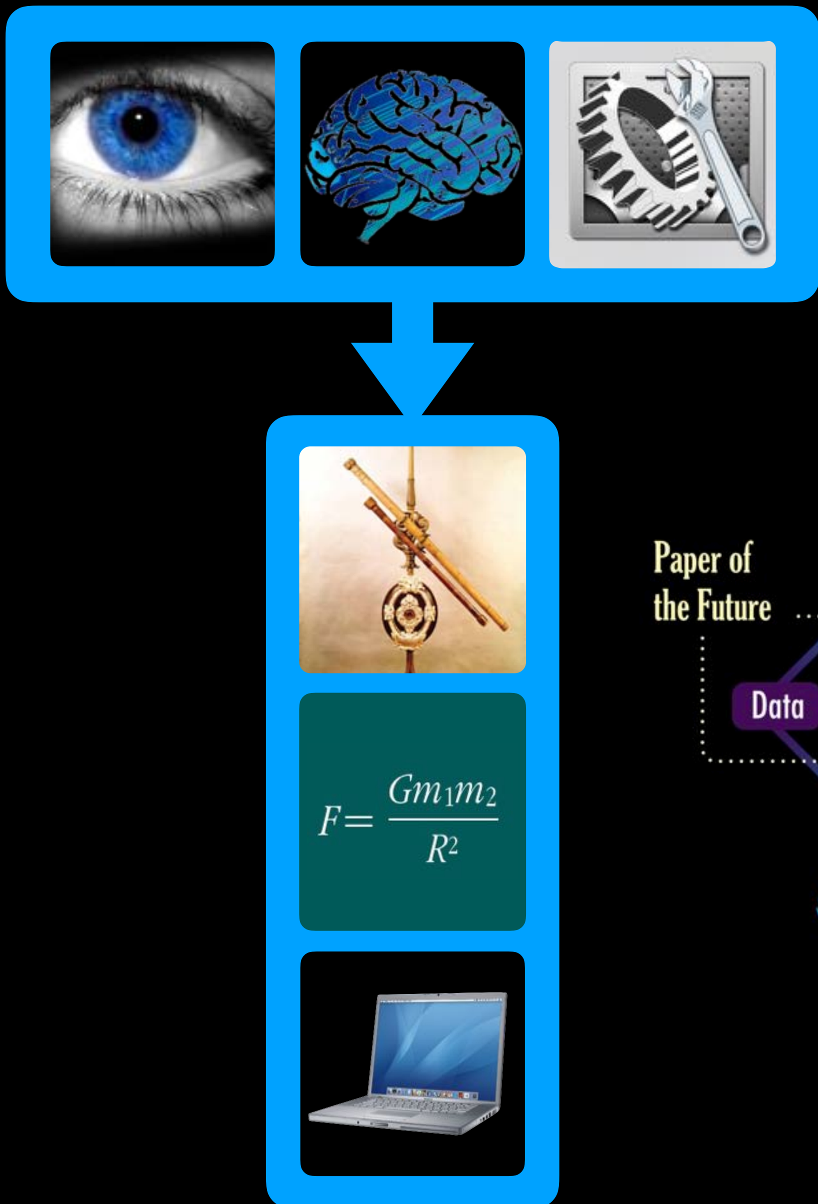
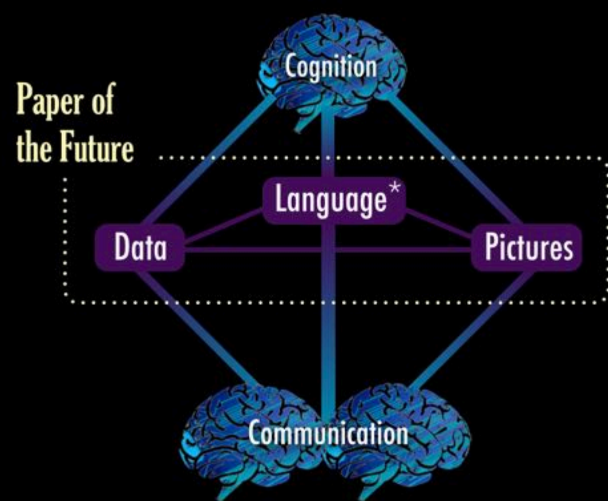
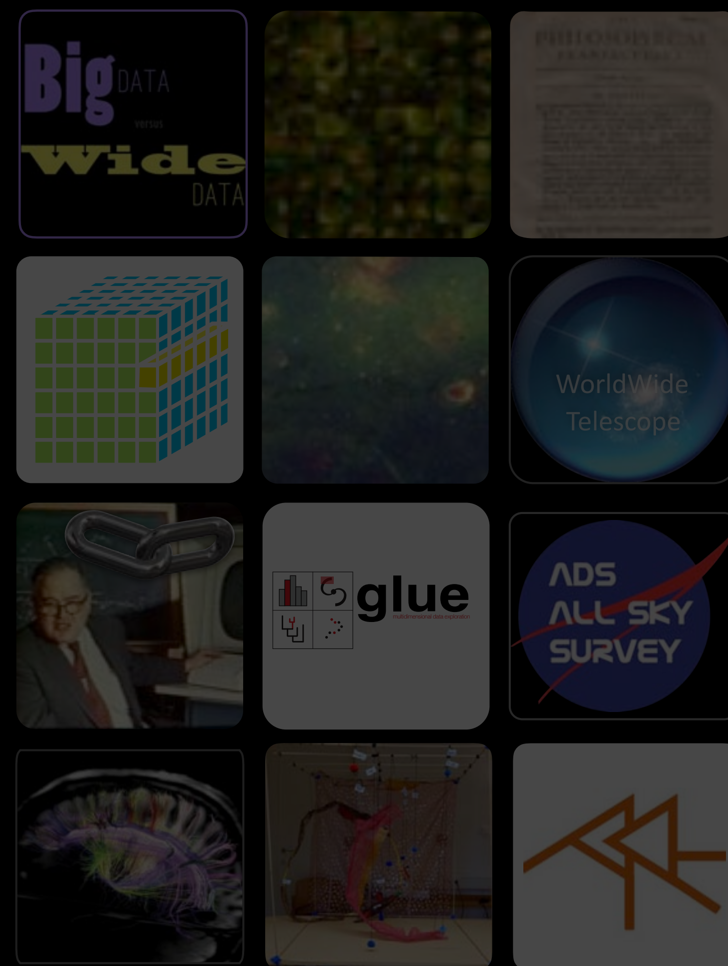
Seeing the Sky

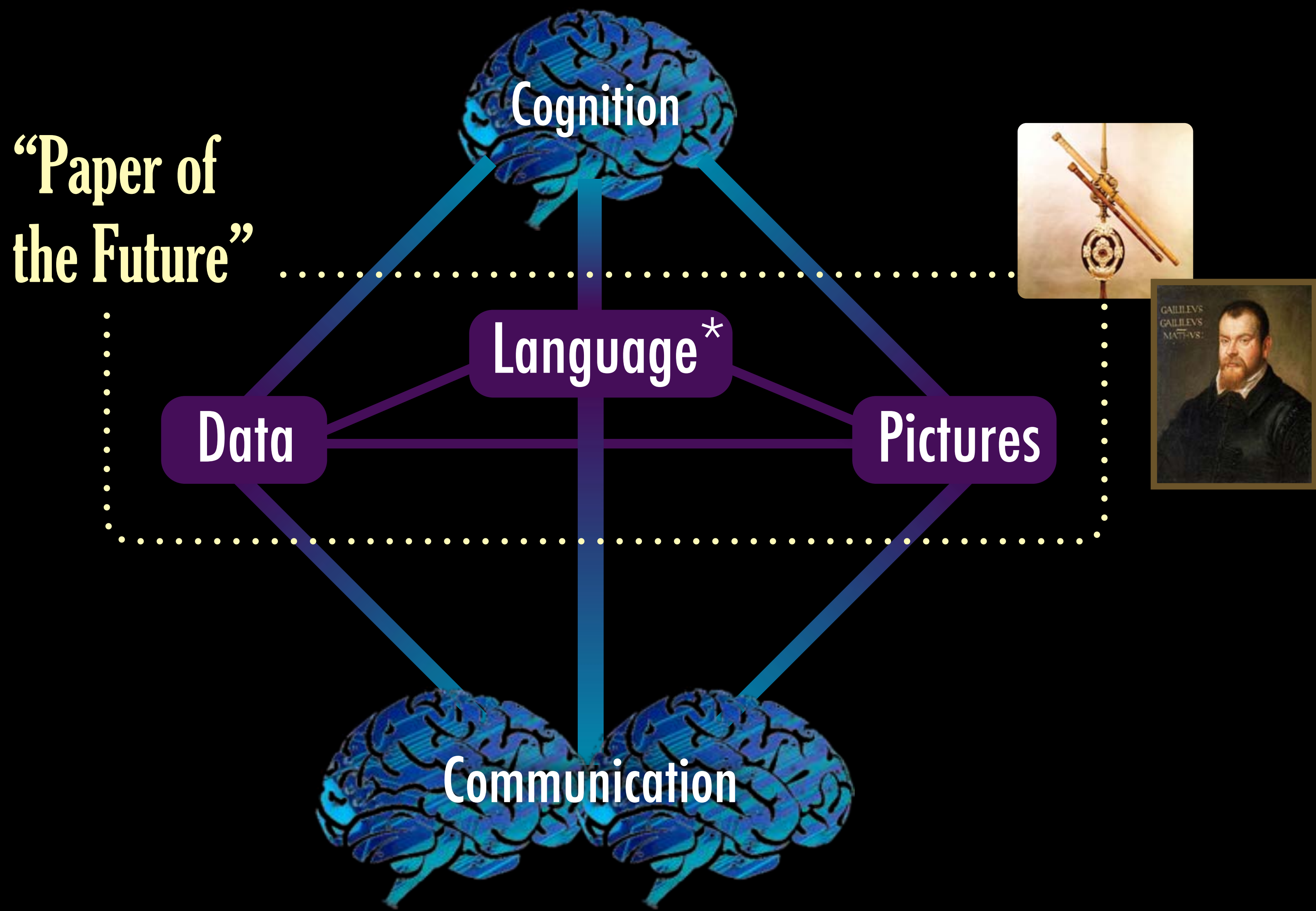
Visualization & Astronomers

Alyssa A. Goodman
Harvard Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study
@aagie


$F=\frac{Gm_1m_2}{R^2}$


Paper of
the Future
Cognition
Language*
Data
Pictures
Communication

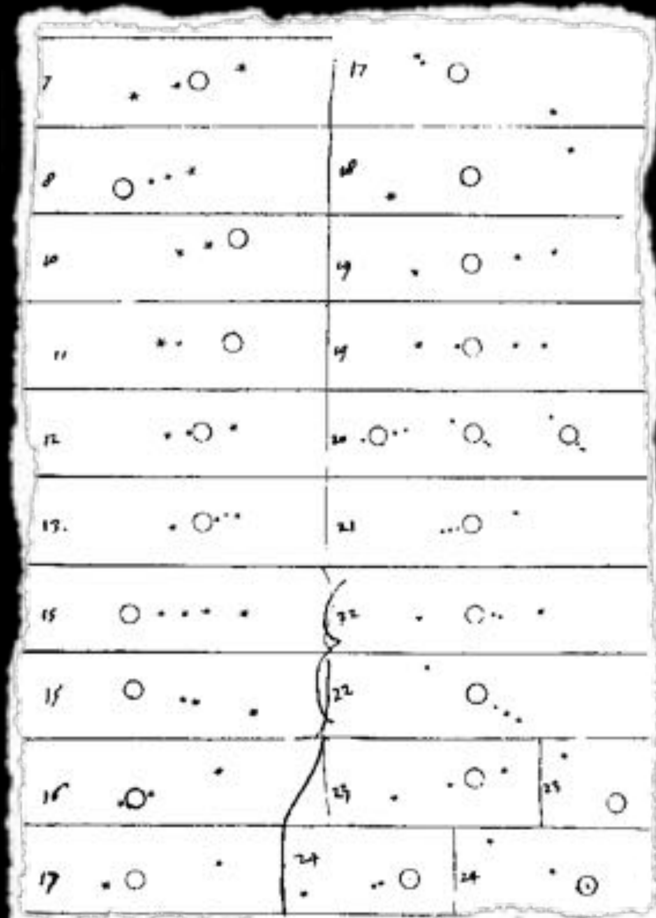

Big DATA
versus
Wide DATA
WorldWide Telescope
glue
ADS ALL SKY SURVEY

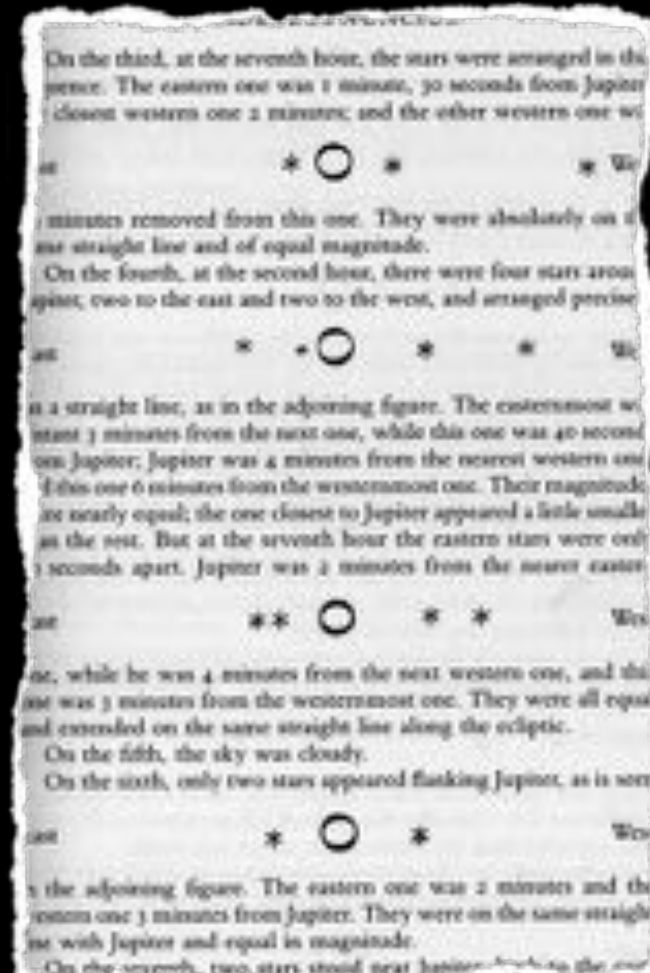


*"Language" includes words & math

Why Galileo is my Hero

Explore-Explain-Explore





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

minutes removed from this one. They were absolutely on t
me straight line and of equal magnitude.
On the fourth, at the second hour, there were four stars arou
piter, two to the east and two to the west, and arranged precise

a straight line, as in the adjoining figure. The easternmost w
tant 3 minutes from the next one, while this one was 40 second
om Jupiter; Jupiter was 4 minutes from the nearest western one
d this one 6 minutes from the westernmost one. Their magnitude
re nearly equal; the one closest to Jupiter appeared a little smalle
an the rest. But at the seventh hour the eastern stars were onl
seconds apart. Jupiter was 2 minutes from the nearer easter

ne, while he was 4 minutes from the next western one, and thi
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 see
the adjoining figure. The eastern one was 2 minutes and the
stern one 3 minutes from Jupiter. They were on the same straigh
ne with Jupiter and equal in magnitude.

Notes for & re-productions of Siderius Nuncius

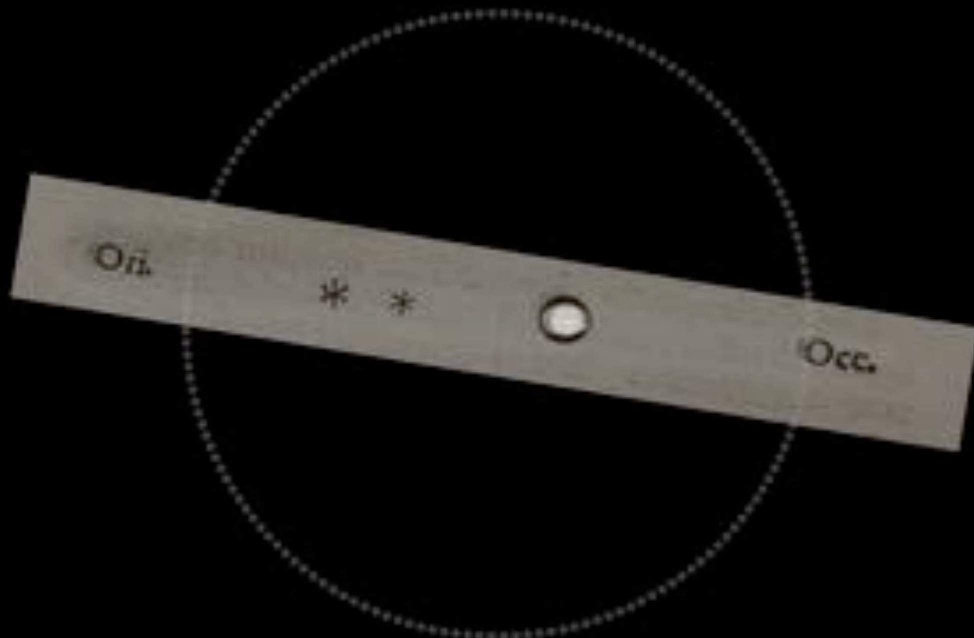
1610

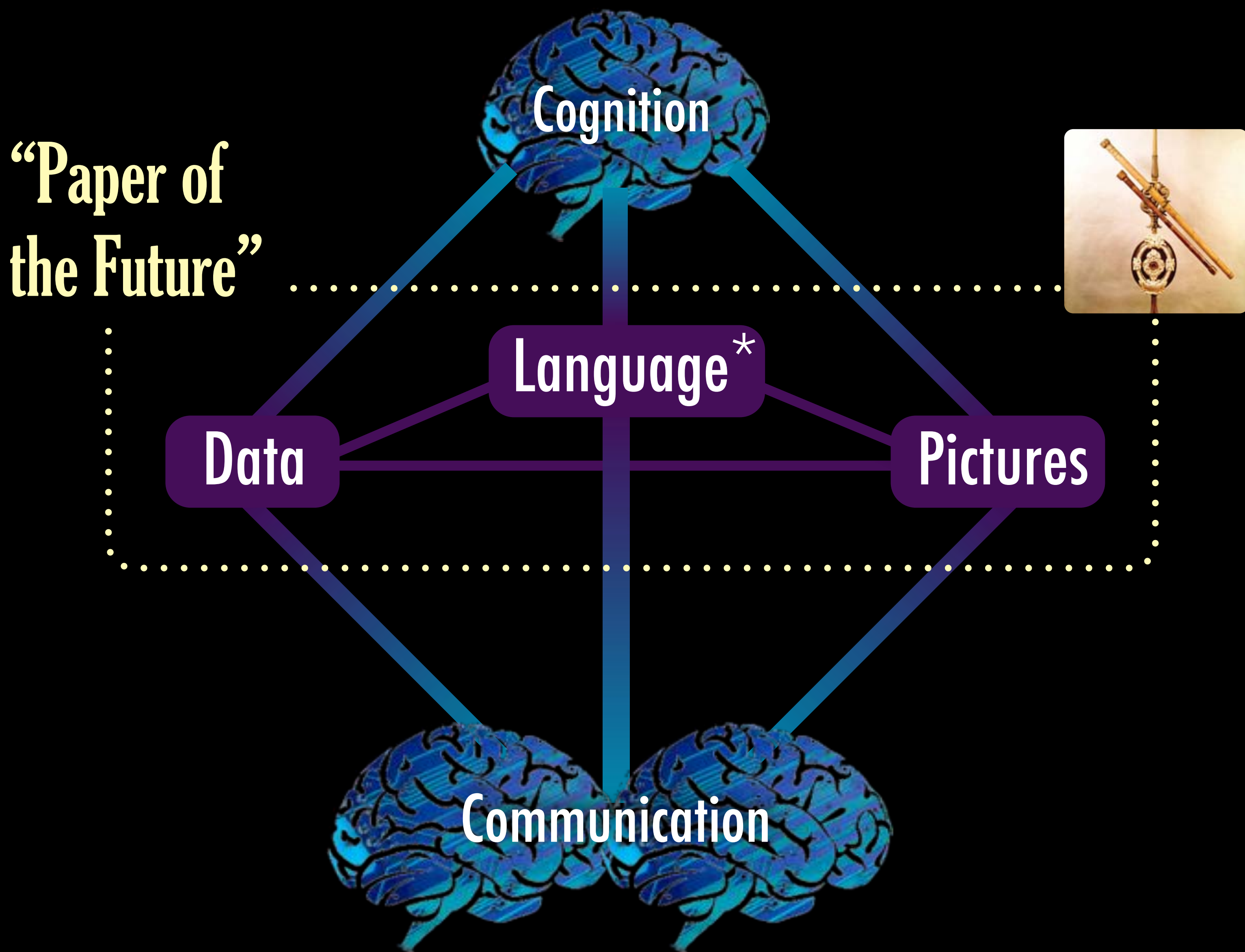
GALILEO'S "NEW ORDER"

Created by Alyssa Goodman, Curtis Wong and Pat Udomprasert,
with advice from Owen Gingerich and David Malin

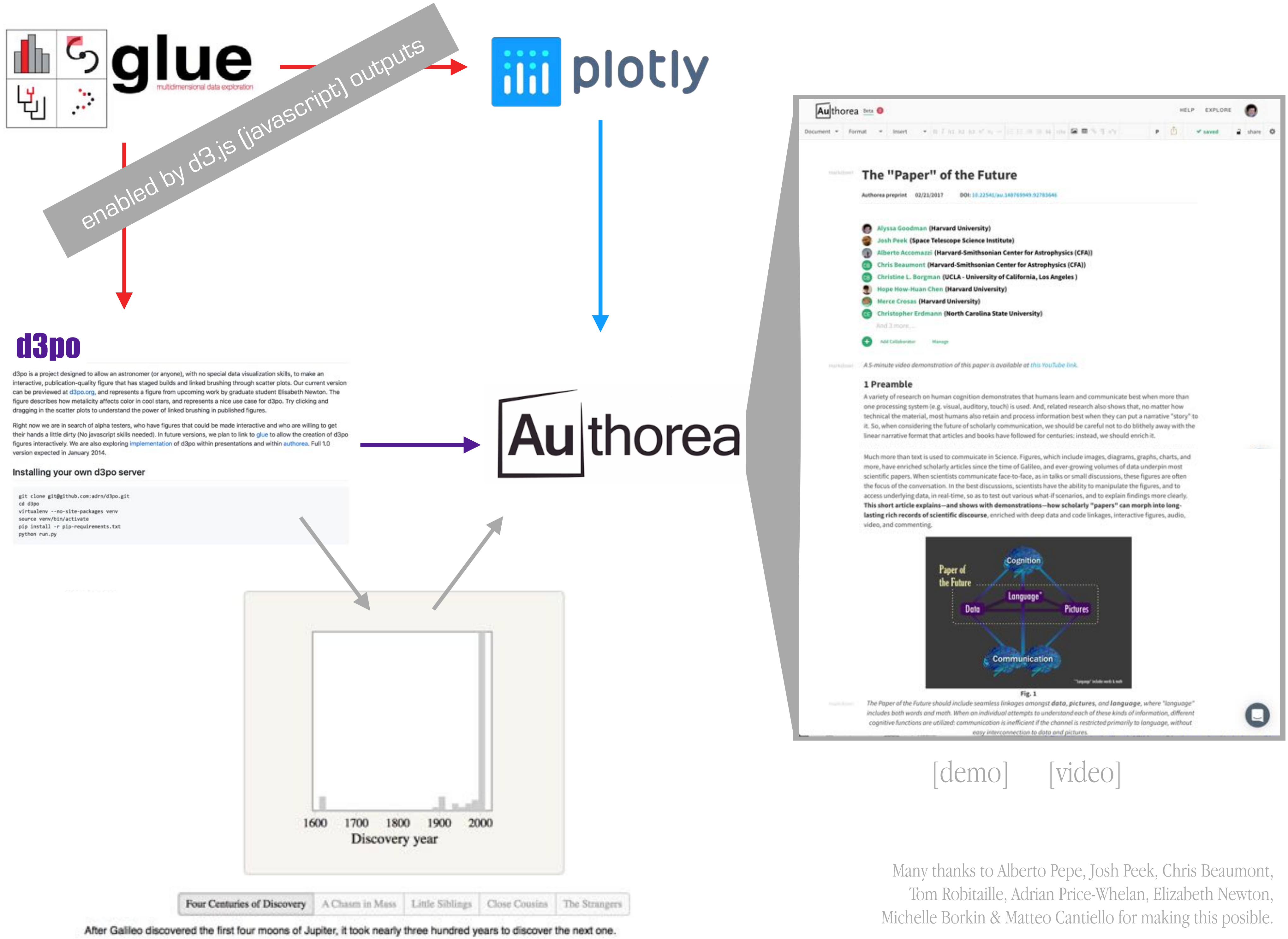
Galileo's New Order, A WorldWide Telescope Tour by Goodman, Wong & Udomprasert 2010
WWT Software Wong (inventor, MS Research), Fay (architect, MS Reseearch), et al., now open source, hosted by AAS, Phil Rosenfield, Director
see wwtambassadors.org for more on WWT Outreach

