Seeing the Sky

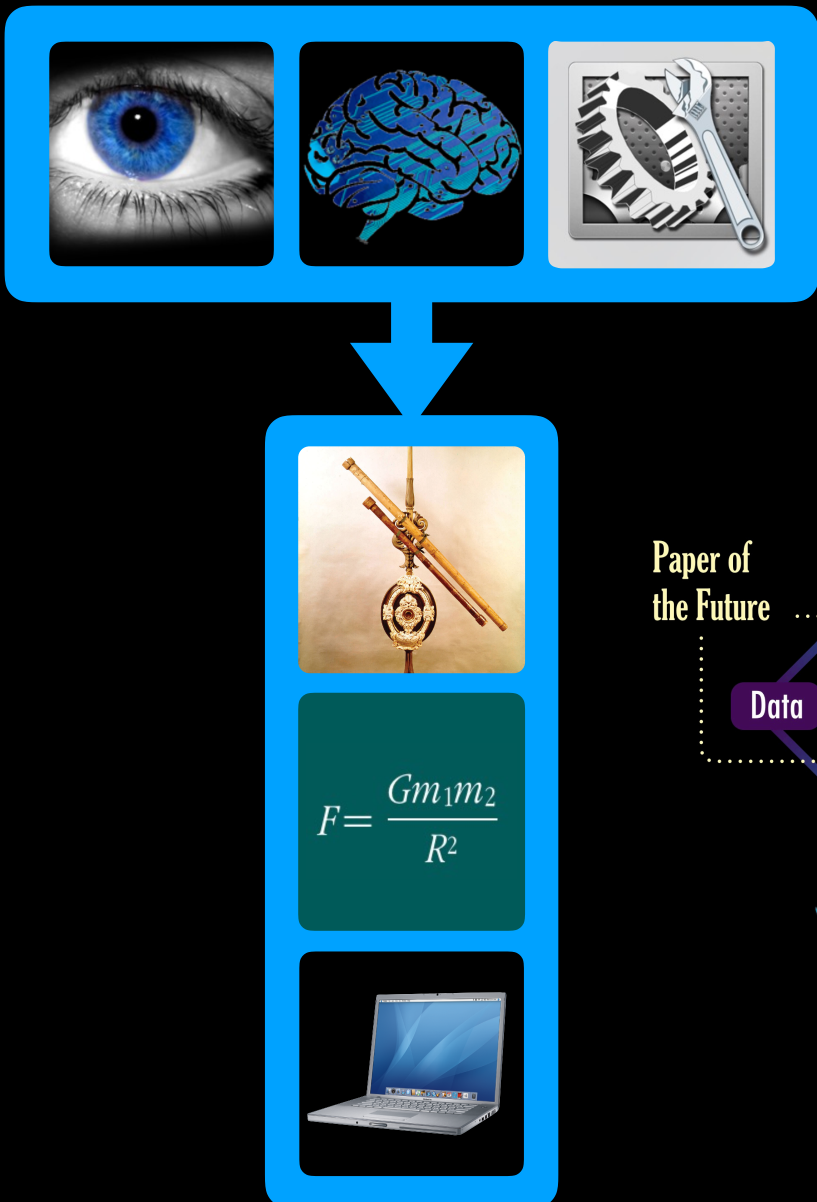
Visualization & Astronomers

David Spergel can change his mind.

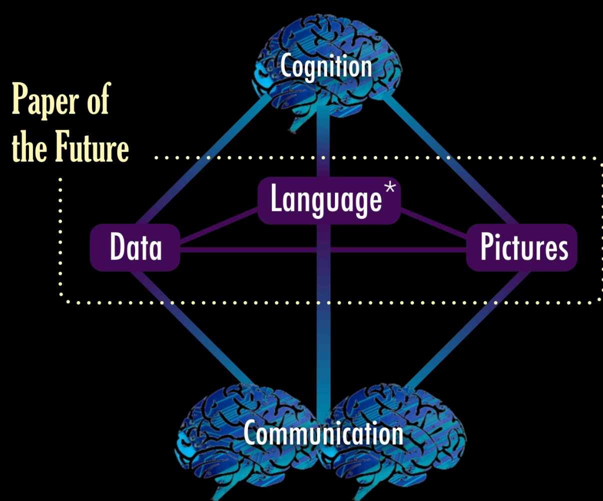
Alyssa A. Goodman

Harvard Smithsonian Center for Astrophysics & Radcliffe Institute for Advanced Study

