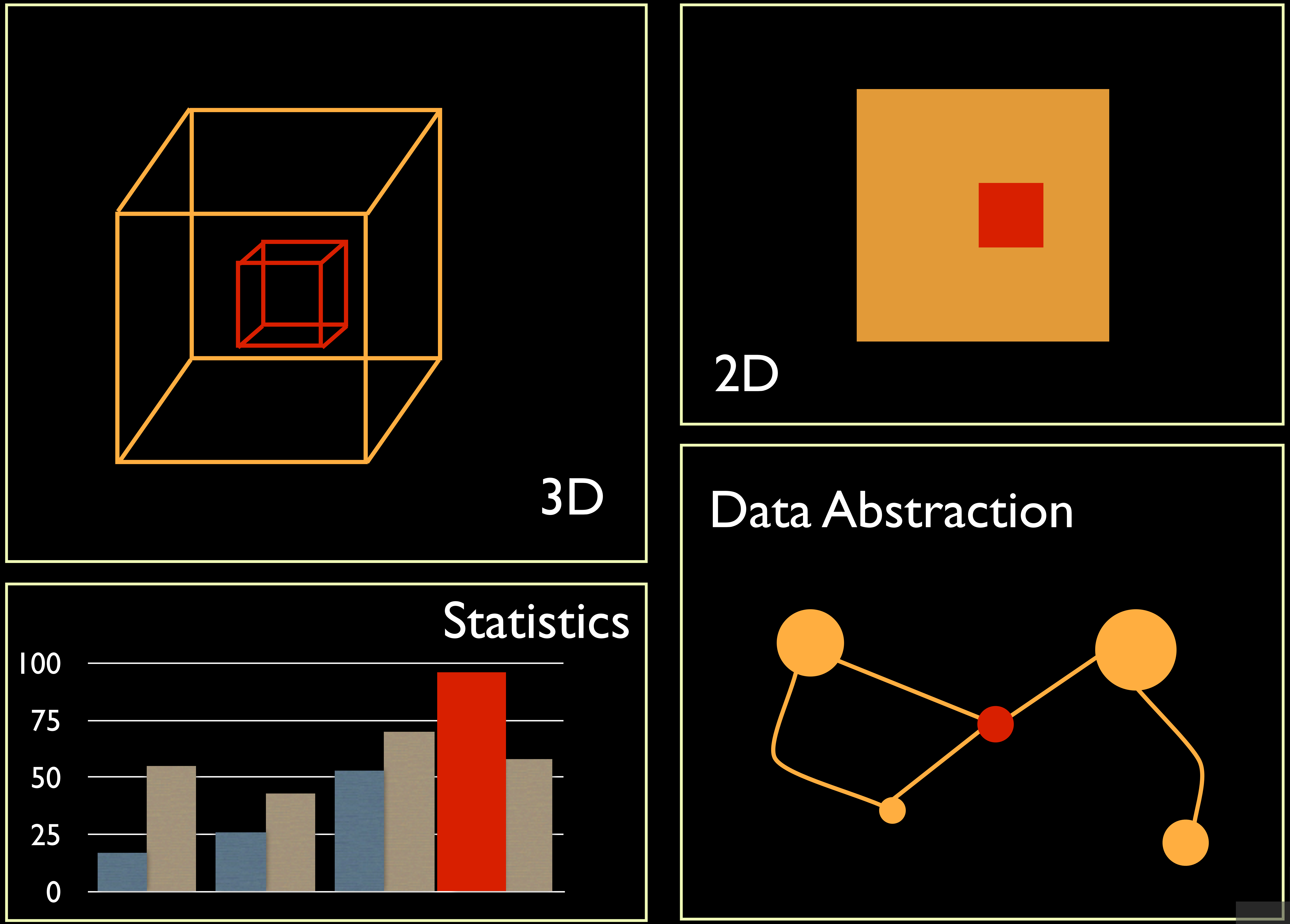


Figure 3 | Schematic illustration of the dendrogram process. Shown is the construction of a dendrogram from a hypothetical one-dimensional emission profile (black). The dendrogram (blue) can be constructed by 'dropping' a test constant emission level (purple) from above in tiny steps (exaggerated in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

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

Linked Views of High-dimensional Data

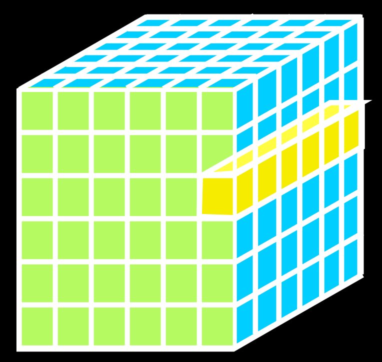


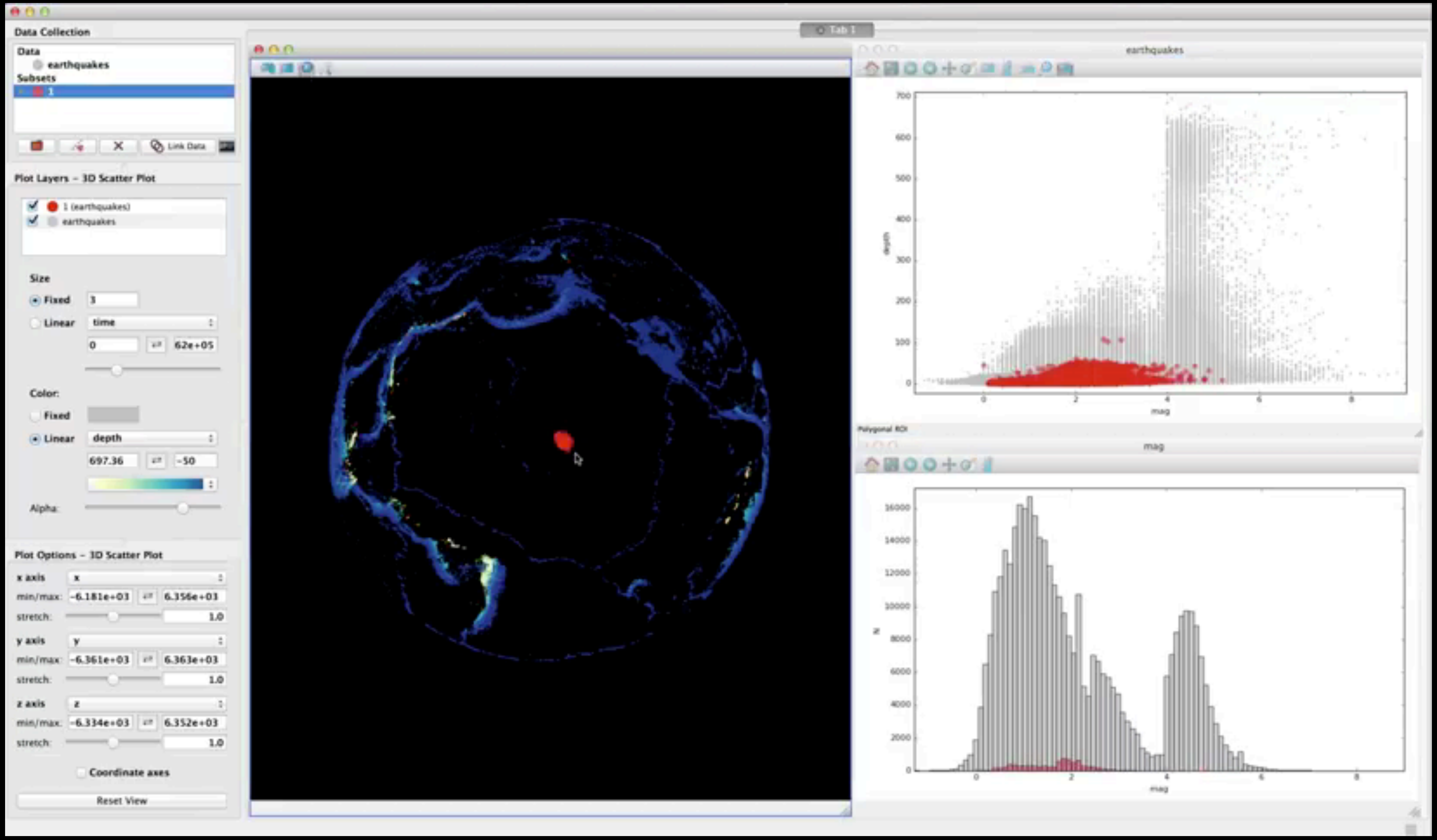


figure, by M. Borkin, reproduced from Goodman 2012, "Principles of High-Dimensional Data Visualization in Astronomy"

Linked Views of High-dimensional Data (in Python)

glue



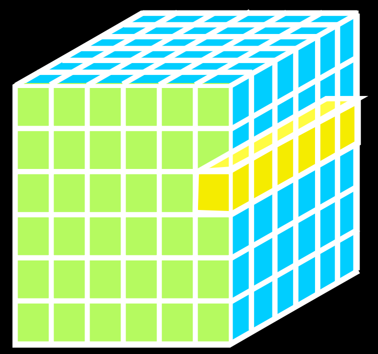


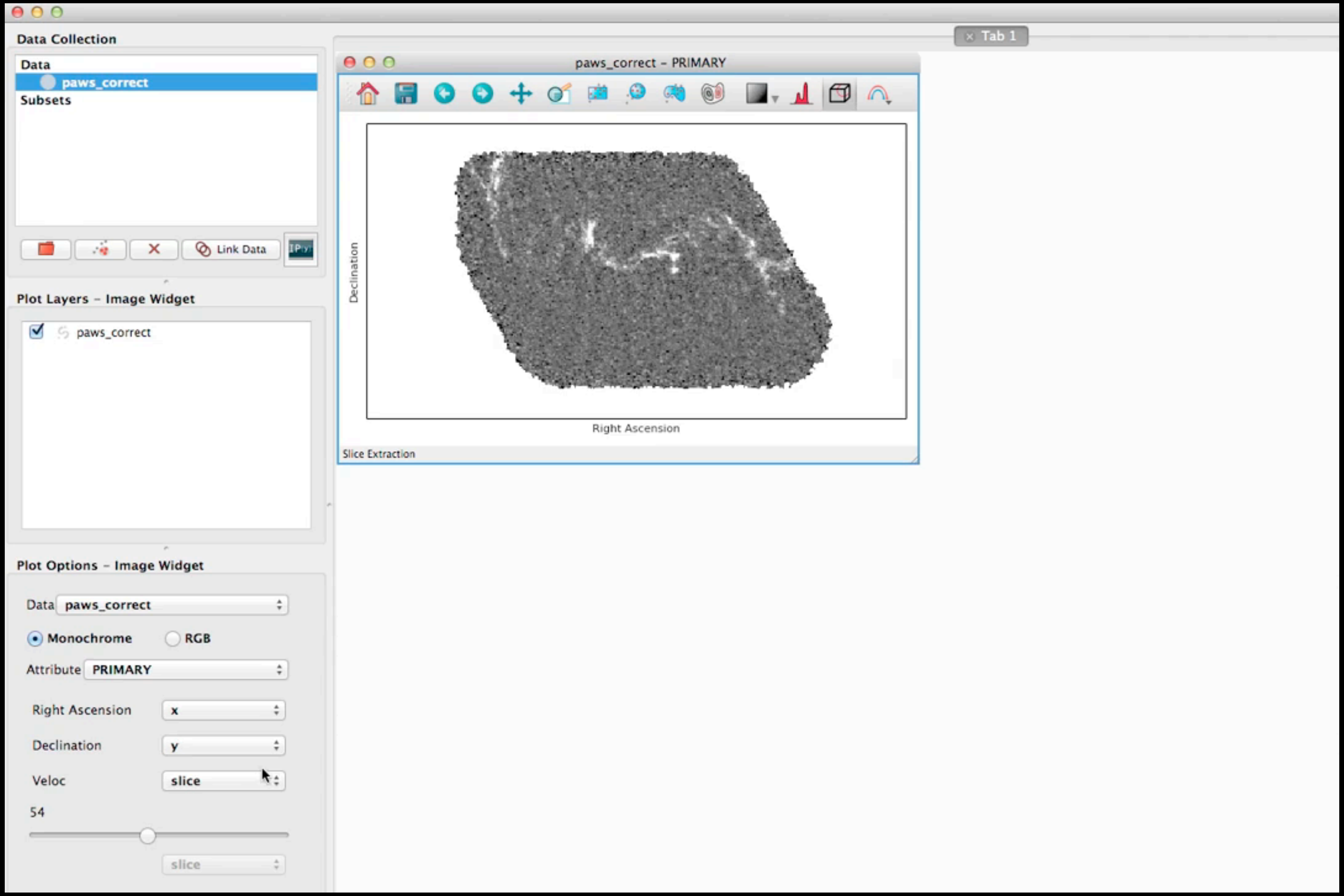
video by Tom Robitaille, lead glue developer

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

Linked Views of High-dimensional Data (in Python)

glue

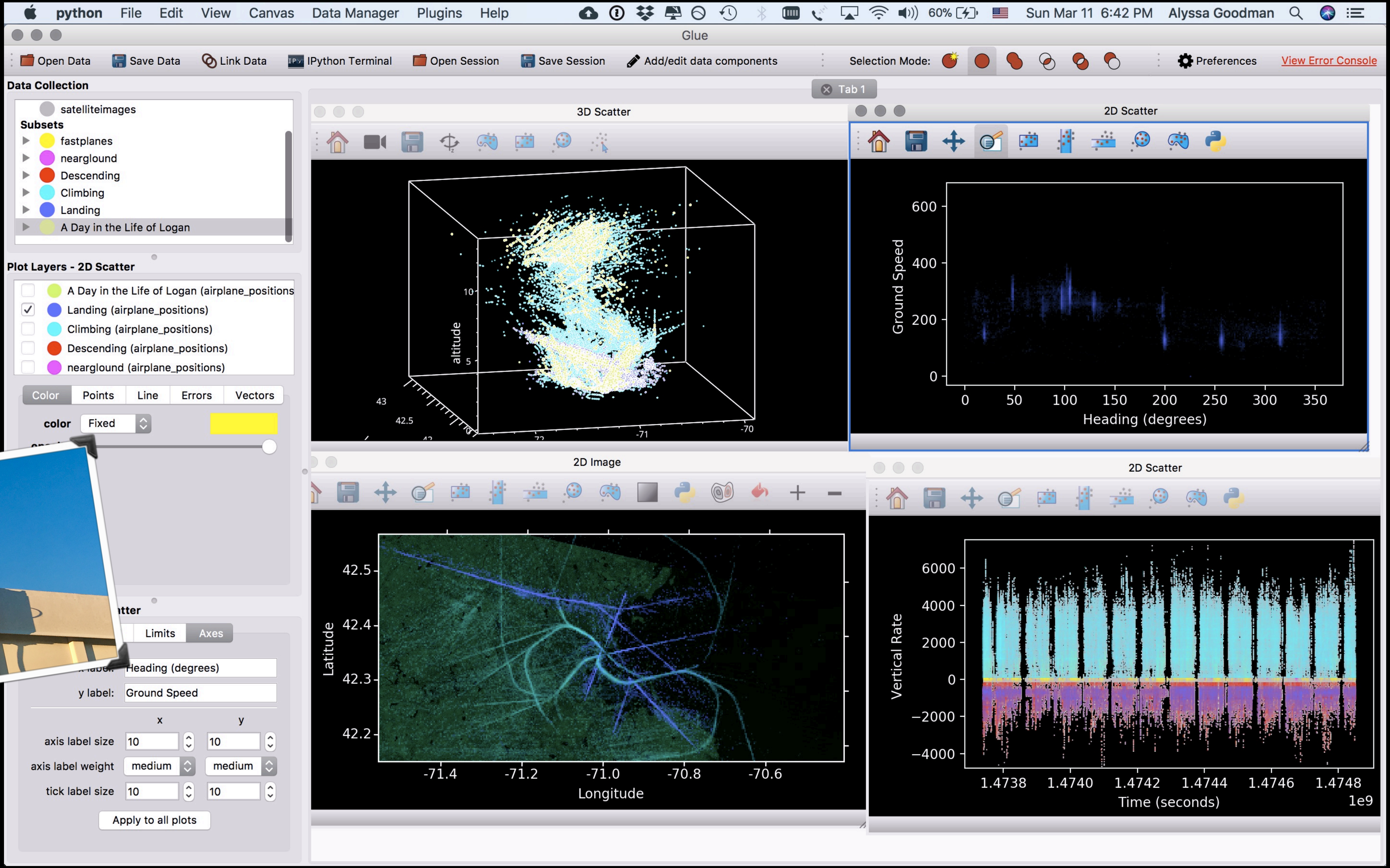


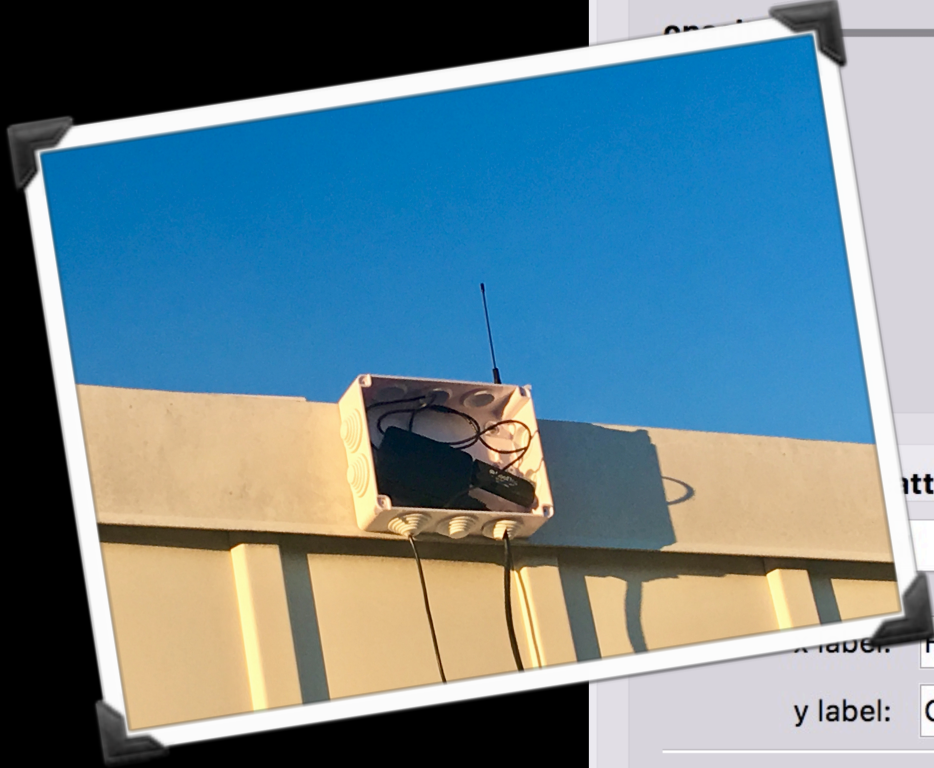


video by Chris Beaumont, glue developer

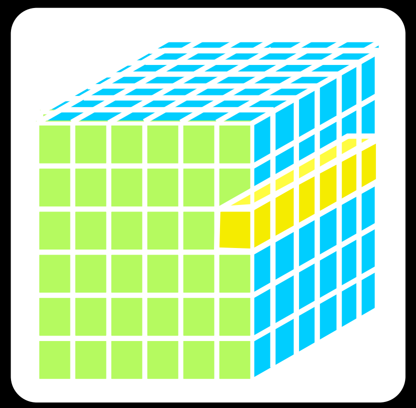
glue created by: C. Beaumont, M. Borkin, M. Breddels, P. Qian, T. Robitaille, and A. Goodman, PI

Linked views & my FBI file. . . (glue's not just for Astronomy)





WorldWide Telescope



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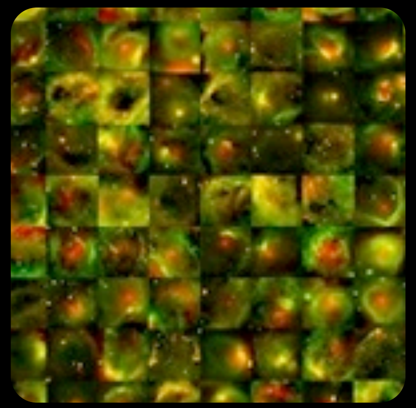

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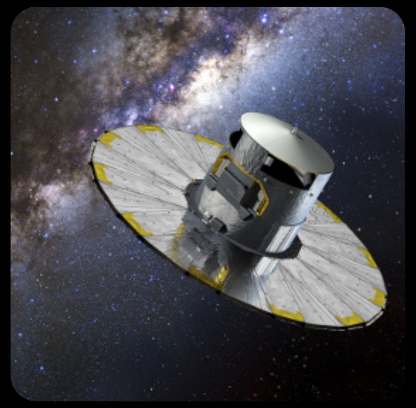