January 11, 1610



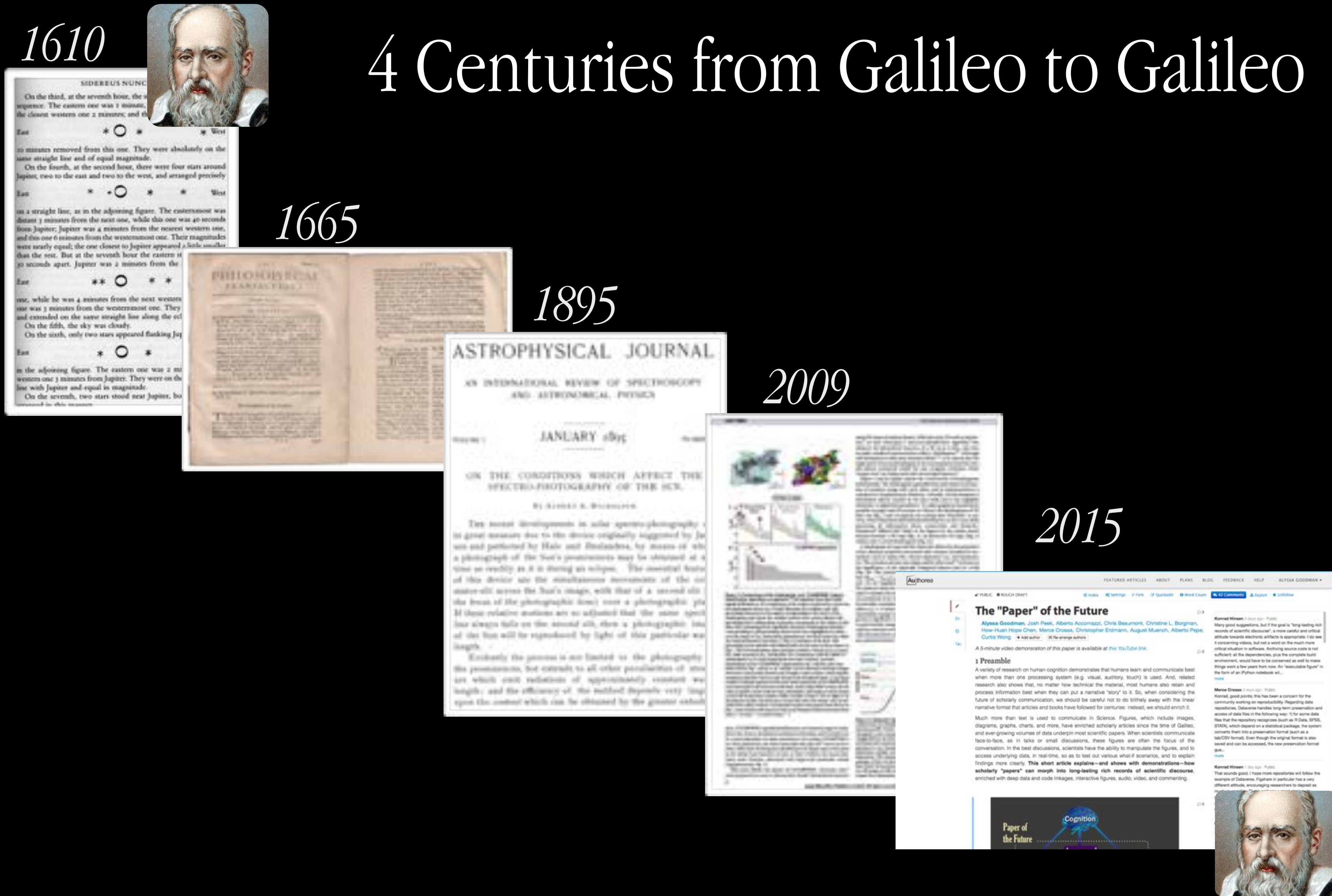


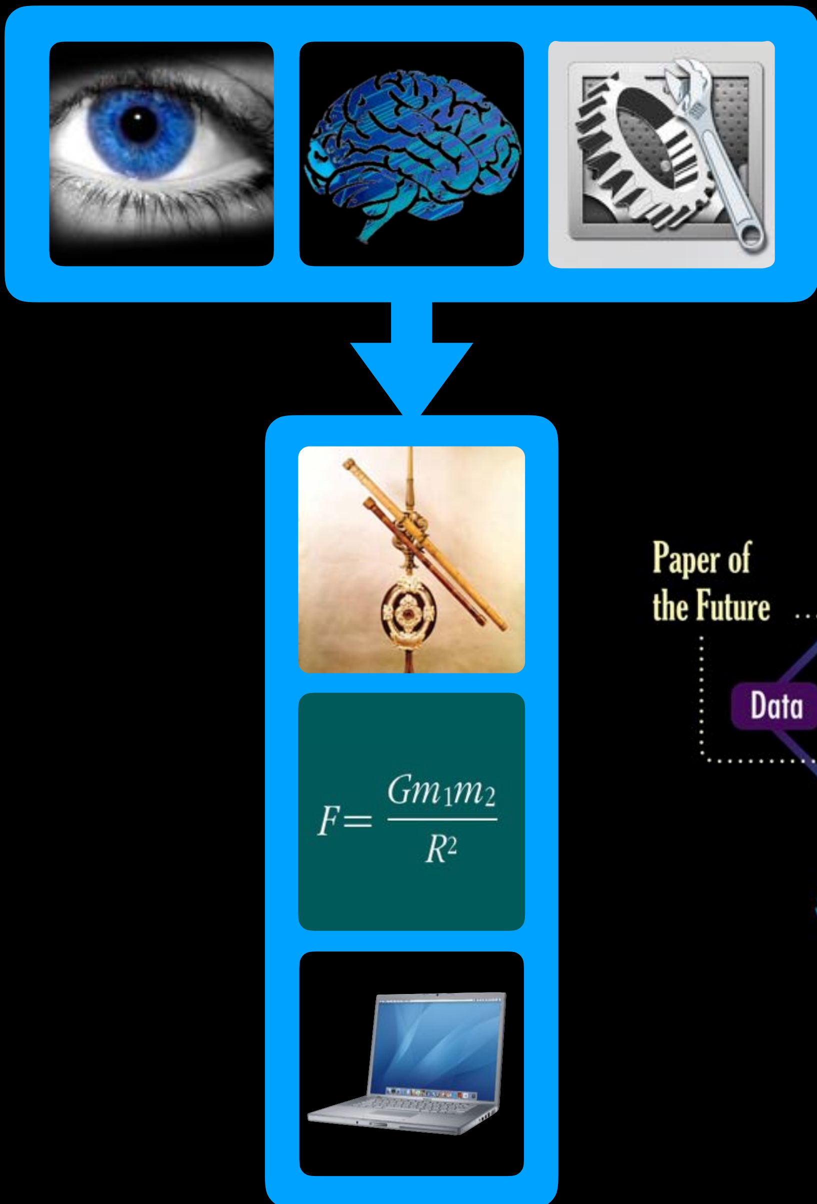
*"Language" includes words & math



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

4 Centuries from Galileo to Galileo

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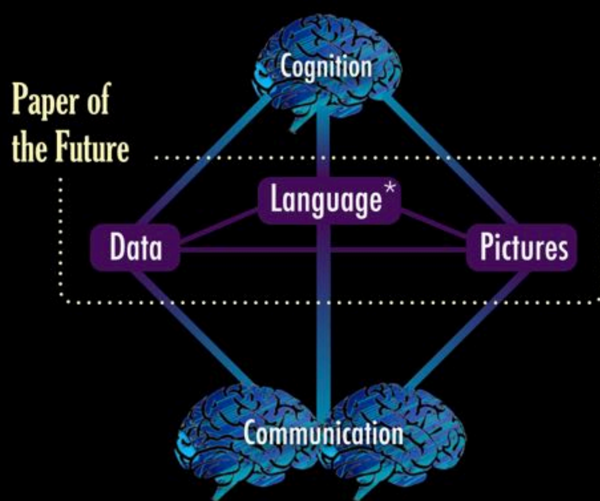
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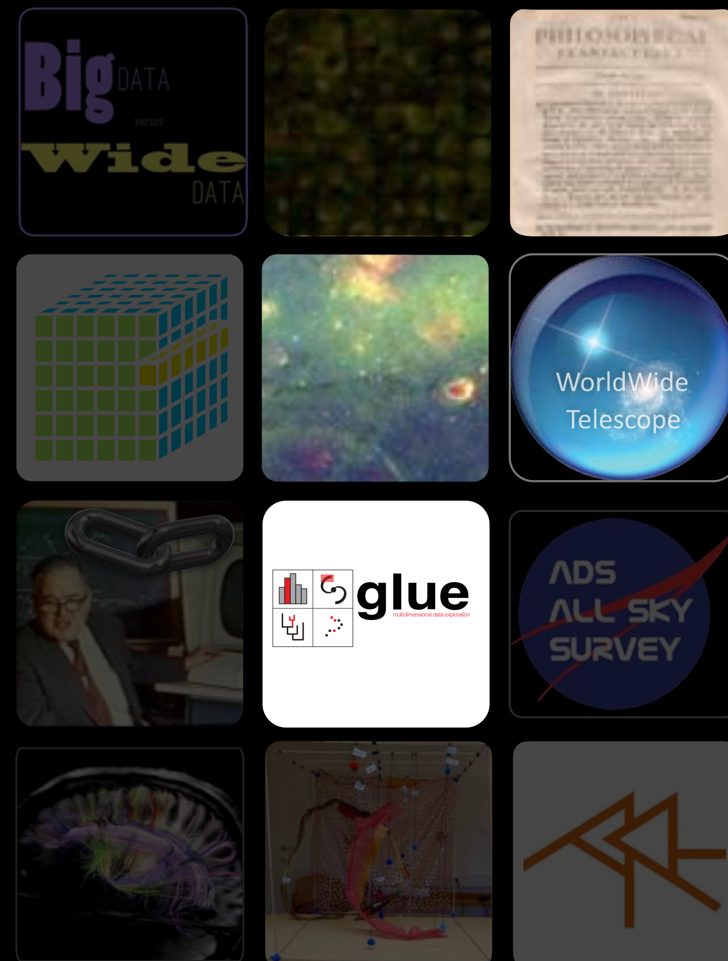
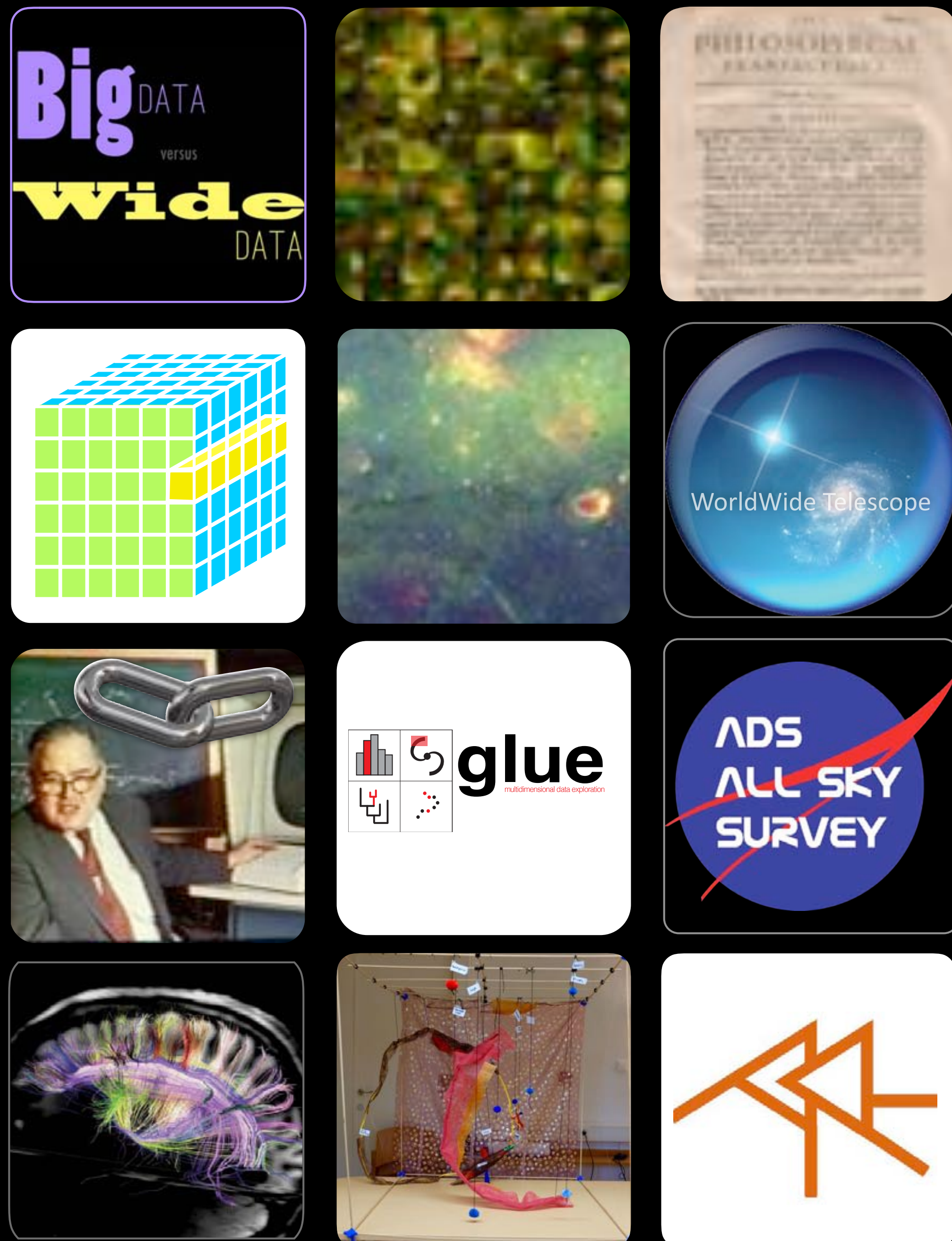

Big DATA
Wide DATA
WorldWide
Telescope
glue
ADS
ALL SKY
SURVEY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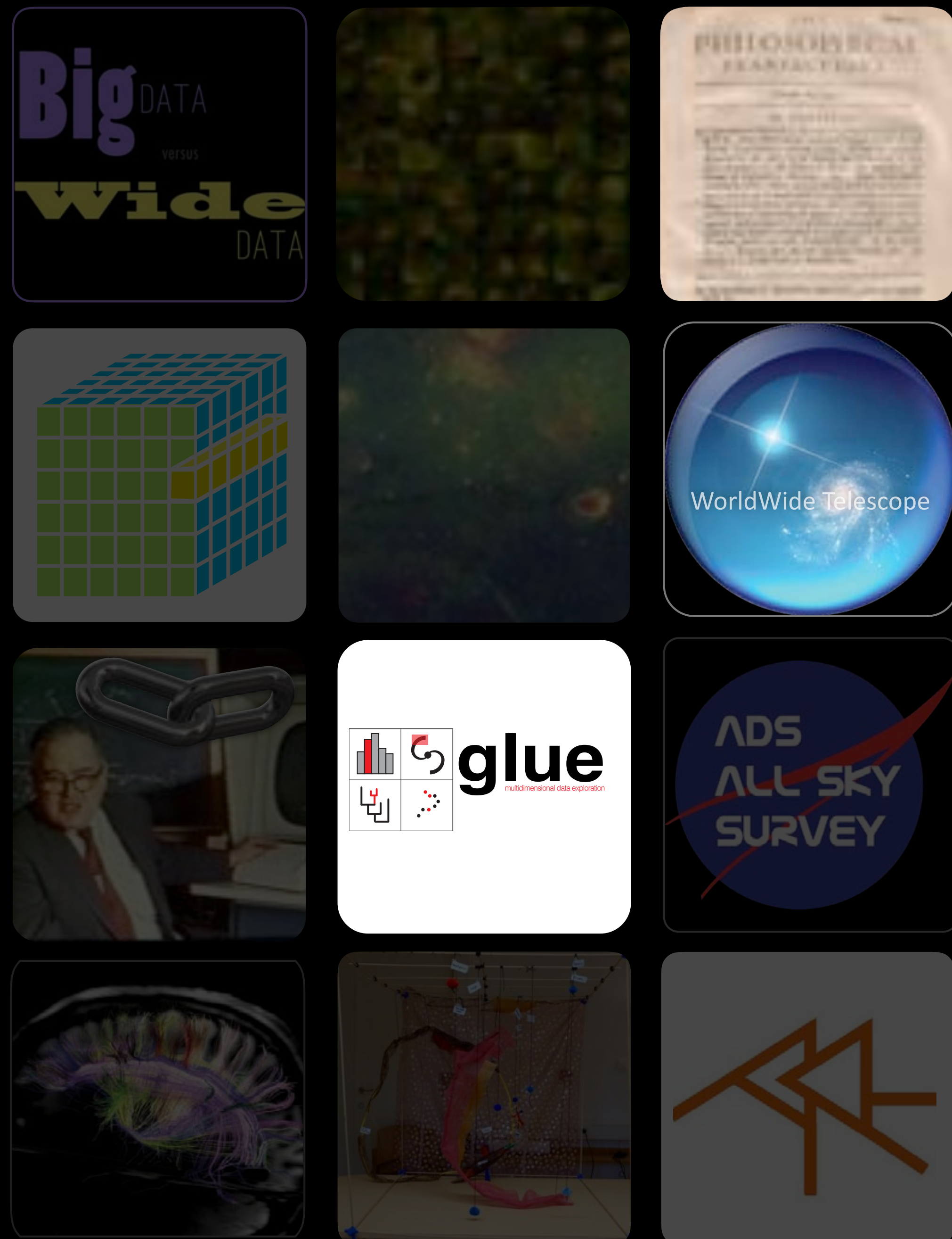
versus
Wide DATA
WorldWide Telescope
glue
multidimensional data exploration
ADS
ALL SKY
SURVEY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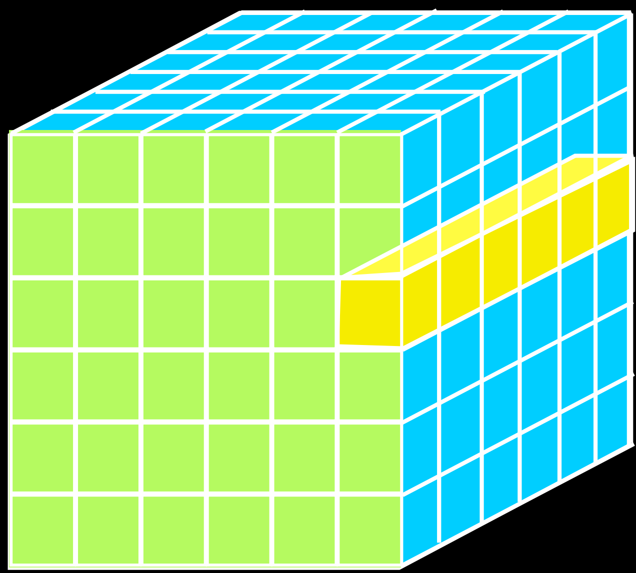


Data, Dimensions, Display

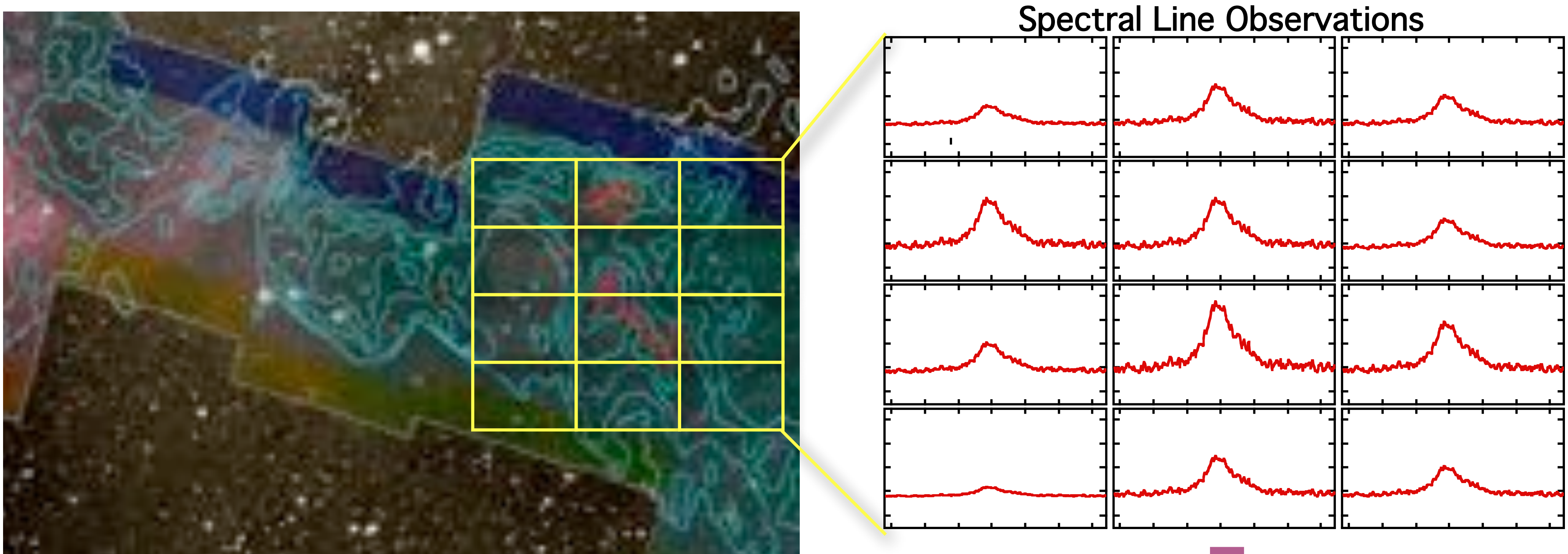
1D: Columns = “Spectra”, “SEDs” or “Time Series”

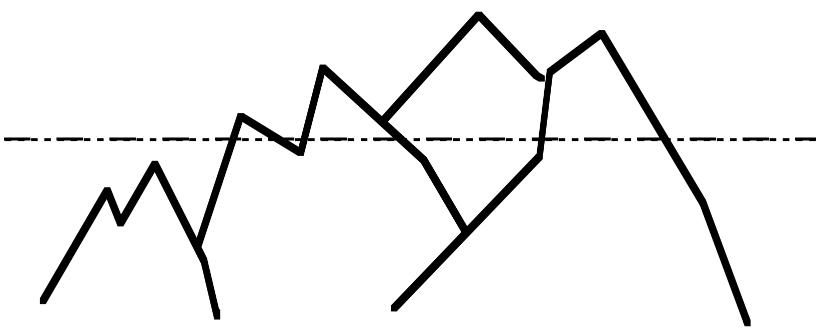
2D: Faces or Slices = “Images”

3D: Volumes = “3D Renderings”, “2D Movies”

4D: Time Series of Volumes = “3D Movies”