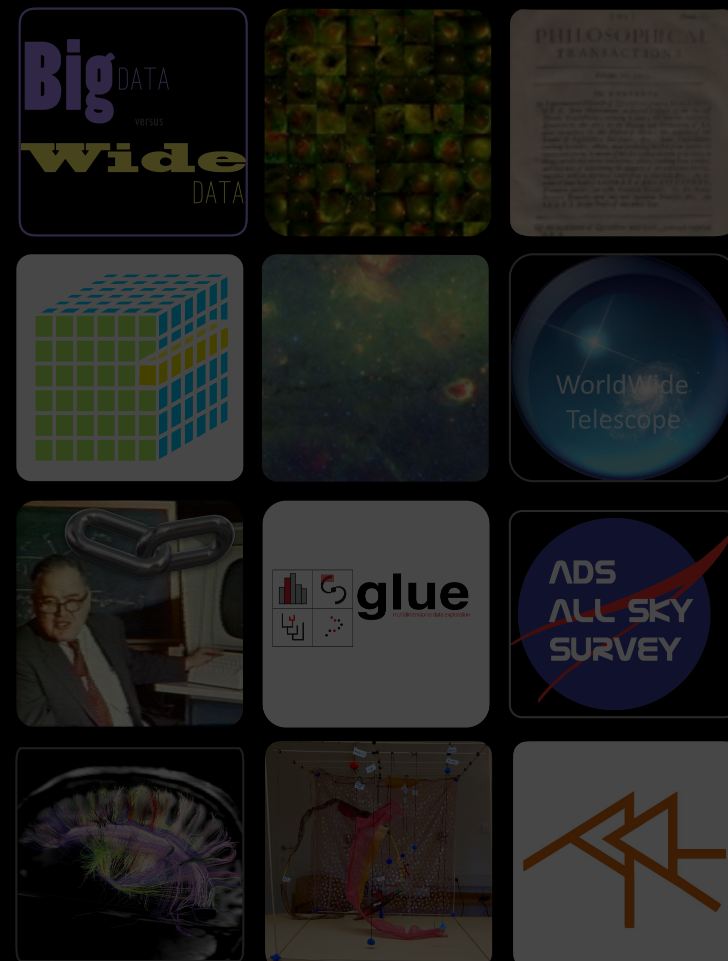
@aagie



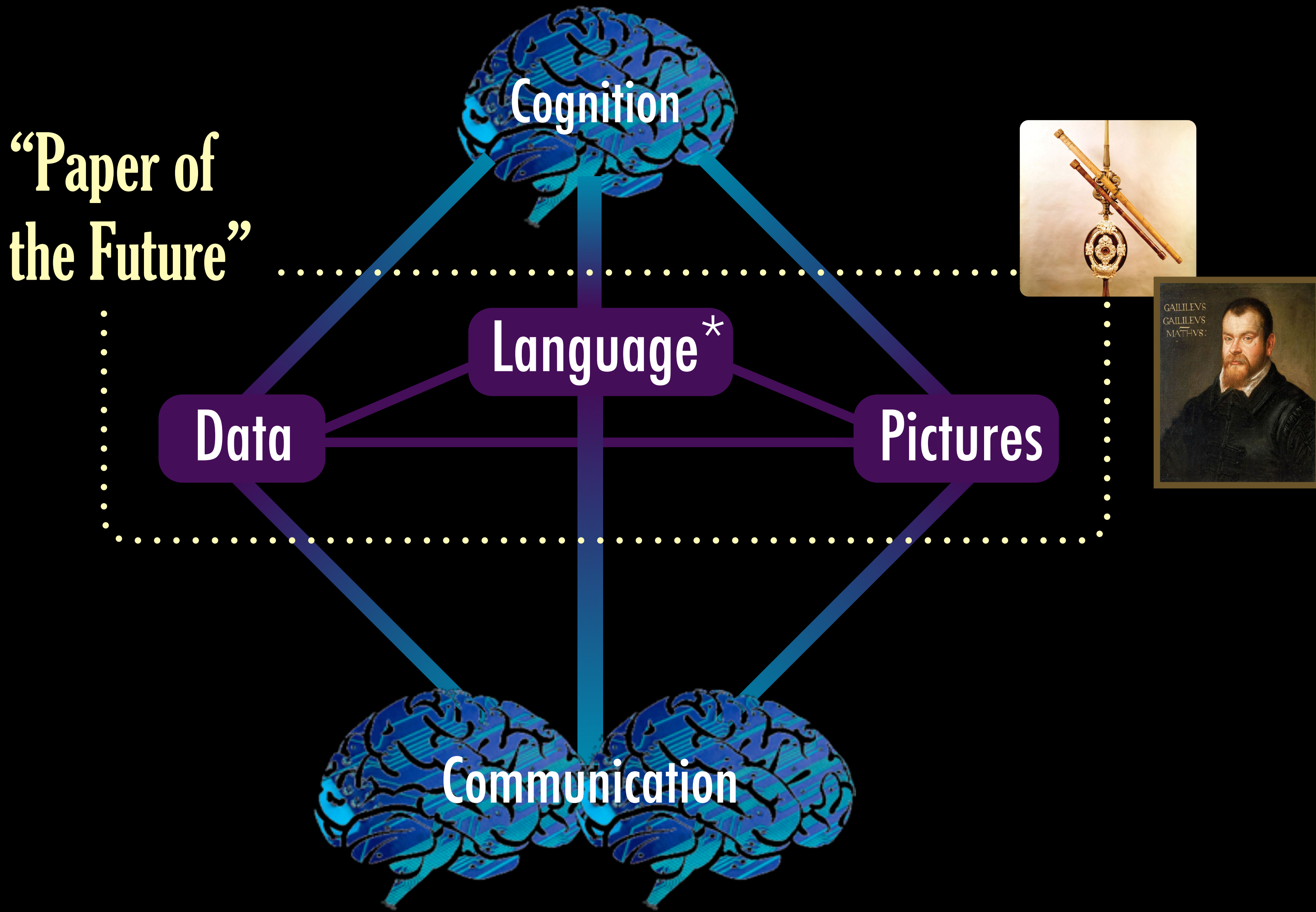
$F = \frac{Gm_1m_2}{R^2}$



Paper of
the Future
Cognition
Language*
Data
Pictures
Communication



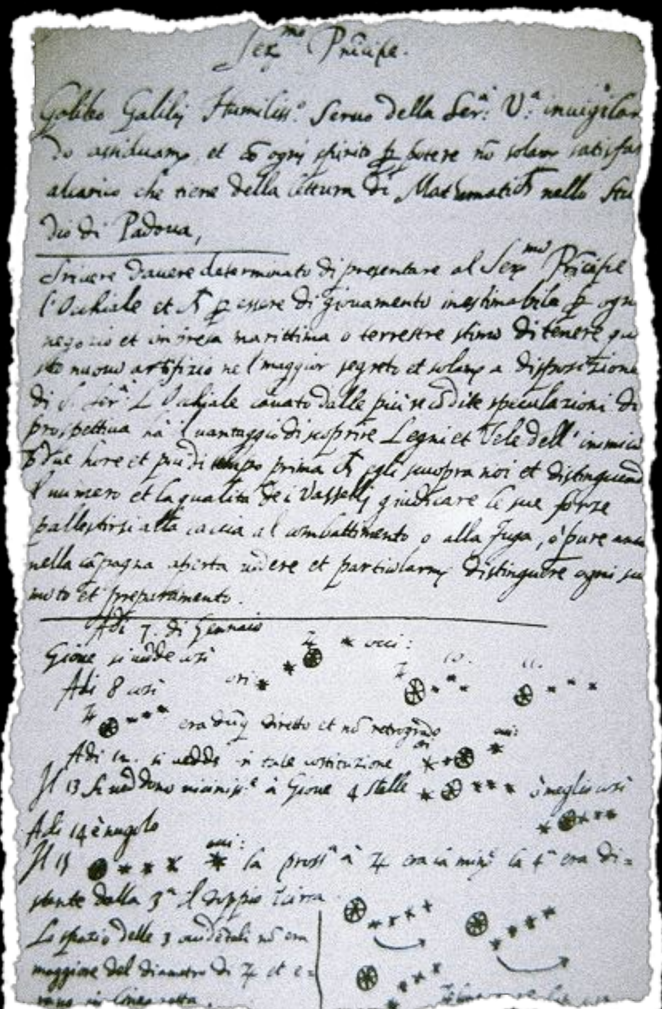
Big DATA
versus
Wide
DATA
WorldWide
Telescope
glue
ADS
ALL SKY
SURVEY



*"Language" includes words & math

Why Galileo is my Hero

Explore-Explain-Explore



Ser.mo Principe.

Galileo Galilei Humiliss.o Servo della Ser.tà V.a invigilando assiduam.te et con ogni spirito per potere non solam.te satisfare al carico che tiene della lettura di Matematiche nello Studio di Padova,

Inoltre d'havere determinato di presentare al Ser.mo Principe l'Occhiale et di poter essere di giovamento inestimabile per ogni negozio et impresa marittima o terrestre stimo di tenere questo nuovo artifizio nel maggior segreto et solam.te a disposizione di V. Ser.tà L'Occhiale cavato dalle più recondite speculazioni di prospettiva ha il vantaggio di scoprire Legni et Vele dell'inimico due hore et più di tempo prima che egli scuopra noi et distinguendo il numero et la qualità dei Vasselli giudicare le sue forze allestirsi alla caccia al combattimento o alla fuga, o pure ancora nella campagna aperta vedere et particolarm.te distinguere ogni suo moto et preparamento.

Adi 7. di Gennaio Giove si vedeva così

Adi 8 così era dunque diretto et non retrogrado

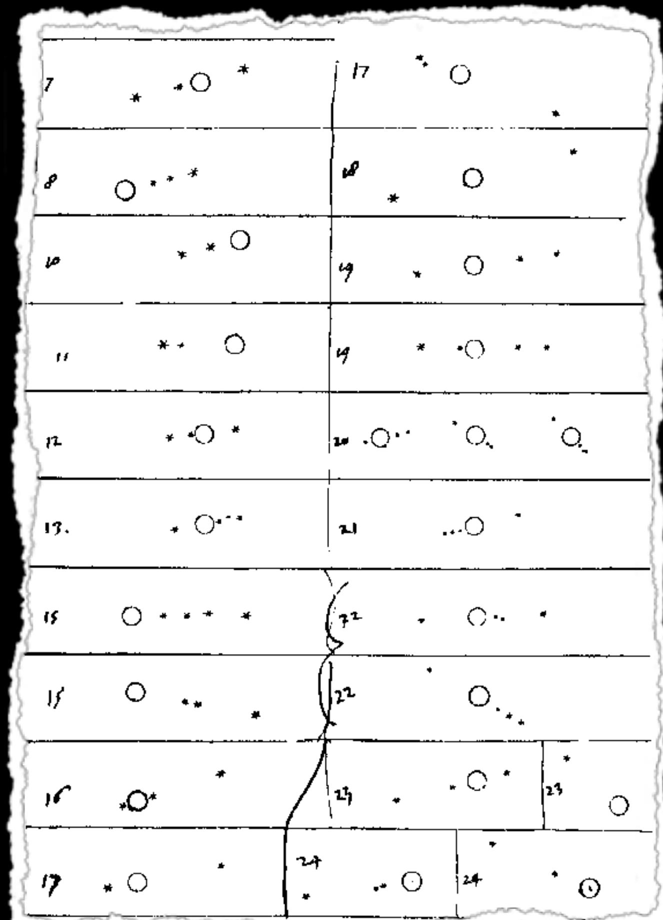
Adi 12. si vedde in tale costituzione

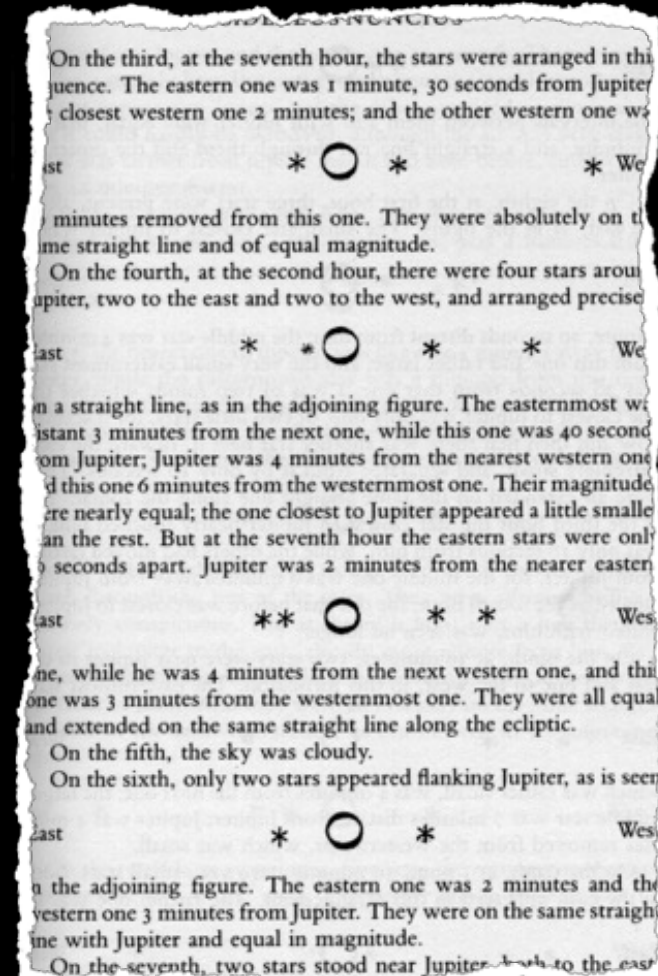
Il 13 si veddono vicinissime à Giove 4 stelle

Adi 14 è nugolo

Il 15 la pross.a à 4 era la mini. la 4.a era distante dalla 3.a il doppio in circa

Lo spatio delle 3 occidentali non era maggiore del diametro di 4 et erano in linea retta





On the third, at the seventh hour, the stars were arranged in thi[s se]quence. The eastern one was 1 minute, 30 seconds from Jupite[r; the] closest western one 2 minutes; and the other western one wa[s]

[E]ast * ○ * * We[st]

[10] minutes removed from this one. They were absolutely on t[he sa]me straight line and of equal magnitude.