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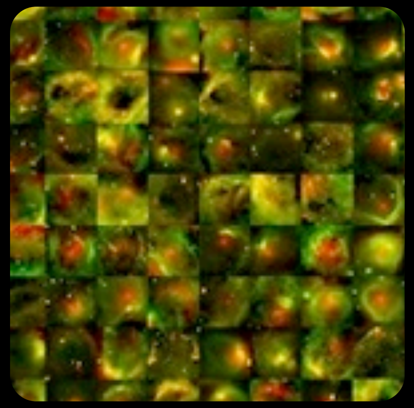
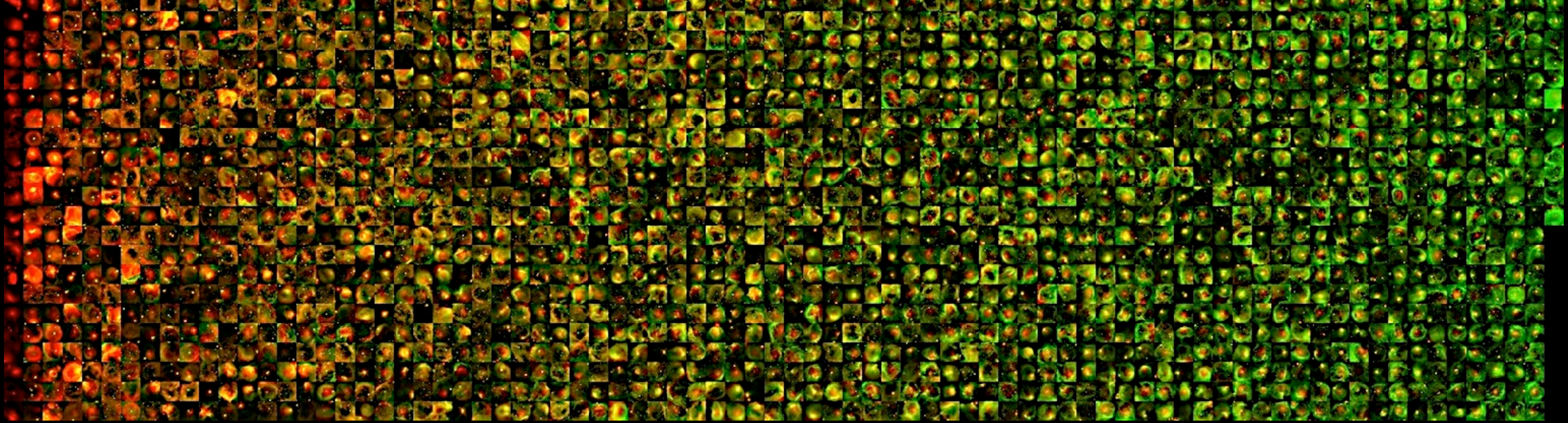


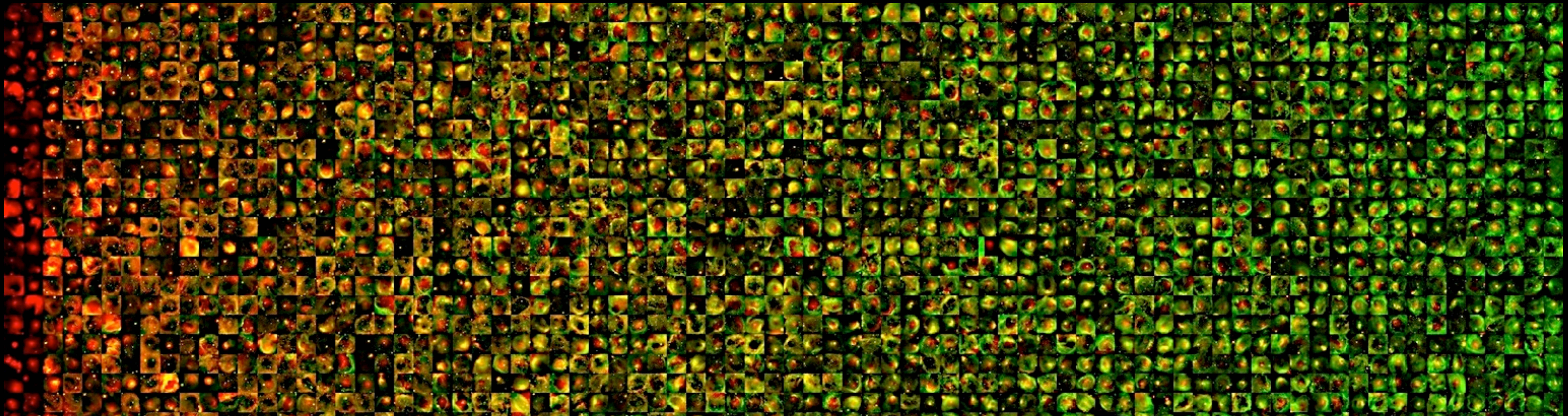
SEAMLESS ASTRONOMY

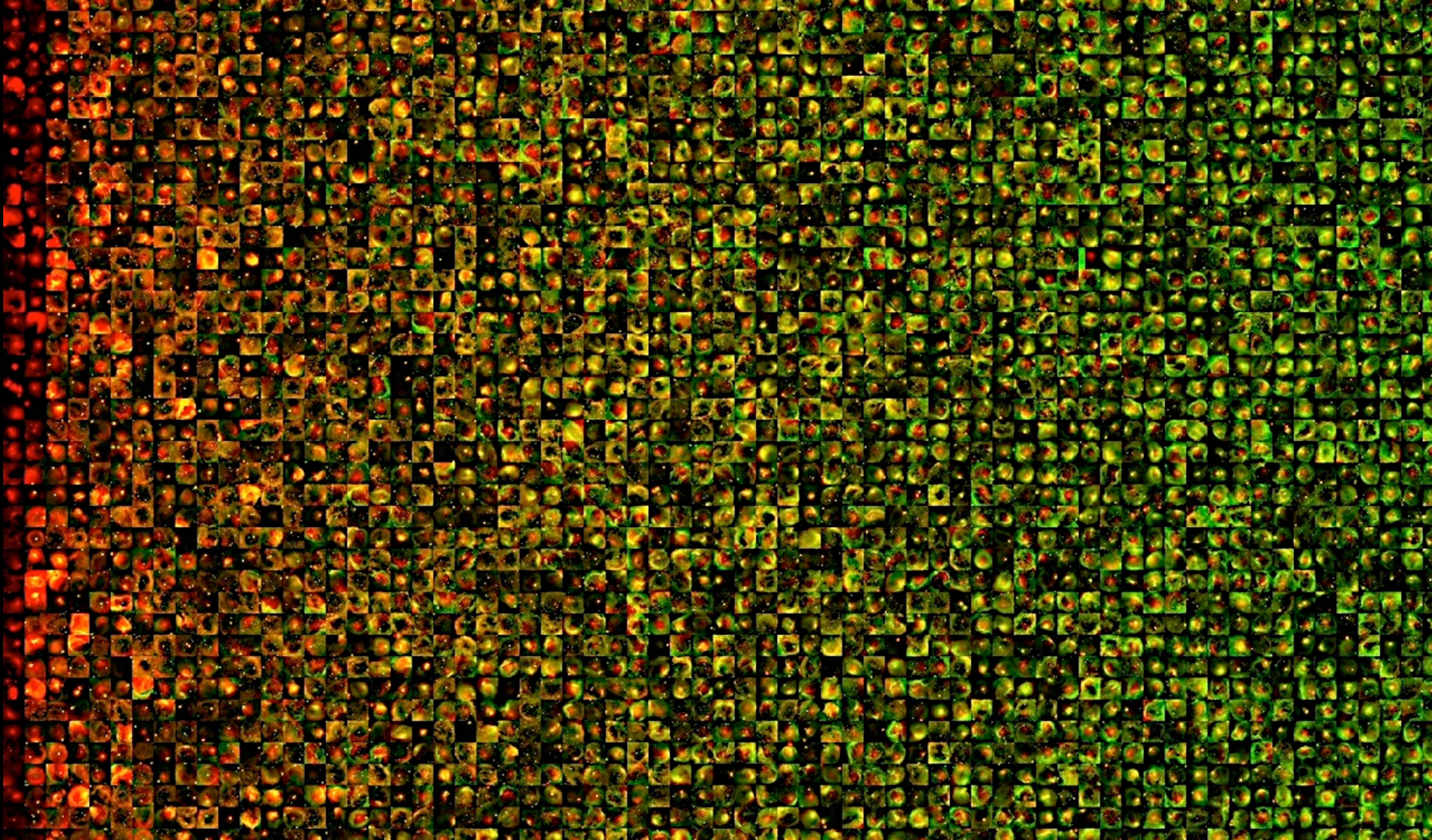
Linking scientific data,publications,and communities

[demo]

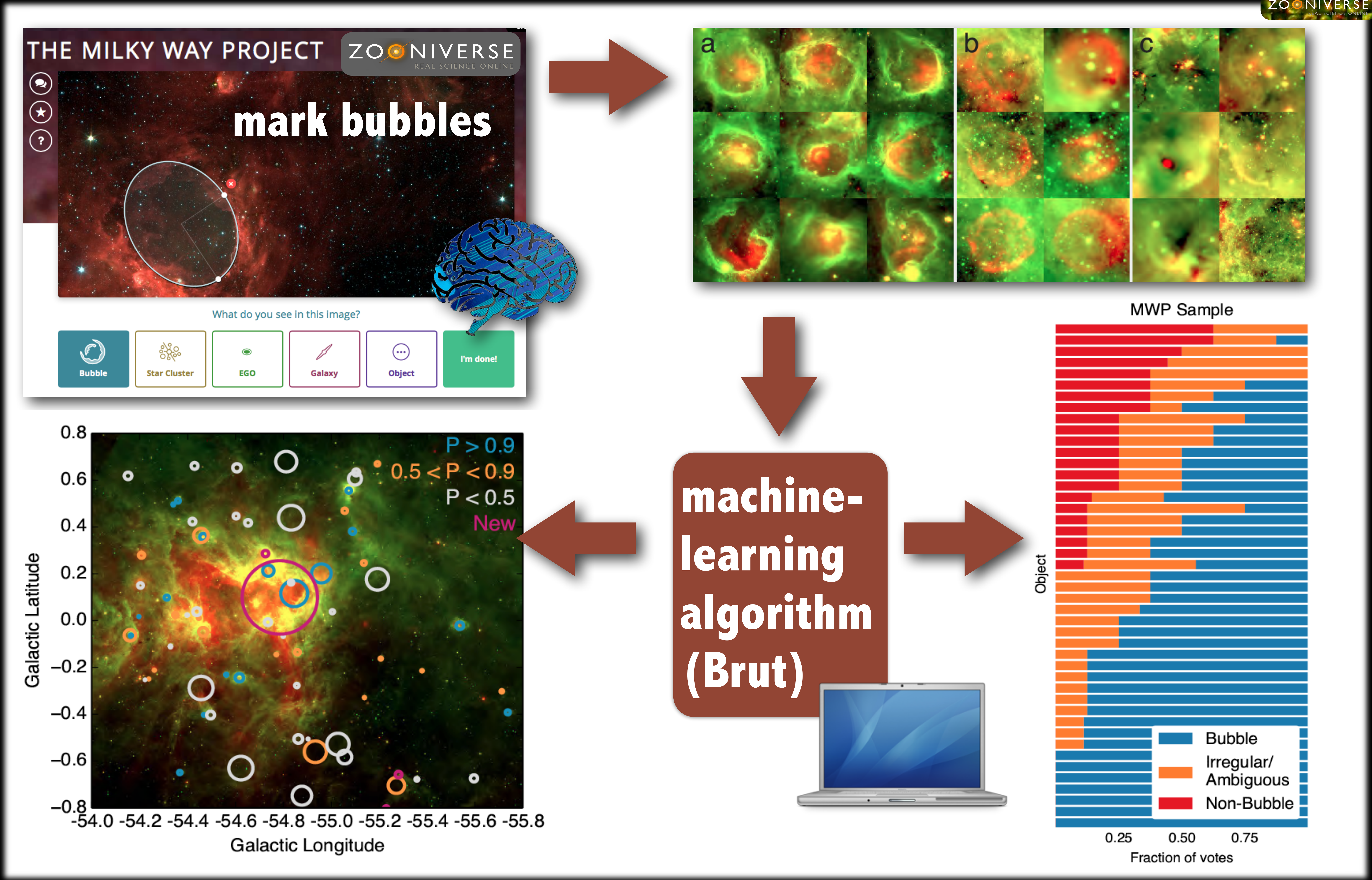


BIG DATA, WIDE DATA

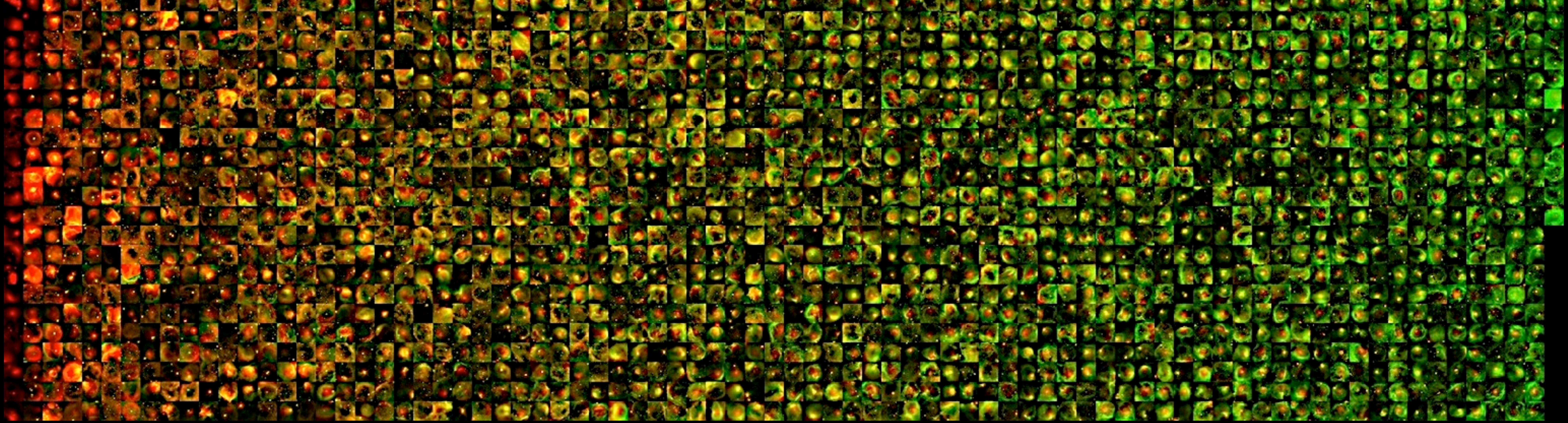




BIG DATA AND "HUMAN-AIDED COMPUTING"



example here from: ***Beaumont****, Goodman, Kendrew, Williams & Simpson 2014; based on* ***Milky Way Project*** *catalog (Simpson et al. 2013), which came from* ***Spitzer/GLIMPSE*** *(Churchwell et al. 2009, Benjamin et al. 2003), cf. Shenoy & Tan 2008 for discussion of HAC;* ***astroml.org*** *for machine learning advice/tools*