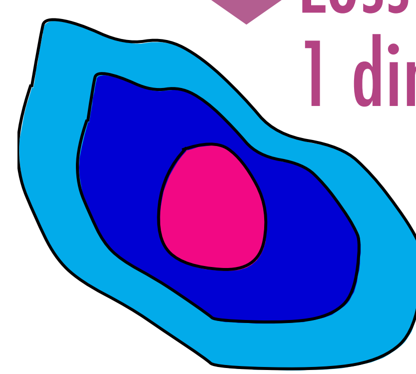
Data, Dimensions, Display



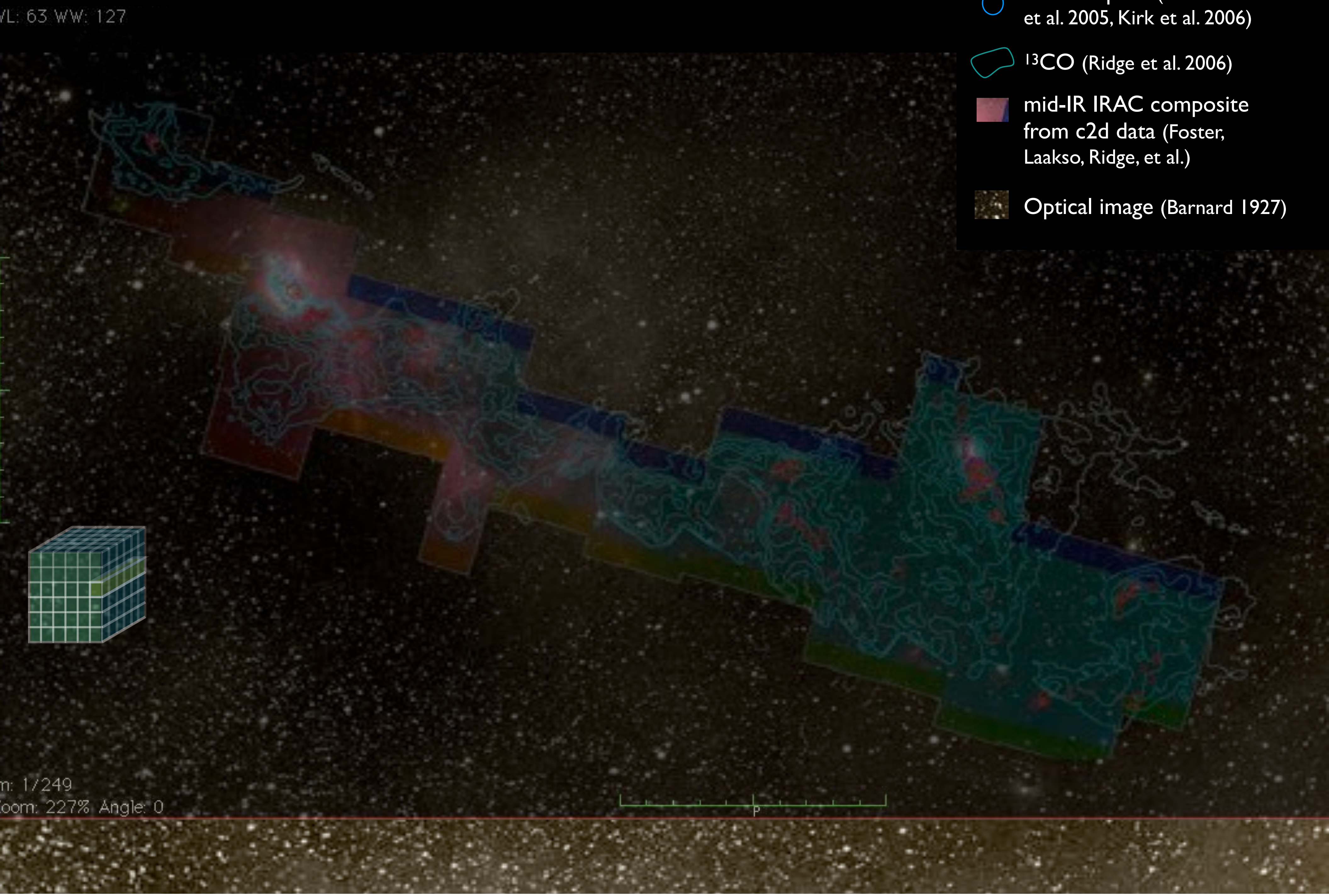


No loss of information

Loss of 1 dimension



Data, Dimensions, Display



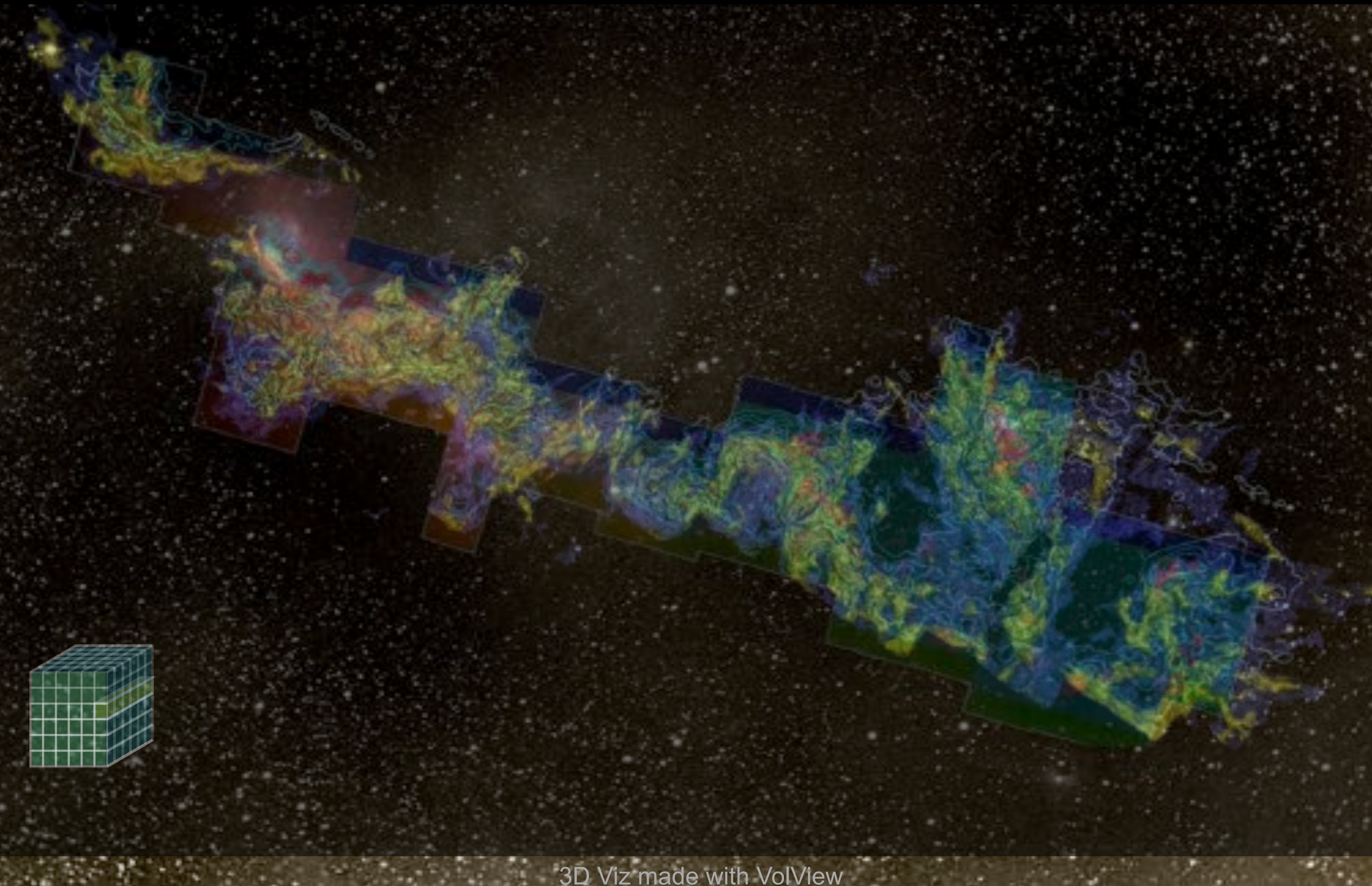
mm peak (Enoch et al. 2006)

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

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

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

Optical image (Barnard 1927)



AstronomicalMedicine@IIC

COMPLETE

2009

3D PDF

High-Dimensional data in a "Paper" on its way to the Future

[demo/video]

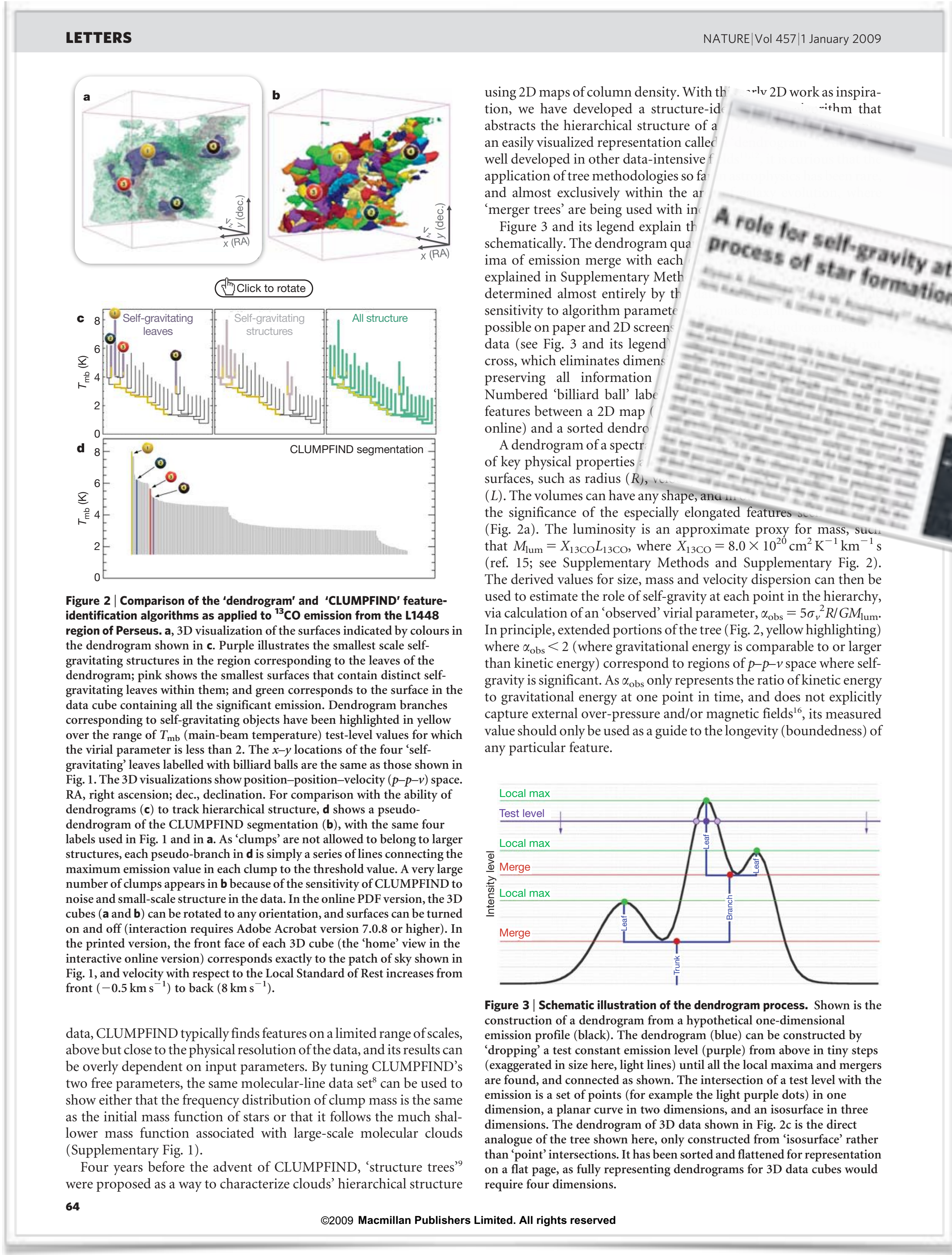


Figure 2 | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. **a**, 3D visualization of the surfaces indicated by colours in the dendrogram shown in **c**. Purple illustrates the smallest scale self-gravitating 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 ($-0.5\ \mathrm{km\,s^{-1}}$) to back ($8\ \mathrm{km\,s^{-1}}$).

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).

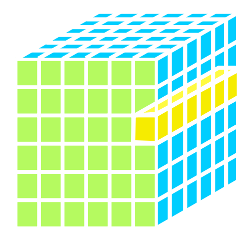
Four years before the advent of CLUMPFIND, 'structure trees'[9] were proposed as a way to characterize clouds' hierarchical structure

using 2D maps of column density. With th ... 2D work as inspira-
tion, we have developed a structure-id ... rithm that
abstracts the hierarchical structure of a
an easily visualized representation callec
well developed in other data-intensive f
application of tree methodologies so fa
and almost exclusively within the ar
'merger trees' are being used with in

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

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

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



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

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

LETTERS

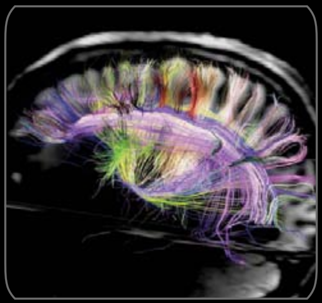
A role for self-gravity at multiple length scales in the process of star formation

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

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

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

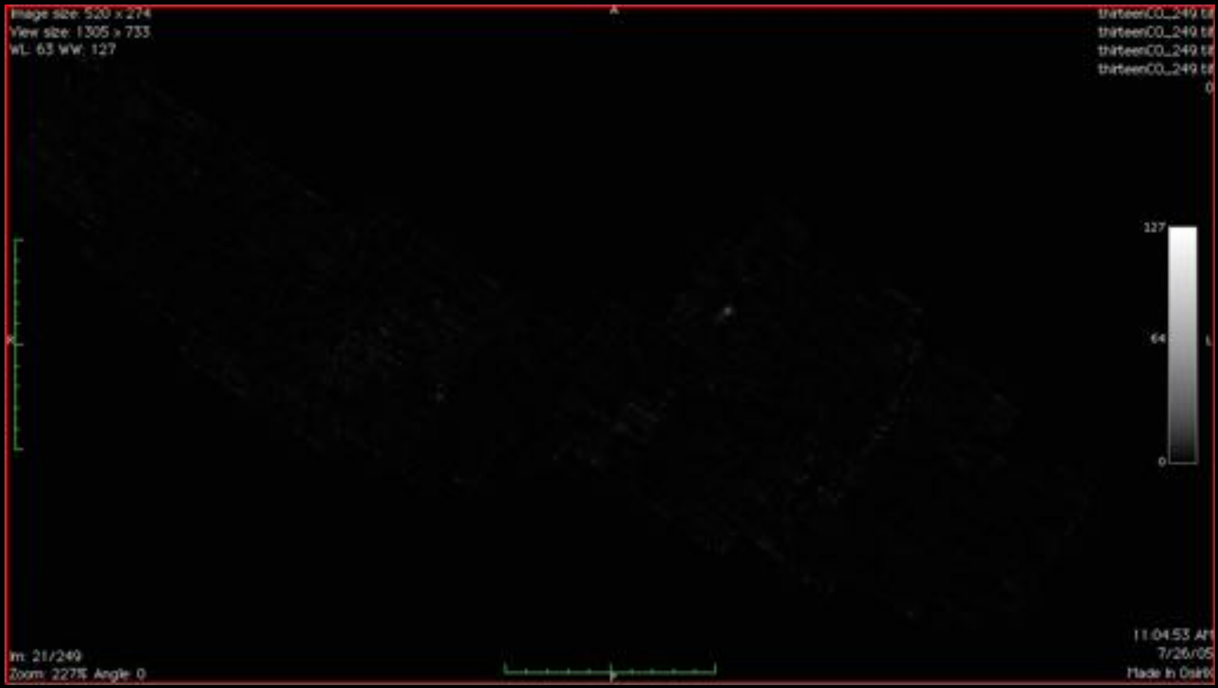
Why AstronomicalMedicine?



"KEITH"

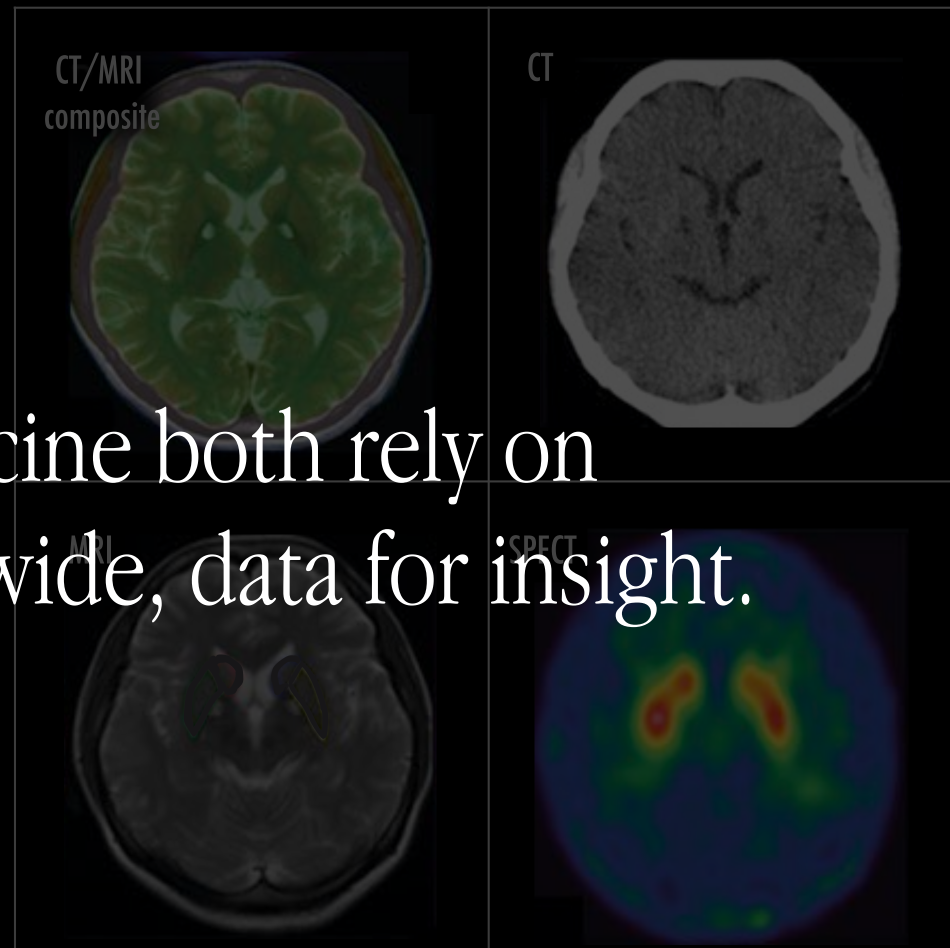
"z" is depth into head

"PERSEUS"



"z" is line-of-sight velocity

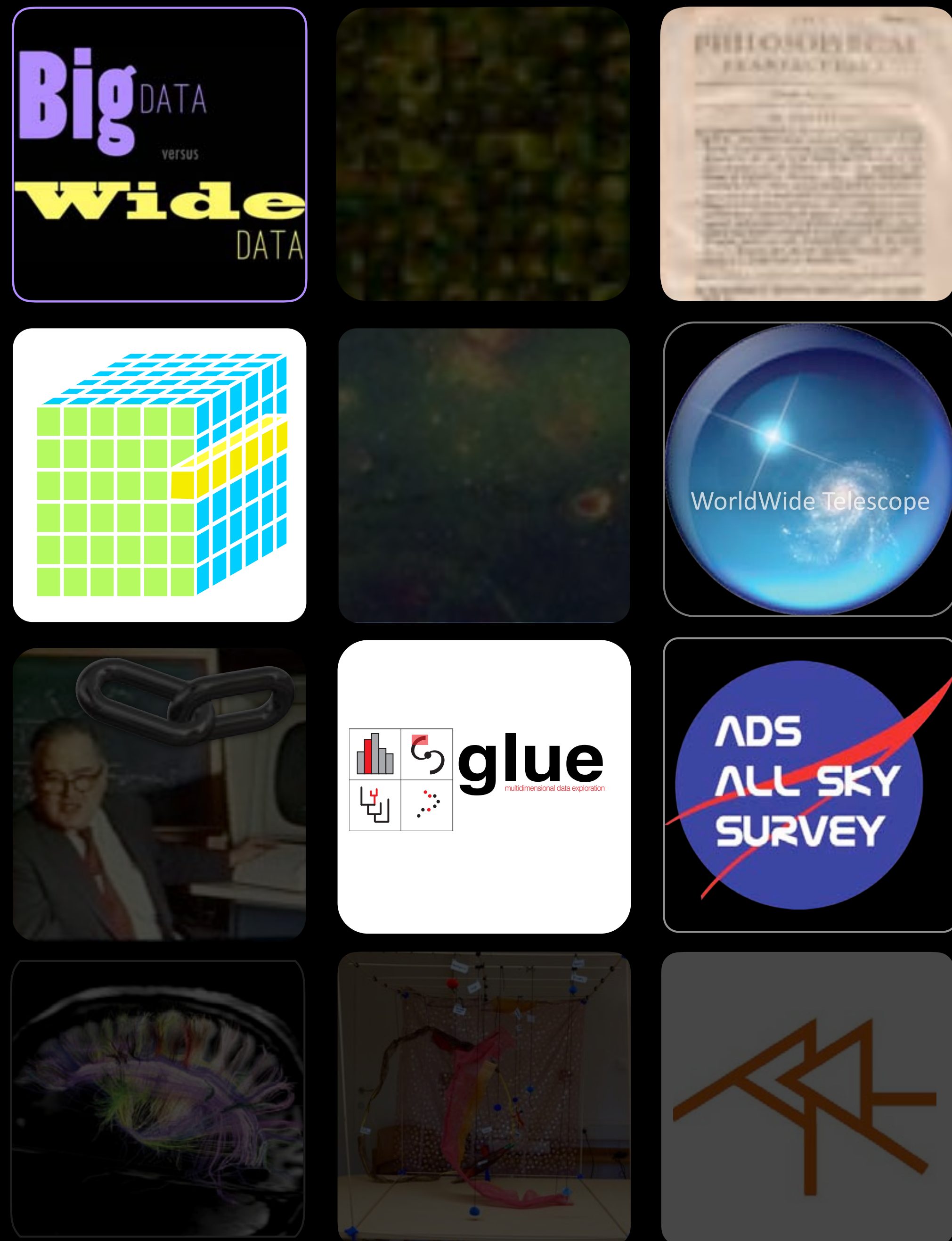
Why AstronomicalMedicine?



Astronomy & Medicine both rely on high-dimensional, big, wide, data for insight.

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

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


Big DATA
versus
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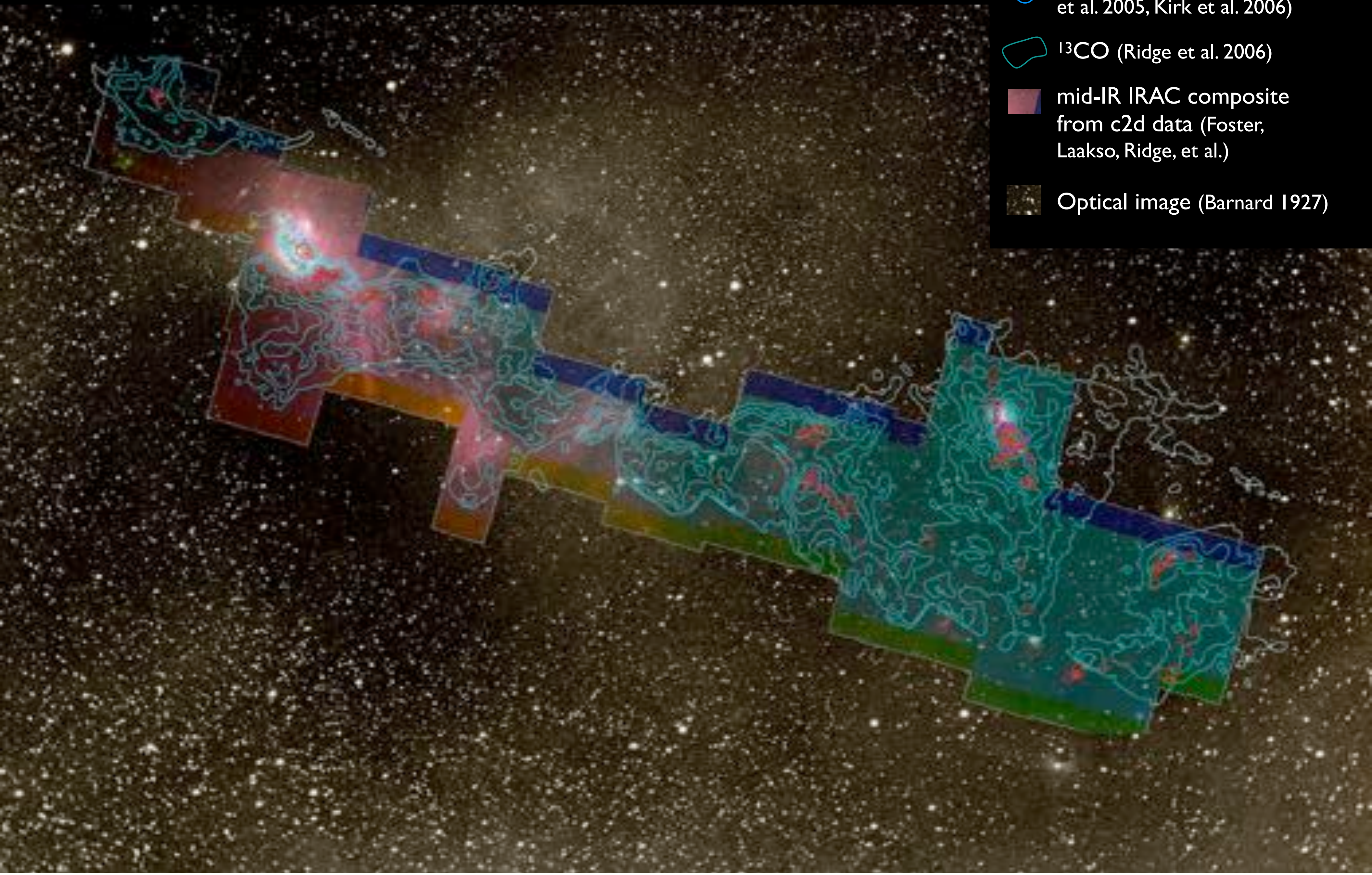
ADS ALL SKY SURVEY