On the fourth, at the second hour, there were four stars arou[nd J]upiter, two to the east and two to the west, and arranged precise[ly]

[E]ast * *○ * * We[st]

[o]n a straight line, as in the adjoining figure. The easternmost w[as d]istant 3 minutes from the next one, while this one was 40 second[s fr]om Jupiter; Jupiter was 4 minutes from the nearest western one [an]d this one 6 minutes from the westernmost one. Their magnitude[s w]ere nearly equal; the one closest to Jupiter appeared a little smalle[r th]an the rest. But at the seventh hour the eastern stars were onl[y 3]0 seconds apart. Jupiter was 2 minutes from the nearer easter[n o]ne, while he was 4 minutes from the next western one, and thi[s] one was 3 minutes from the westernmost one. They were all equal and extended on the same straight line along the ecliptic.

[E]ast ** ○ * * Wes[t]

On the fifth, the sky was cloudy.

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

[E]ast * ○ * Wes[t]

[i]n the adjoining figure. The eastern one was 2 minutes and the [w]estern one 3 minutes from Jupiter. They were on the same straigh[t l]ine with Jupiter and equal in magnitude.

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

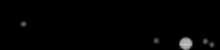
Notes for & re-productions of Siderius Nuncius

1610

GALILEO'S "NEW ORDER"

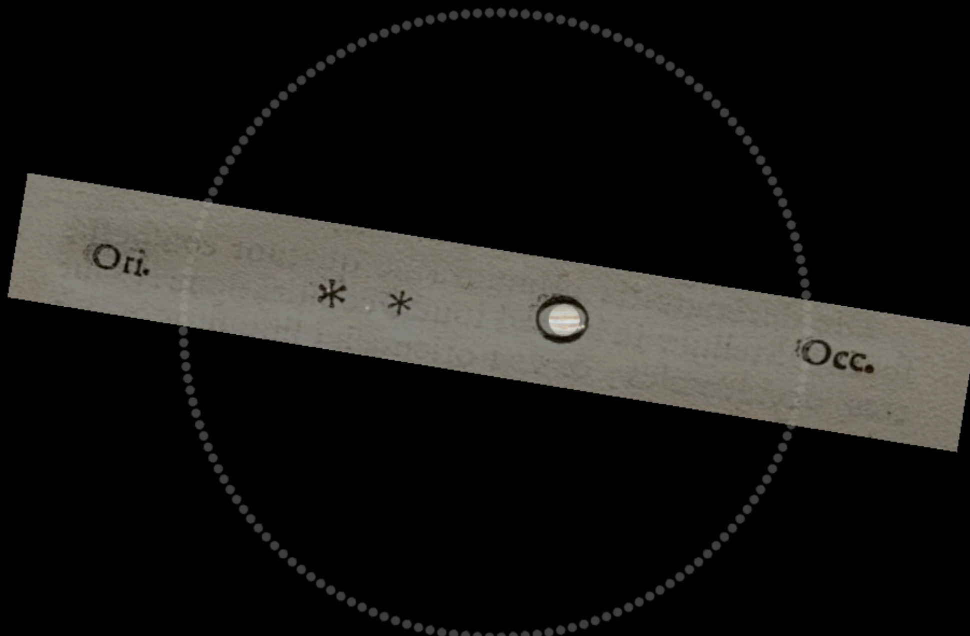
Created by Alyssa Goodman, Curtis Wong and Pat Udomprasert,

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



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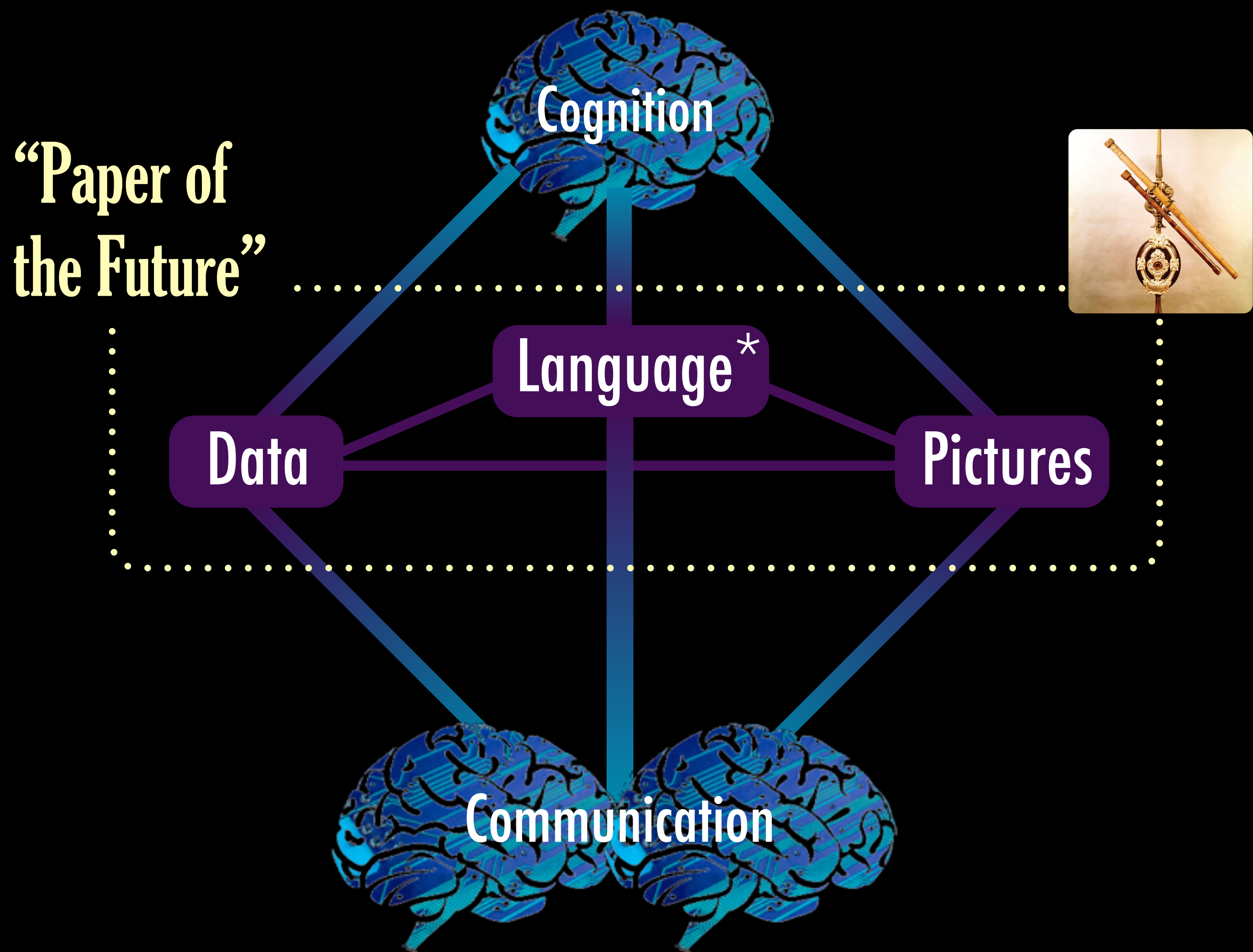
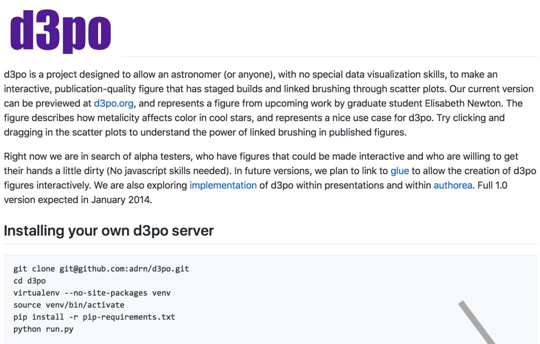