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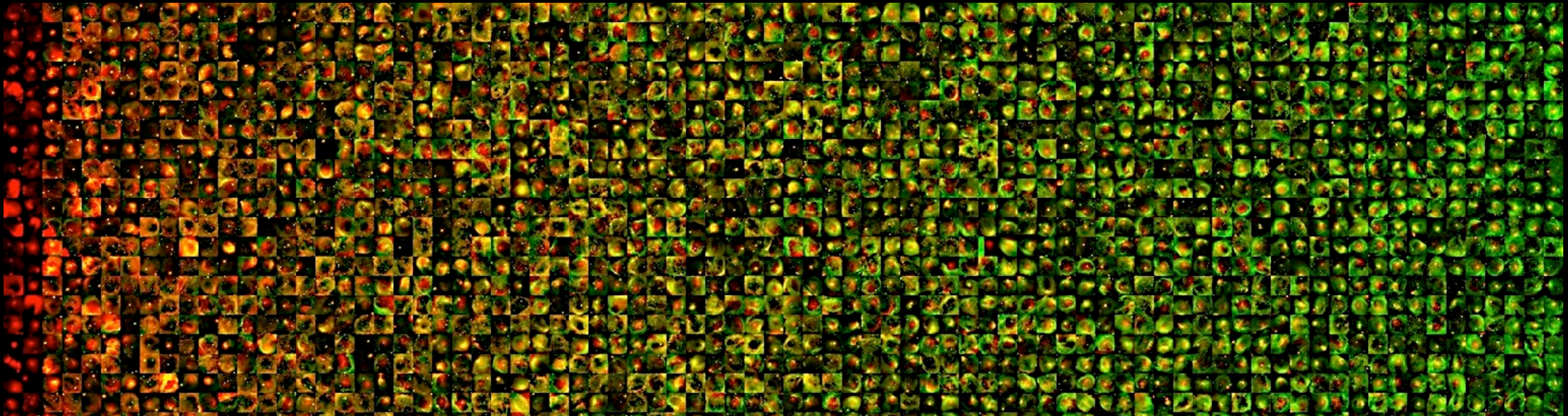
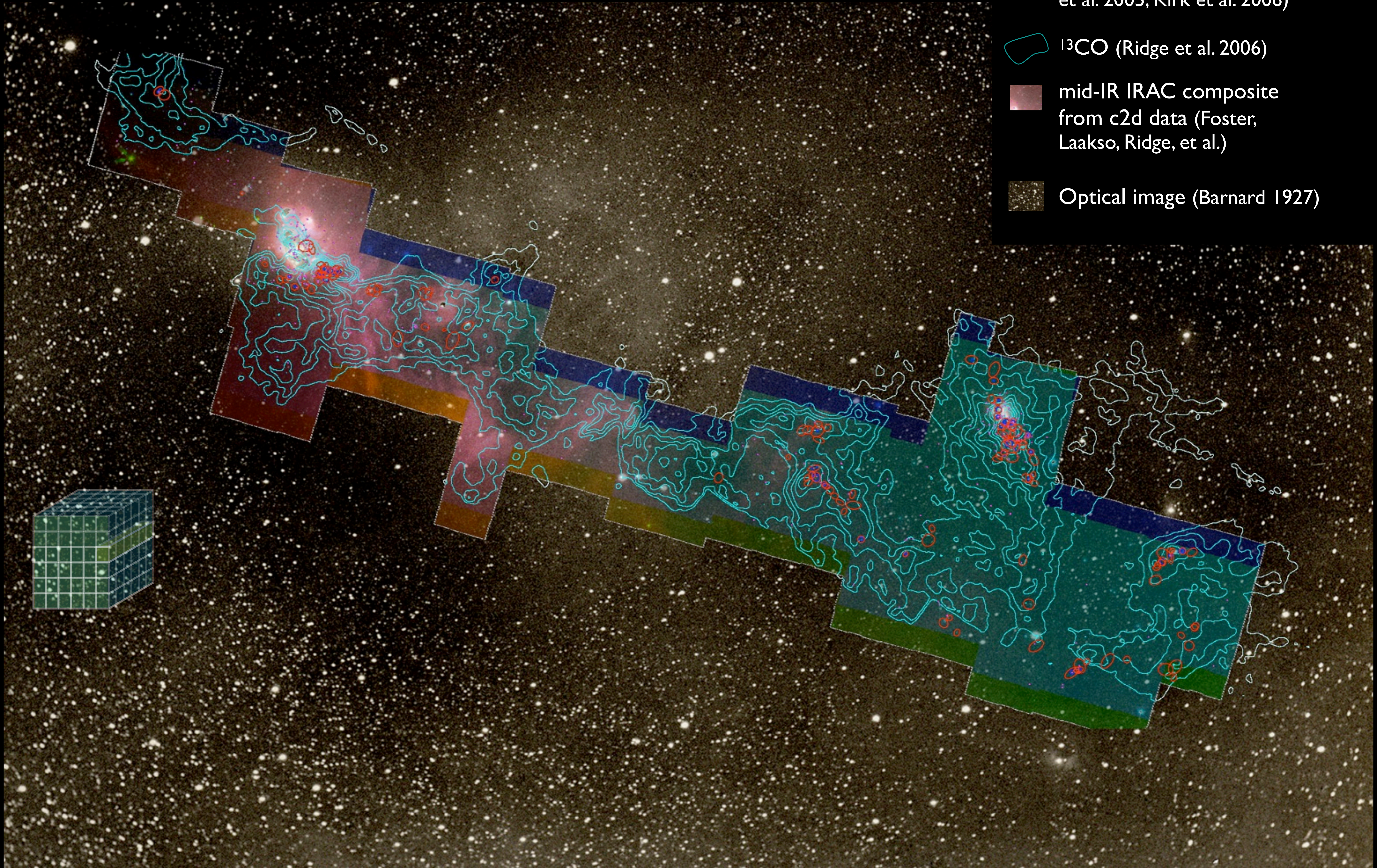
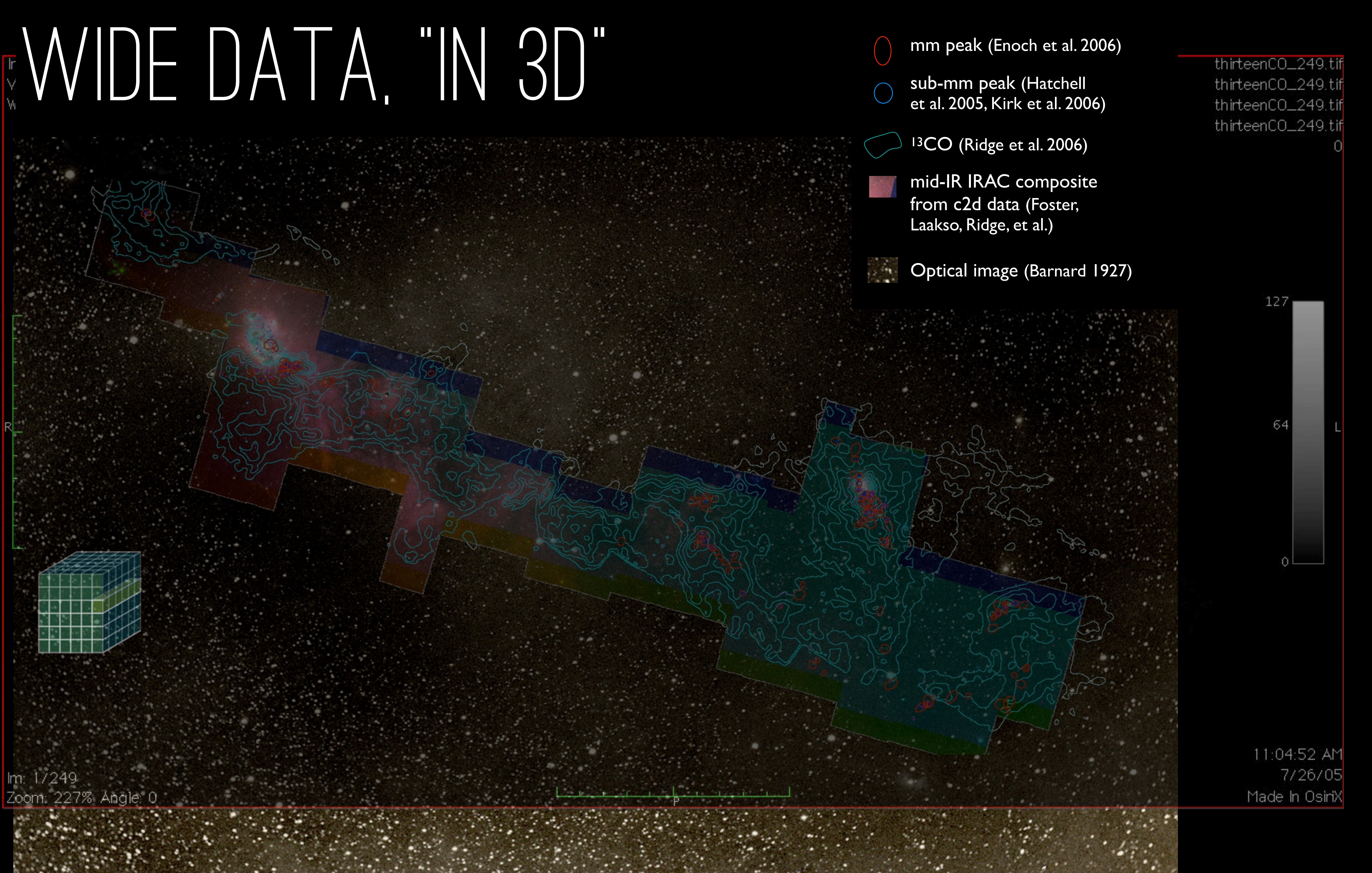
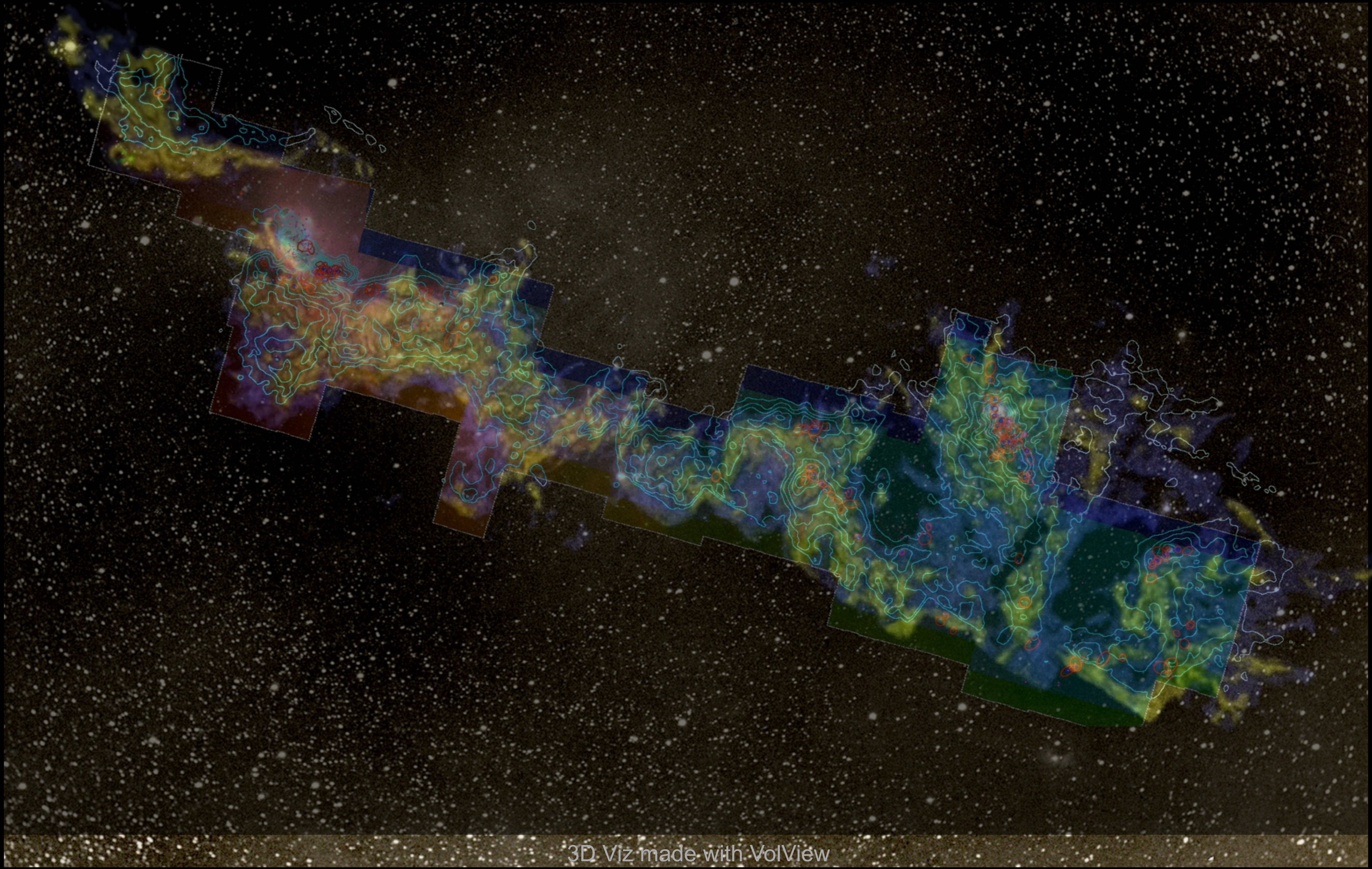


WIDE DATA


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

WIDE DATA, "IN 3D"





AstronomicalMedicine@IIC

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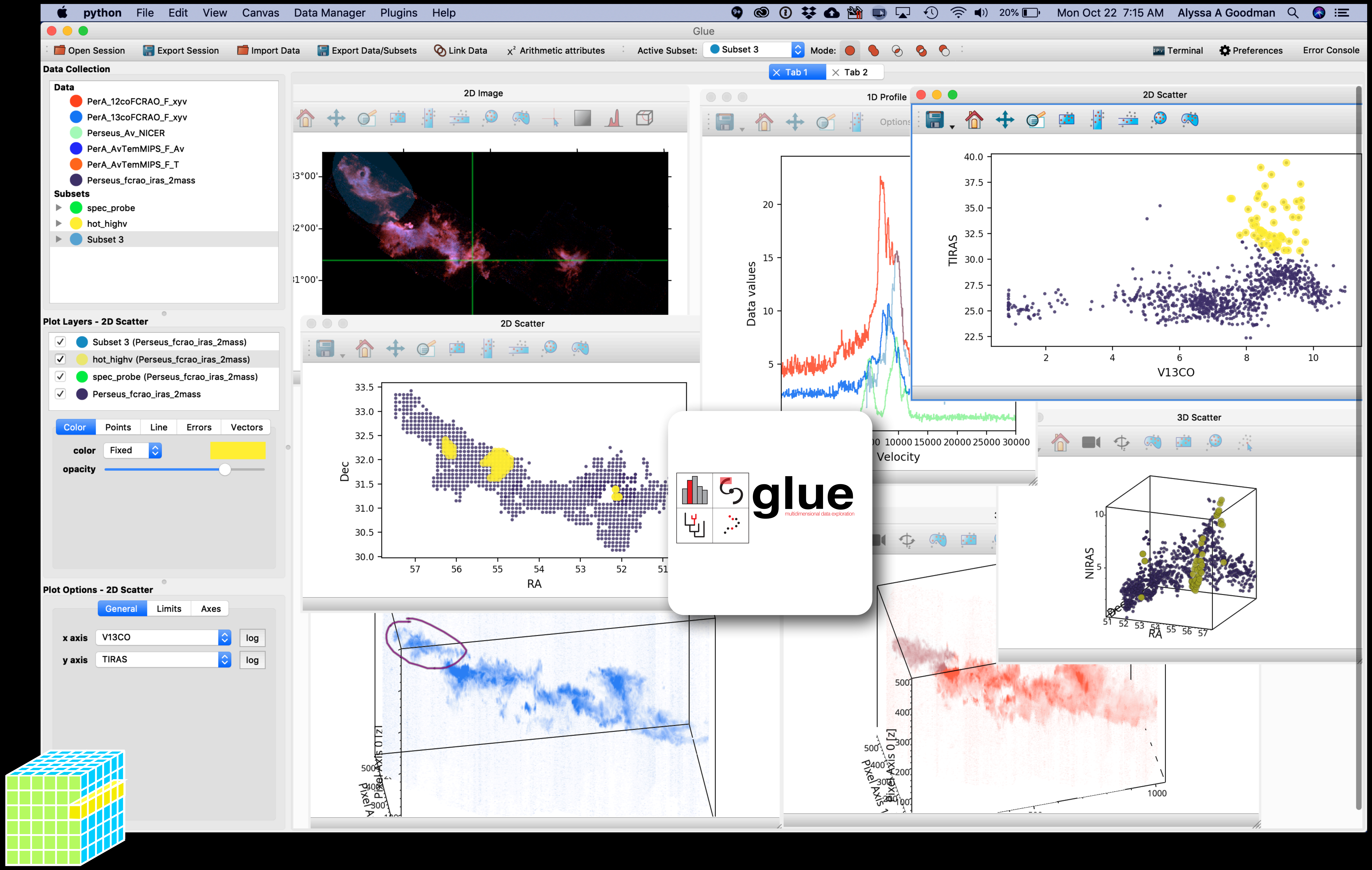
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Mon Oct 22 7:15 AM Alyssa A Goodman
Glue
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Subset 3
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Error Console
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Subset 3
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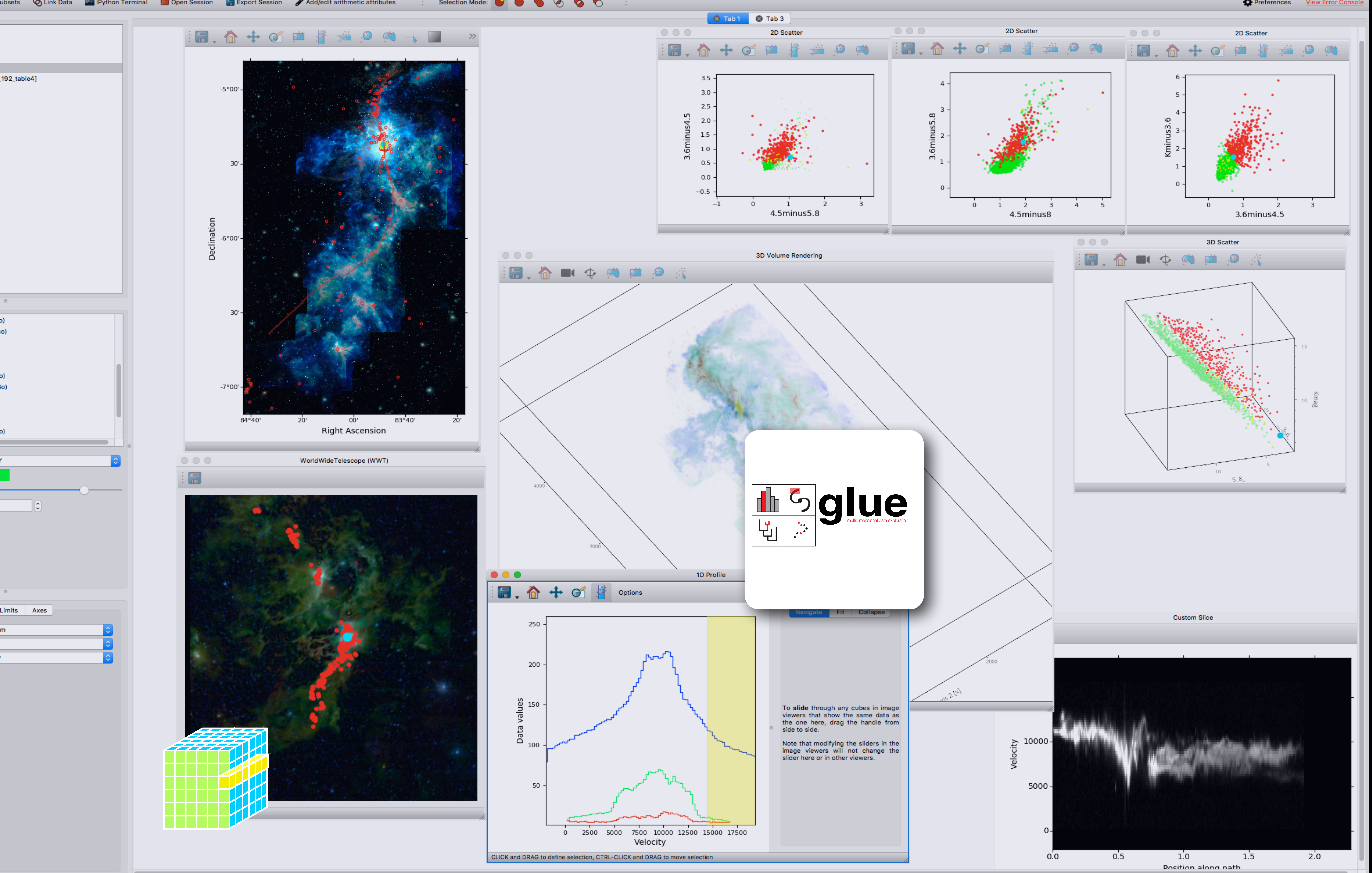
multidimensional data exploration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Note that modifying the sliders in the image viewers will not change the slider here or in other viewers.
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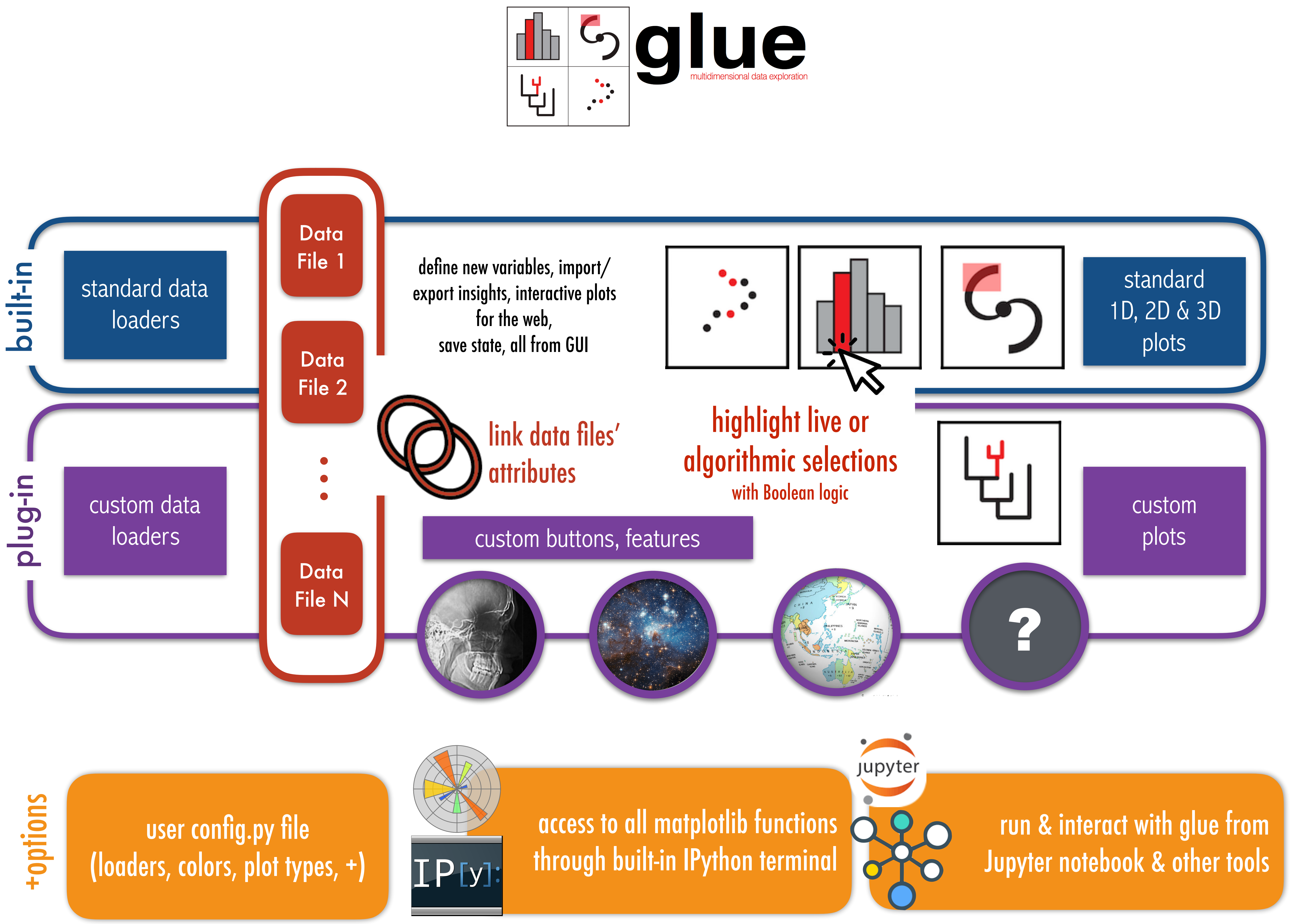