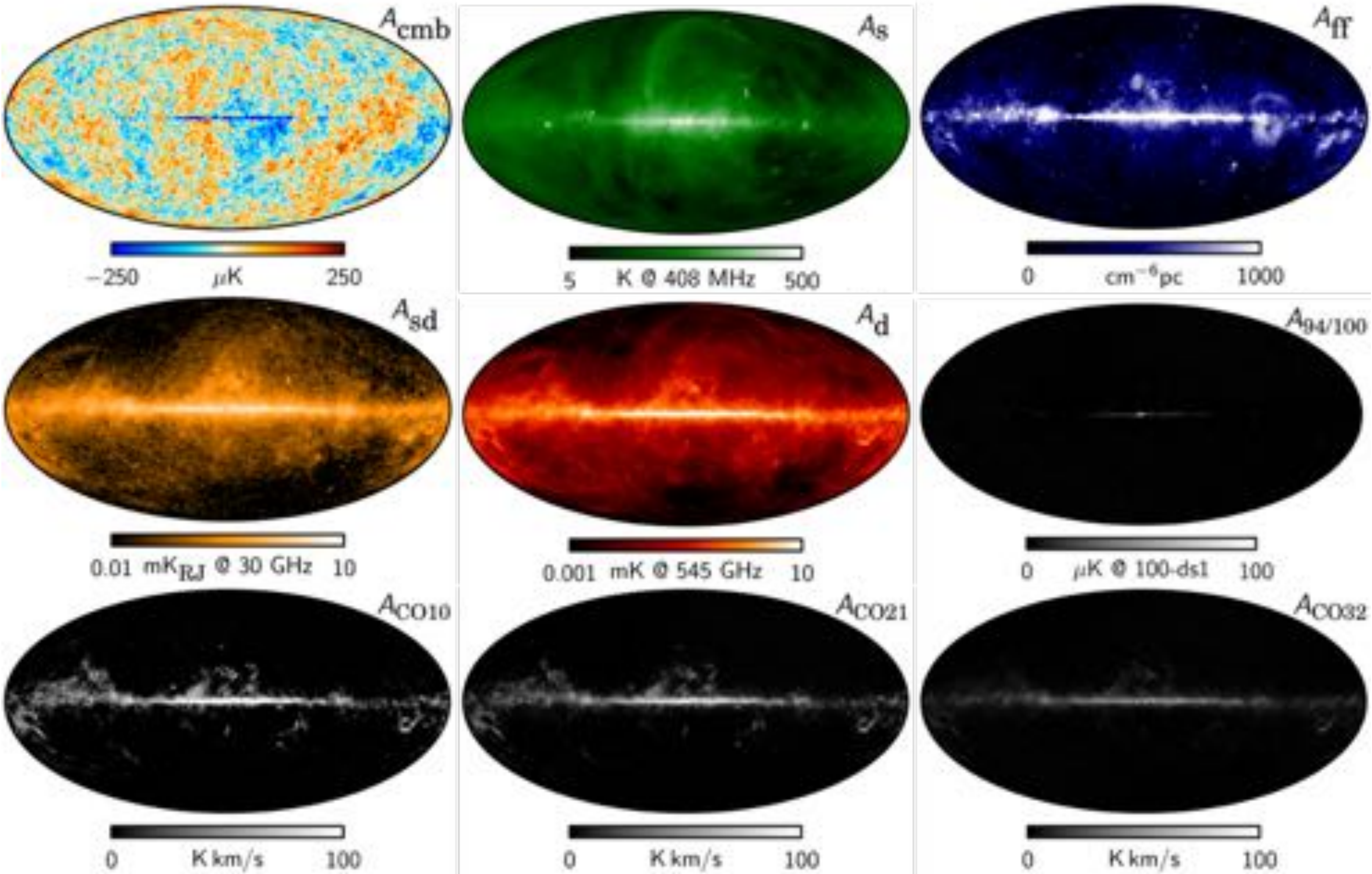
WIDE DATA

Big DATA versus Wide DATA

COMPLETE



WIDE DATA

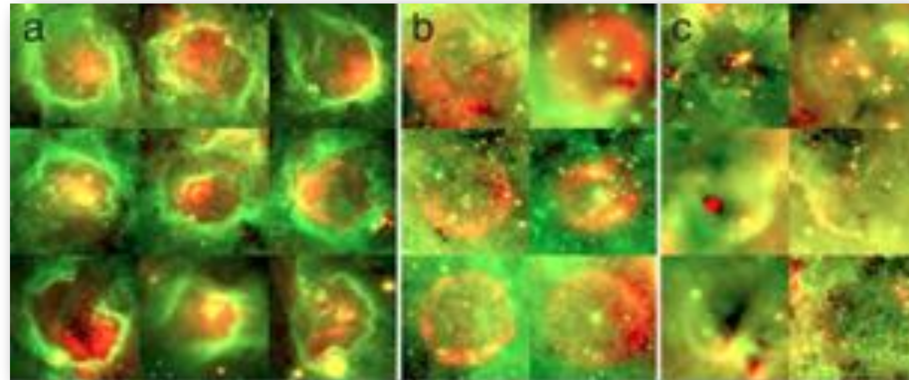


Temperature Foreground amplitudes from Commander, Planck Data [Feb 2015]

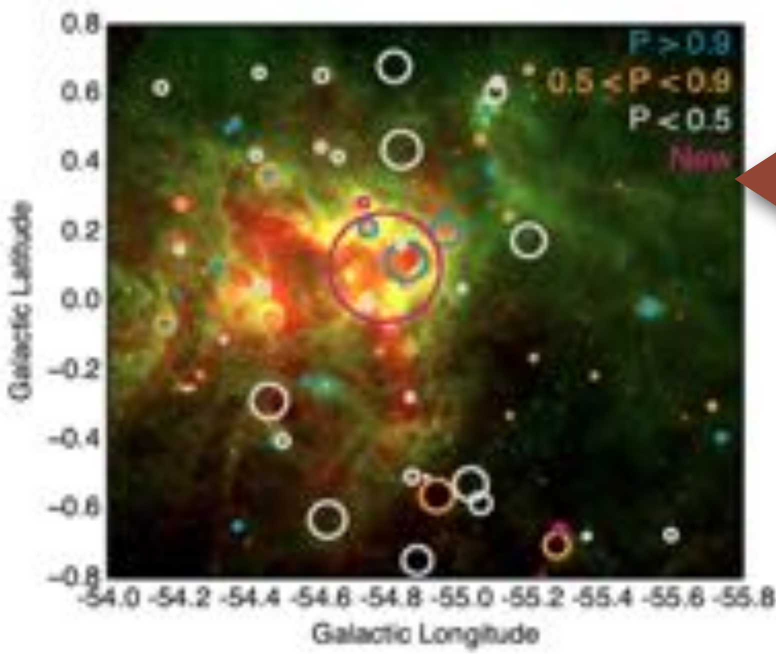
BIG DATA


Explore
Guided Tours
Search
View
Settings
Big DATA
versus
Wide
DATA
WorldWide Telescope
ZOONIVERSE

BIG DATA AND "HUMAN-AIDED COMPUTING"

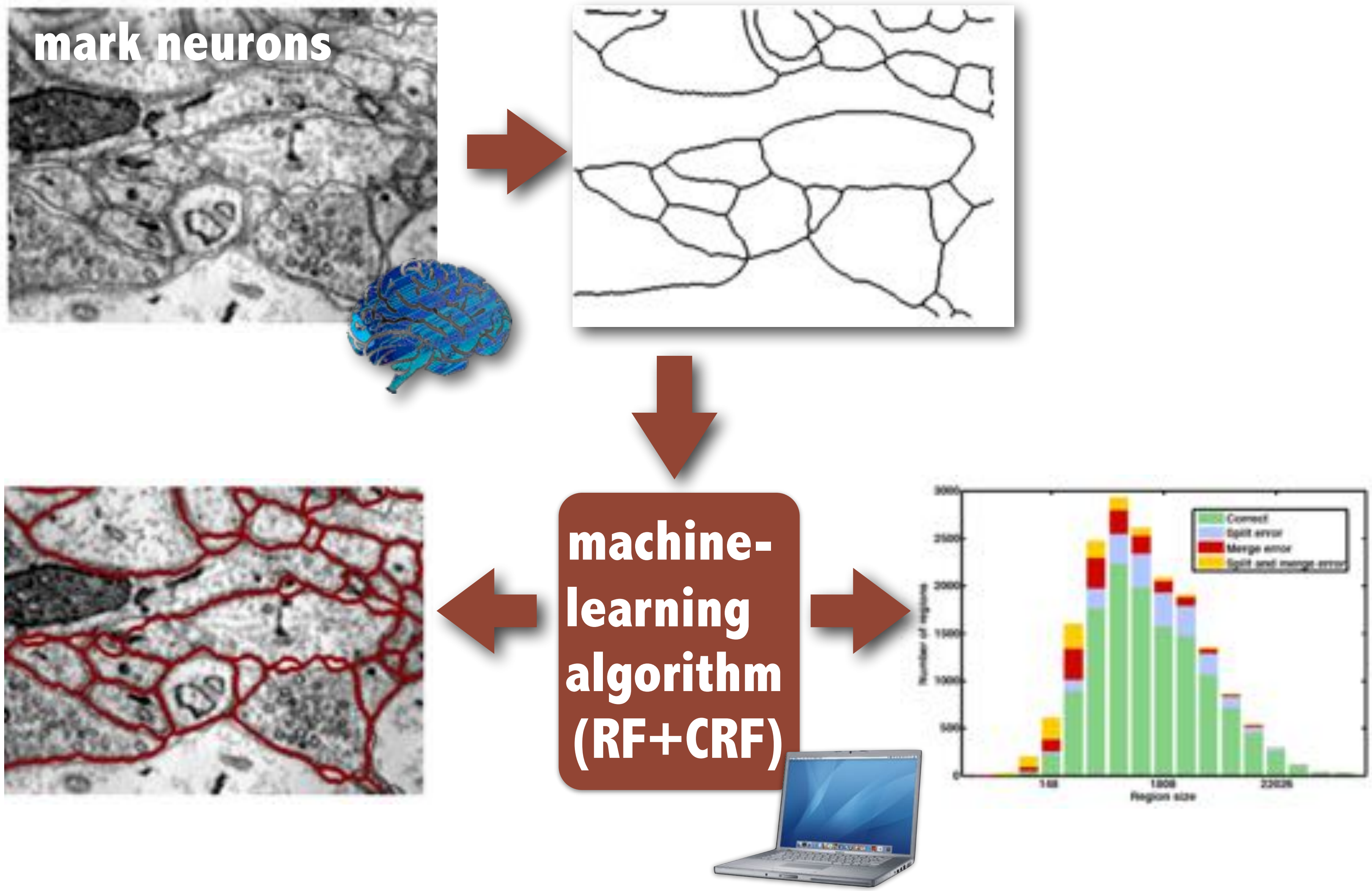


machine-learning algorithm (Brut)



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*

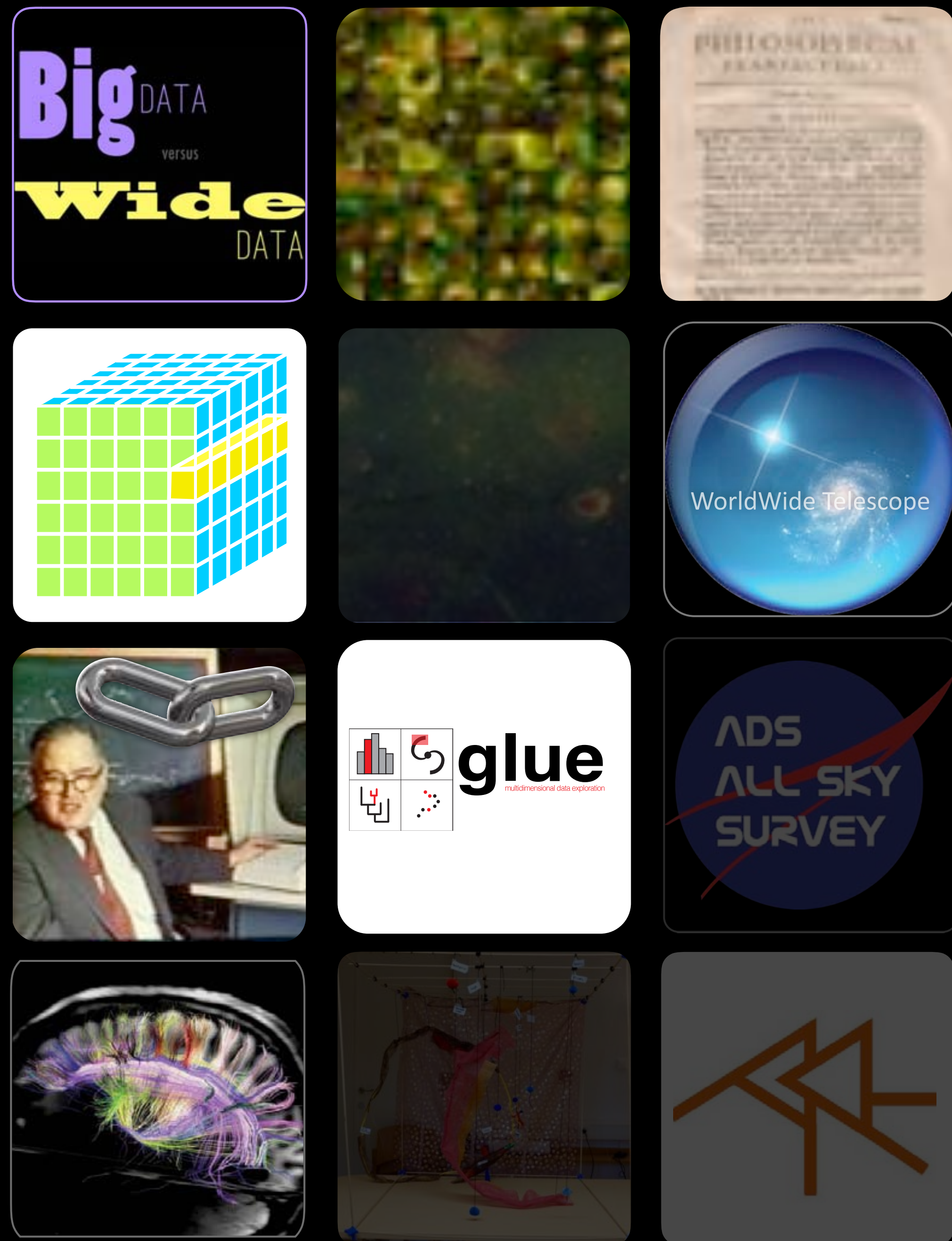
BIG DATA AND "HUMAN-AIDED COMPUTING"



example here from: Kaynig...Lichtman...Pfister et al. 2013, "Large-Scale Automatic Reconstruction of Neuronal Processes from Electron Microscopy Images"; cf. Shenoy & Tan 2008 for discussion of HAC; ***astroml.org*** *for machine learning advice/tools (Note: RF=Random Forest; CRF=Conditional Random Fields.)*

BIG AND WIDE DATA

Movie: Volker Springel, formation of a cluster of galaxies. Millenium Simulation requires 25TB for output.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3D PDF

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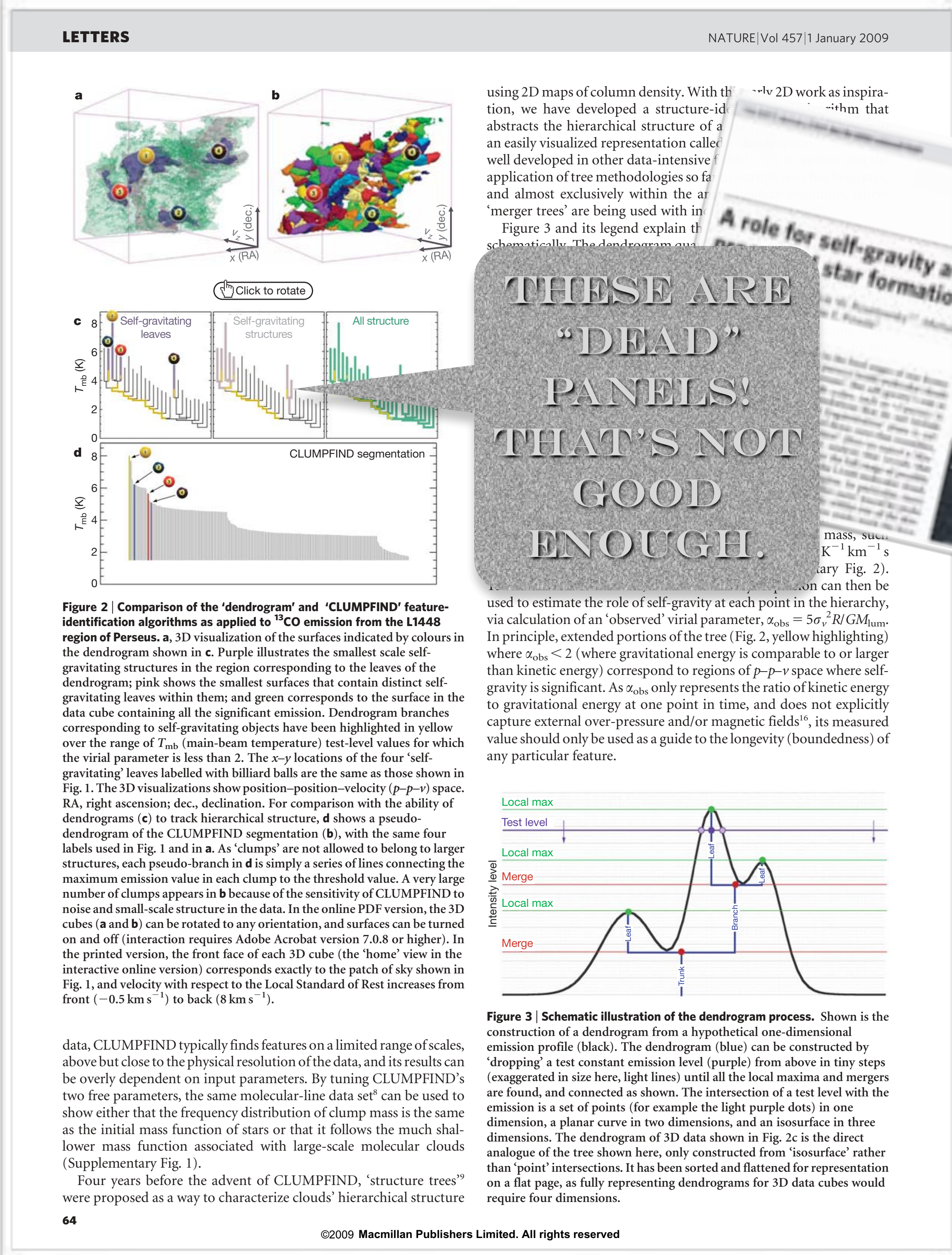

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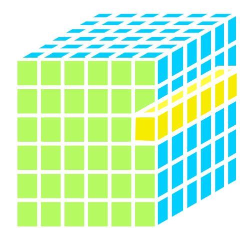
Figure 3 and its legend explain th…

… mass, such … $\mathrm{K^{-1}\ km^{-1}\ s}$ … tary Fig. 2). … on 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.

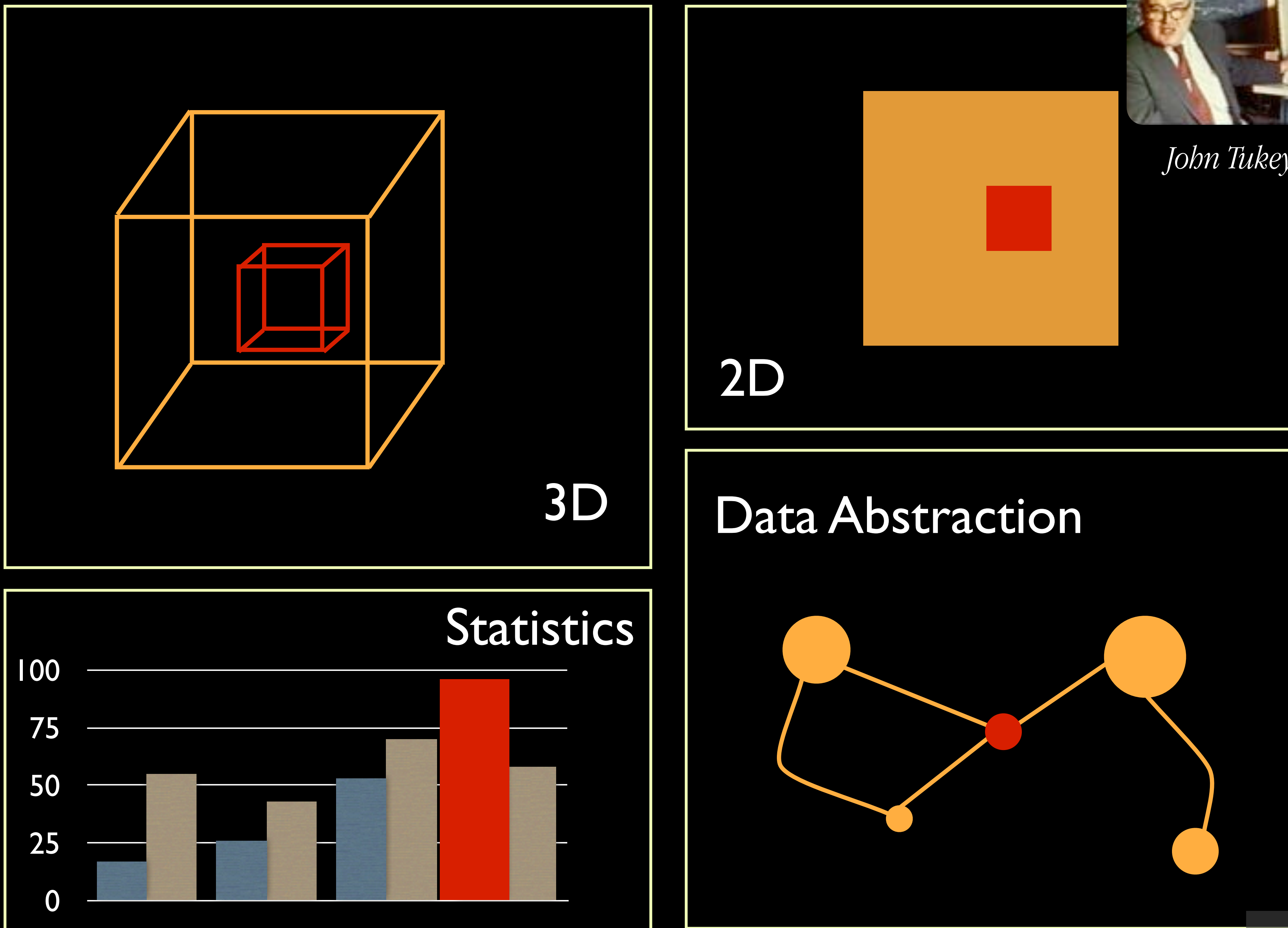
THESE ARE "DEAD" PANELS! THAT'S NOT GOOD ENOUGH.