*“Language” includes words & math

glue
multidimensional data exploration

enabled by d3.js [javascript] outputs

plotly



d3po

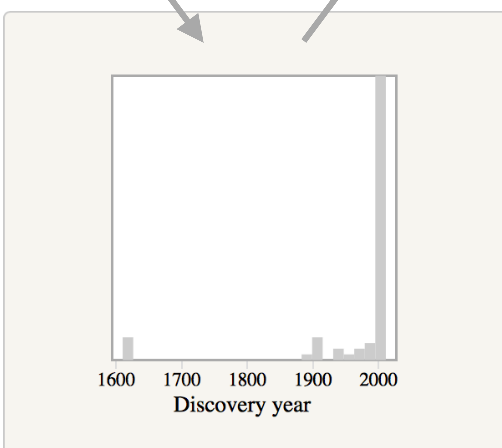
d3po is a project designed to allow an astronomer (or anyone), with no special data visualization skills, to make an interactive, publication-quality figure that has staged builds and linked brushing through scatter plots. Our current version can be previewed at d3po.org, and represents a figure from 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

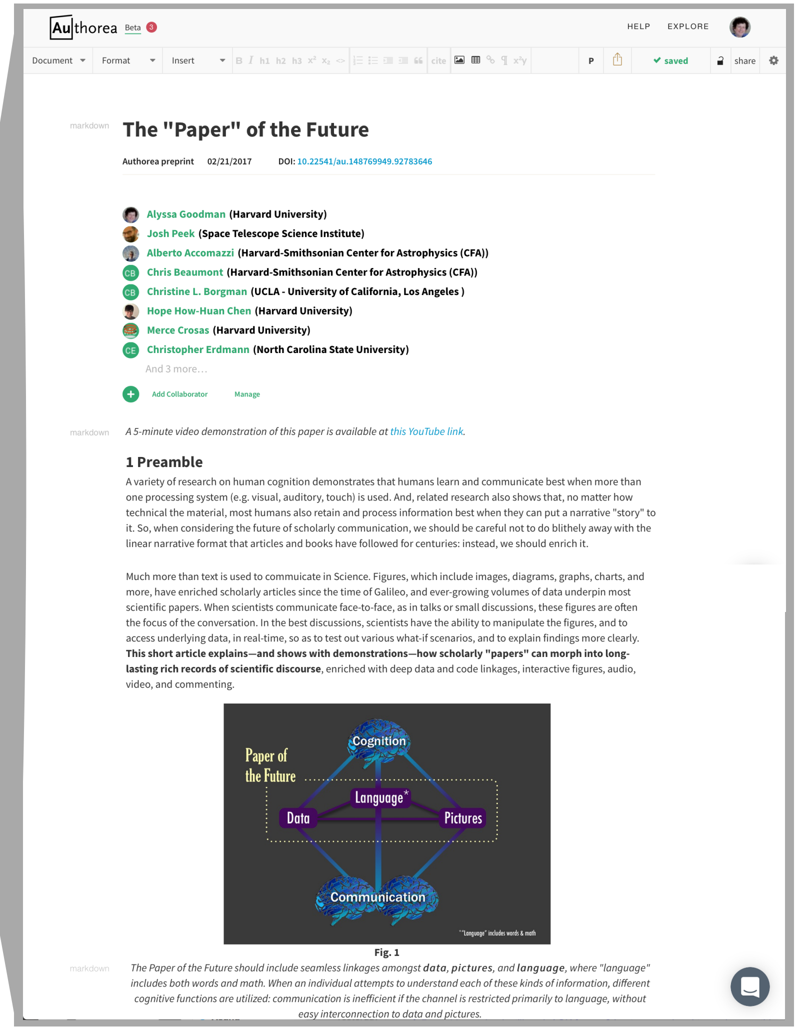
```
git clone git@github.com:adrn/d3po.git
cd d3po
virtualenv --no-site-packages venv
source venv/bin/activate
pip install -r pip-requirements.txt
python run.py
```

Authorea



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

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



Authorea Beta

HELP EXPLORE

Document Format Insert saved share

The "Paper" of the Future

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

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Chris Beaumont (Harvard-Smithsonian Center for Astrophysics (CFA))
Christine L. Borgman (UCLA - University of California, Los Angeles)
Hope How-Huan Chen (Harvard University)
Merce Crosas (Harvard University)
Christopher Erdmann (North Carolina State University)
And 3 more...

Add Collaborator Manage

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

1 Preamble

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

Much more than text is used to commucate 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.

Paper of the Future
Cognition
Language*
Data
Pictures
Communication
*"Language" includes words & math

Fig. 1

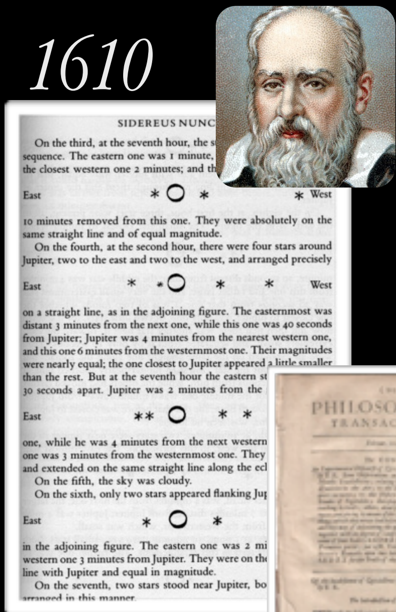
*The Paper of the Future should include seamless linkages amongst **data**, **pictures**, and **language**, where "language" includes both words and math. When an individual attempts to understand each of these kinds of information, different cognitive functions are utilized: communication is inefficient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

[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.