glueviz.org

[demo]
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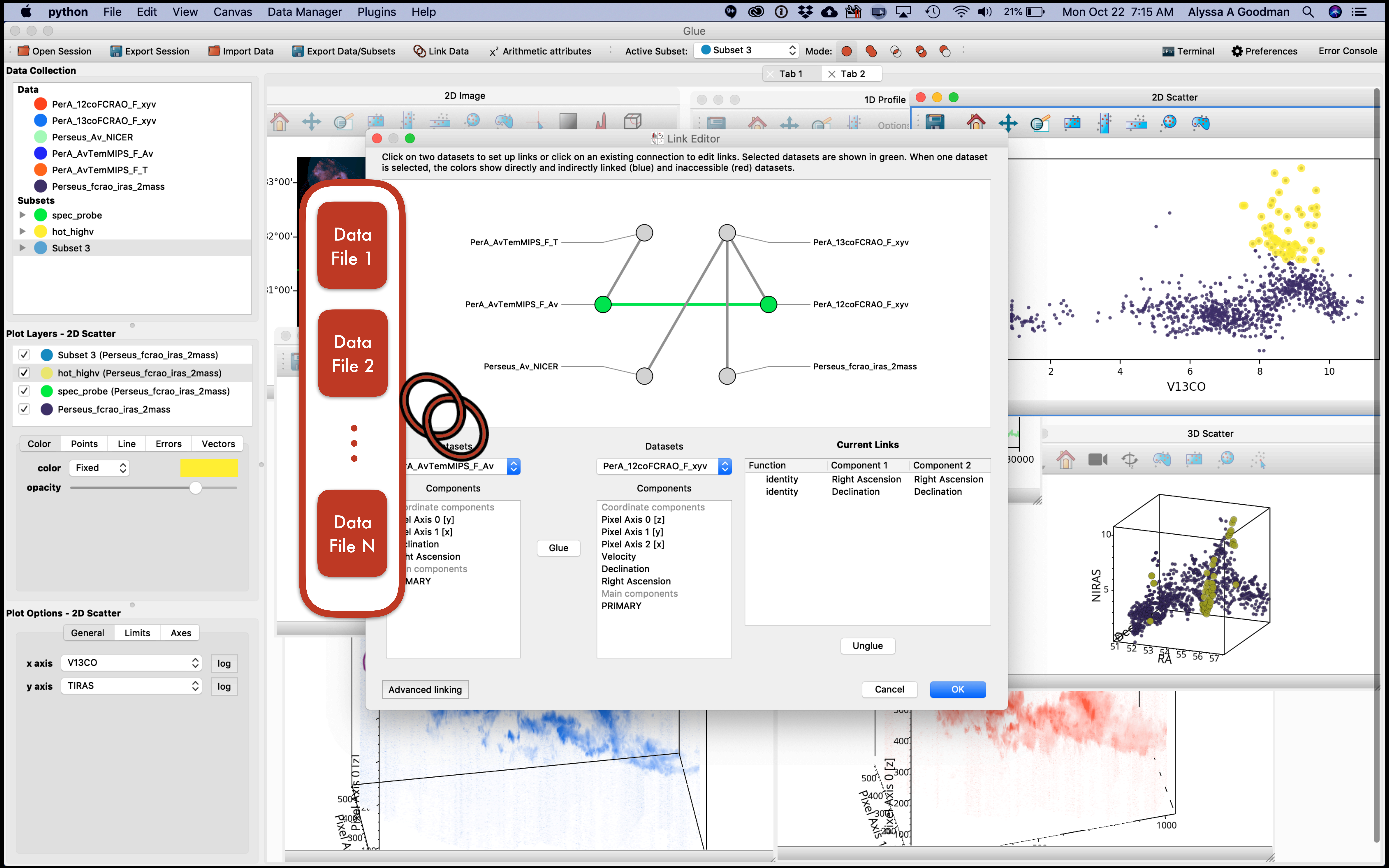
[publishing]


python File Edit View Canvas Data Manager Plugins Help
Mon Oct 22 7:15 AM Alyssa A Goodman
Glue
Open Session
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Arithmetic attributes
Active Subset:
Subset 3
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Error Console
Data Collection
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Data File 1
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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.
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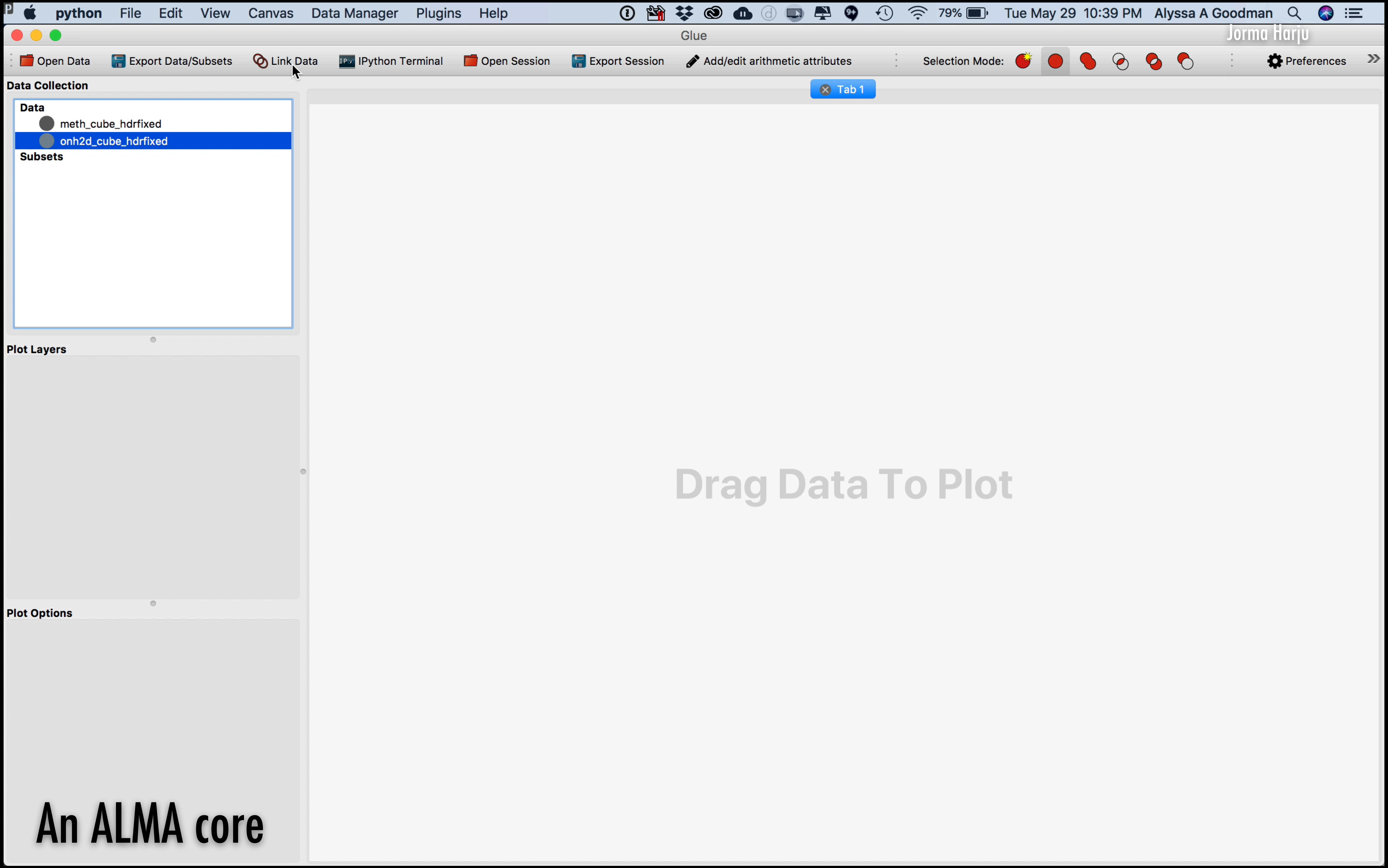
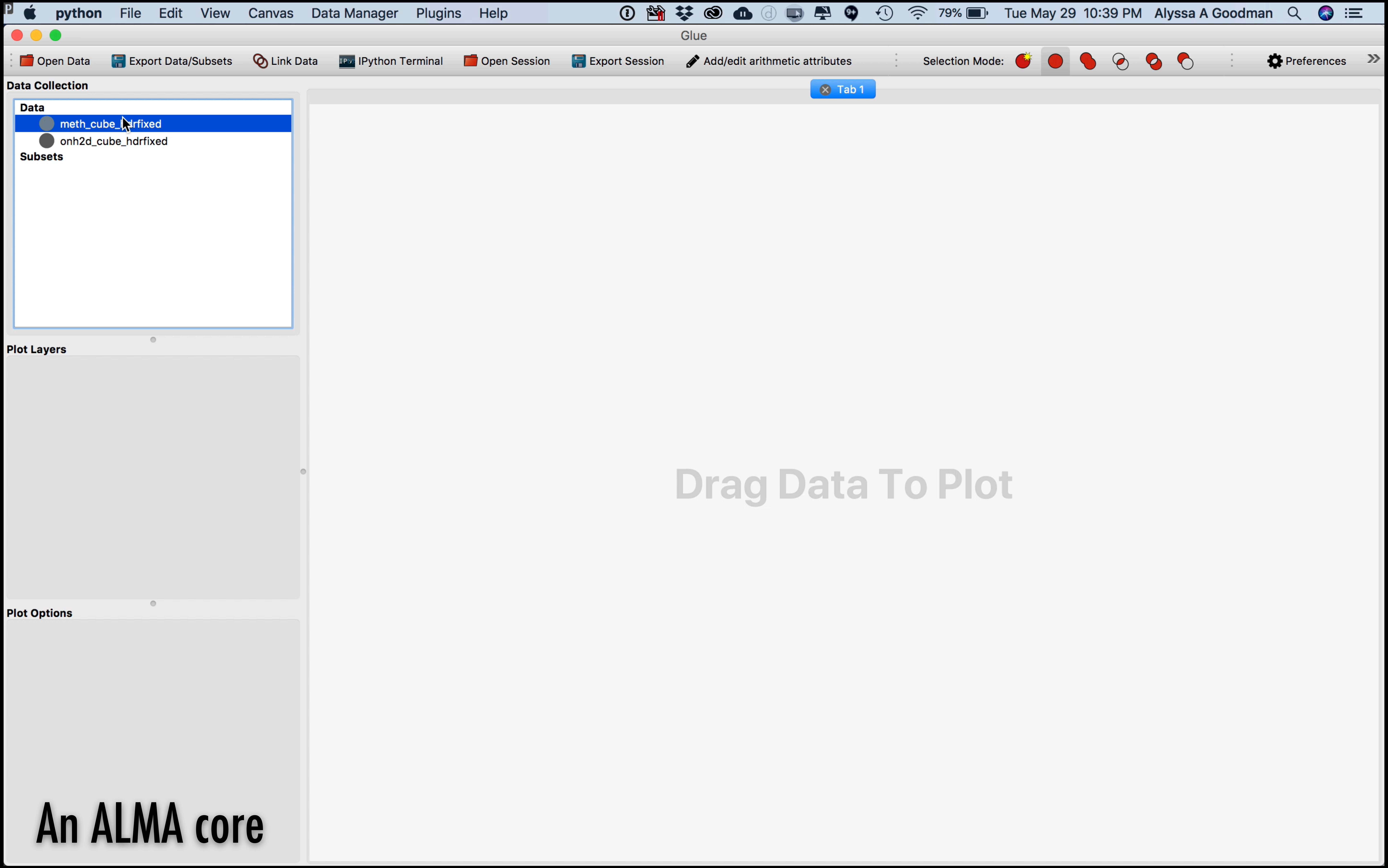
Coordinate components
Pixel Axis 0 [z]
Pixel Axis 1 [y]
Pixel Axis 2 [x]
Velocity
Declination
Right Ascension
Main components
PRIMARY
Glue
Current Links
Function
Component 1
Component 2
identity
Right Ascension
Right Ascension
identity
Declination
Declination
Unglue
Advanced linking
Cancel
OK
V13CO
NIRAS
RA

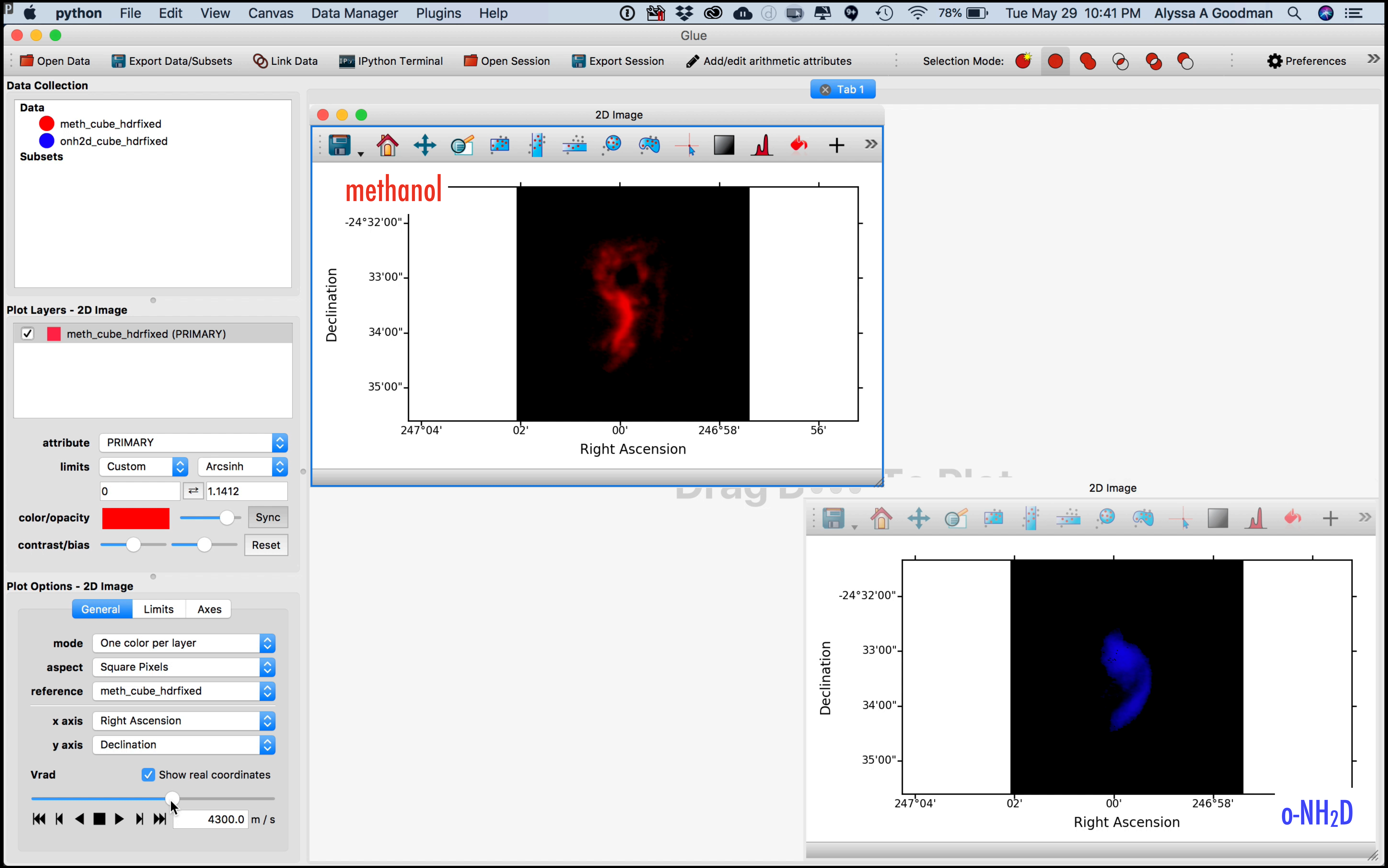
“No merging of data sets—just glue them.”



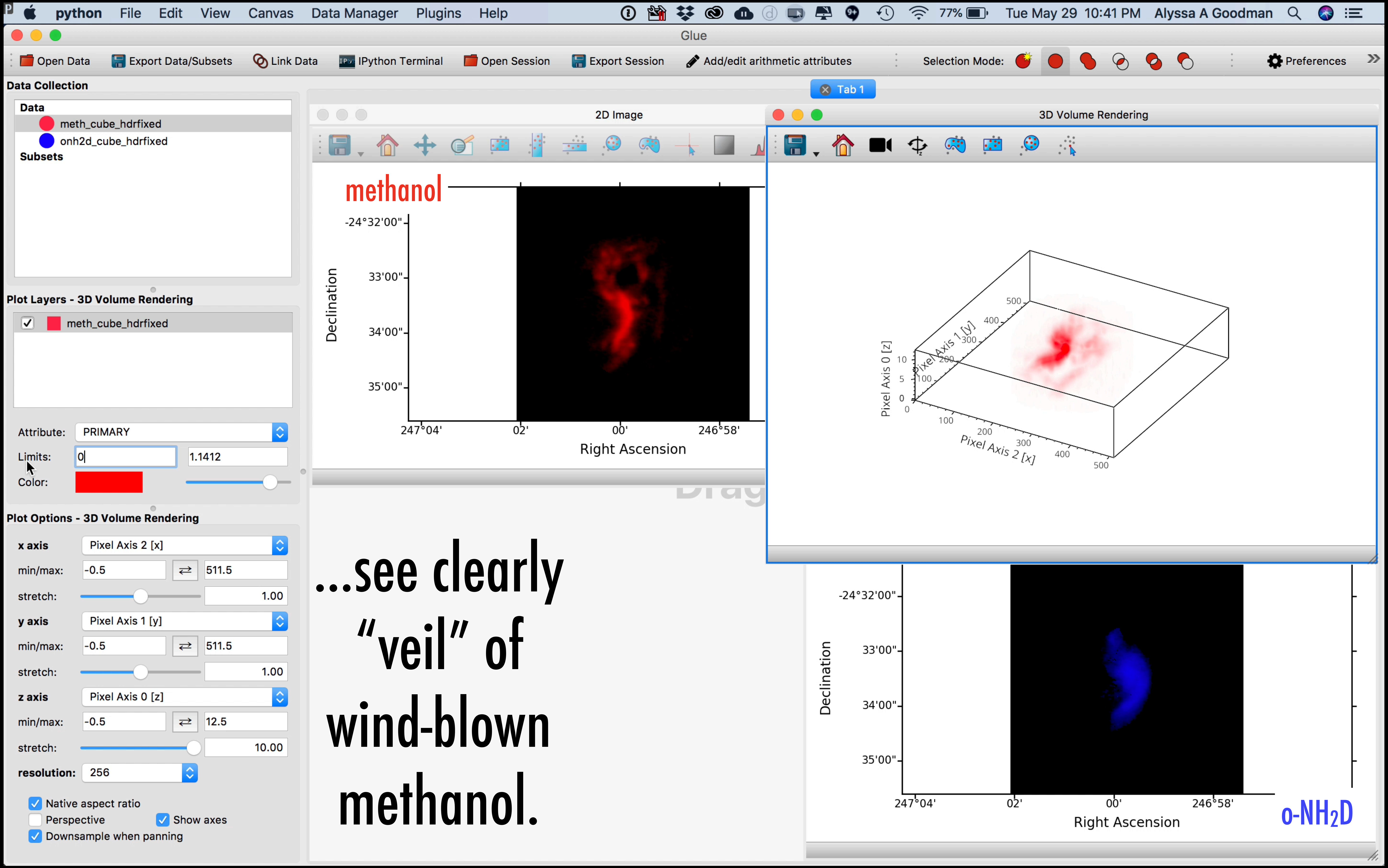
Just drag to visualize, e.g. series of 2D "channel maps."



Adjust so each tracer is a different color.