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

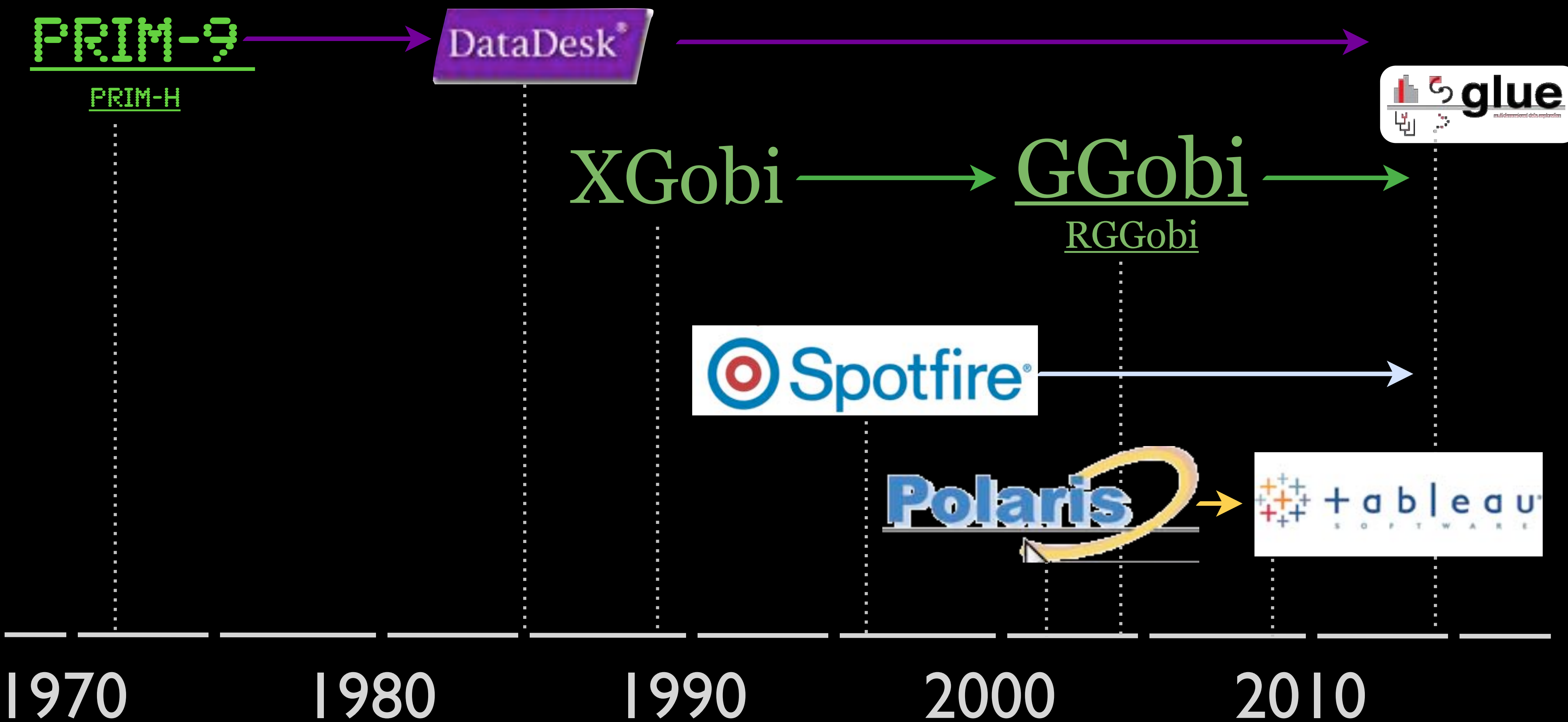
Linked Views of High-dimensional Data

John Tukey



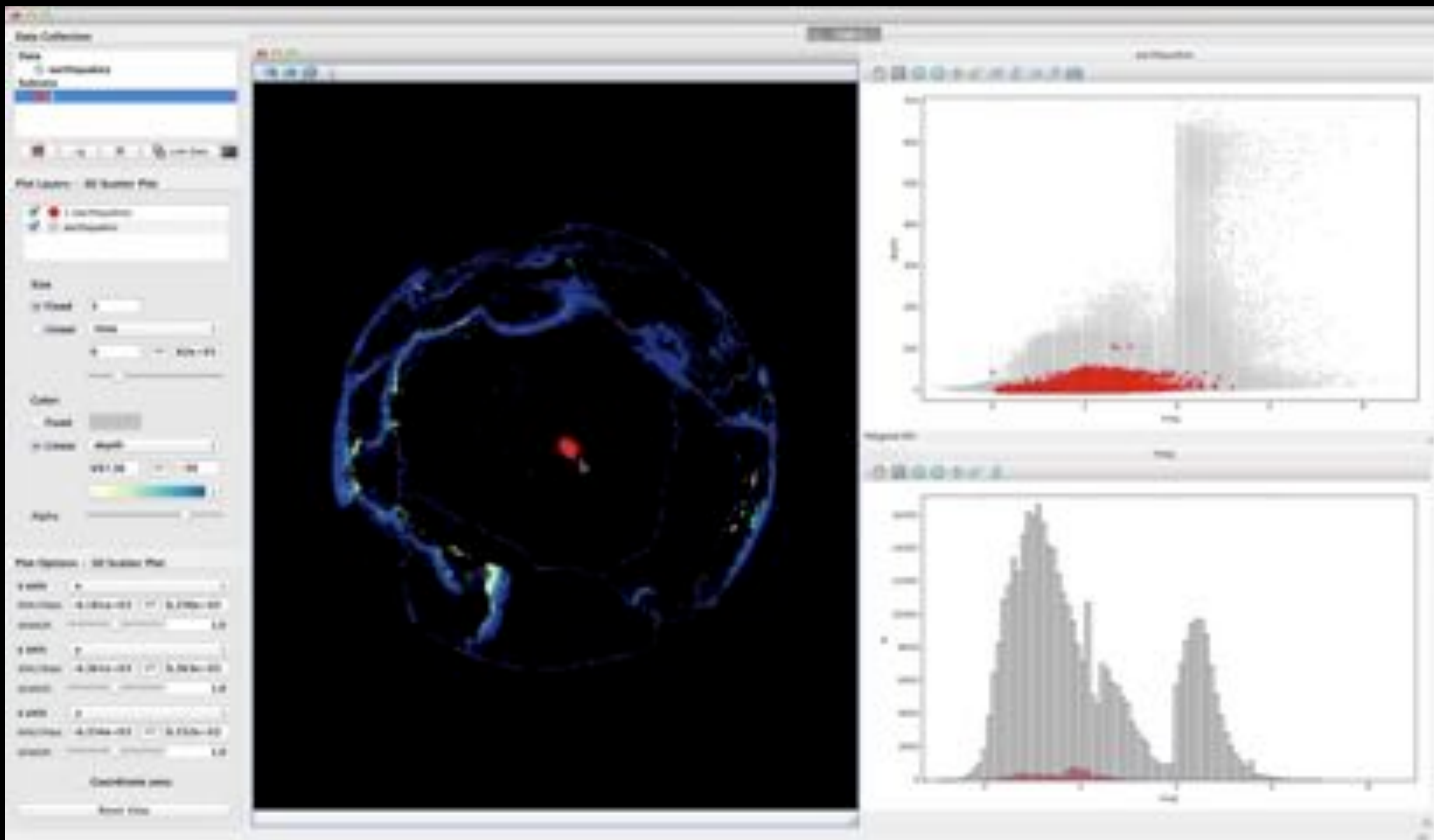
figure, by M. Borkin, reproduced from Goodman 2012, "Principles of High-Dimensional Data Visualization in Astronomy"

JOHN TUKEY'S LEGACY



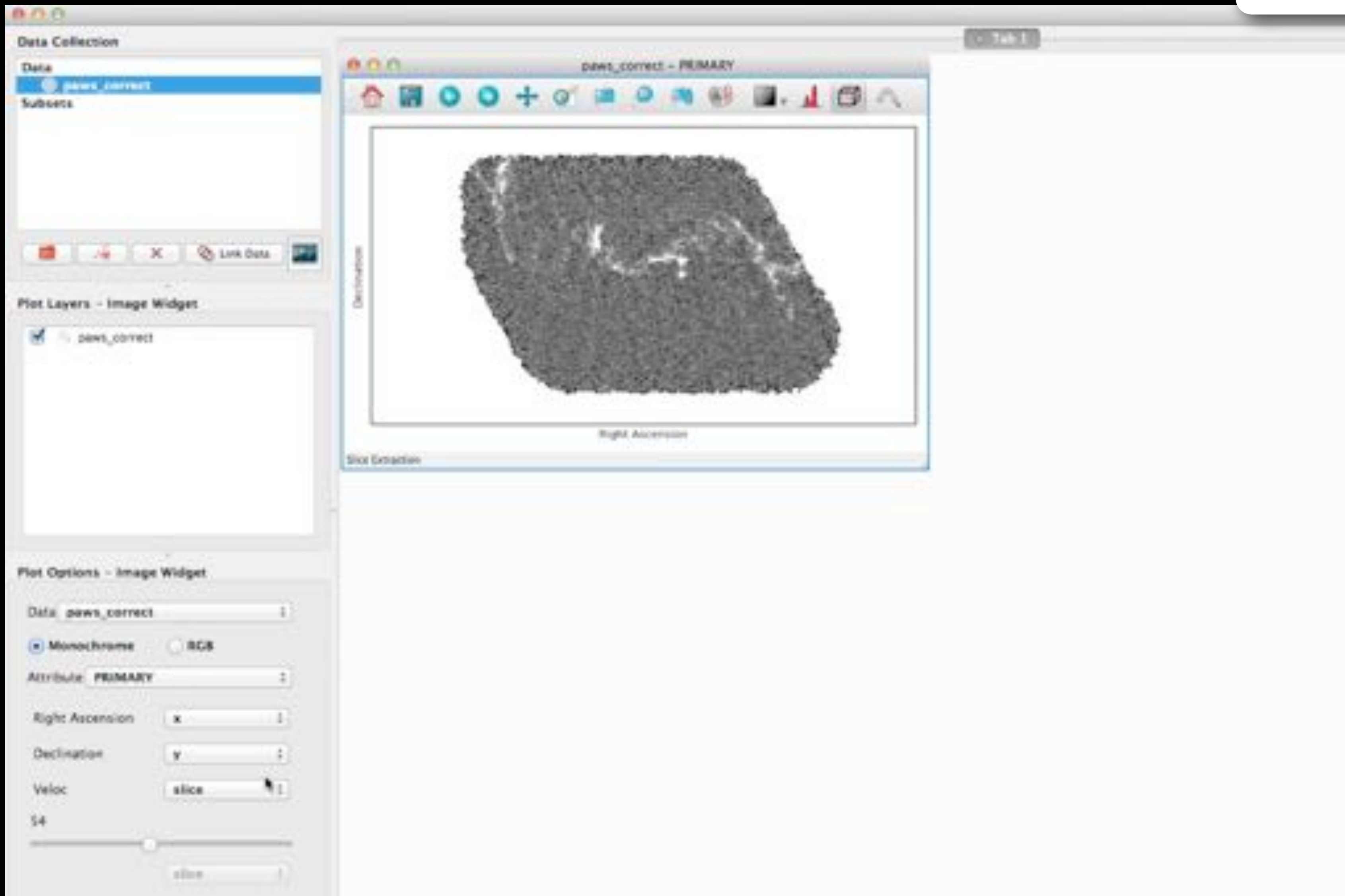
LINKED VIEWS OF HIGH-DIMENSIONAL DATA (IN PYTHON)
GLUE

glue

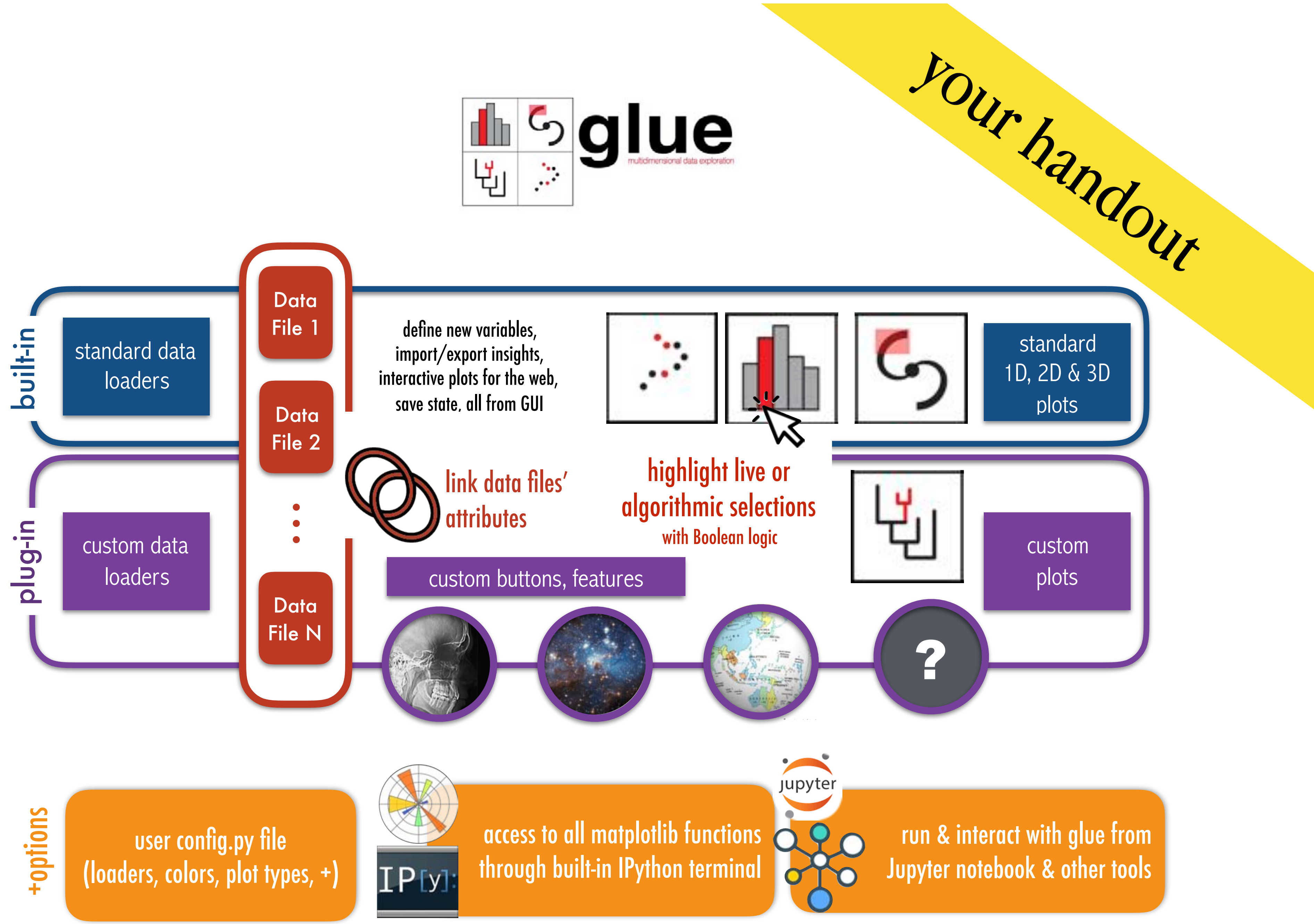


video by Tom Robitaille, lead glue developer
glue created by: C. Beaumont, M. Borkin, P. Qian, T. Robitaille, and A. Goodman, PI

LINKED VIEWS OF HIGH-DIMENSIONAL DATA (IN PYTHON)
GLUE



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


your handout
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

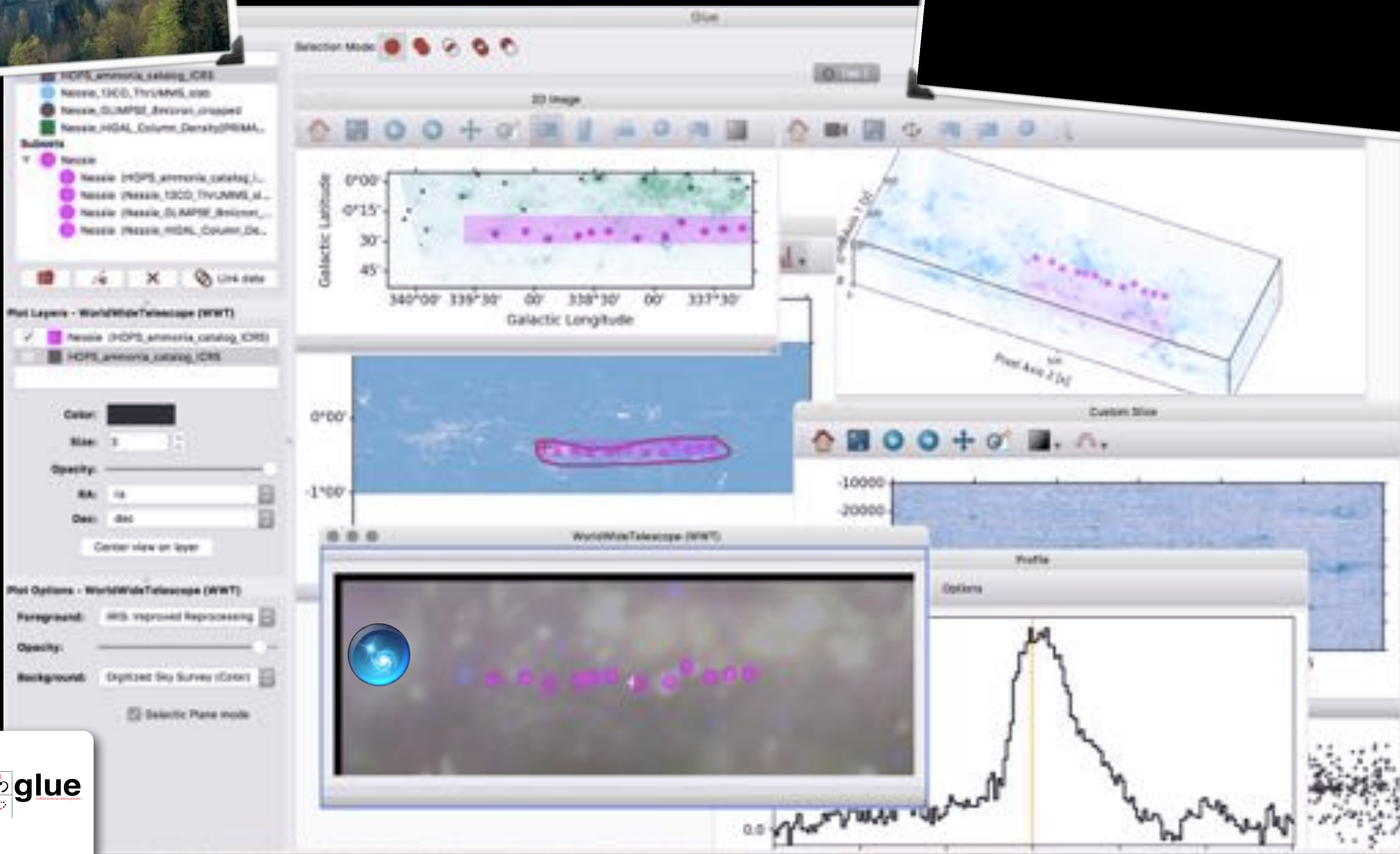
glueviz.org

What is visualization (and all this software) for?

INSIGHT

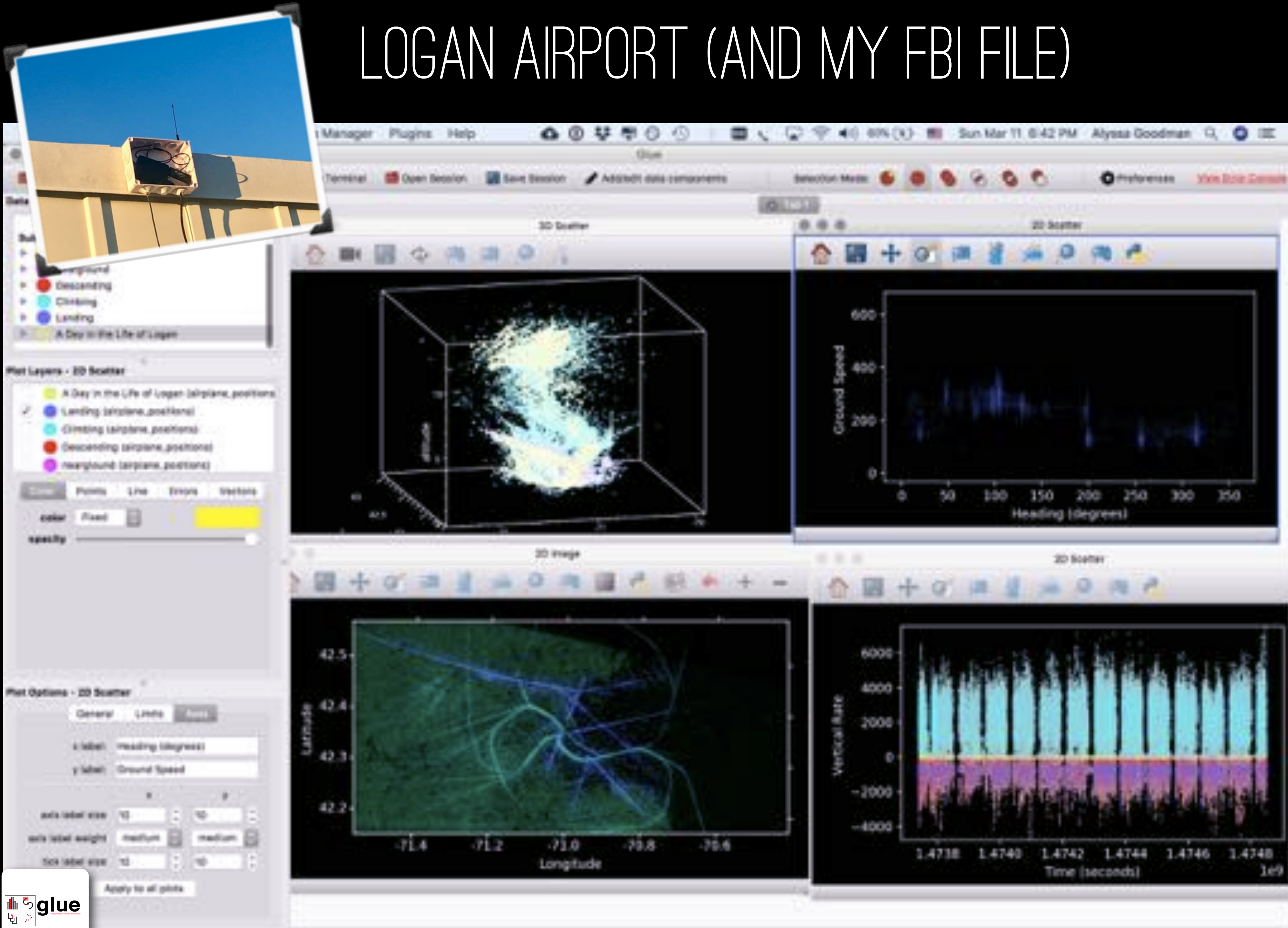
CONTEXT	PATTERN RECOGNITION	EVALUATION
Spatial	Ideas	Algorithms
Non-Spatial	Outliers	Errors

GLUEING TOGETHER THE MILKY WAY

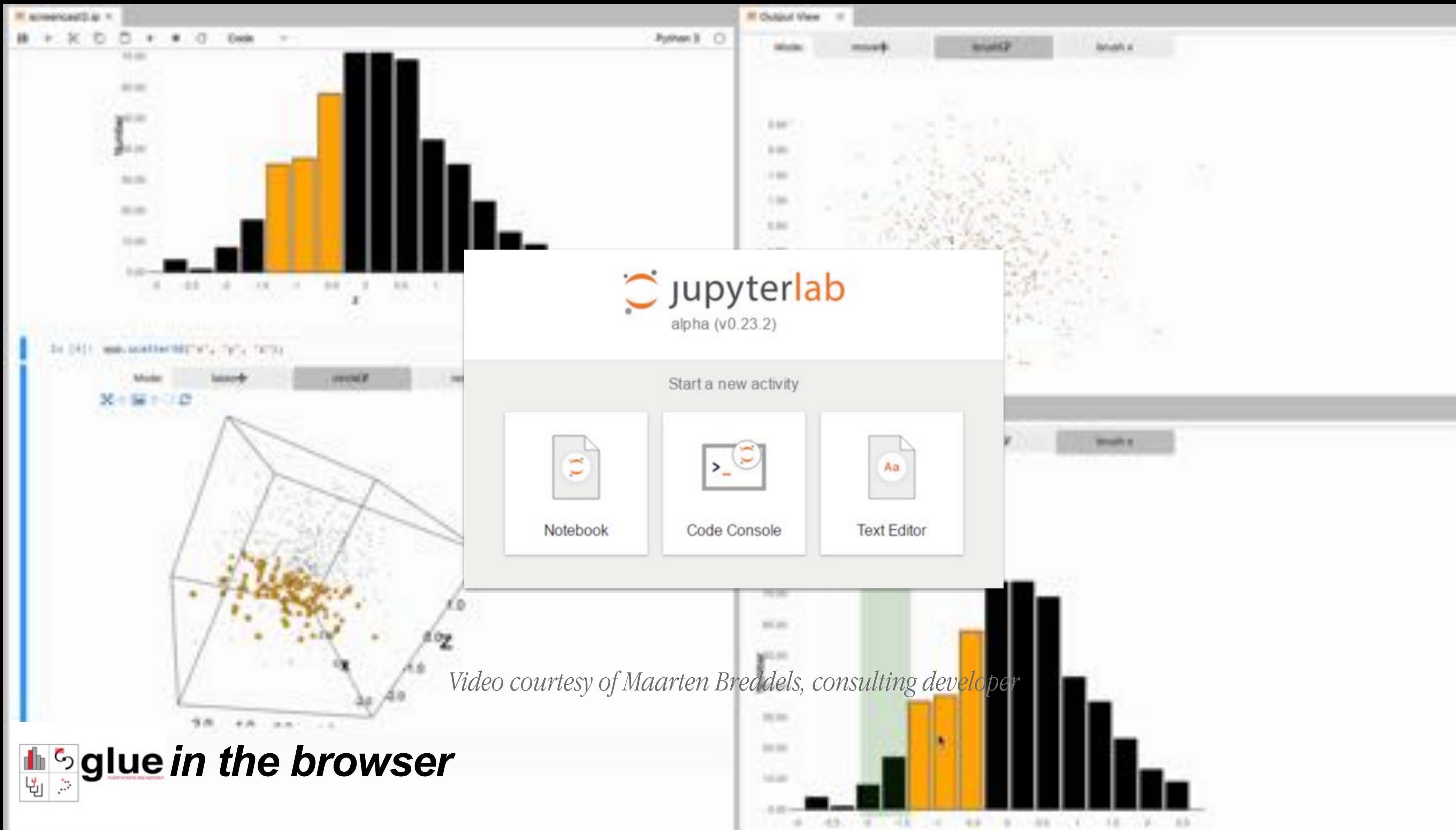


glue

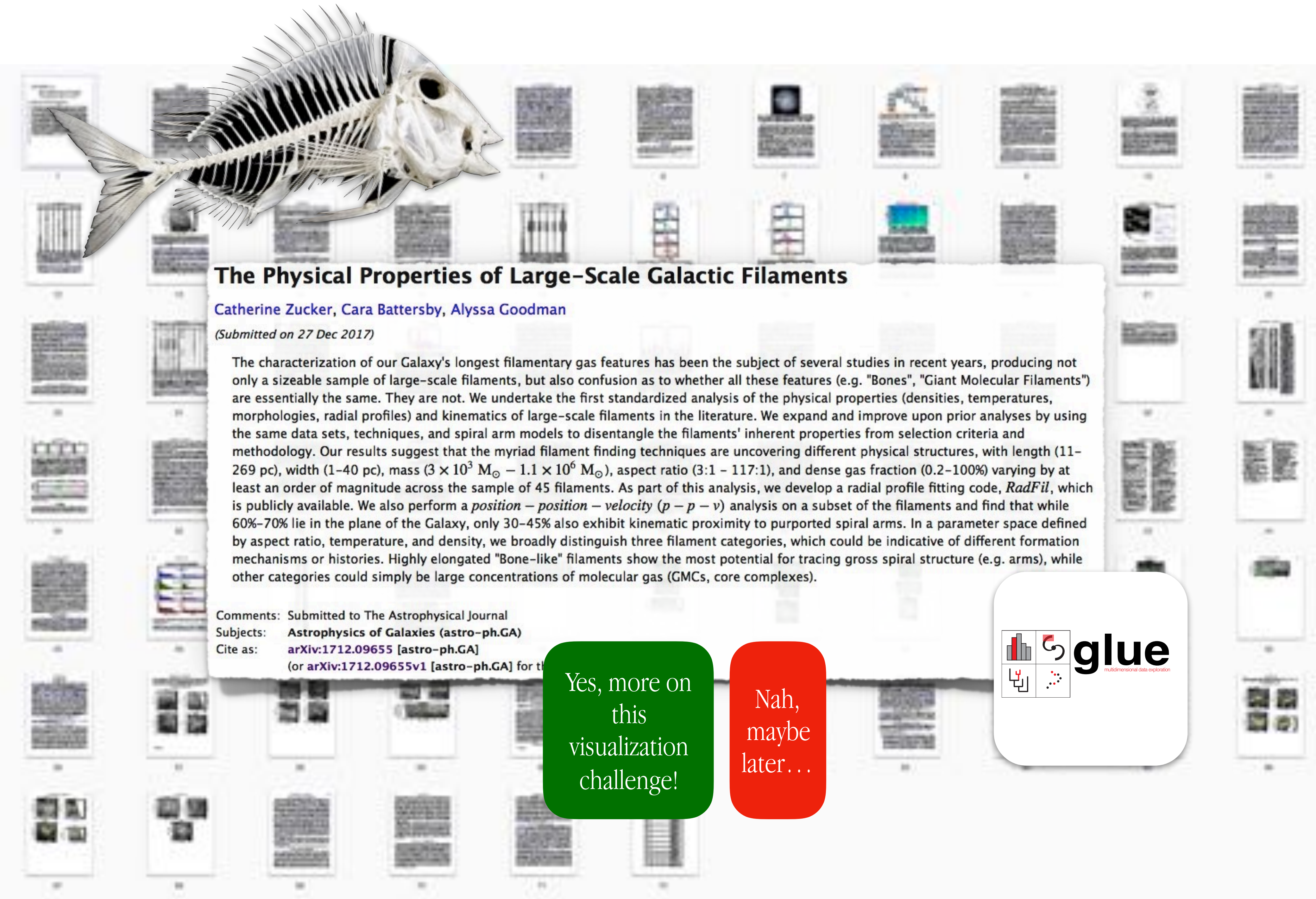
LOGAN AIRPORT (AND MY FBI FILE)