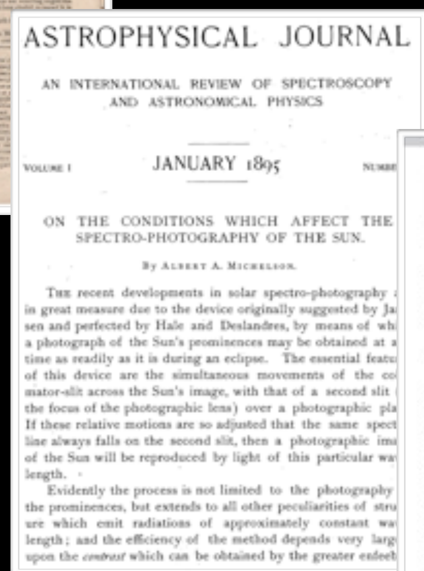
4 Centuries from Galileo to Galileo

1610

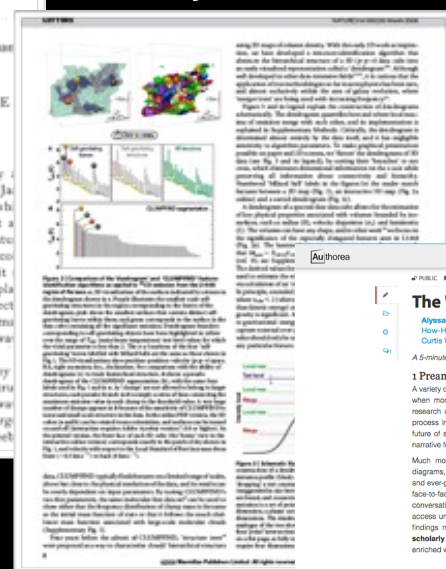


1665

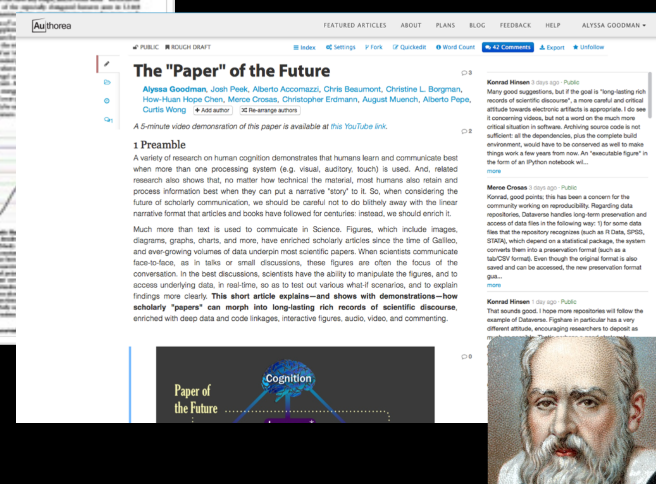
1895

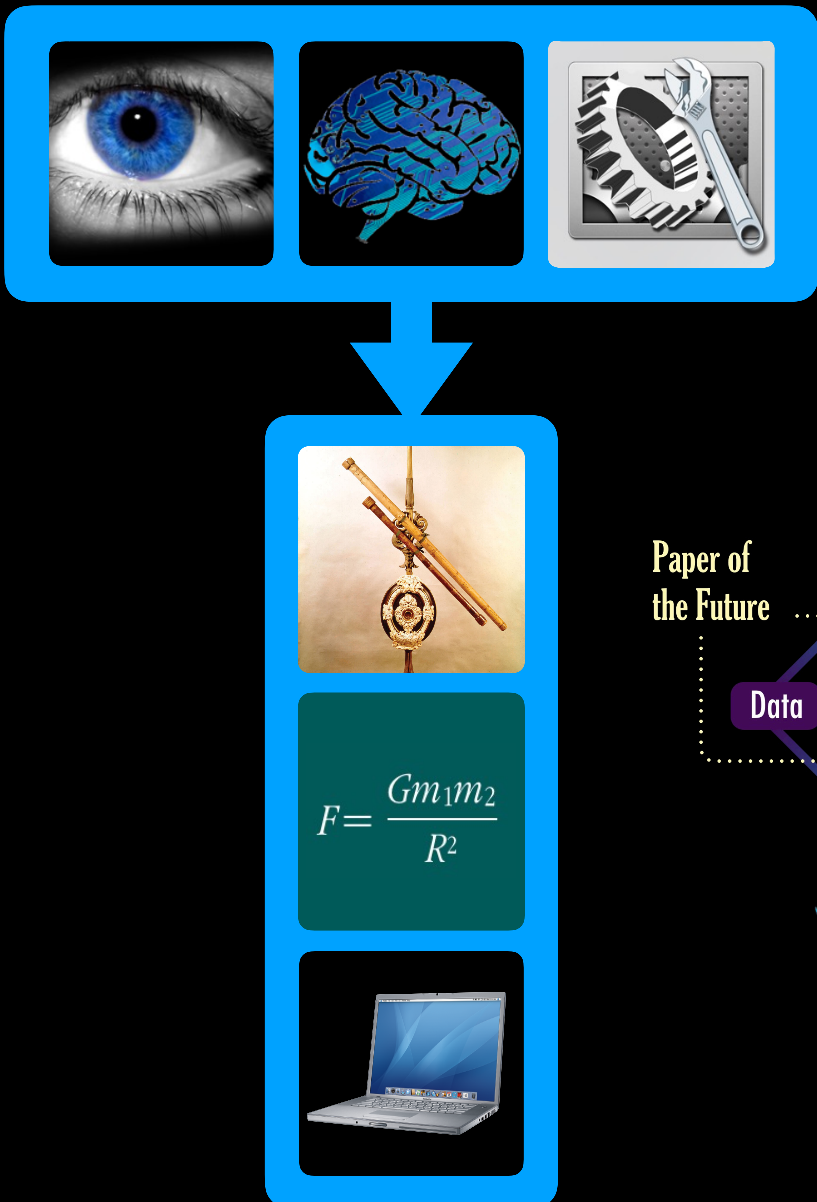


2009

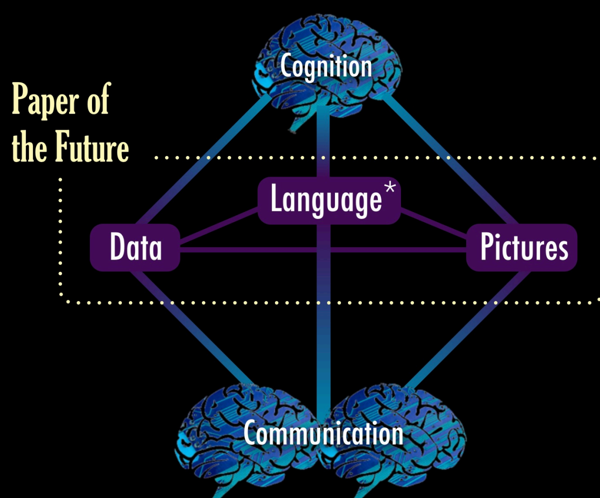


2015





F= Gm1m2 / R2



Paper of
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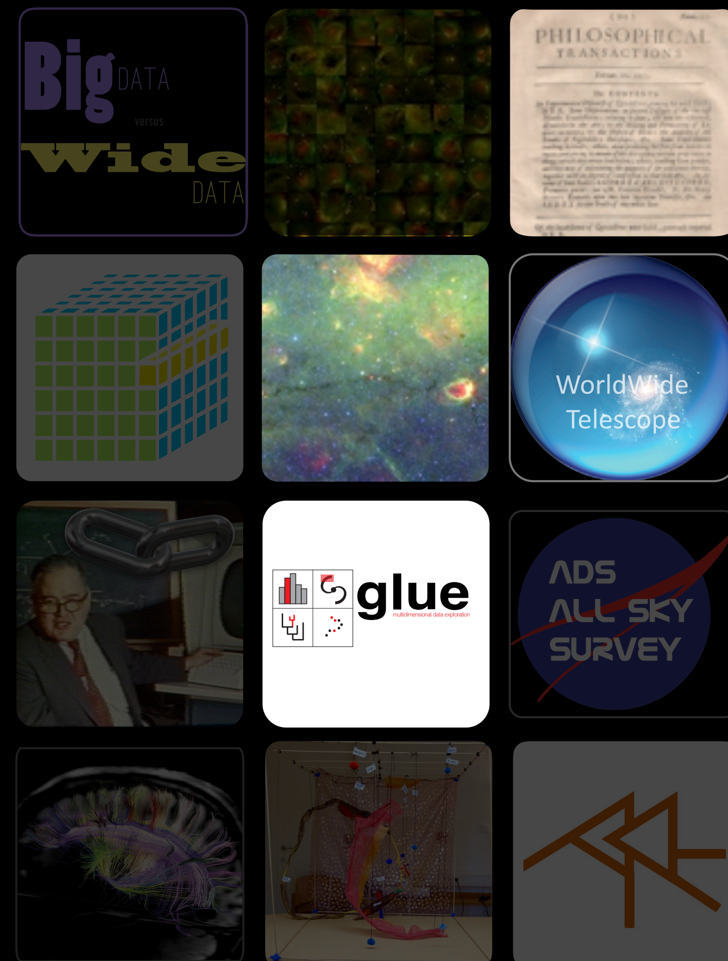
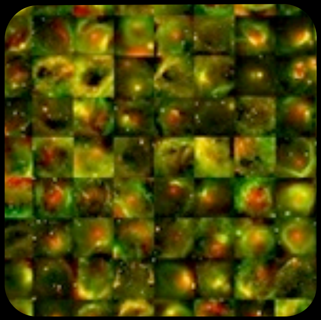
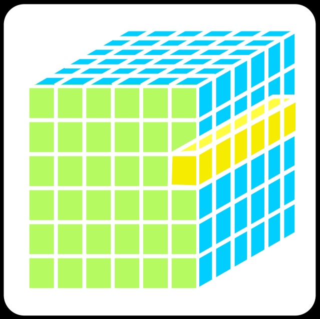


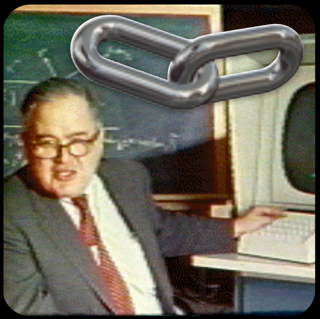
Big DATA
versus
Wide DATA
PHILOSOPHICAL TRANSACTIONS
WorldWide Telescope
glue
ADS ALL SKY SURVEY