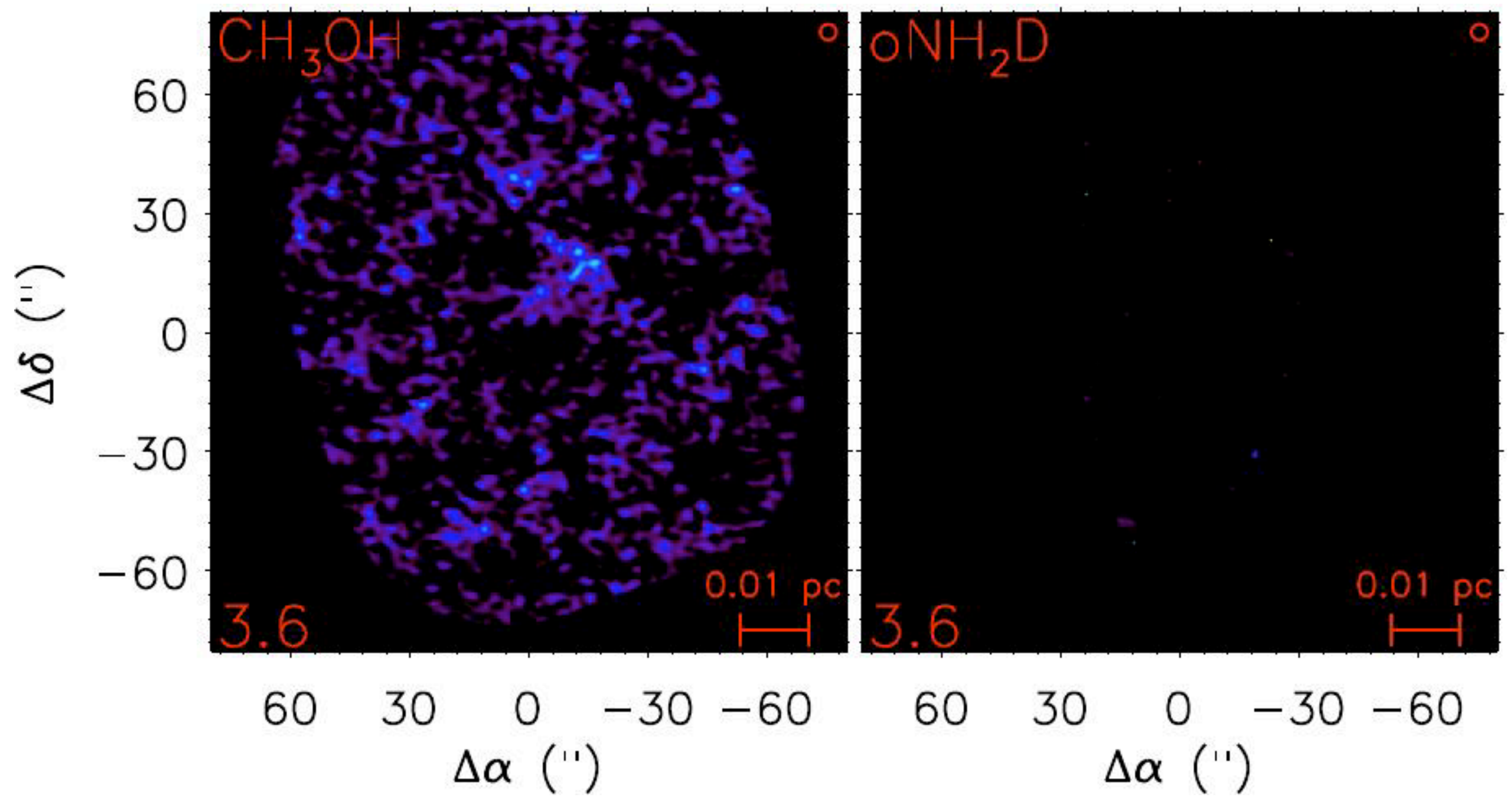
Create 3D views...

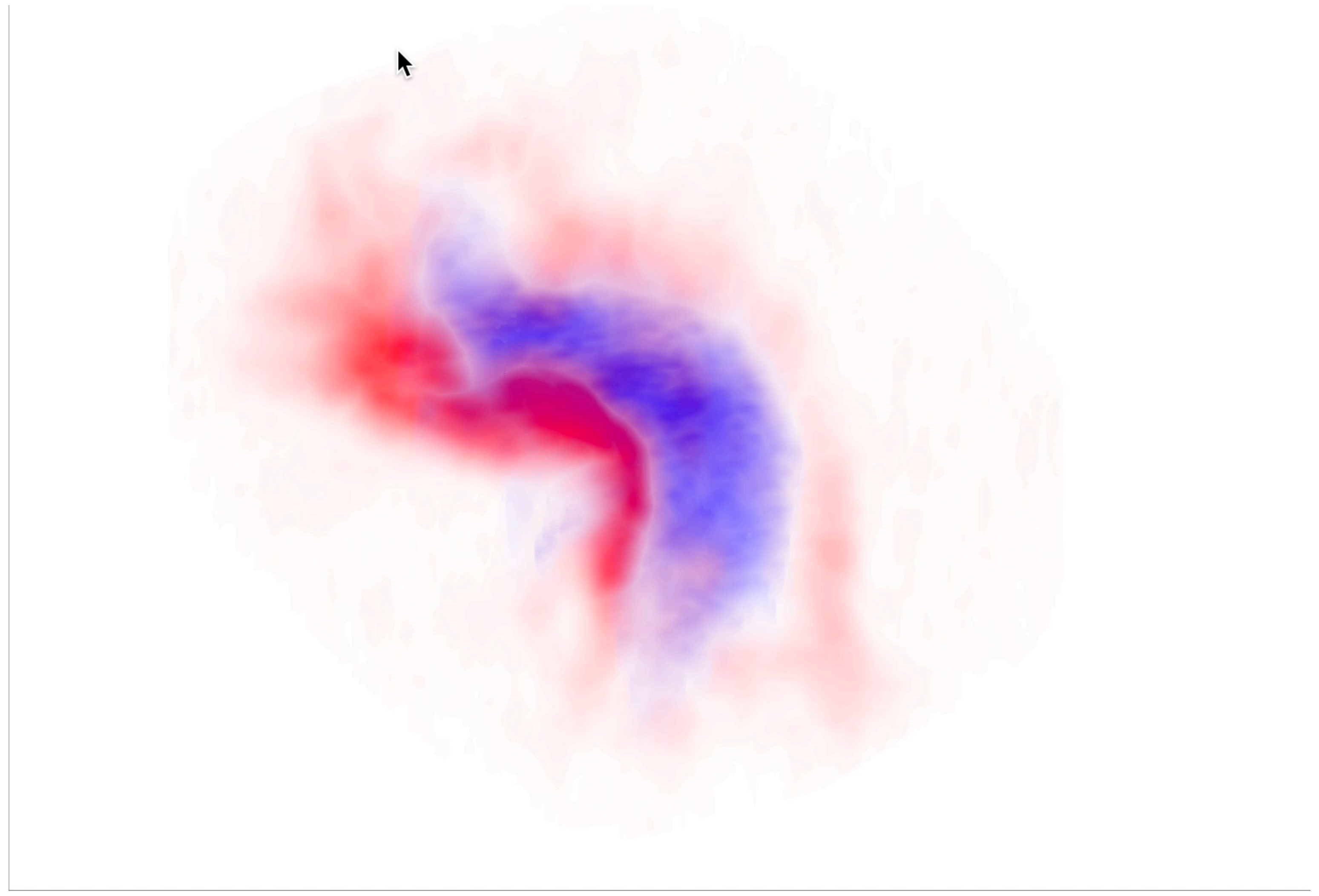


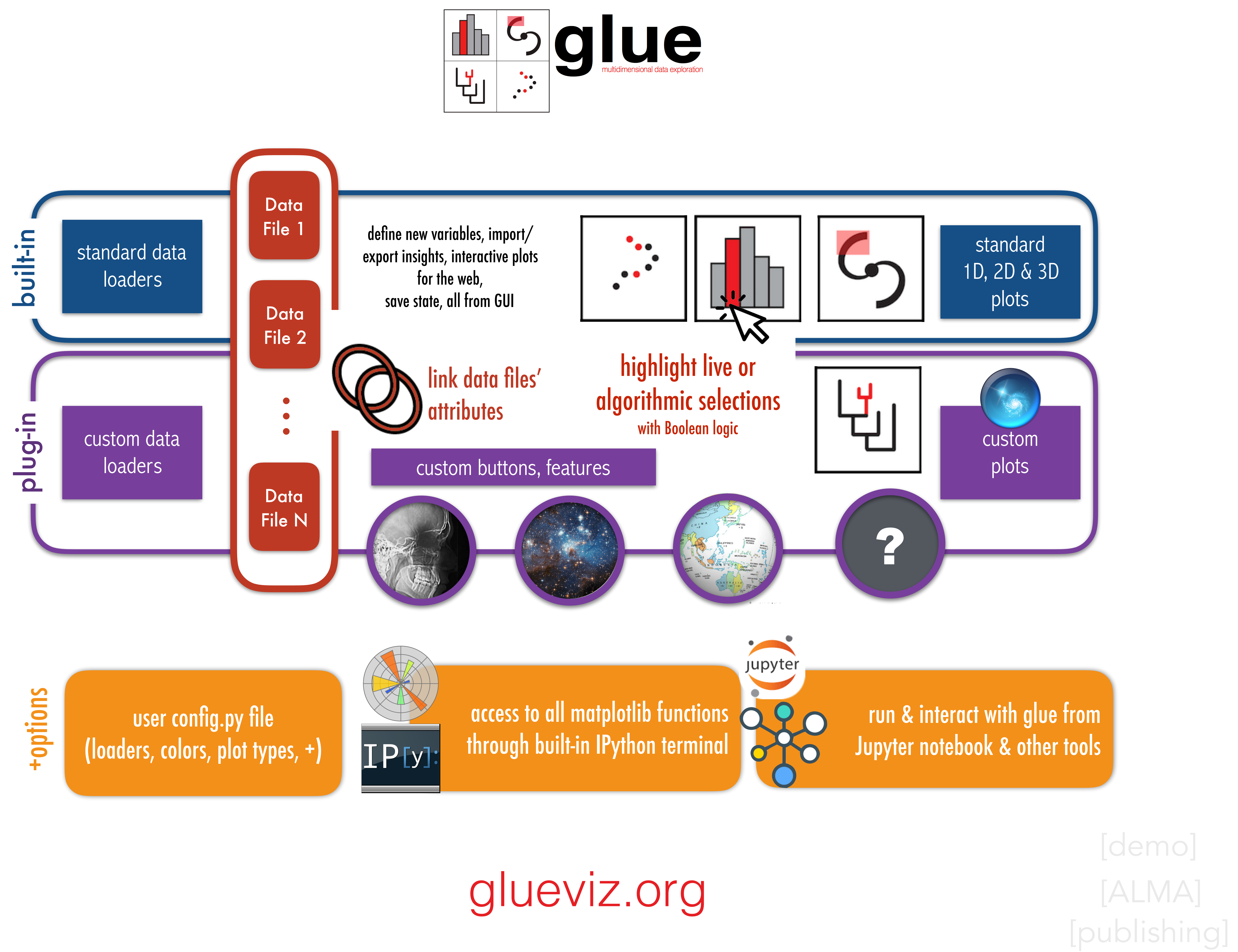
...see clearly "veil" of wind-blown methanol.

Traditional Rainbow Channel maps

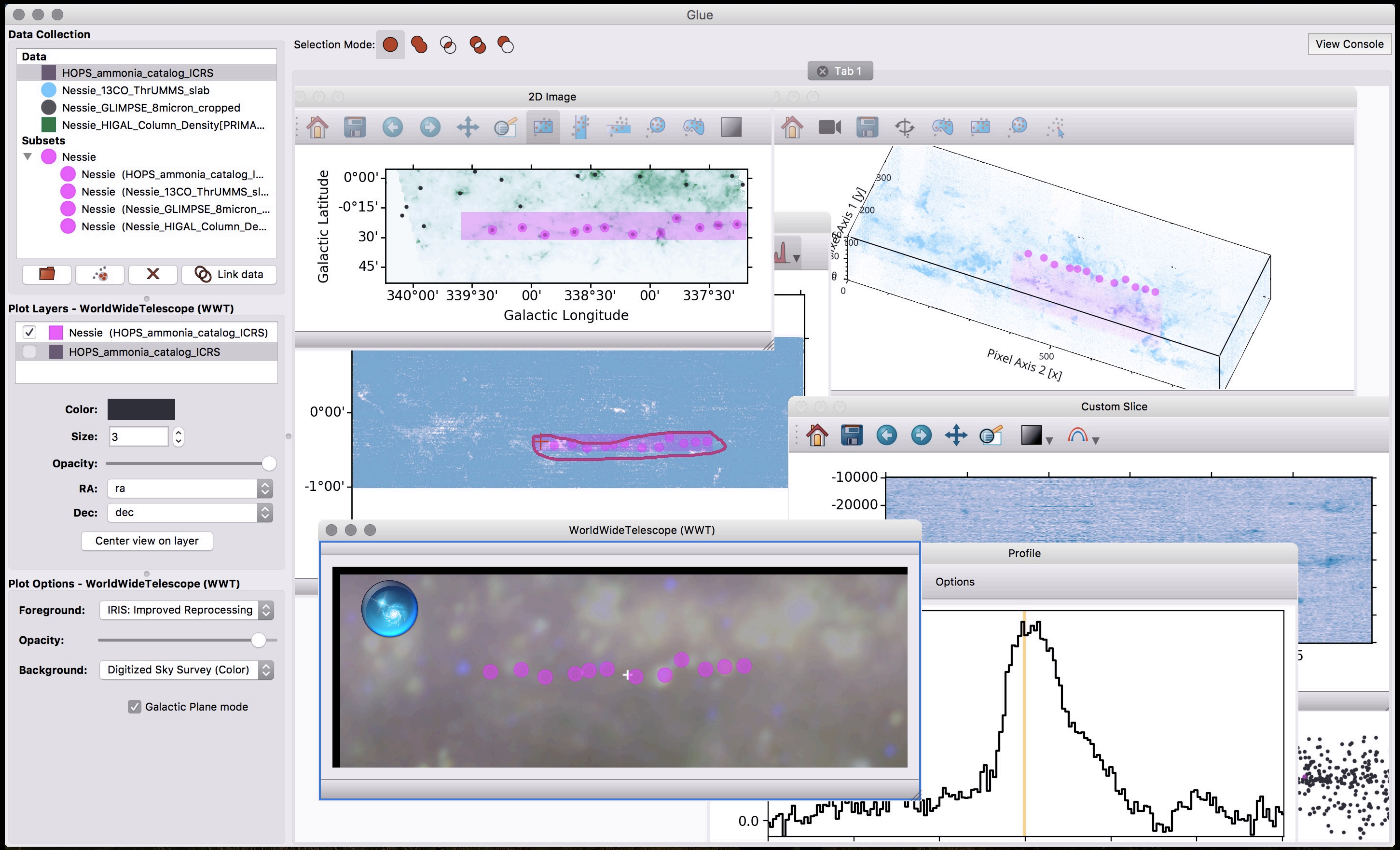
glue



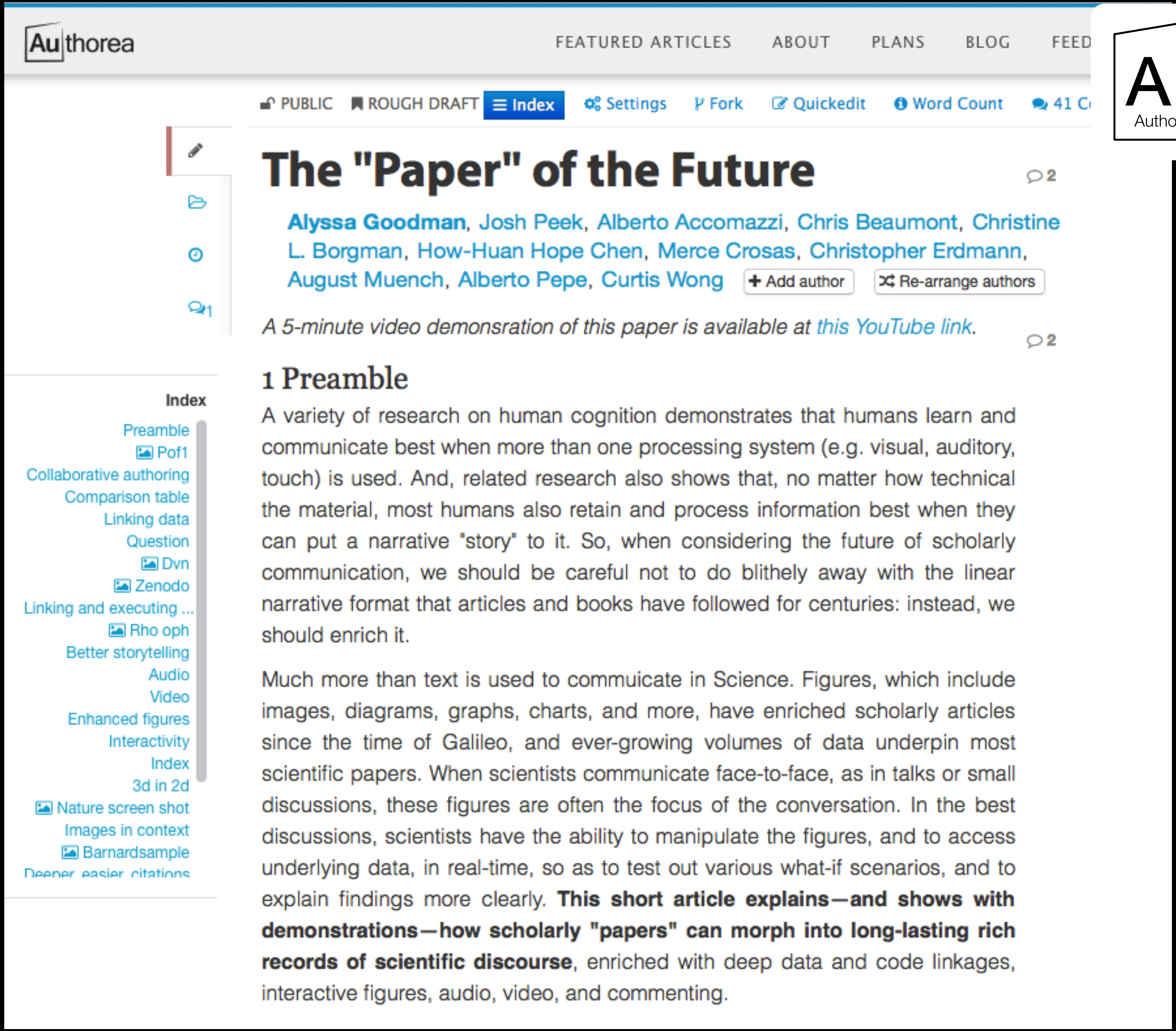



glue
multidimensional data exploration
built-in
standard data loaders
Data File 1
Data File 2
Data File N
define new variables, import/ export insights, interactive plots for the web, save state, all from GUI
standard 1D, 2D & 3D plots
plug-in
custom data loaders
link data files' attributes
highlight live or algorithmic selections
with Boolean logic
custom buttons, features
custom plots
?
+options
user config.py file (loaders, colors, plot types, +)
IP[y]:
access to all matplotlib functions through built-in IPython terminal
jupyter
run & interact with glue from Jupyter notebook & other tools
glueviz.org
[demo]
[ALMA]
[publishing]

WorldWide Telescope as a plug-in to glue



But…
Publishing?