JUPYTER LAB: GLUE IN THE BROWSER



Video courtesy of Maarten Breddels, consulting developer



The Physical Properties of Large-Scale Galactic Filaments

Catherine Zucker, Cara Battersby, Alyssa Goodman

(Submitted on 27 Dec 2017)

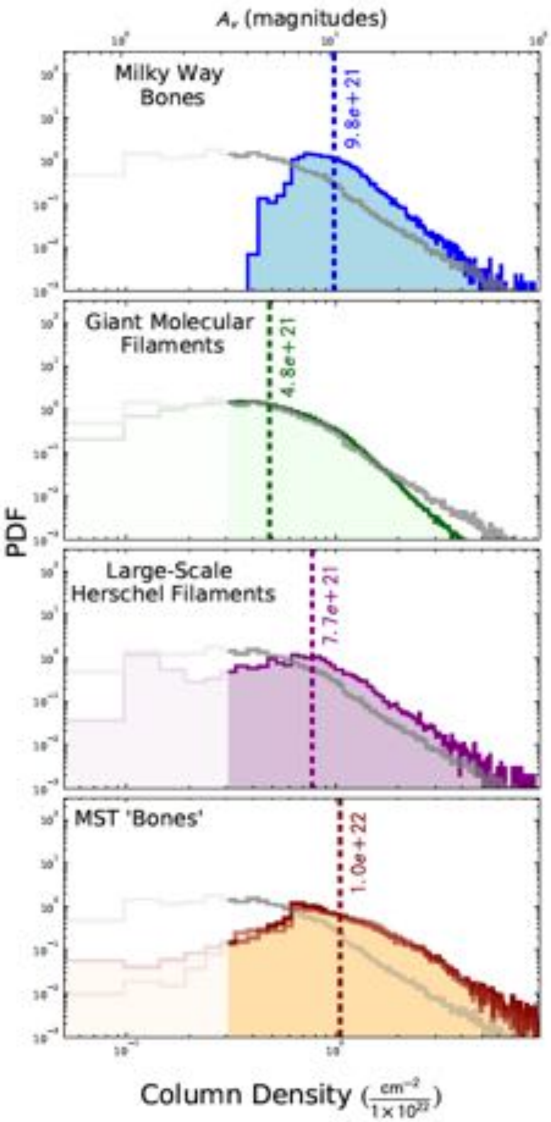
The characterization of our Galaxy's longest filamentary gas features has been the subject of several studies in recent years, producing not only a sizeable sample of large-scale filaments, but also confusion as to whether all these features (e.g. "Bones", "Giant Molecular Filaments") are essentially the same. They are not. We undertake the first standardized analysis of the physical properties (densities, temperatures, morphologies, radial profiles) and kinematics of large-scale filaments in the literature. We expand and improve upon prior analyses by using the same data sets, techniques, and spiral arm models to disentangle the filaments' inherent properties from selection criteria and methodology. Our results suggest that the myriad filament finding techniques are uncovering different physical structures, with length (11–269 pc), width (1–40 pc), mass ($3 \times 10^3\ M_\odot - 1.1 \times 10^6\ M_\odot$), aspect ratio (3:1 – 117:1), and dense gas fraction (0.2–100%) varying by at least an order of magnitude across the sample of 45 filaments. As part of this analysis, we develop a radial profile fitting code, *RadFil*, which is publicly available. We also perform a $position - position - velocity$ ($p-p-v$) analysis on a subset of the filaments and find that while 60%–70% lie in the plane of the Galaxy, only 30–45% also exhibit kinematic proximity to purported spiral arms. In a parameter space defined by aspect ratio, temperature, and density, we broadly distinguish three filament categories, which could be indicative of different formation mechanisms or histories. Highly elongated "Bone-like" filaments show the most potential for tracing gross spiral structure (e.g. arms), while other categories could simply be large concentrations of molecular gas (GMCs, core complexes).

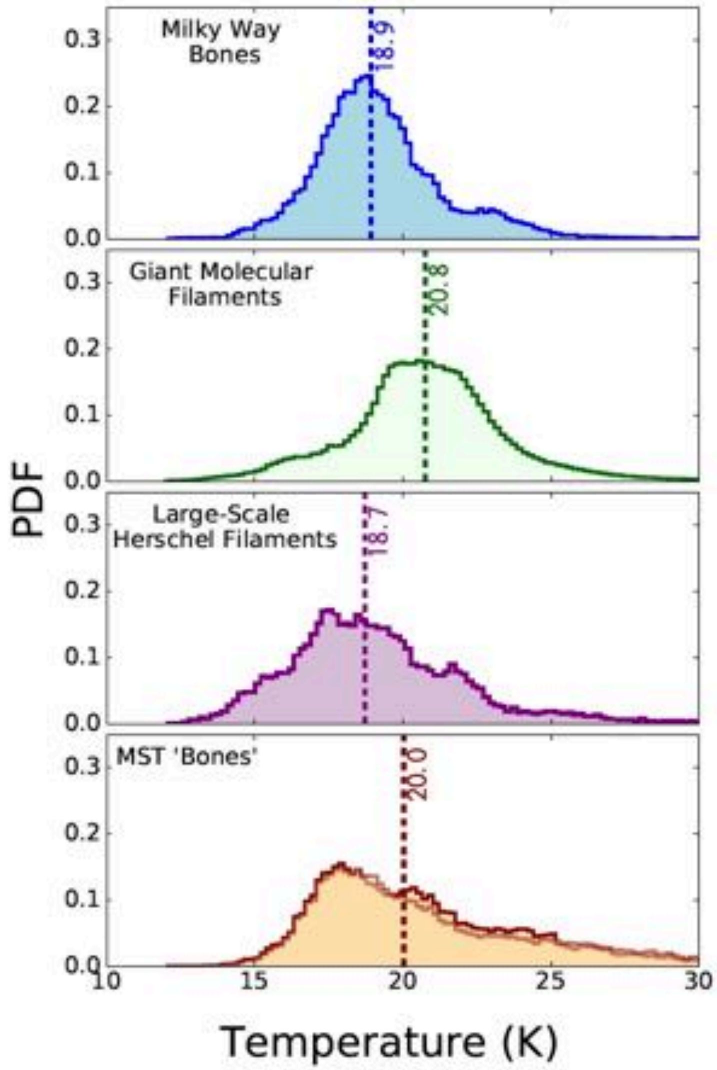
Comments: Submitted to The Astrophysical Journal
Subjects: **Astrophysics of Galaxies (astro-ph.GA)**
Cite as: arXiv:1712.09655 [astro-ph.GA]
(or arXiv:1712.09655v1 [astro-ph.GA] for t

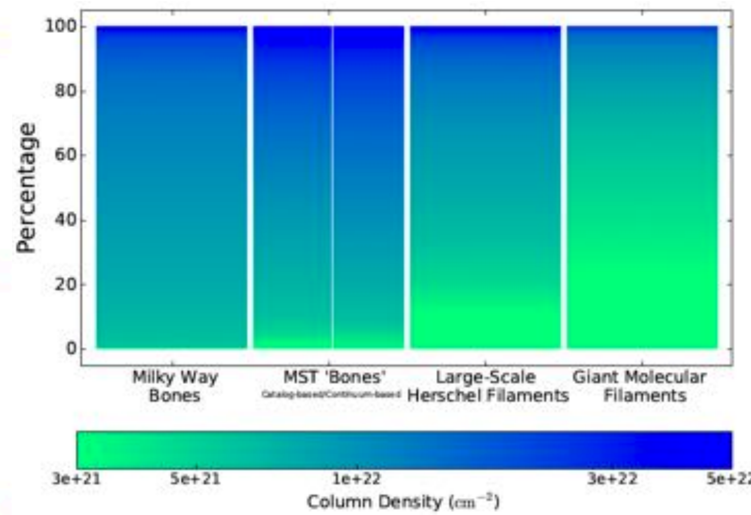
The Physical Properties of Large-Scale Galactic Filaments

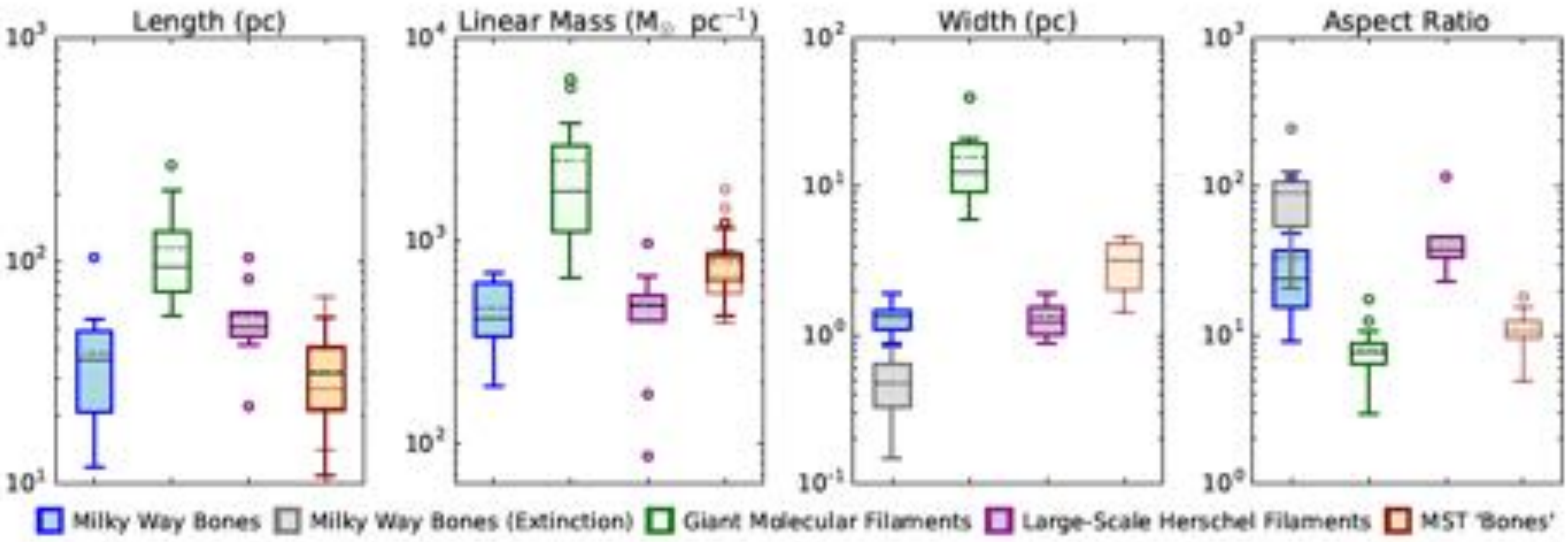
a visualization saga…

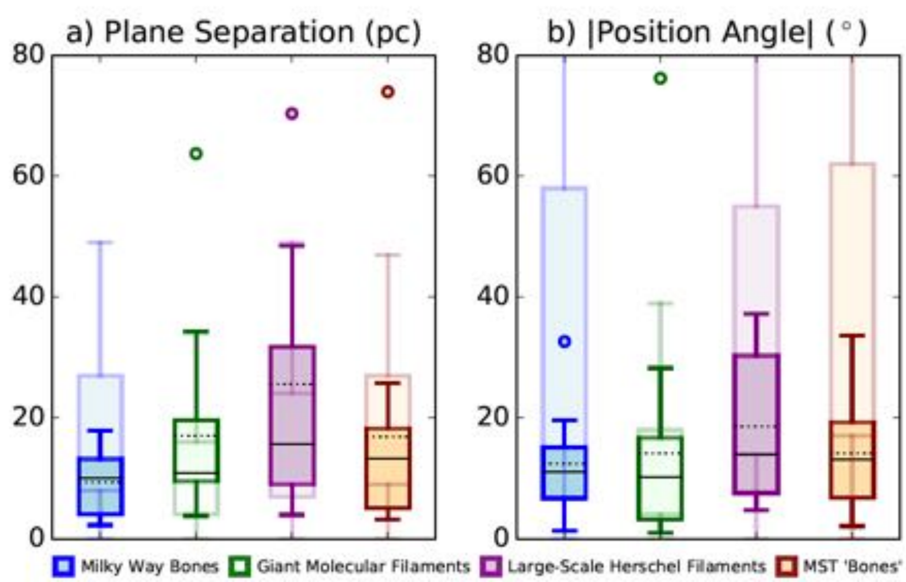
Catherine Zucker, Cara Battersby, Alyssa Goodman

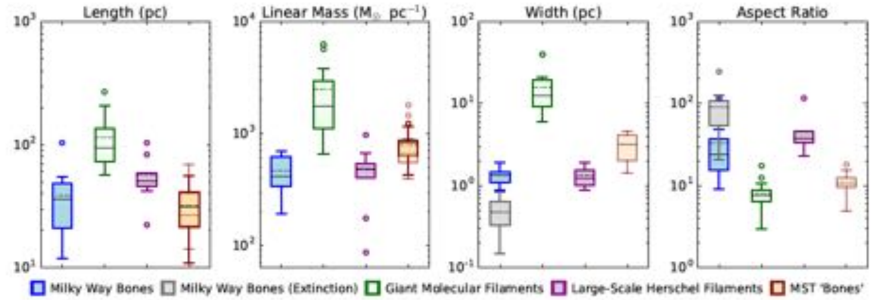


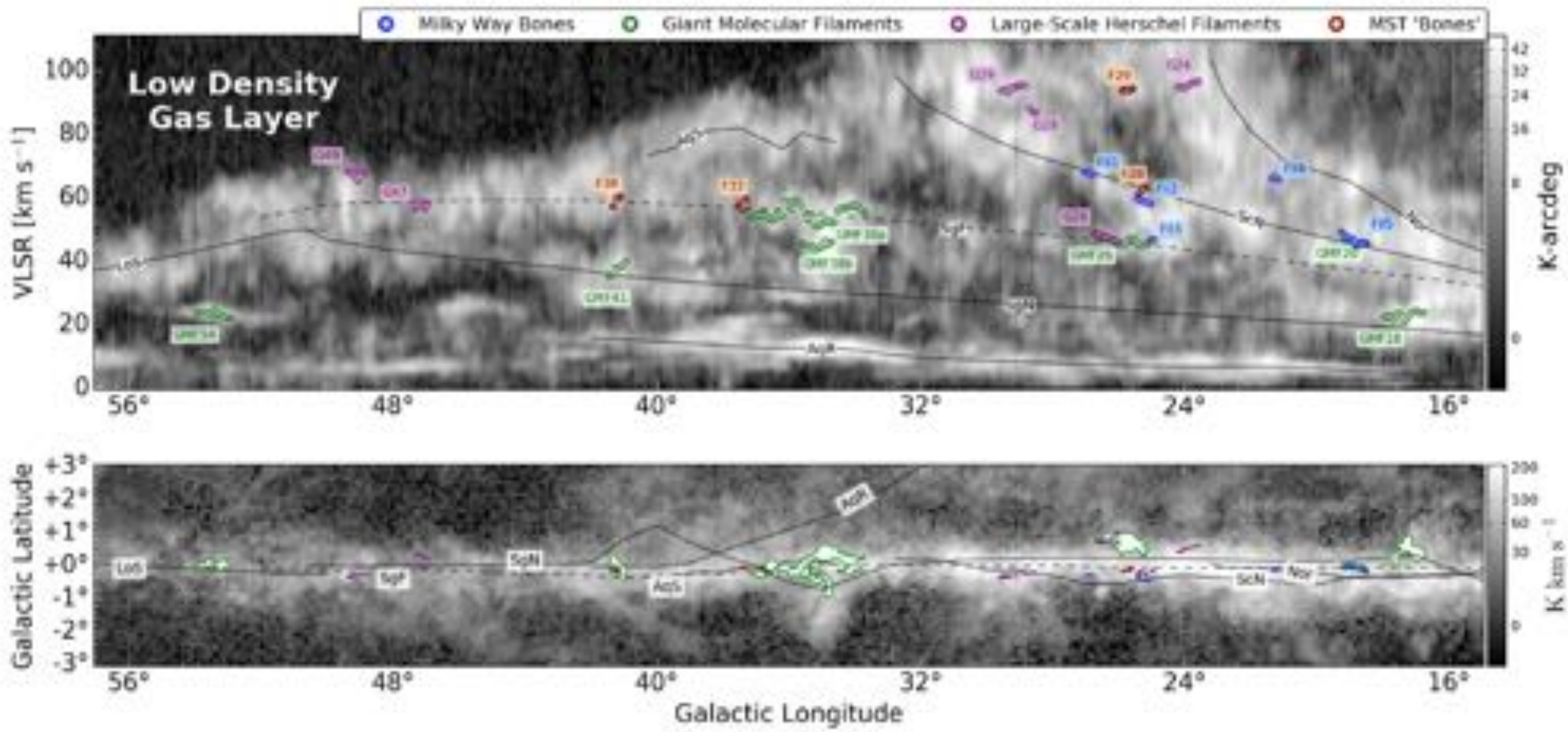


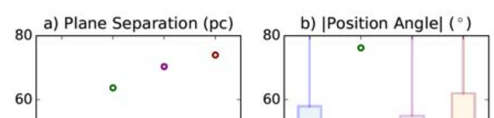


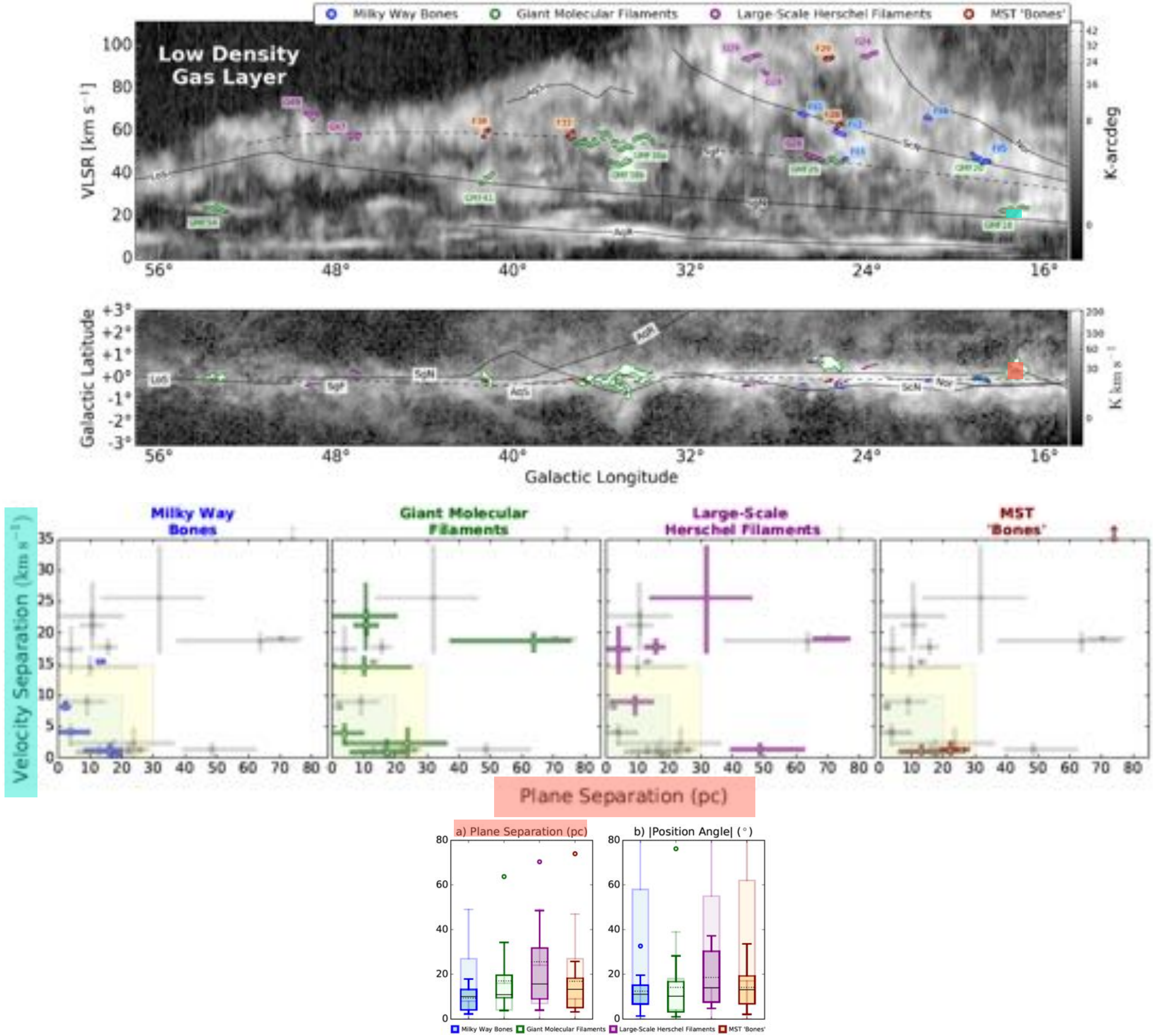

Length (pc)
Linear Mass ($M_\odot$ pc^{-1})
Width (pc)
Aspect Ratio
10^3
10^2
10^1
10^4
10^3
10^2
10^2
10^1
10^0
10^{-1}
10^3
10^2
10^1
10^0
Milky Way Bones
Milky Way Bones (Extinction)
Giant Molecular Filaments
Large-Scale Herschel Filaments
MST 'Bones'


a) Plane Separation (pc)
b) |Position Angle| ($^\circ$)
80
60
40
20
0
80
60
40
20
0
Milky Way Bones
Giant Molecular Filaments
Large-Scale Herschel Filaments
MST 'Bones'

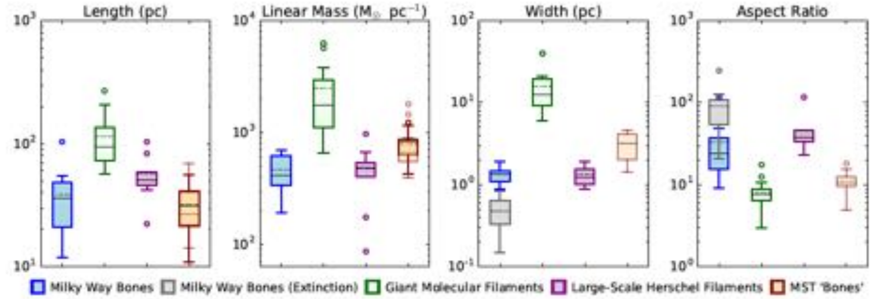

Length (pc)
Linear Mass (M☉ pc⁻¹)
Width (pc)
Aspect Ratio
Milky Way Bones
Milky Way Bones (Extinction)
Giant Molecular Filaments
Large-Scale Herschel Filaments
MST 'Bones'