Big DATA versus Wide DATA



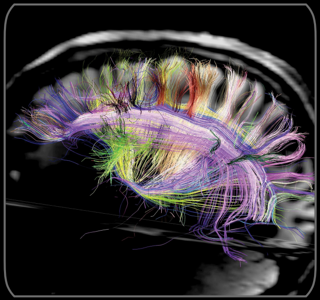


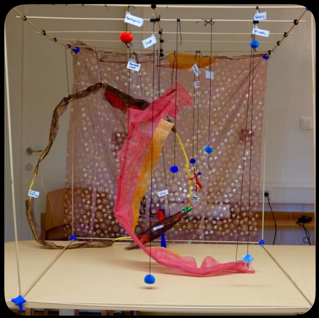
WorldWide Telescope

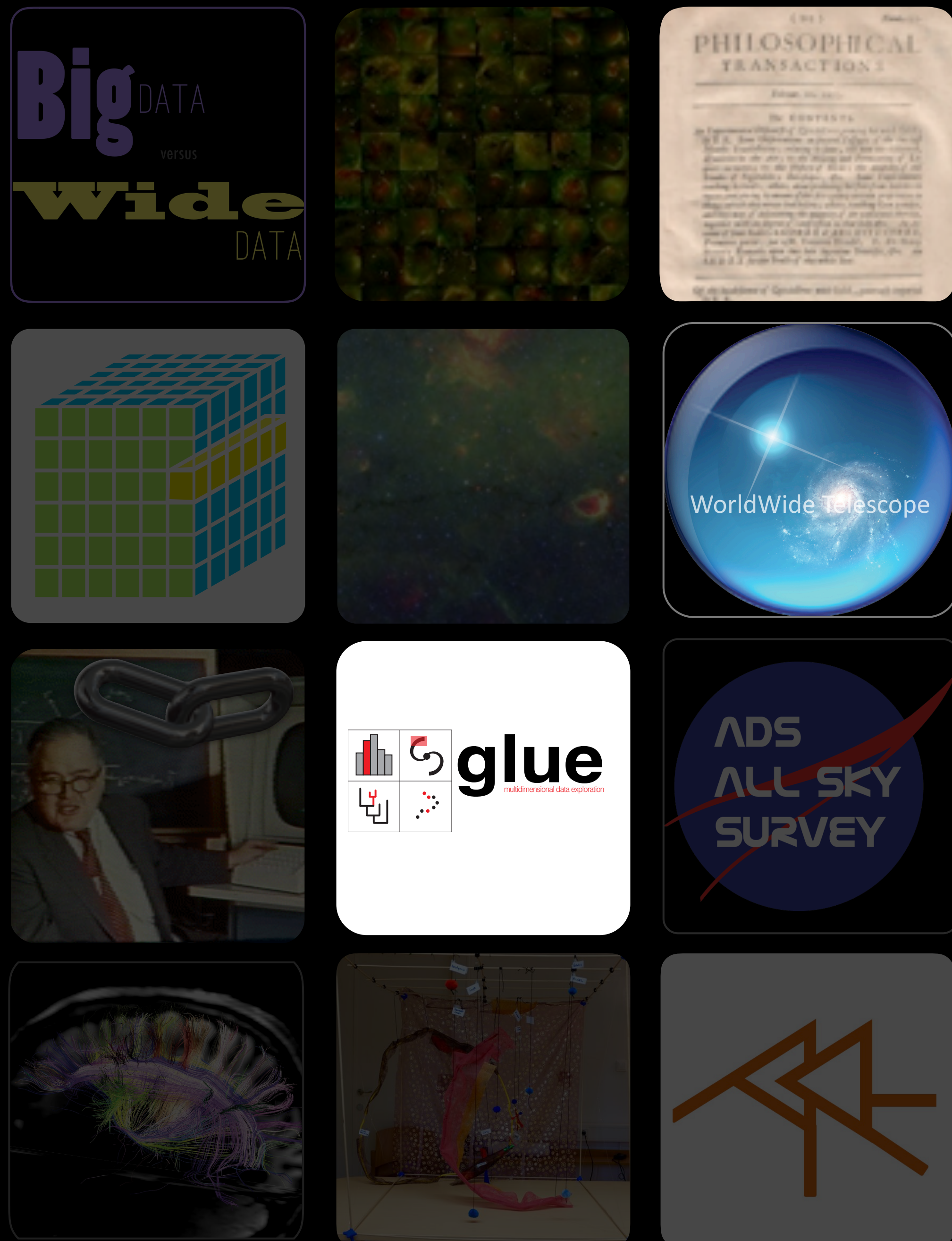


glue
multidimensional data exploration

ADS
ALL SKY
SURVEY






Big DATA
versus
Wide DATA
PHILOSOPHICAL TRANSACTIONS
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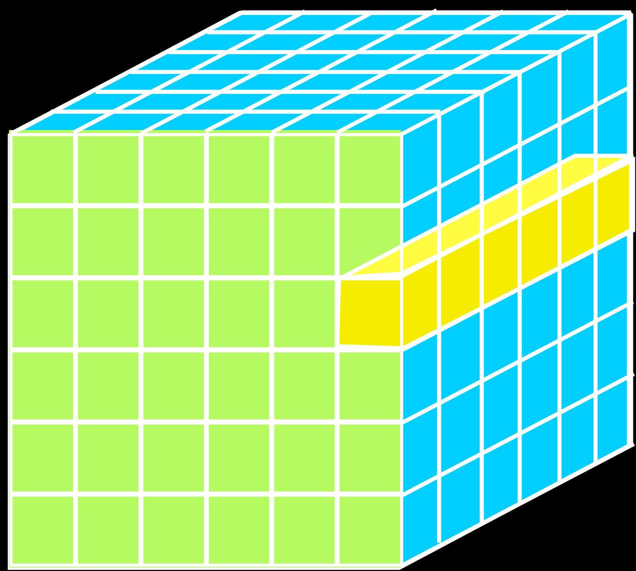
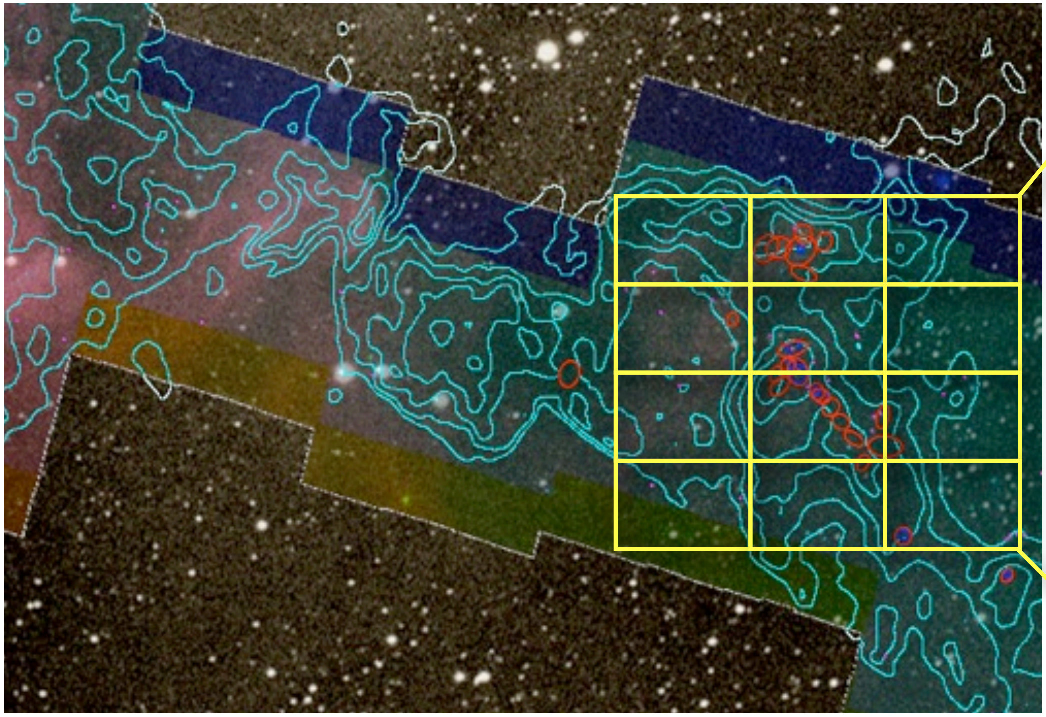
ADS ALL SKY SURVEY