Au|thorea FEATURED ARTICLES ABOUT PLANS BLOG FEED

PUBLIC ROUGH DRAFT Index Settings Fork Quickedit Word Count 41 C

The "Paper" of the Future

2

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

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

2

1 Preamble

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

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

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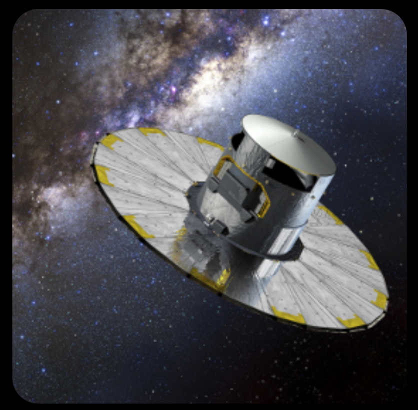
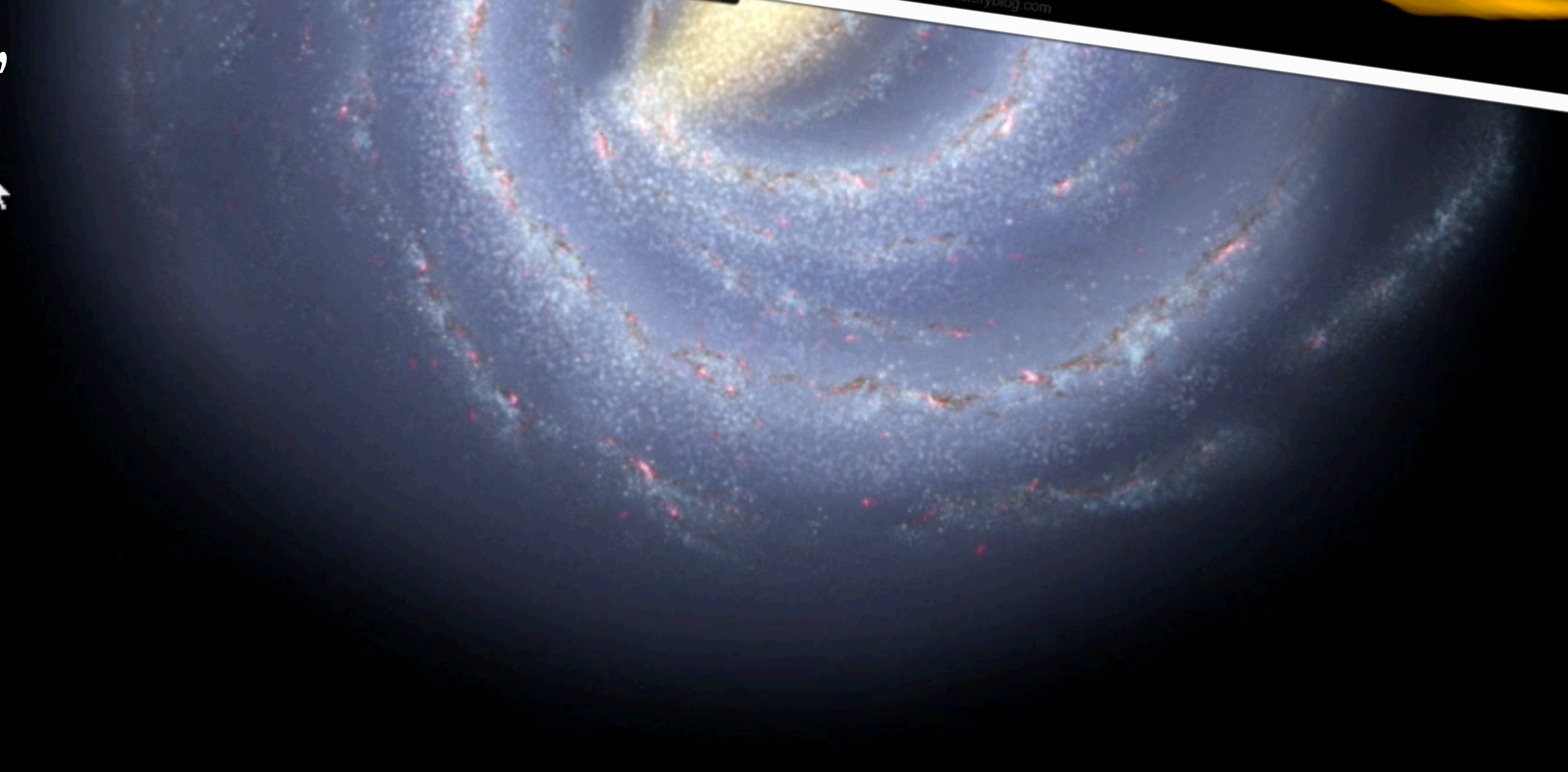


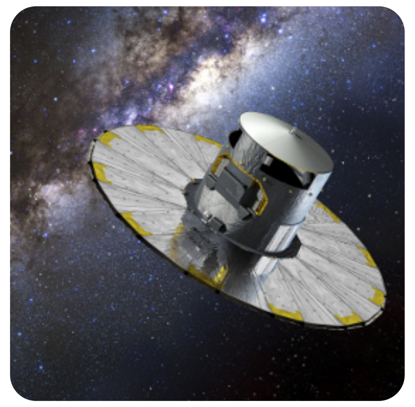
Gaia & the Milky Way

WorldWide Telescope



"Galactic Plane"

The Milky Way
(Artist's Conception)



Draft version March 2, 2019
Typeset using LaTeX default style in AASTeX62

A Large Catalog of Accurate Distances to Local Molecular Clouds: The Gaia DR2 Edition

Catherine Zucker,[1,*] Joshua S. Speagle,[1,*] Edward F. Schlafly,[2] Gregory M. Green,[3] Douglas P. Finkbeiner,[1]
Alyssa A. Goodman,[1,4] and João Alves[4,5]

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[2] *Lawrence Berkeley National Laboratory, One Cyclotron Road, Berkeley, CA 94720, USA*
[3] *Kavli Institute for Particle Astrophysics and Cosmology, Physics and Astrophysics Building, 452 Lomita Mall, Stanford, CA 94305, USA*
[4] *Radcliffe Institute for Advanced Study, Harvard University, 10 Garden St, Cambridge, MA 02138*
[5] *University of Vienna, Department of Astrophysics, Türkenschanzstraße 17, 1180 Vienna, Austria*

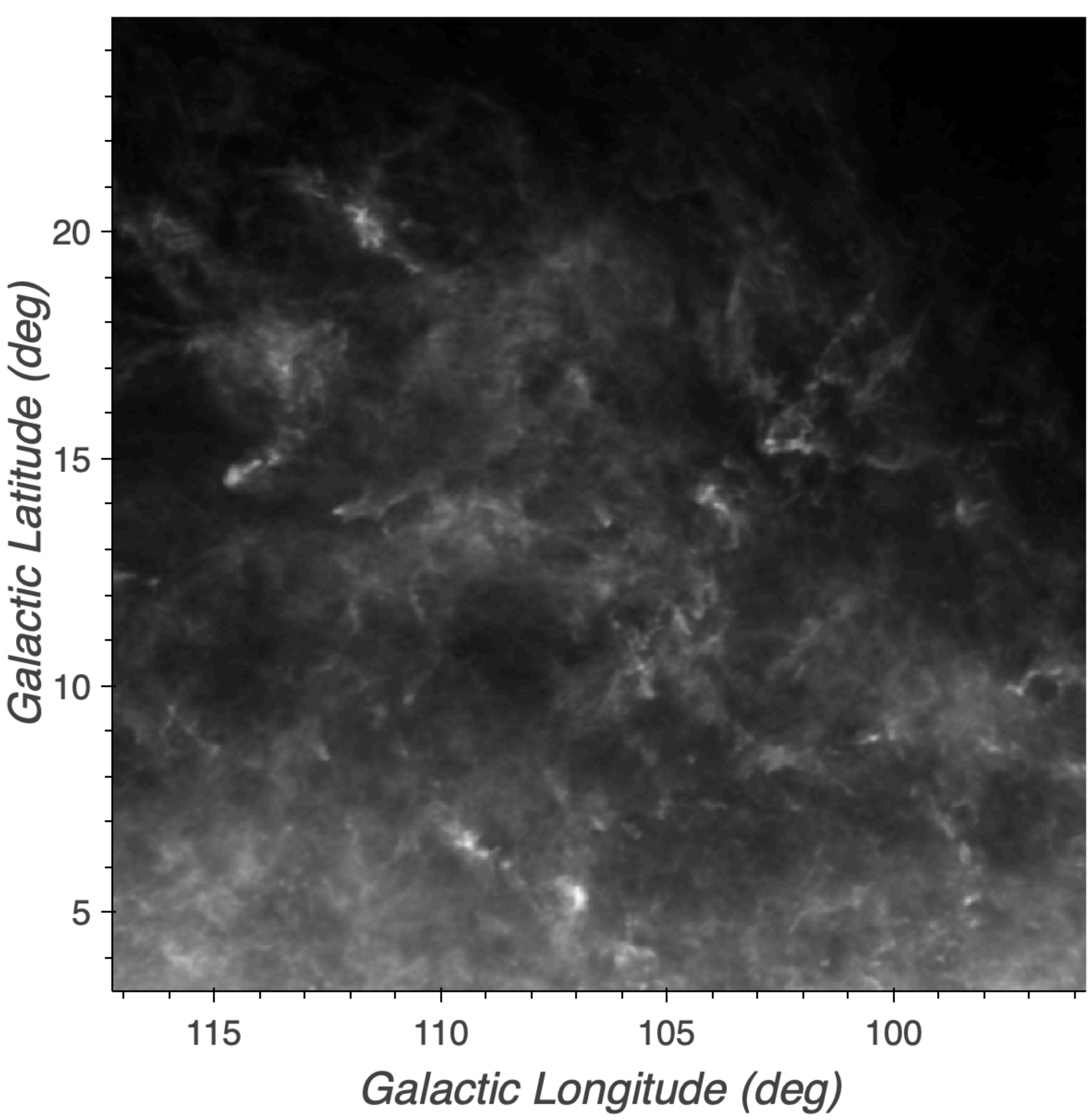
ABSTRACT

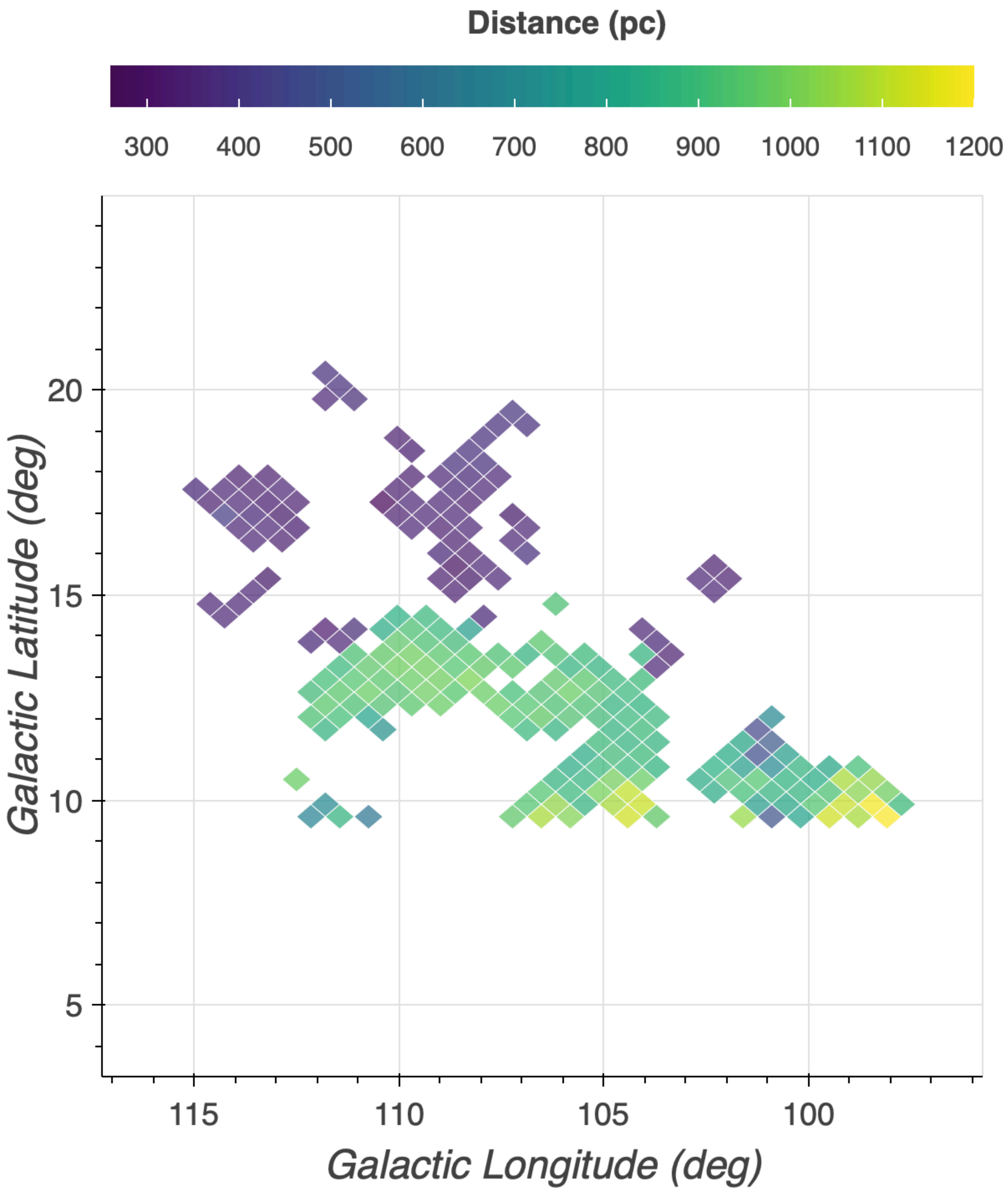
We present a uniform catalog of accurate distances to local molecular clouds informed by the Gaia DR2 data release. Our methodology builds on that of Schlafly et al. (2014). First, we infer the distance and extinction to stars along sightlines towards the clouds using optical and near-infrared photometry. When available, we incorporate knowledge of the stellar distances obtained from Gaia DR2 parallax measurements. We model these per-star distance-extinction estimates as being caused by a dust screen with a 2-D morphology derived from Planck at an unknown distance, which we then fit for using a nested sampling algorithm. We provide updated distances to the Schlafly et al. (2014) sightlines towards the Dame et al. (2001) and Magnani et al. (1985) clouds, finding good agreement with the earlier work. For a subset of 27 clouds, we construct interactive pixelated distance maps to further study detailed cloud structure, and find several clouds which display clear distance gradients and/or are comprised of multiple components. We use these maps to determine robust average distances to these clouds. The characteristic combined uncertainty on our distances is $\approx 5-6\%$, though this can be higher for clouds at farther distances, due to the limitations of our single-cloud model.

Keywords: ISM: clouds, ISM: dust, extinction, stars: distances, methods: statistical

Zucker et al. 2019

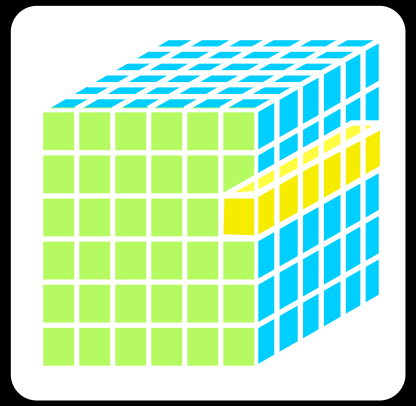
Cepheus



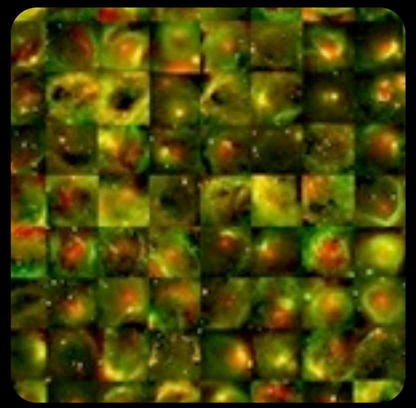


Interactive Gaia-reliant figure from Zucker et al. 2019— https://faun.rc.fas.harvard.edu/czucker/Paper_Figures/Cepheus.html

WorldWide Telescope



glue



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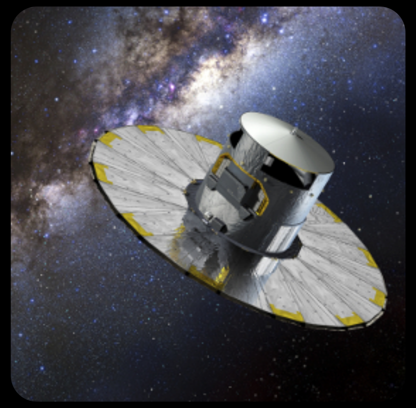


10 ViZ

10QViz.org

≡ 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?

Join the 10QViz Conversation!

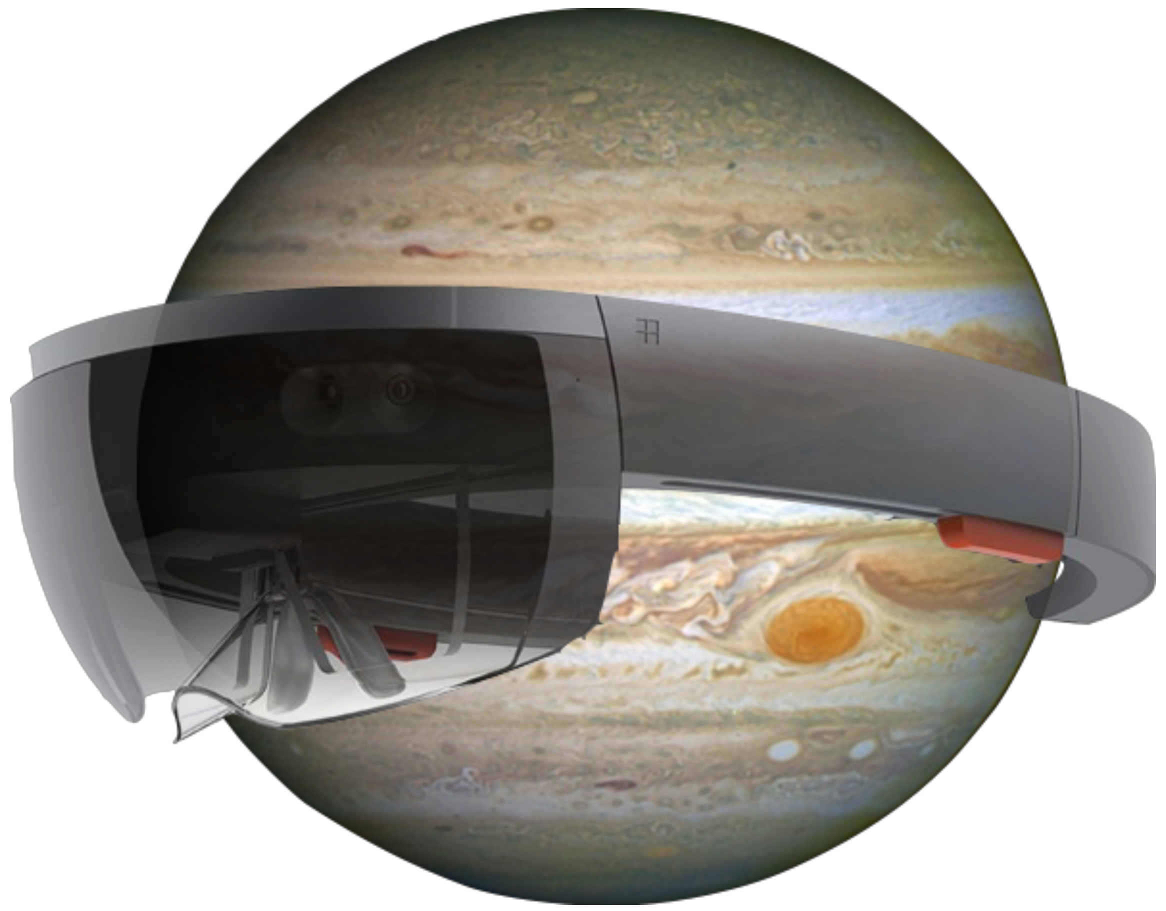
To learn more about this site, please visit the ***About*** *page.*

To read an in-process manuscript giving the scholarship behind the recommendations on this site, see Coltekin & Goodman 2018.

Bonus anyone?