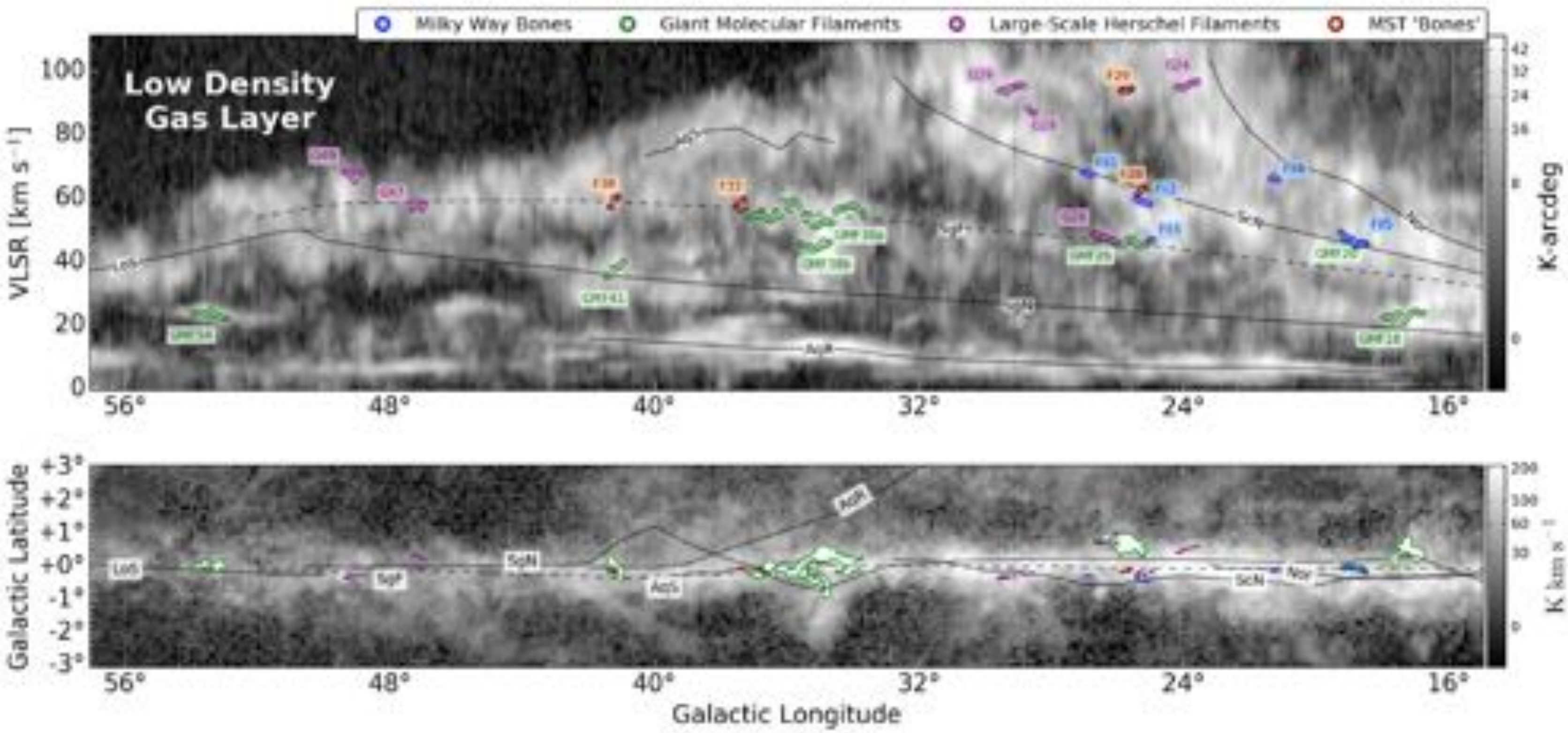

Milky Way Bones
Giant Molecular Filaments
Large-Scale Herschel Filaments
MST 'Bones'
Low Density Gas Layer
VLSR [km s⁻¹]
K·arcdeg
Galactic Latitude
K km s⁻¹
Galactic Longitude
56°
48°
40°
32°
24°
16°

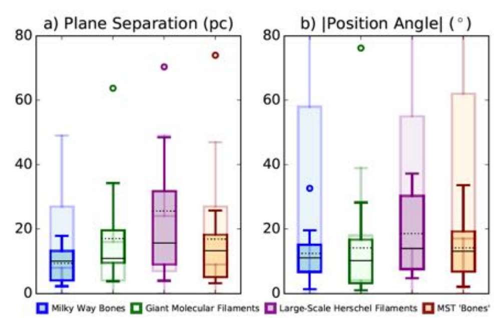

a) Plane Separation (pc)
b) |Position Angle| (°)
Milky Way Bones
Giant Molecular Filaments
Large-Scale Herschel Filaments
MST 'Bones'

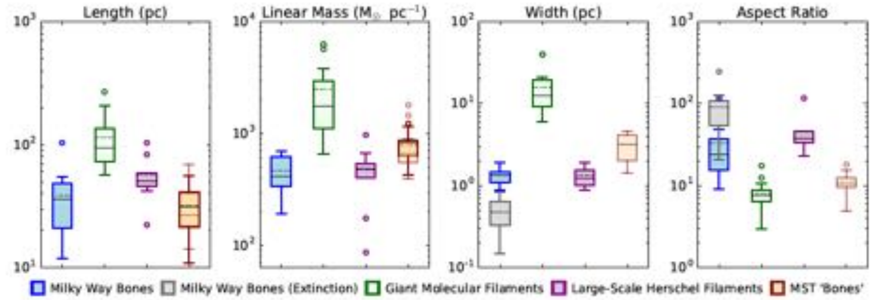


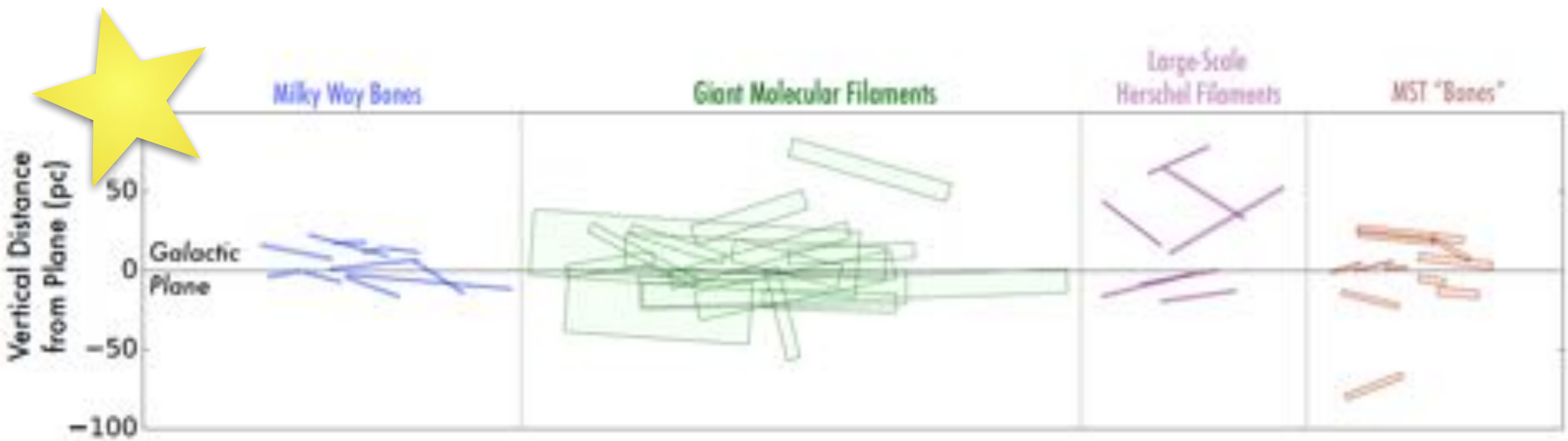
Milky Way Bones
Giant Molecular Filaments
Large-Scale Herschel Filaments
MST 'Bones'
Low Density Gas Layer
VLSR [km s⁻¹]
K-arcdeg
Galactic Latitude
Galactic Longitude
K km s⁻¹
Velocity Separation (km s⁻¹)
Plane Separation (pc)
a) Plane Separation (pc)
b) |Position Angle| (°)

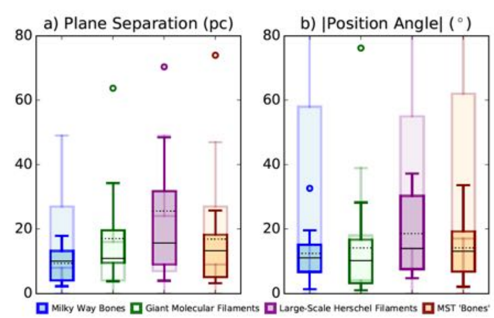

Length (pc)
Linear Mass (M☉ pc⁻¹)
Width (pc)
Aspect Ratio
Milky Way Bones
Milky Way Bones (Extinction)
Giant Molecular Filaments
Large-Scale Herschel Filaments
MST 'Bones'

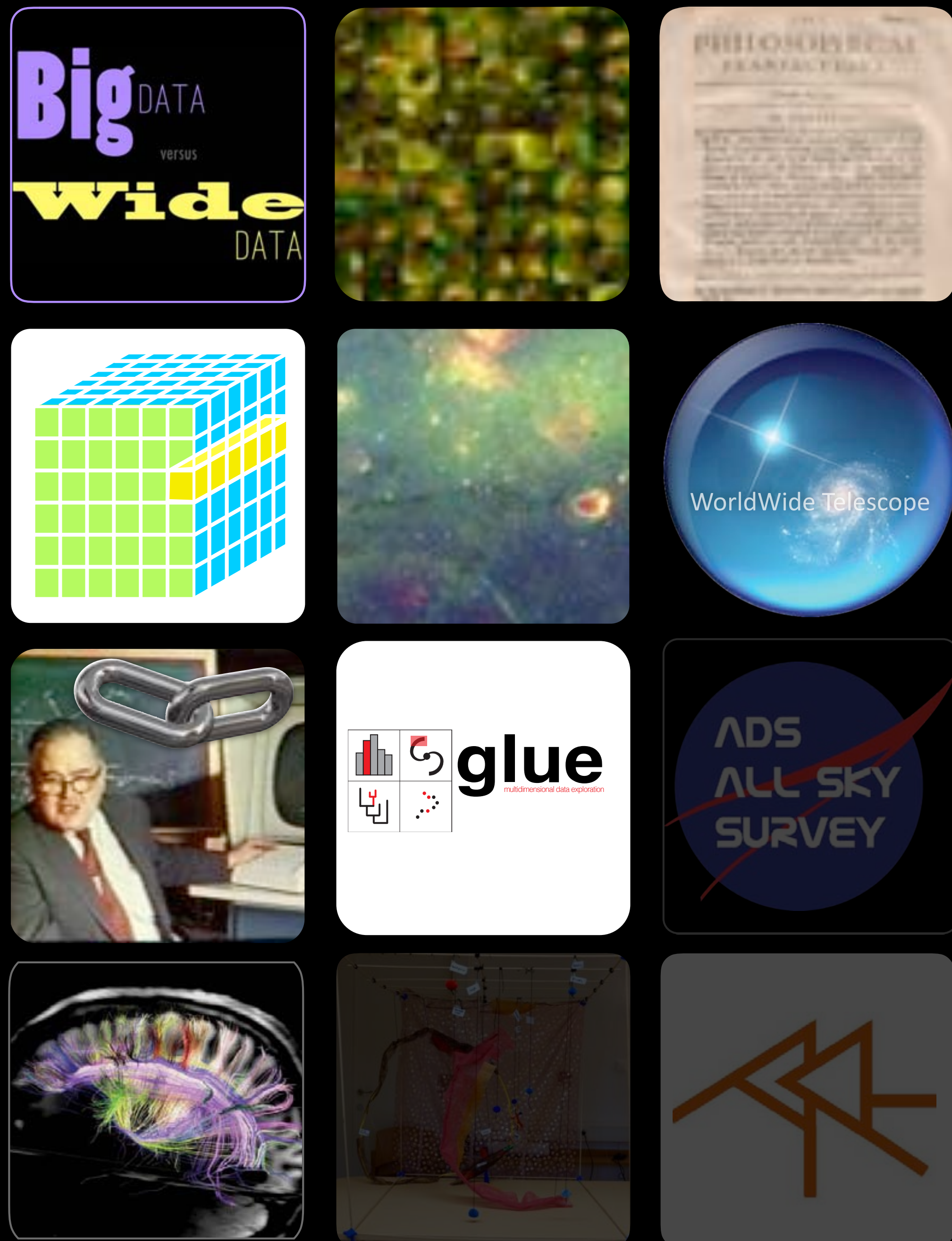

Milky Way Bones
Giant Molecular Filaments
Large-Scale Herschel Filaments
MST 'Bones'
Low Density Gas Layer
VLSR [km s⁻¹]
K·arcdeg
Galactic Latitude
K km s⁻¹
Galactic Longitude
56°
48°
40°
32°
24°
16°
AqR
SgN
ScN
AqS
SgF
LoS
Nor


a) Plane Separation (pc)
b) |Position Angle| (°)
Milky Way Bones
Giant Molecular Filaments
Large-Scale Herschel Filaments
MST 'Bones'

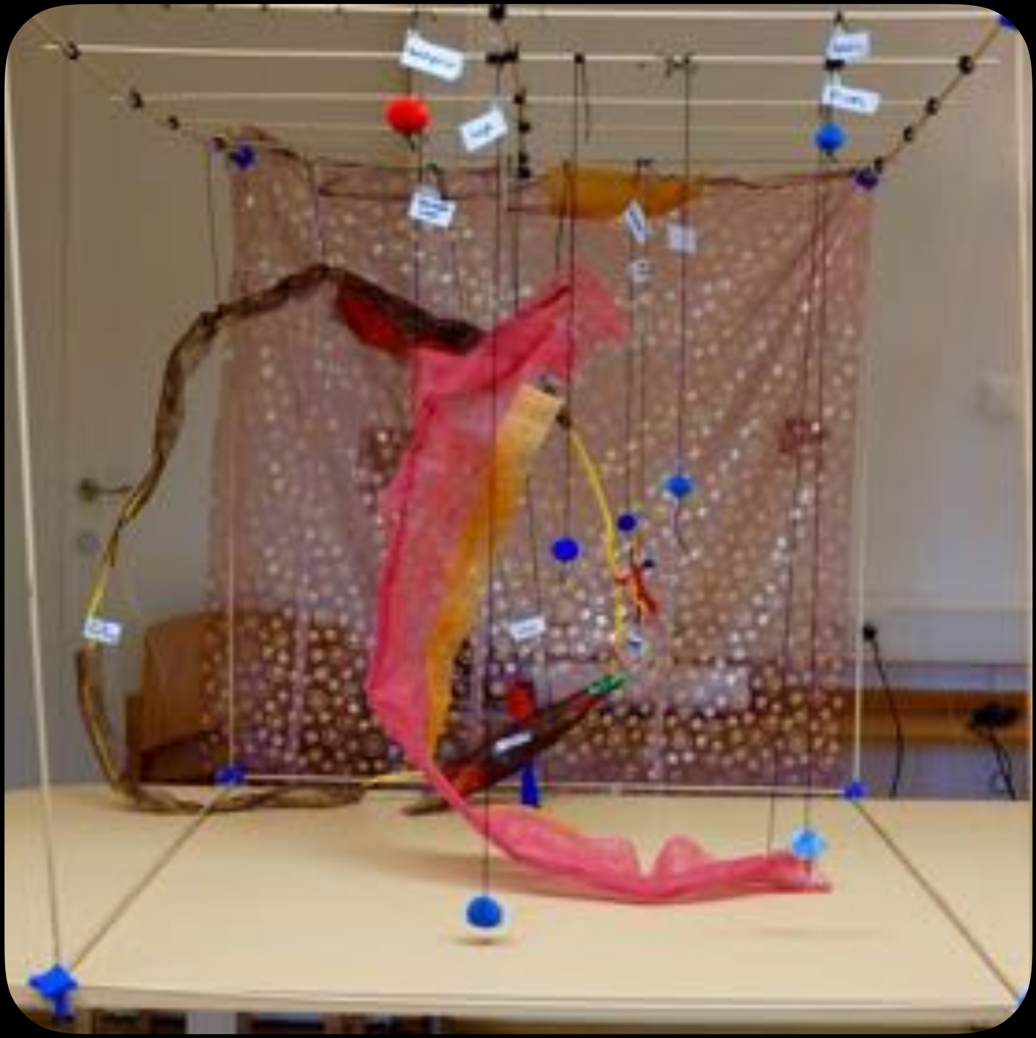

Length (pc)
Linear Mass (M☉ pc⁻¹)
Width (pc)
Aspect Ratio
Milky Way Bones
Milky Way Bones (Extinction)
Giant Molecular Filaments
Large-Scale Herschel Filaments
MST 'Bones'


Milky Way Bones
Giant Molecular Filaments
Large-Scale Herschel Filaments
MST "Bones"
Vertical Distance from Plane (pc)
Galactic Plane
50
0
−50
−100


a) Plane Separation (pc)
b) |Position Angle| (°)
Milky Way Bones
Giant Molecular Filaments
Large-Scale Herschel Filaments
MST 'Bones'

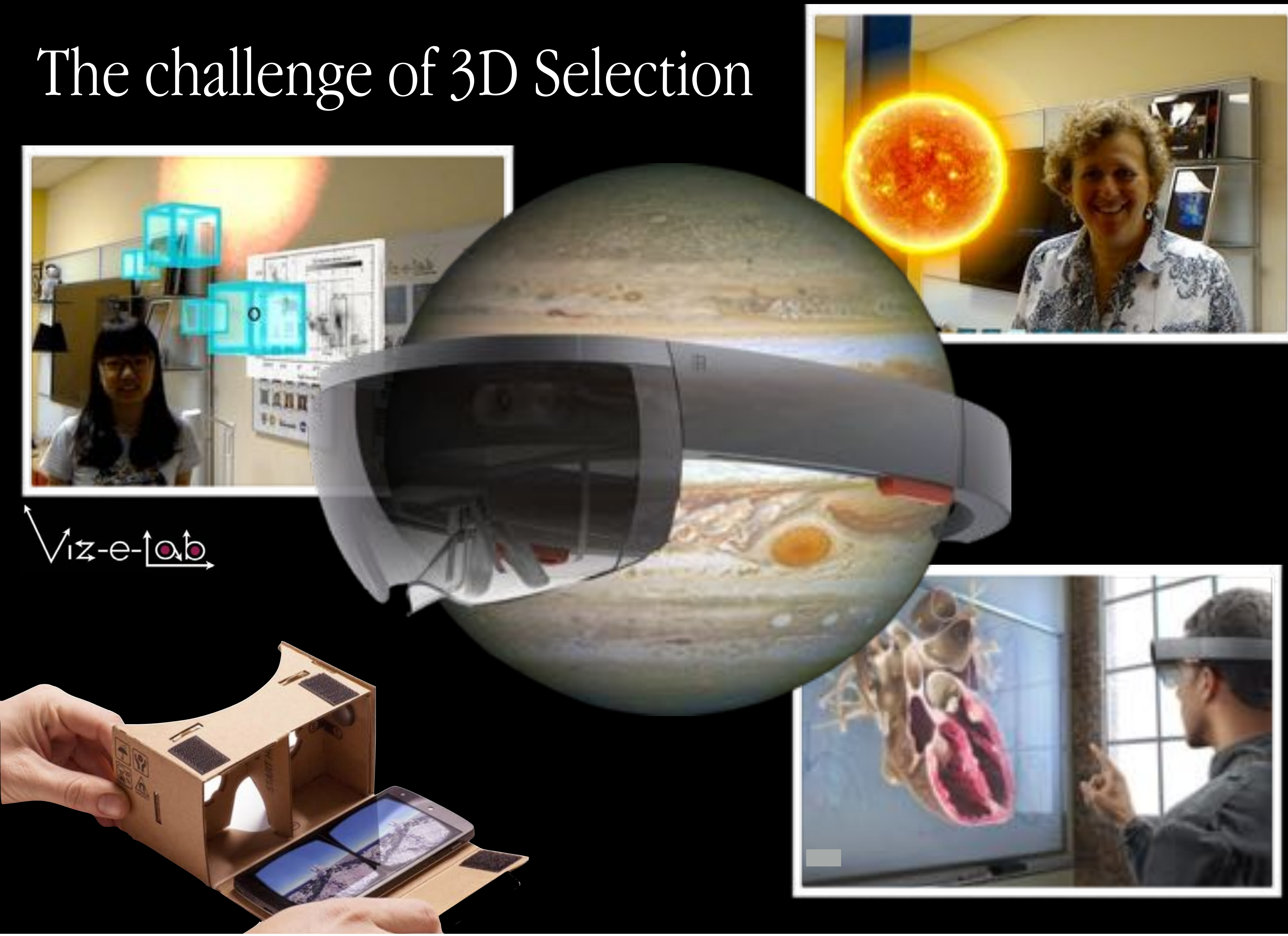

Big DATA
versus
Wide DATA
WorldWide Telescope
glue
multidimensional data exploration
ADS
ALL SKY
SURVEY

The challenge of 3D Selection

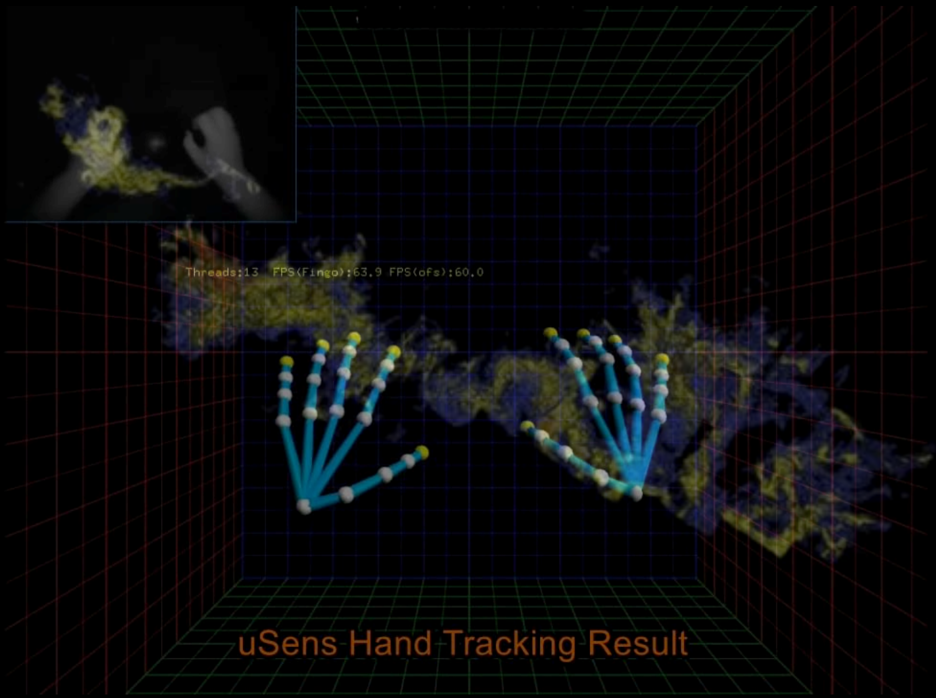


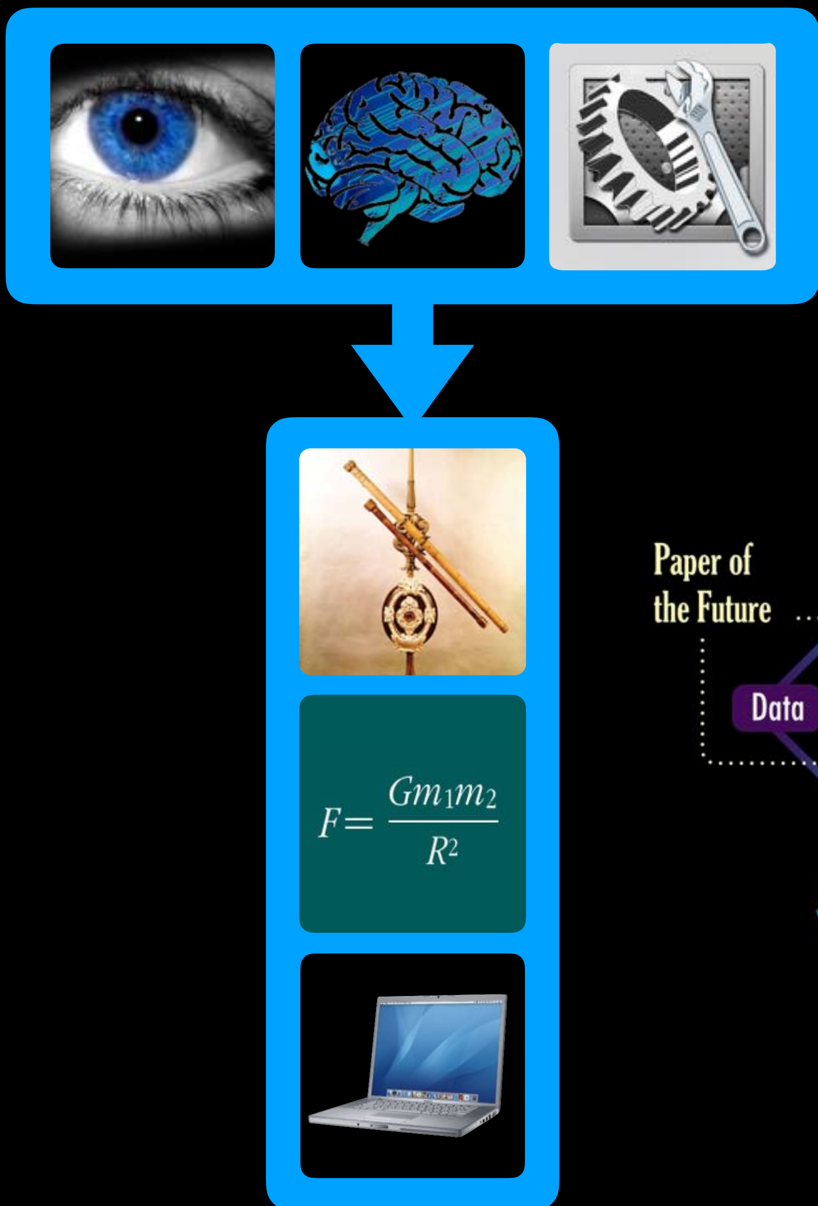
A state-of-the-art 3D model of the stars & gas near the Orion nebula, created at Orion (un)plugged, Vienna, 2015.
Expert builders (~20 total) include: Joao Alves, John Bally, Alyssa Goodman & Eddie Schlafly. (cf. "Image & Meaning" workshops by Felice Frankel)
YouTube video explanation; WWT Tour