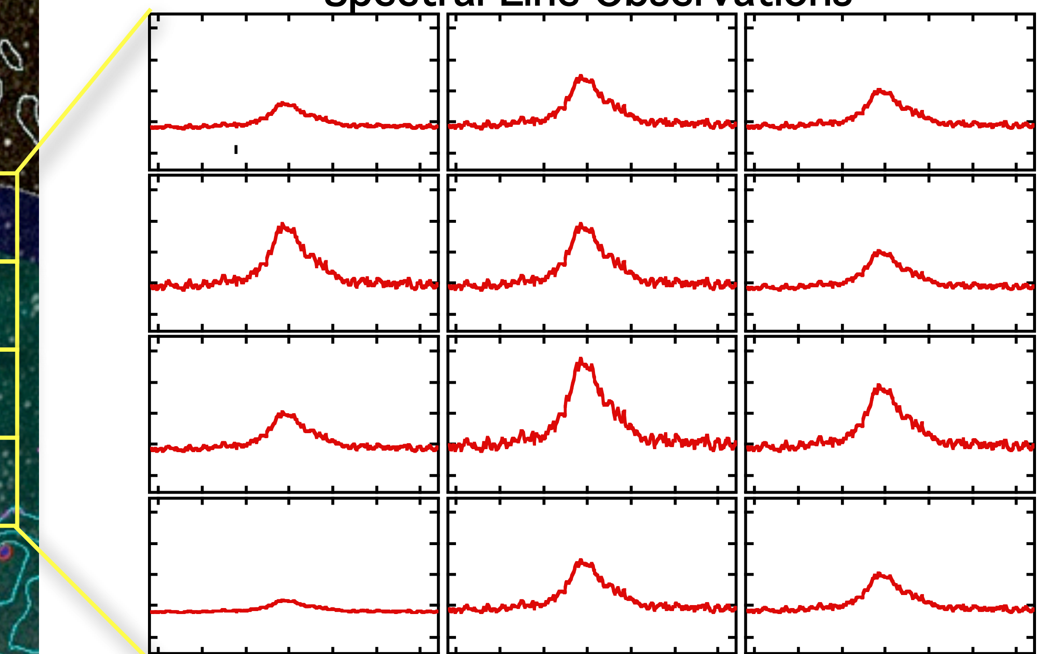


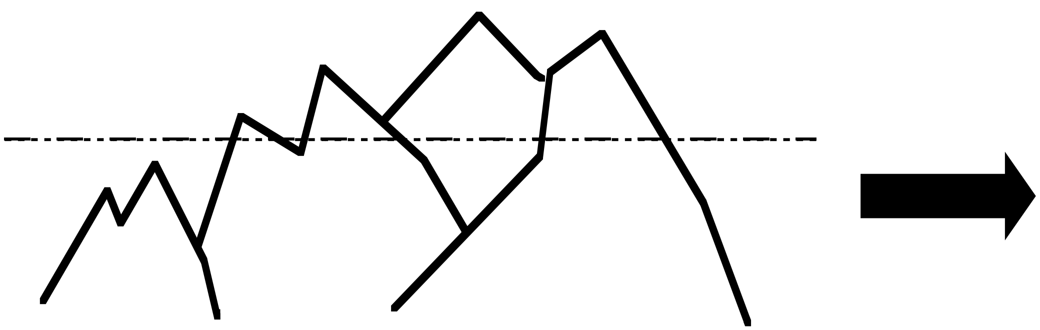
Data, Dimensions, Display

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”