PredictionX

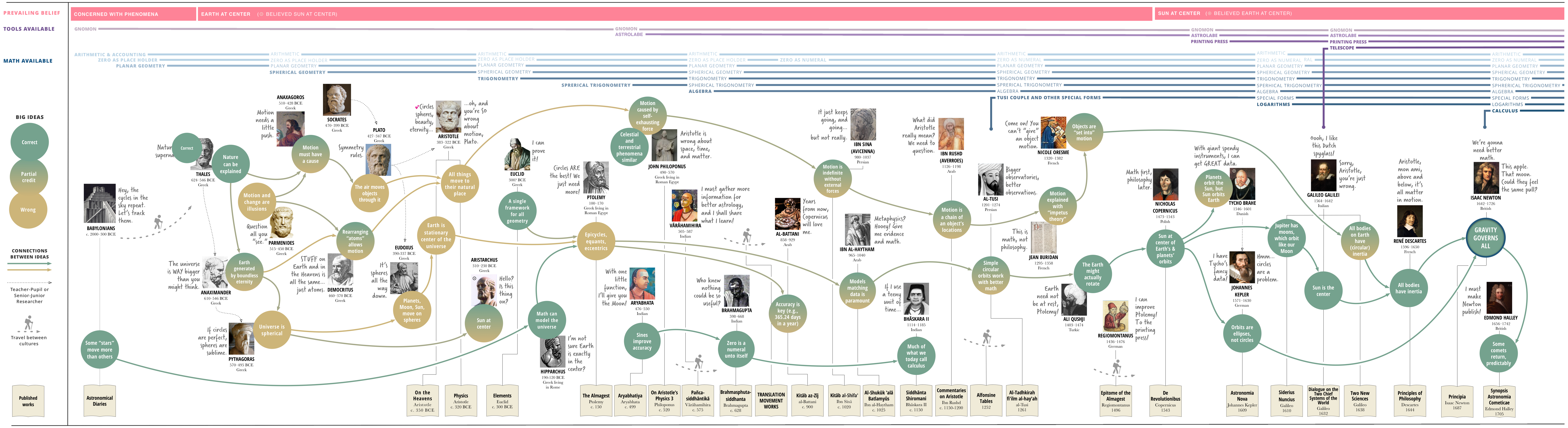
Infoviz



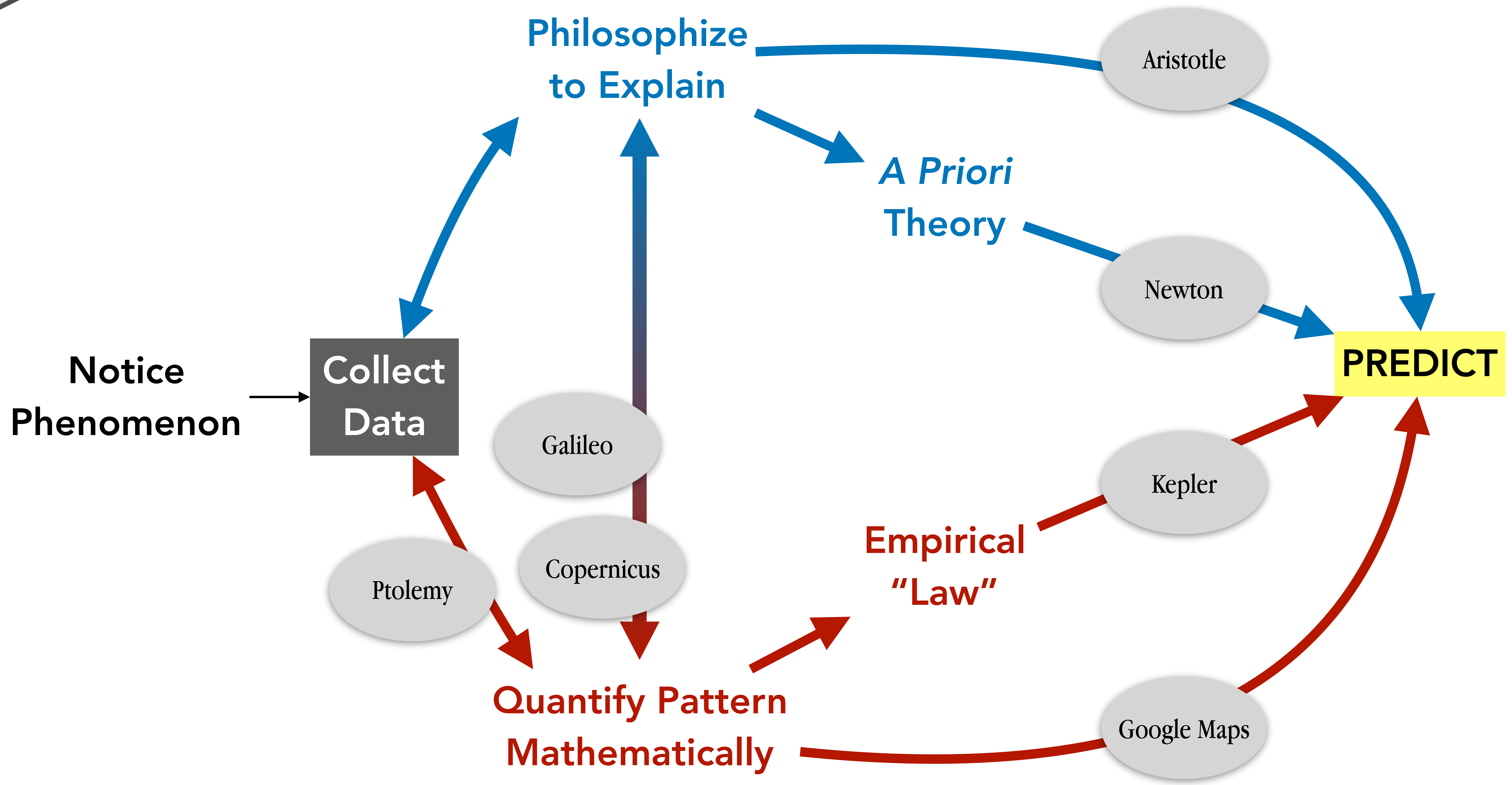
3D selection

PREDICTIONX

The Path to Newton

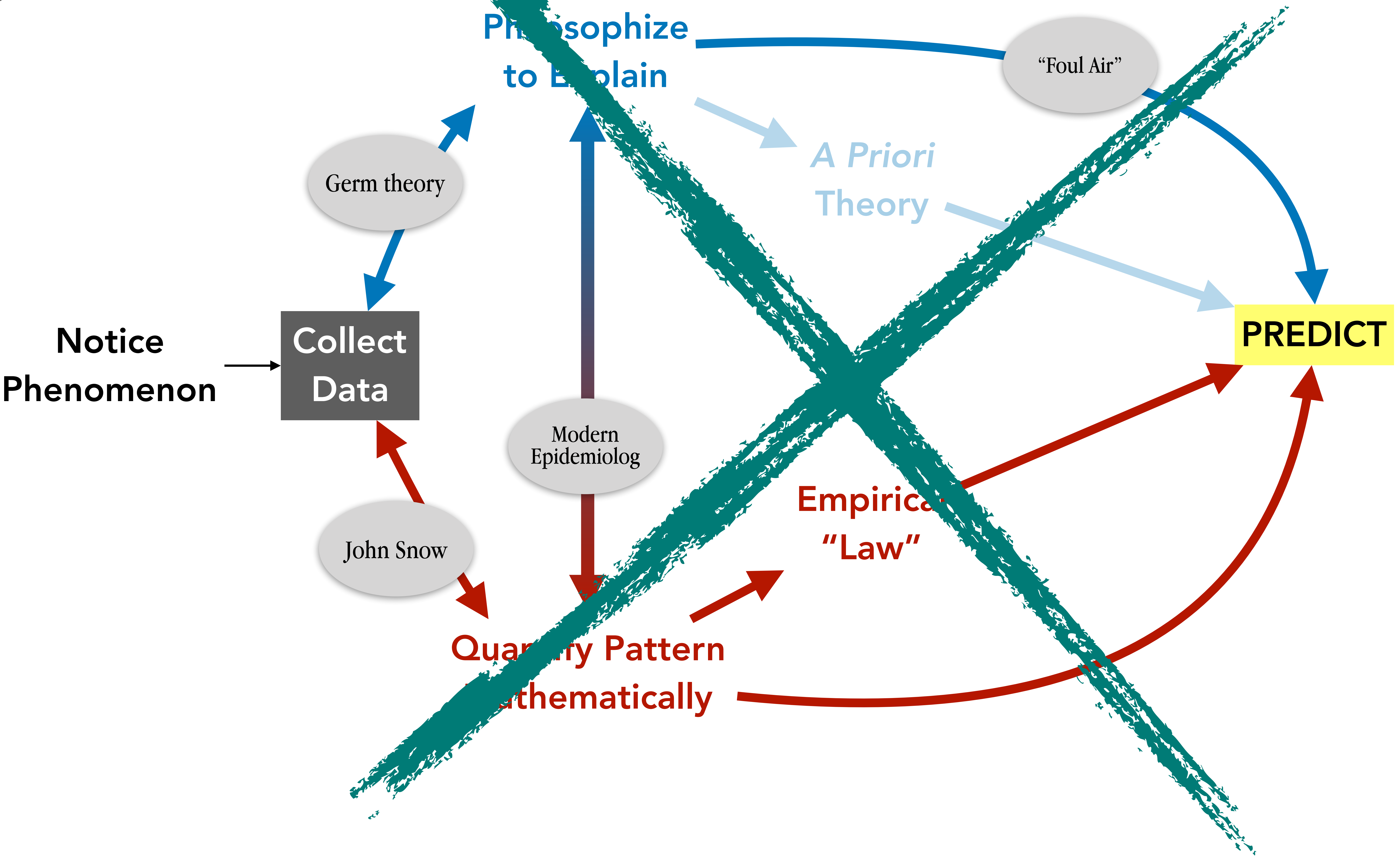


Version 1 (Terrible)



PREDICTIVE SYSTEMS

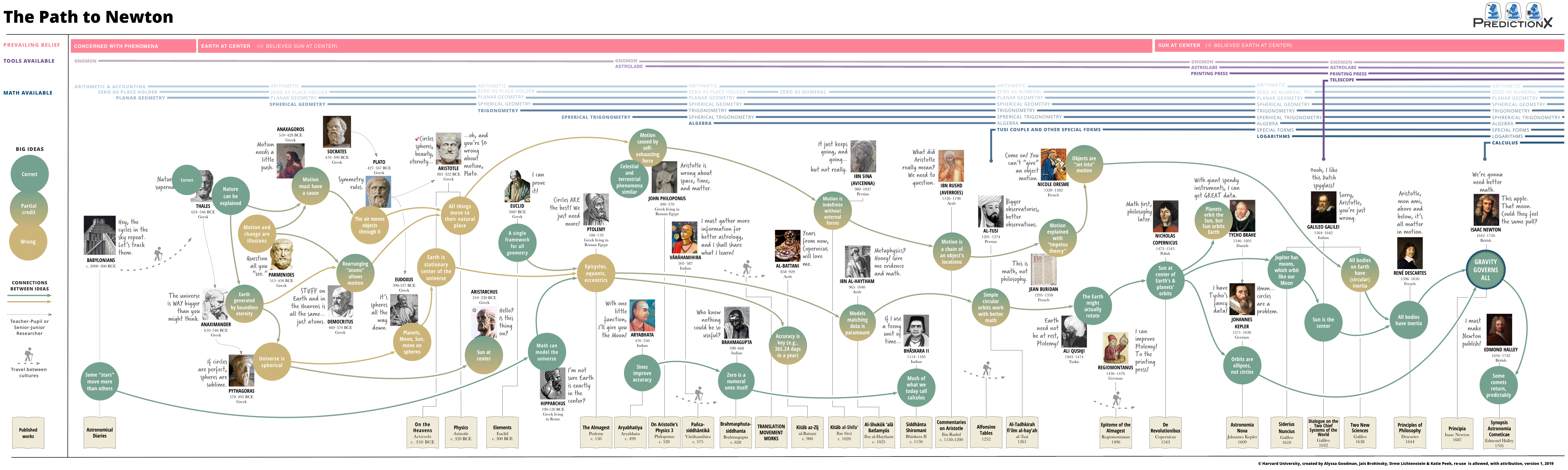
Version 1 (Terrible)



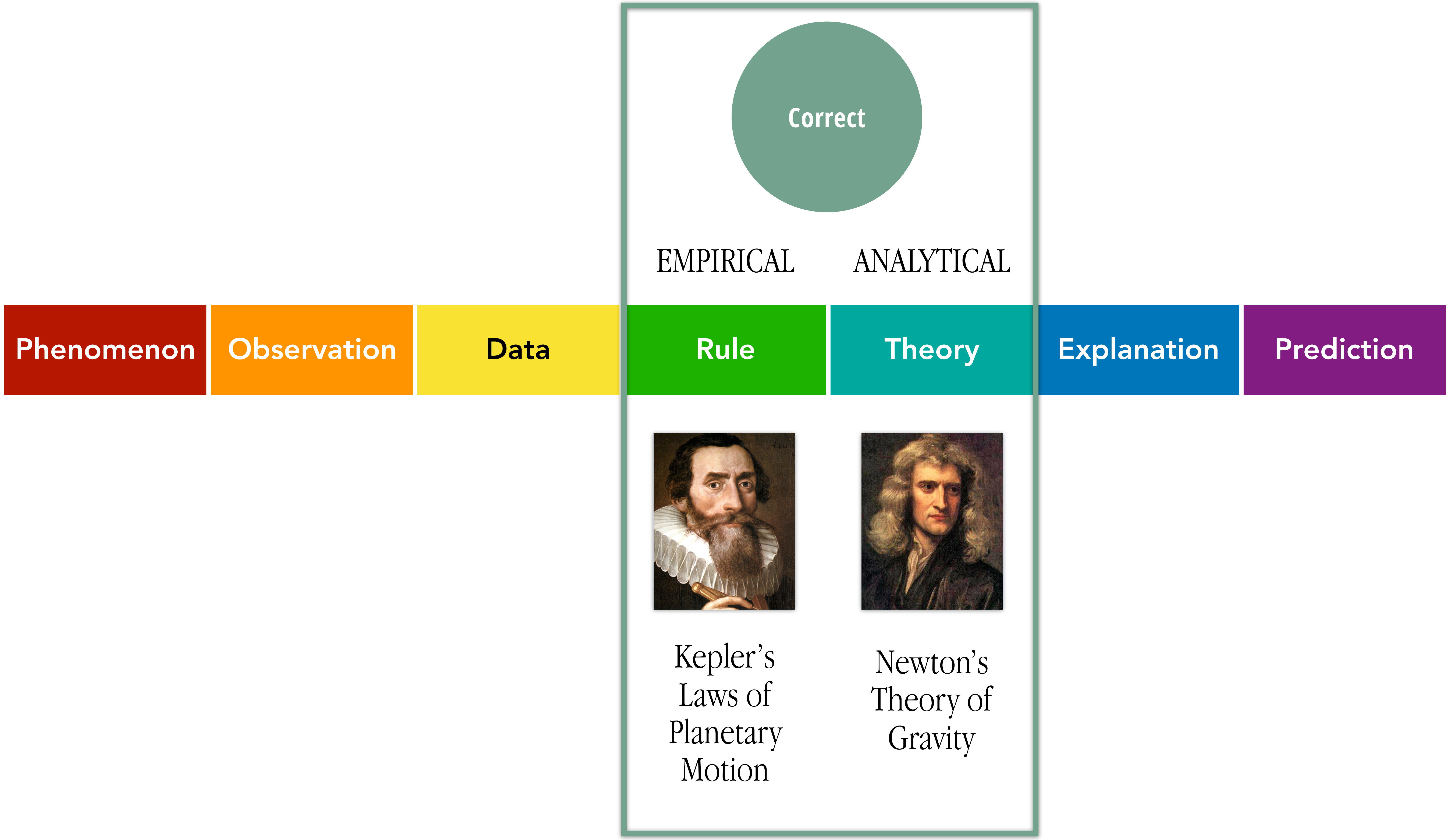
Version 2 . . . Simplify!

PREDICTIVE SYSTEMS

Phenomenon | Observation* | Data | Rule | Theory | Explanation | Prediction

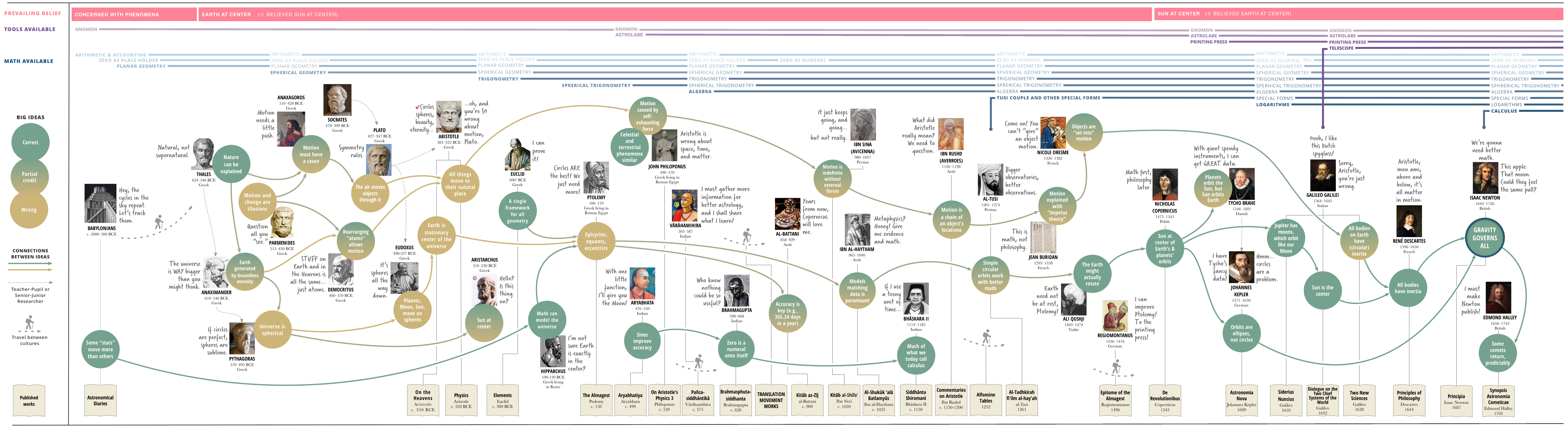


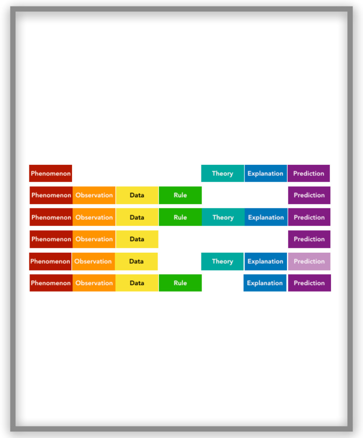
or, Experiment


Correct
EMPIRICAL
ANALYTICAL
Phenomenon
Observation
Data
Rule
Theory
Explanation
Prediction
Kepler's Laws of Planetary Motion
Newton's Theory of Gravity

Phenomenon	Observation	Data	Rule	Theory	Explanation	Prediction

The Path to Newton



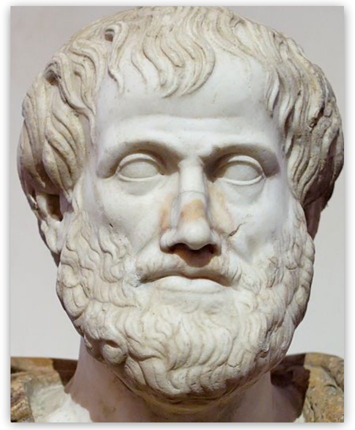


Wrong

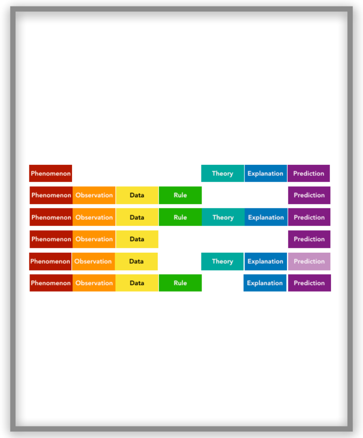
EMPIRICAL | ANALYTICAL

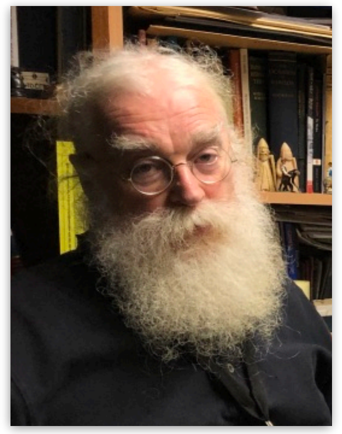
Phenomenon	Observation	Data	Rule	Theory	Explanation	Prediction

Ptolemy's Epicycles

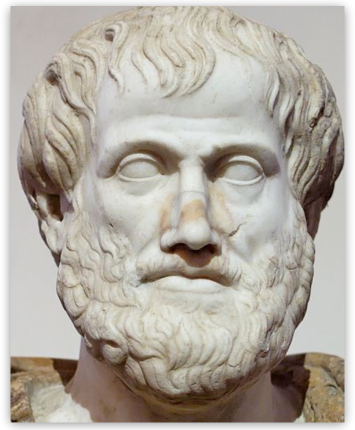


Aristotle's Natural Philosophy



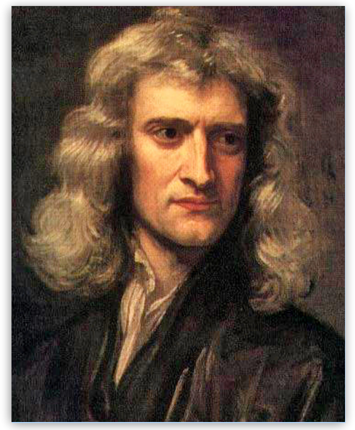


Babylonians



Aristotle

Kepler



Newton

Babylonians	Phenomenon	Observation	Data	Rule			
Aristotle	Phenomenon	Observation			Theory	Explanation	Prediction
Kepler	Phenomenon	Observation	Data	Rule			Prediction
Newton	Phenomenon	Observation	Data	Rule	Theory	Explanation	Prediction

PREDICTIVE SYSTEMS

EMPIRICAL | STATISTICAL

Phenomenon	Observation*	Data	Rule	Theory	Explanation	Prediction

Mendel's Rules

Darwin's Theory of Evolution

or, Experiment

PREDICTIVE SYSTEMS

Mendel

Phenomenon	Observation	Data	Rule			Prediction

Darwin

Phenomenon	Observation	Data		Theory	Explanation	Prediction

Mendel

Phenomenon	Observation	Data	Rule			Prediction

Darwin

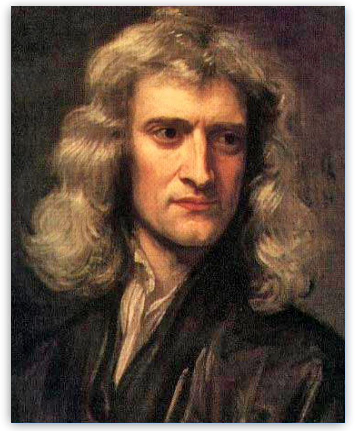
Phenomenon	Observation	Data		Theory	Explanation	Prediction