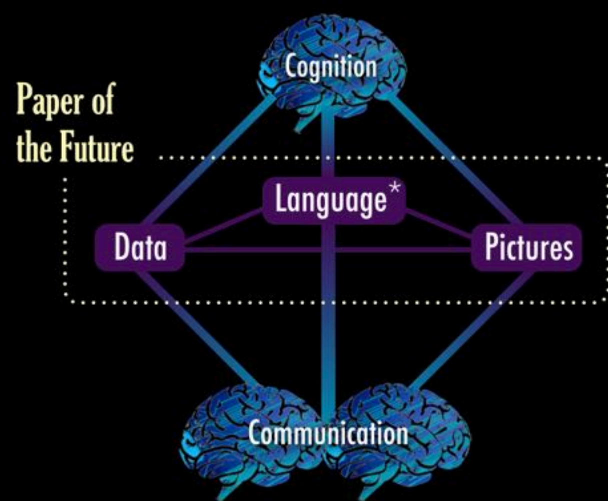
The challenge of 3D Selection

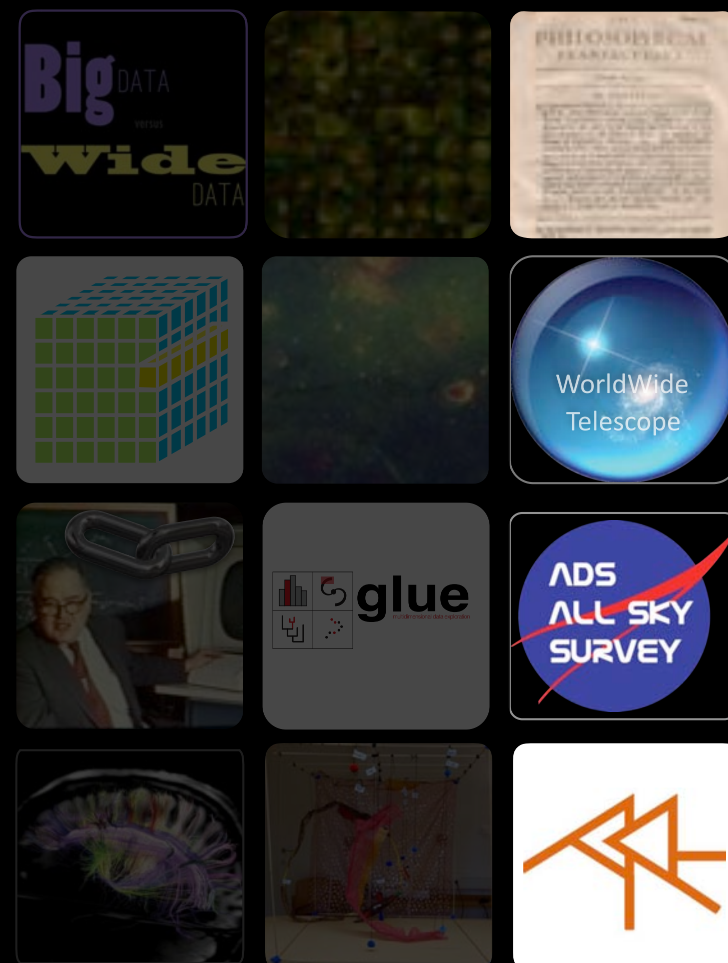


The challenge of 3D Selection




$F = \frac{G m_1 m_2}{R^2}$


Paper of
the Future
Cognition
Language*
Data
Pictures
Communication


Big DATA
Wide DATA
WorldWide
Telescope
glue
ADS
ALL SKY
SURVEY

Literature as (a filter for) Data

Many thanks to Alberto Pepe, August Muench, Thomas Boch, Jonathan Fay, Michael Kurtz, Alberto Accomazzi, Julie Steffen, Laura Trouille, David Hogg, Dustin Lang, Christopher Stumm, Chris Beaumont & Phil Rosenfield for making this all work!

Bringing "Dead" Data Back to Life

Authorea beta

HELP EXPLORE

5.3.3 Putting images in Context

Most observational astronomy has the unique feature of having a specific space to which the data are attached: the celestial sphere. As such, it makes sense for us to attach our images to locations. The AstroExplorer tool (cite) and the ADS All Sky Survey can allow images to be treated as data, in the sense that they can be "put back" on the Sky in context. Here's a sample, using an image from Barnard that is 100 years old (update). Click the caption's link to see it on the Sky in WorldWide Telescope.

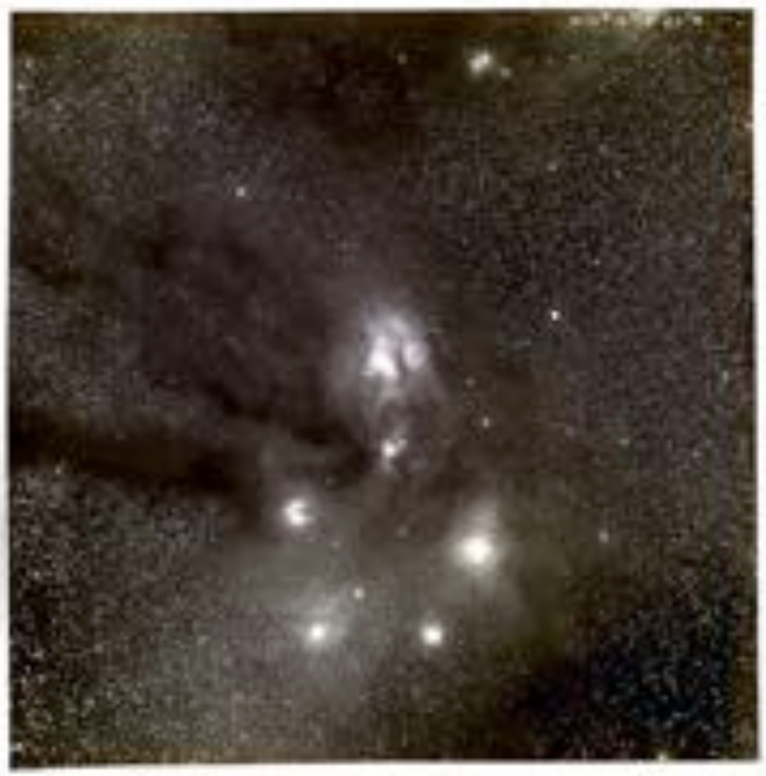


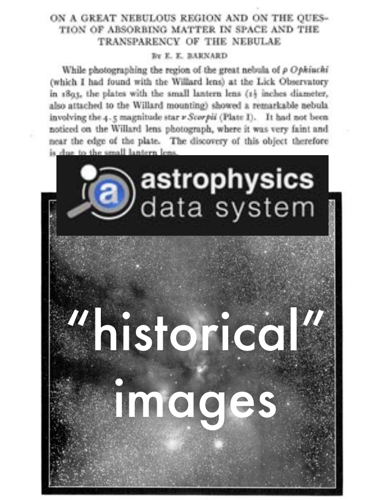
Fig. 7

Click here to see this image on the Sky in your browser (using HTML5 WorldWide Telescope). Original image source.

ADS All-Sky Survey & Astronomy Rewind

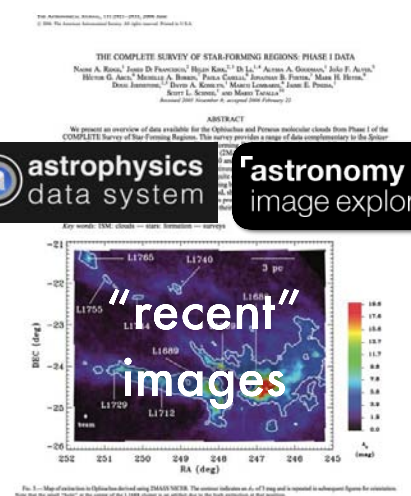
"putting articles and images (back) on the Sky"

1. Images Extracted from Journal Articles


ON A GREAT NEBULOUS REGION AND ON THE QUESTION OF ABSORBING MATTER IN SPACE AND THE TRANSPARENCY OF THE NEBULAE

By E. E. BARNARD

While photographing the region of the great nebula of ρ Ophiuchi (which I had found with the Willard lens) at the Lick Observatory in 1893, the plates with the small lantern lens (1½ inches diameter, also attached to the Willard mounting) showed a remarkable nebula involving the 4.5 magnitude star ν Scorpii (Plate I). It had not been noticed on the Willard lens photograph, where it was very faint and near the edge of the plate. The discovery of this object therefore is due to the small lantern lens.


THE COMPLETE SURVEY OF STAR-FORMING REGIONS: PHASE I DATA

ABSTRACT

We present an overview of data available for the Ophiuchus and Perseus molecular clouds from Phase I of the COMPLETE Survey of Star-Forming Regions.

2. Missing coordinate metadata added back to images, either...

...automatically, applying astrometry.net to wide-field optical images, or

Astrometry.net

via "Astronomy Rewind" Zooniverse Citizen Science Project

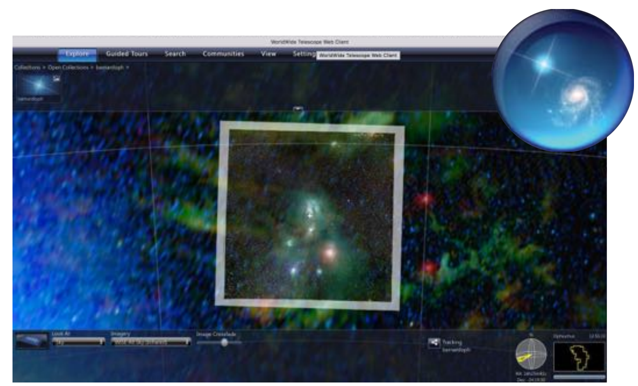
ZOONIVERSE

3. "Solved" images returned to ADS & Astronomy Image Explore[r]

astrophysics data system

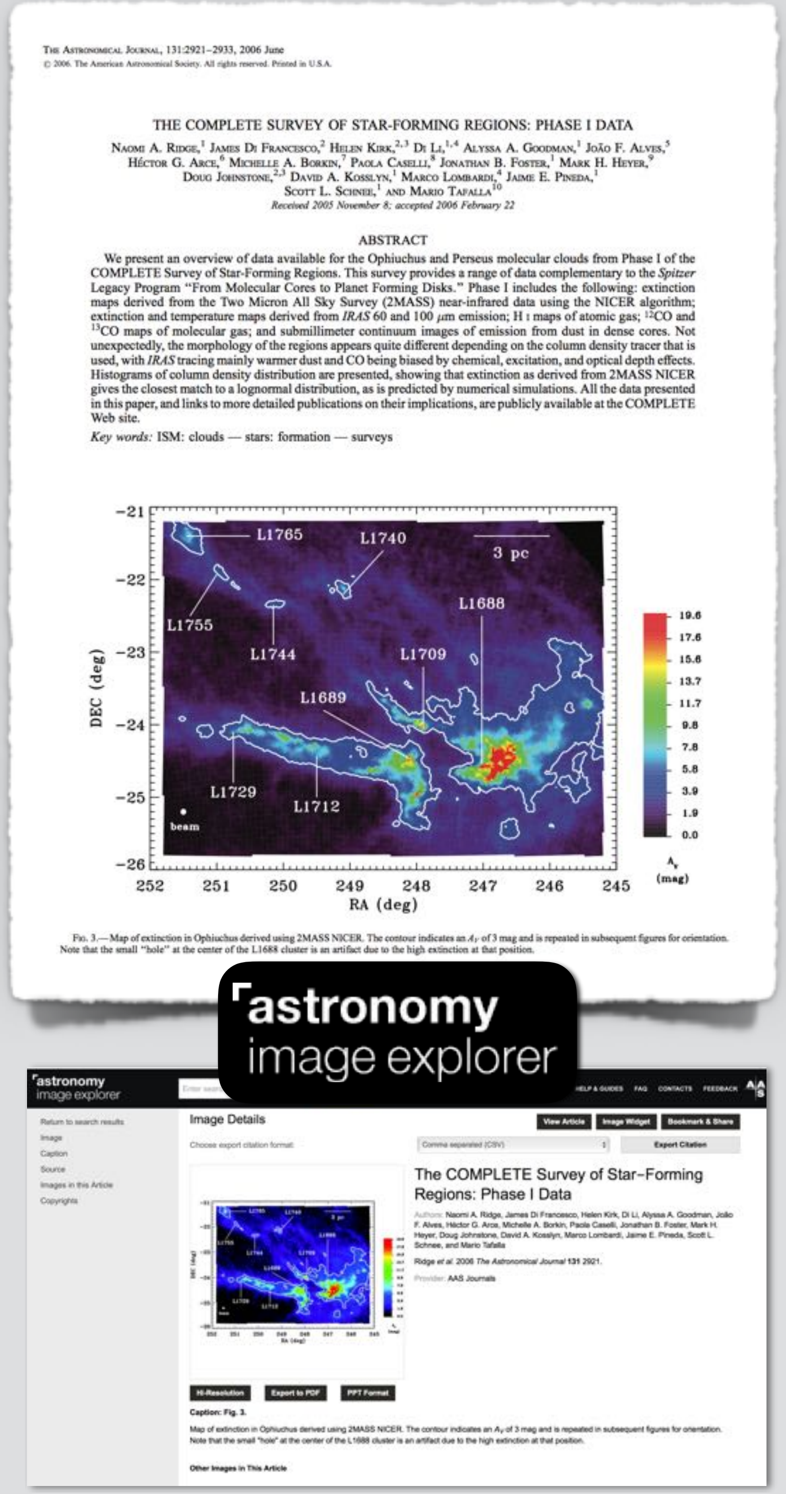
astronomy image explorer

4. New button in Astronomy Image Explorer offers image-in-context, using AAS' WorldWide Telescope in the browser



ADS	WorldWide Telescope	Zooniverse	Astrometry.net	ADS All Sky Survey	Astronomy Image Explorer	Astronomy Rewind
1992	2008	2009	2011	2014	2014	2017

click entries on the timeline to try out services



Who, How, and Who's Paying?

The **ADS All Sky Survey** was first funded via a 2012 grant from the **NASA ADAP** program to Seamless Astronomy, in collaboration with CDS, Astrometry.net and Microsoft Research.

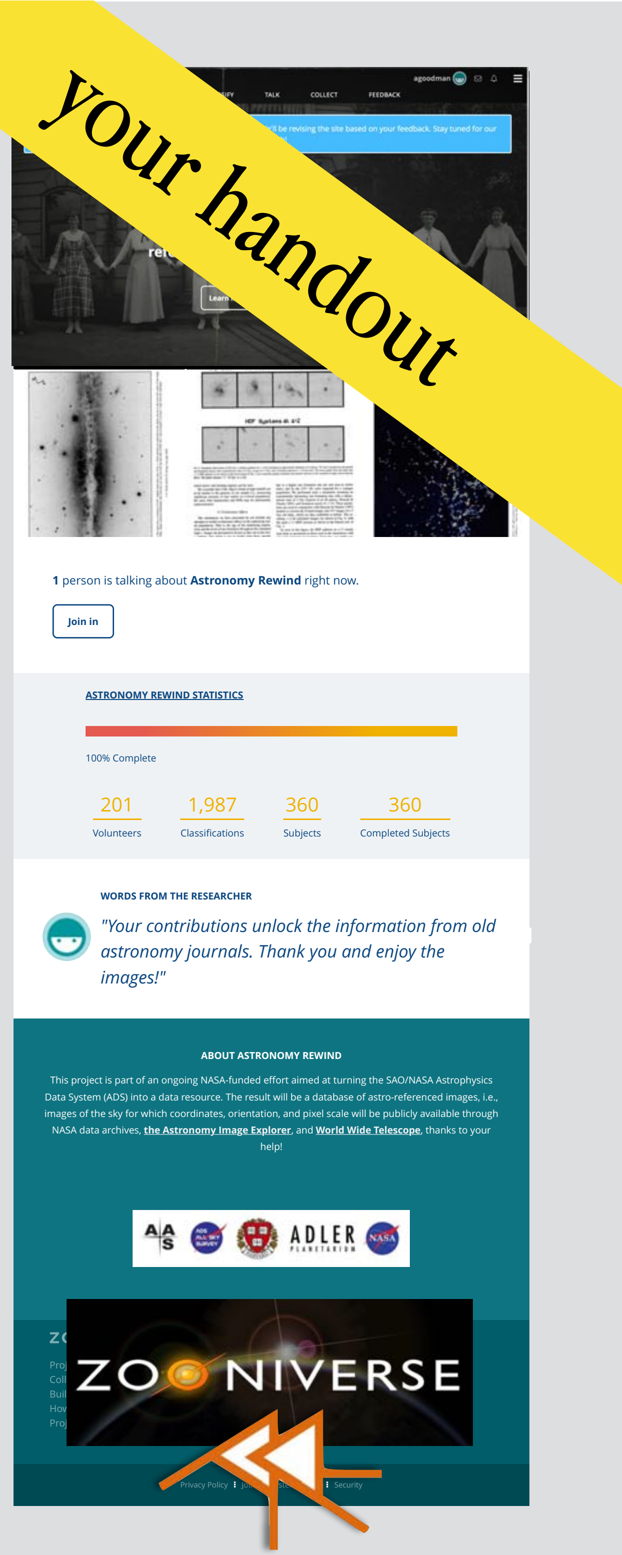
Articles-on-the-Sky
was first deployed in 2014, using APIs from WWT (Microsoft Research, now AAS) and CDS (Aladin)

Images-on-the-Sky
relies on the astrometry.net, Zooniverse, IOP/AAS Astronomy Image Explorer and WorldWide Telescope platforms, and it is funded by the **American Astronomical Society**, in addition to the NASA ADAP grant.

These projects rely on open source sofware, primarily hosted on **GitHub**.

PI to contact for more information
Alyssa Goodman, Harvard
agoodman@cfa.harvard.edu

SEAMLESS ASTRONOMY
Linking scientific data, publications, and communities



Seeing the Sky

Visualization & Astronomers

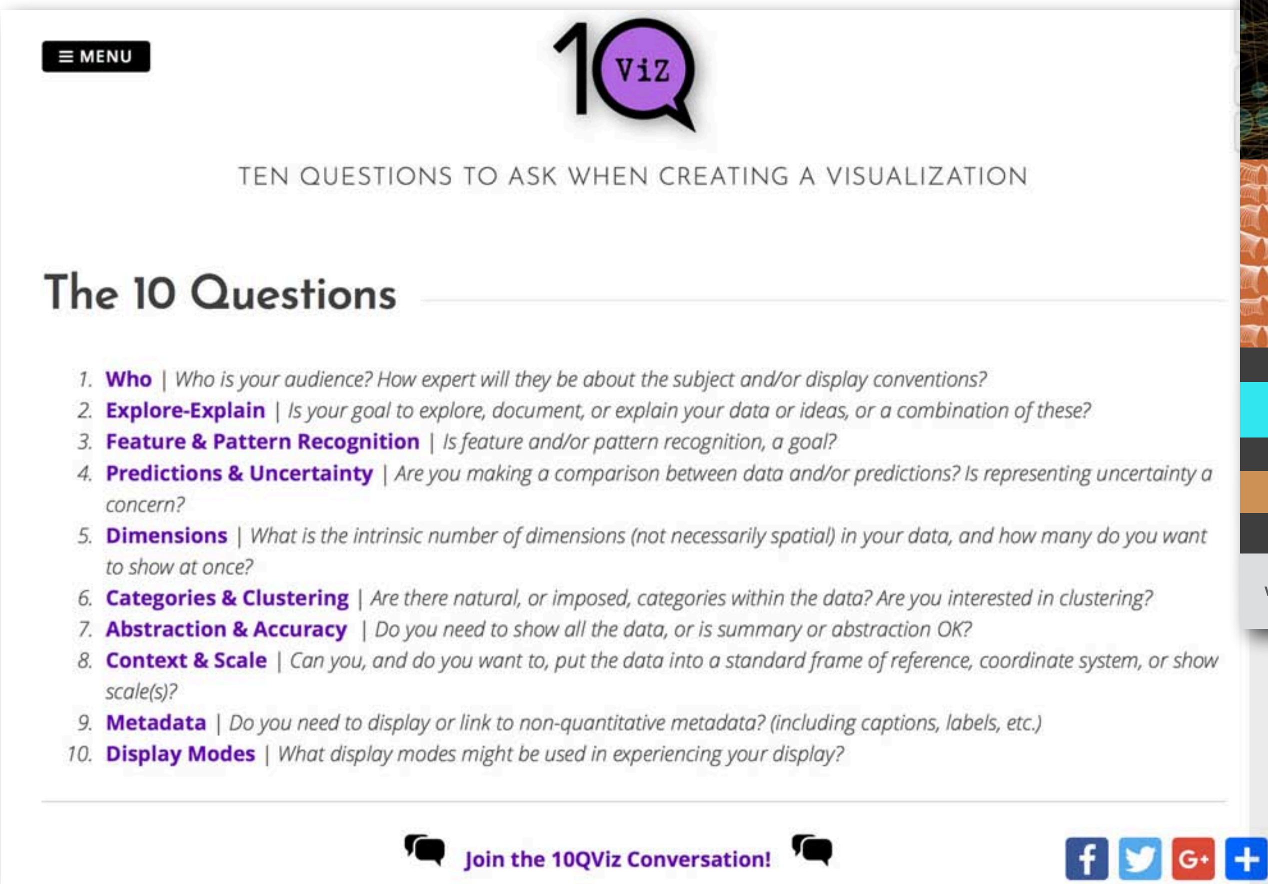
Alyssa A. Goodman

Harvard Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

@aagie

HARVARD UNIVERSITY Microsoft Research NSF SEAMLESS ASTRONOMY Linking scientific data, publications, and communities Authorea NASA AAS AMERICAN ASTRONOMICAL SOCIETY Enhancing and sharing humanity's scientific understanding of the universe since 1899.

To continue the conversation…



≡ MENU

10 Viz

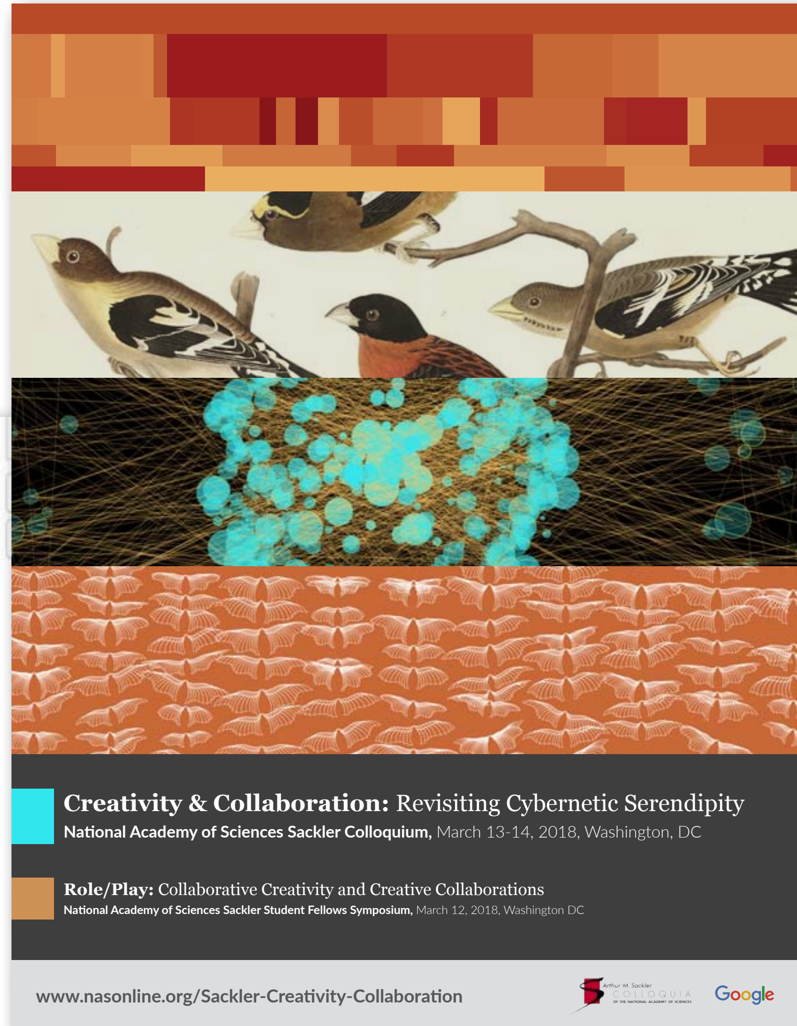
TEN QUESTIONS TO ASK WHEN CREATING A VISUALIZATION

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. **Feature & Pattern Recognition** | *Is feature and/or pattern recognition, a goal?*
4. **Predictions & Uncertainty** | *Are you making a comparison between data and/or predictions? Is representing uncertainty a concern?*
5. **Dimensions** | *What is the intrinsic number of dimensions (not necessarily spatial) in your data, and how many do you want to show at once?*
6. **Categories & Clustering** | *Are there natural, or imposed, categories within the data? Are you interested in clustering?*
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!

10qviz.org with Arzu Çöltekin (beta 2017, release 2018)



Creativity & Collaboration at NAS March 2018
with Ben Shneiderman, Maneesh Agrawala, Roger Malina, Youngmoo Kim & Donna Cox