"YOUR" WORLD (BIOLOGY)

MY WORLD (PHYSICS)

Kepler

Phenomenon	Observation	Data	Rule			Prediction



Newton

Phenomenon	Observation	Data	Rule	Theory	Explanation	Prediction

Mendel

Phenomenon | Observation | Data | Rule | Prediction

Darwin

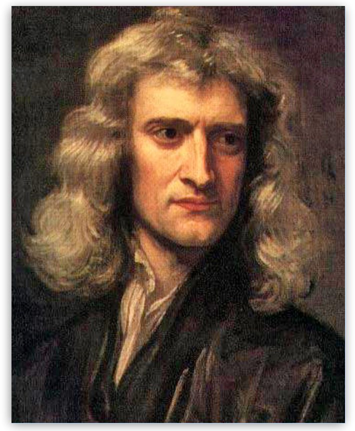
Phenomenon | Observation | Data | Theory | Explanation | Prediction

NO FULLY PREDICTIVE GENERAL THEORY

FULLY PREDICTIVE GENERAL THOERY

Kepler

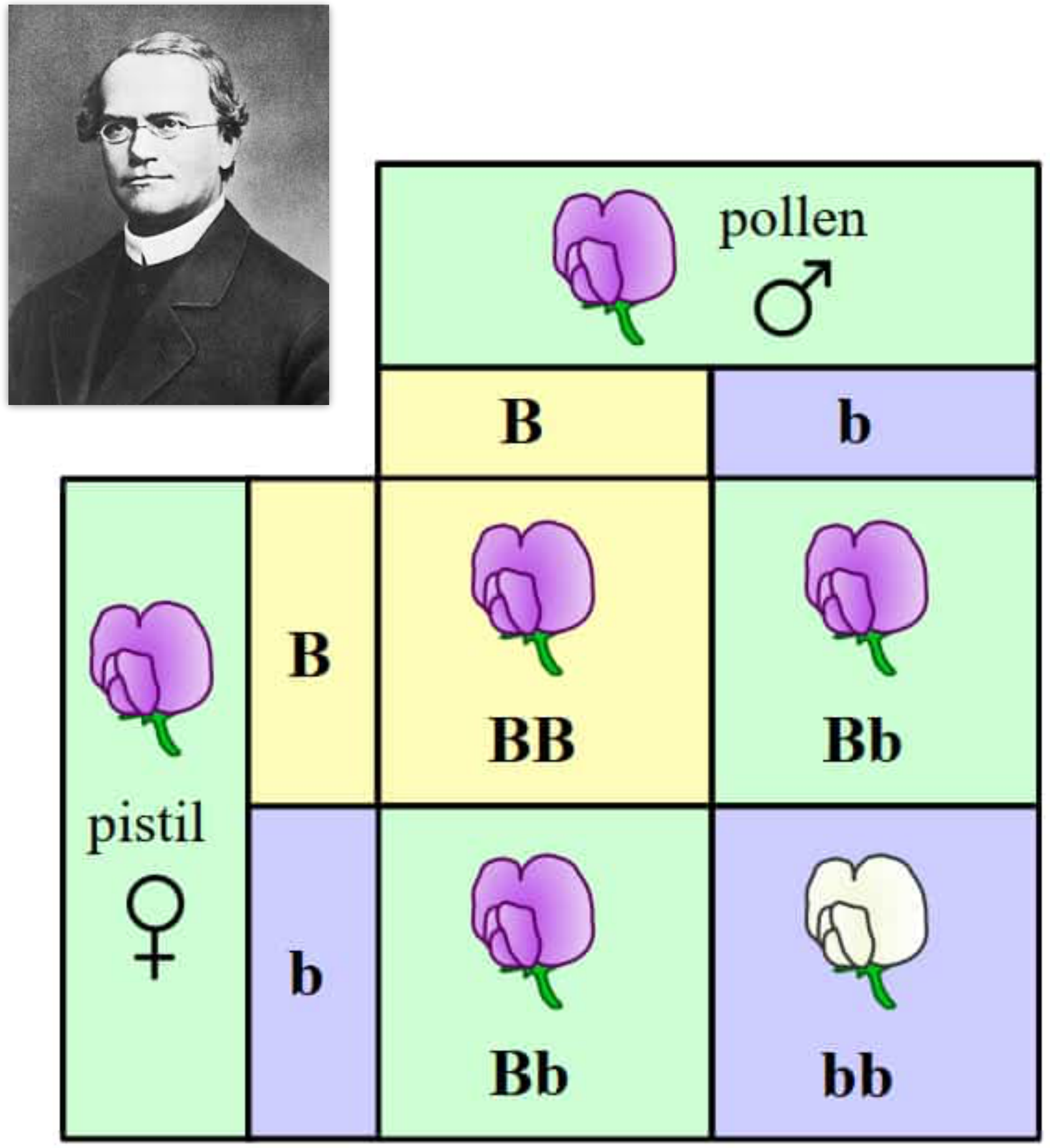
Phenomenon | Observation | Data | Rule | Prediction

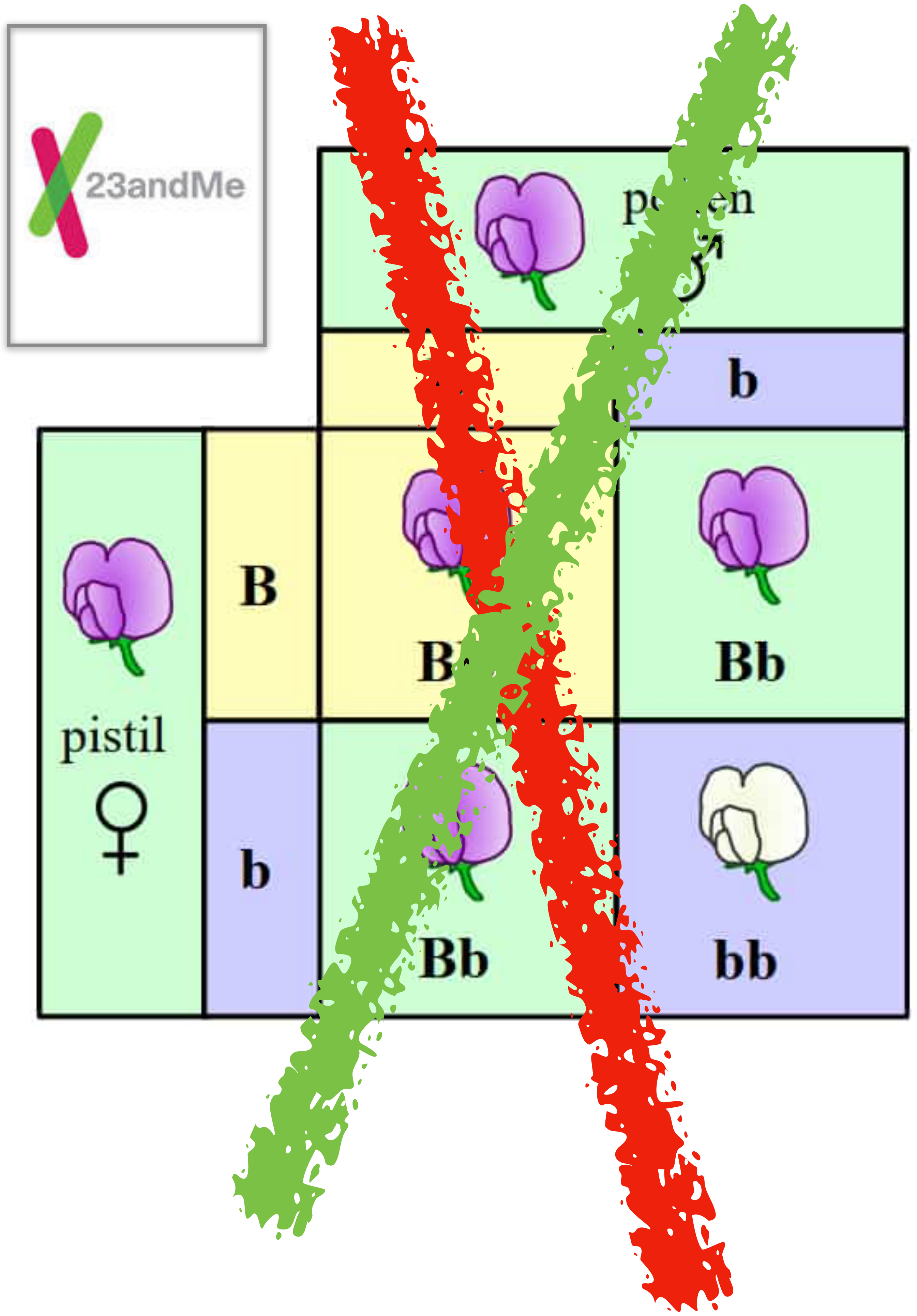


Newton

Phenomenon | Observation | Data | Rule | Theory | Explanation | Prediction

NO FULLY PREDICTIVE GENERAL THEORY





THE FUTURE OF THE FUTURE

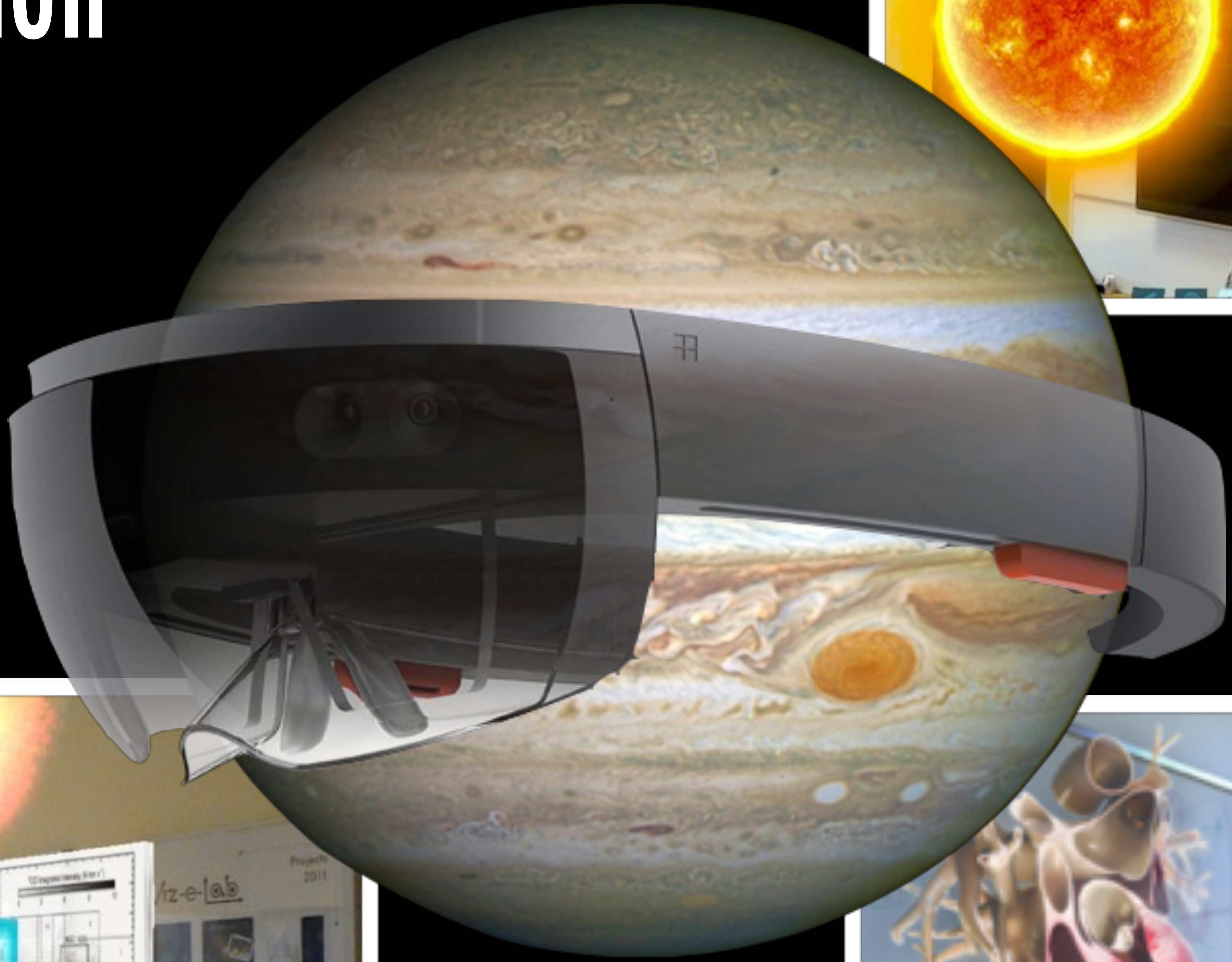
20th century

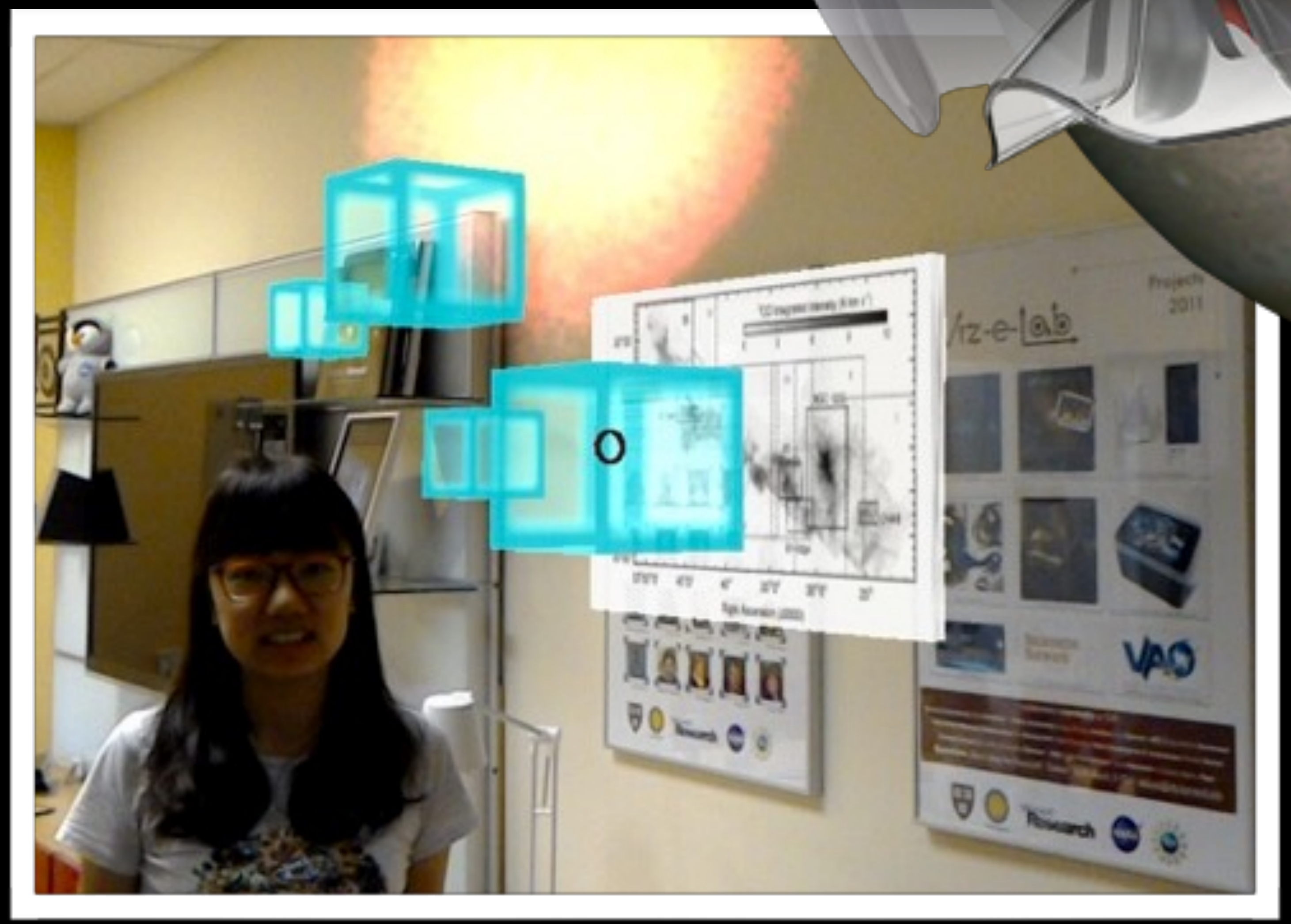
Phenomenon → Observation → Data → Rule → Theory → Explanation → Prediction

21st century?

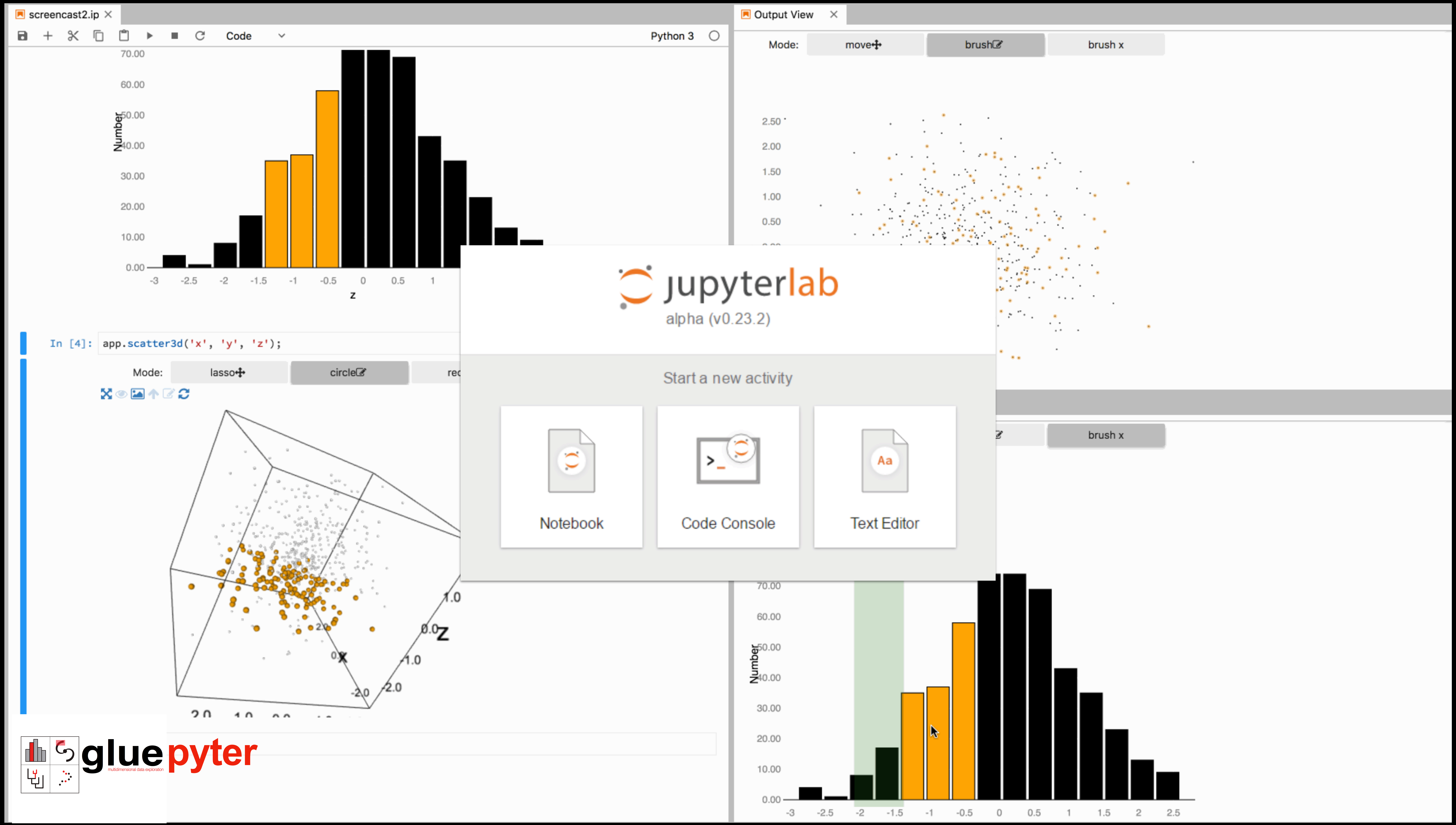
Phenomenon → Observation → Data → "machine learning" → Prediction

The challenge of 3D Selection





Coming next: glue in the browser



Video courtesy of Maarten Breddels, consulting developer

This is all possible, and happening now.

Not for everyone, though.

Critical to *evaluate adoption* & *refine* solutions
Michelle Borkin is doing this for glue
—look for results in Borkin, Goodman, Munzner et al. 2019