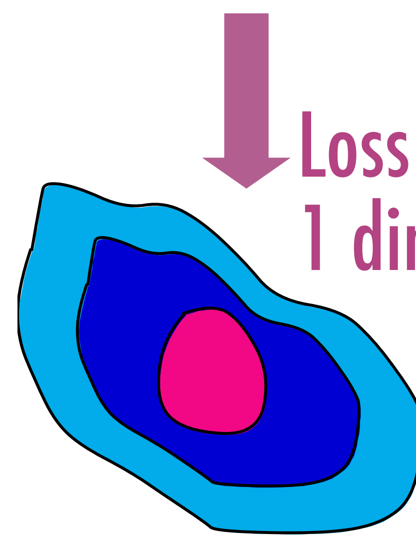
Data, Dimensions, Display





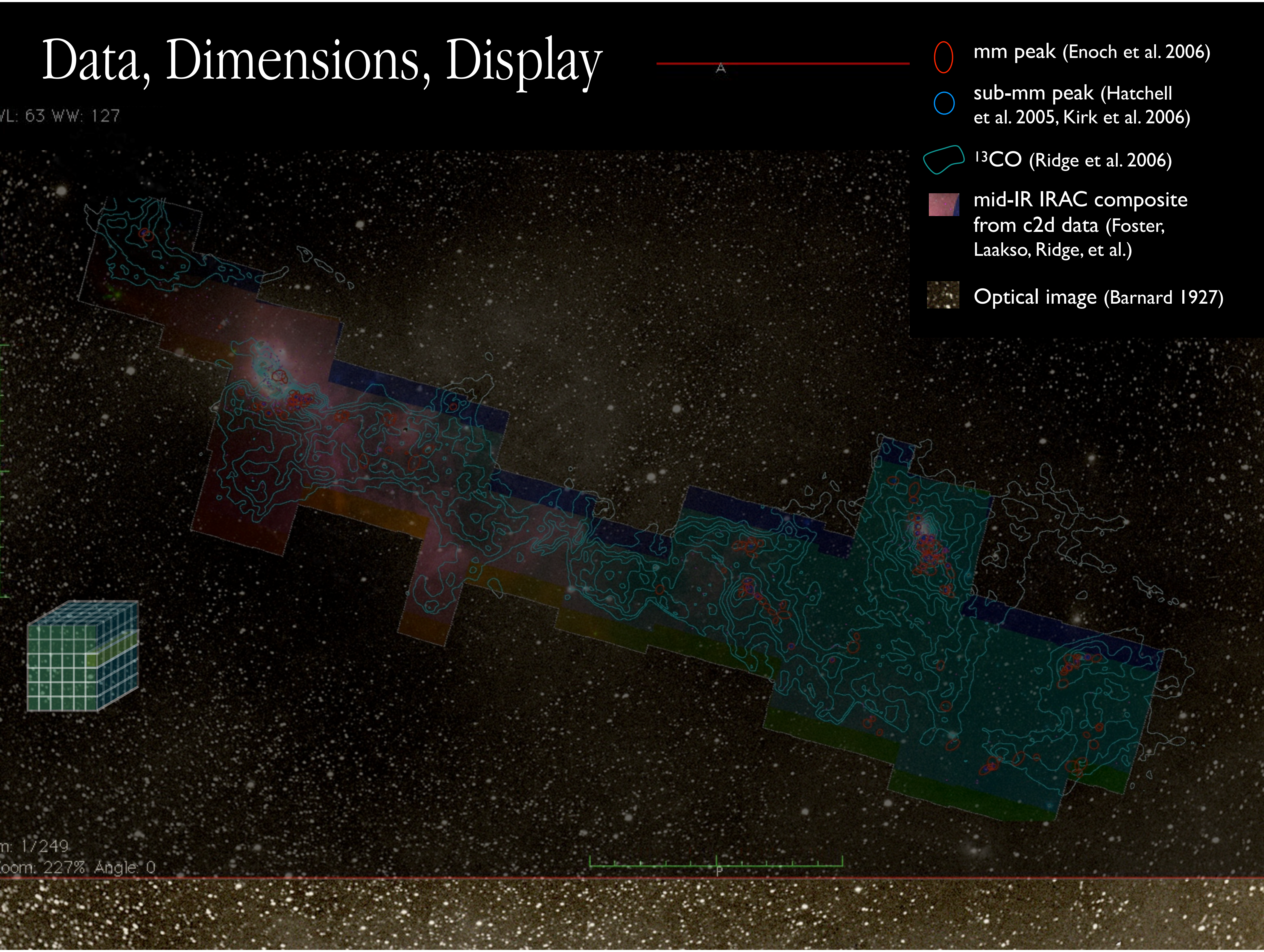


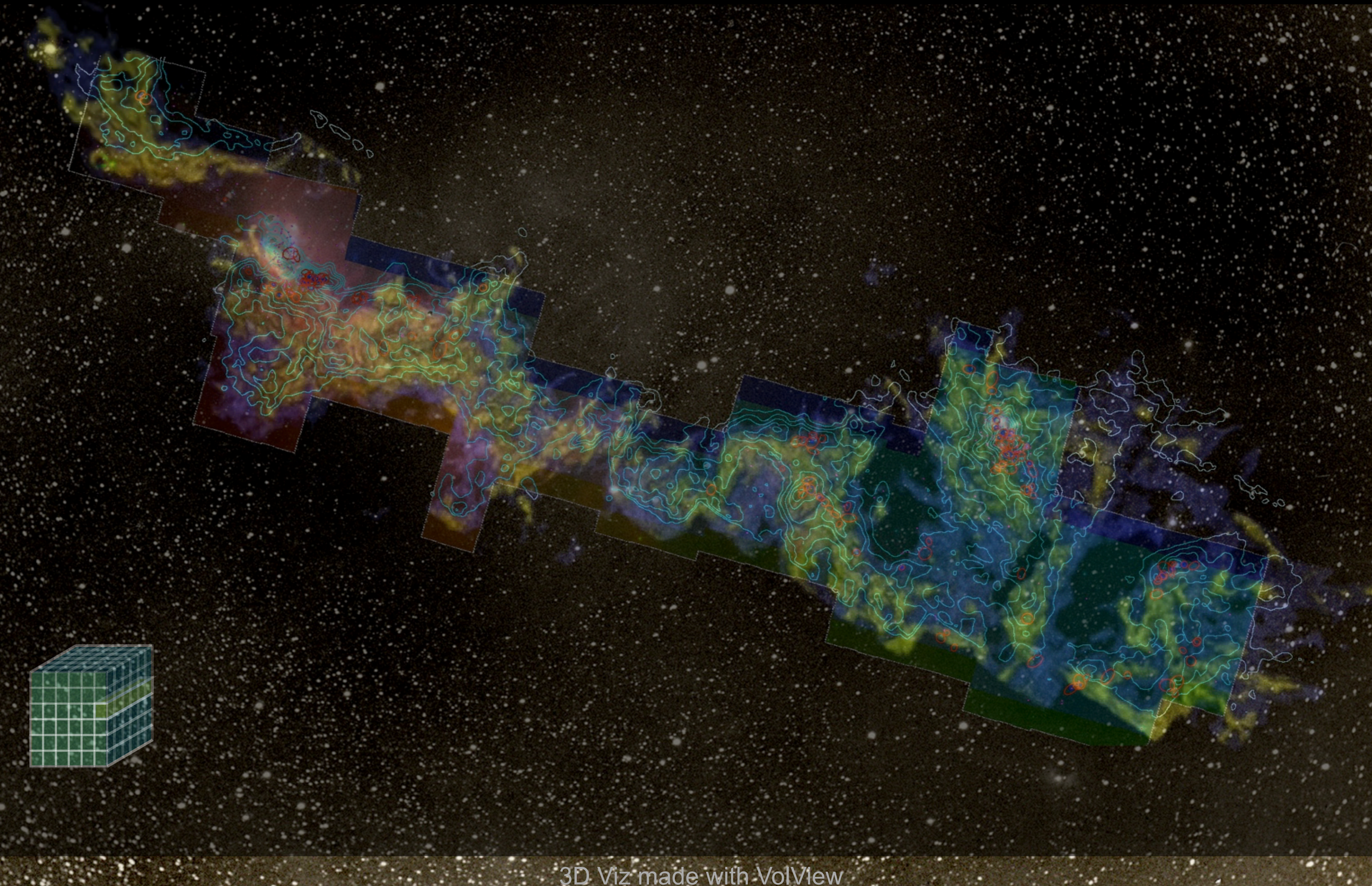
No loss of information



Loss of 1 dimension

Data, Dimensions, Display





AstronomicalMedicine@IIC

COMPLETE

2009

3D PDF

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

[demo/video]

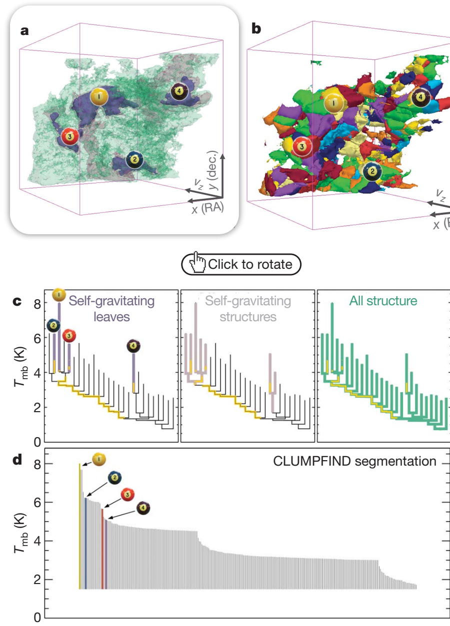


Figure 2 | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. a, 3D visualization of the surfaces indicated by colours in the dendrogram shown in **c**. Purple illustrates the smallest scale self-gravitating 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 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 th
schematically. The dendrogram qua
ima of emission merge with each
explained in Supplementary Meth
determined almost entirely by th
sensitivity to algorithm paramet
possible on paper and 2D screen
data (see Fig. 3 and its legend
cross, which eliminates dimen
preserving all information
Numbered 'billiard ball' lab
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 $X_{13CO} = 8.0 \times 10^{20}$ 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, $\alpha_{obs} = 5\sigma_v^2 R / G M_{lum}$. 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.

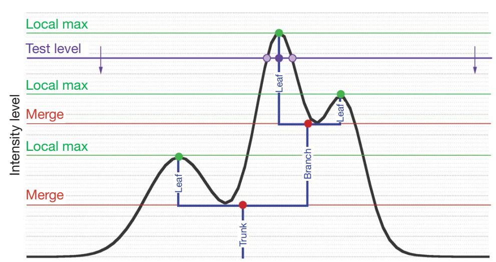
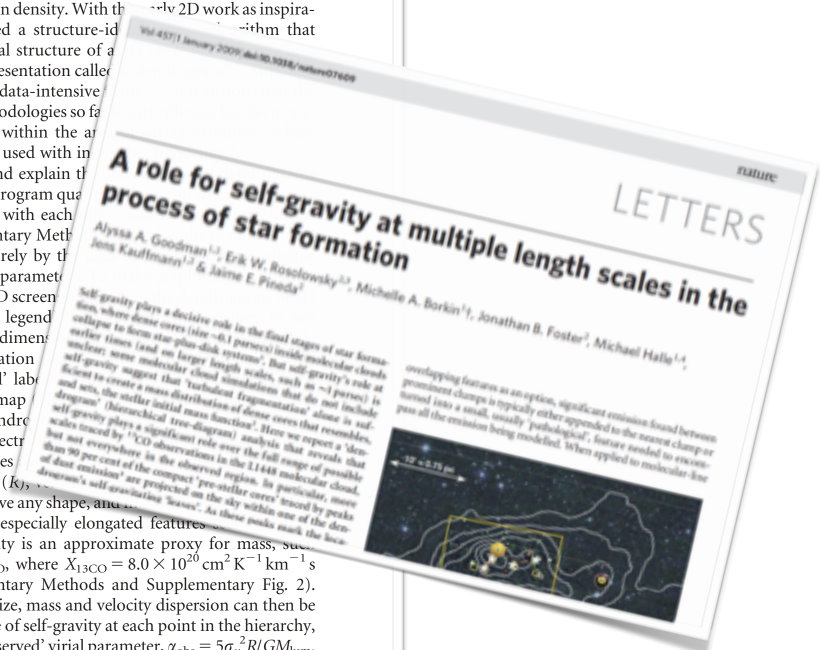
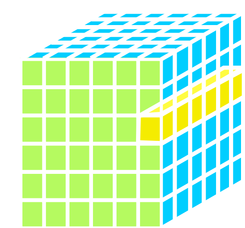


Figure 3 | Schematic illustration of the dendrogram process. Shown is the construction of a dendrogram from a hypothetical one-dimensional emission profile (black). The dendrogram (blue) can be constructed by 'dropping' a test constant emission level (purple) from above in tiny steps (exaggerated in 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**

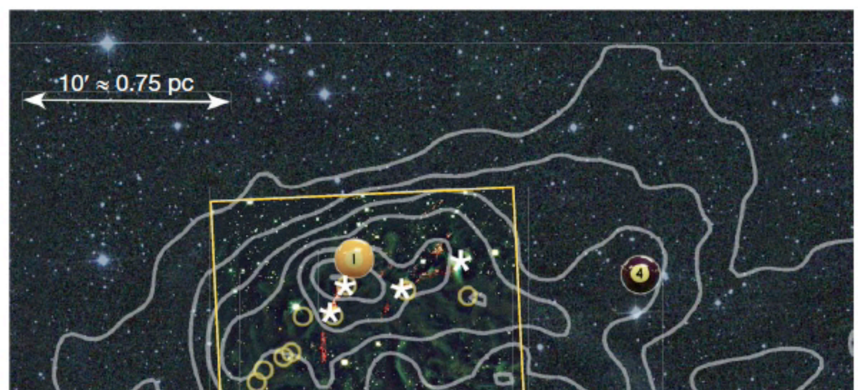
LETTERS

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

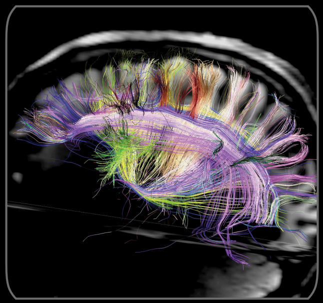
Alyssa A. Goodman[1,2], Erik W. Rosolowsky[2,3], Michelle A. Borkin[1]†, Jonathan B. Foster[2], Michael Halle[1,4], Jens Kauffmann[1,2] & Jaime E. Pineda[2]

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

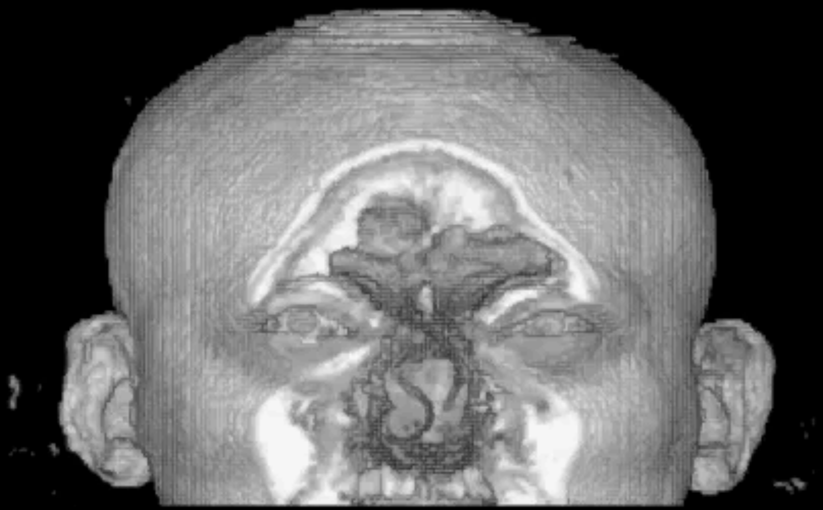


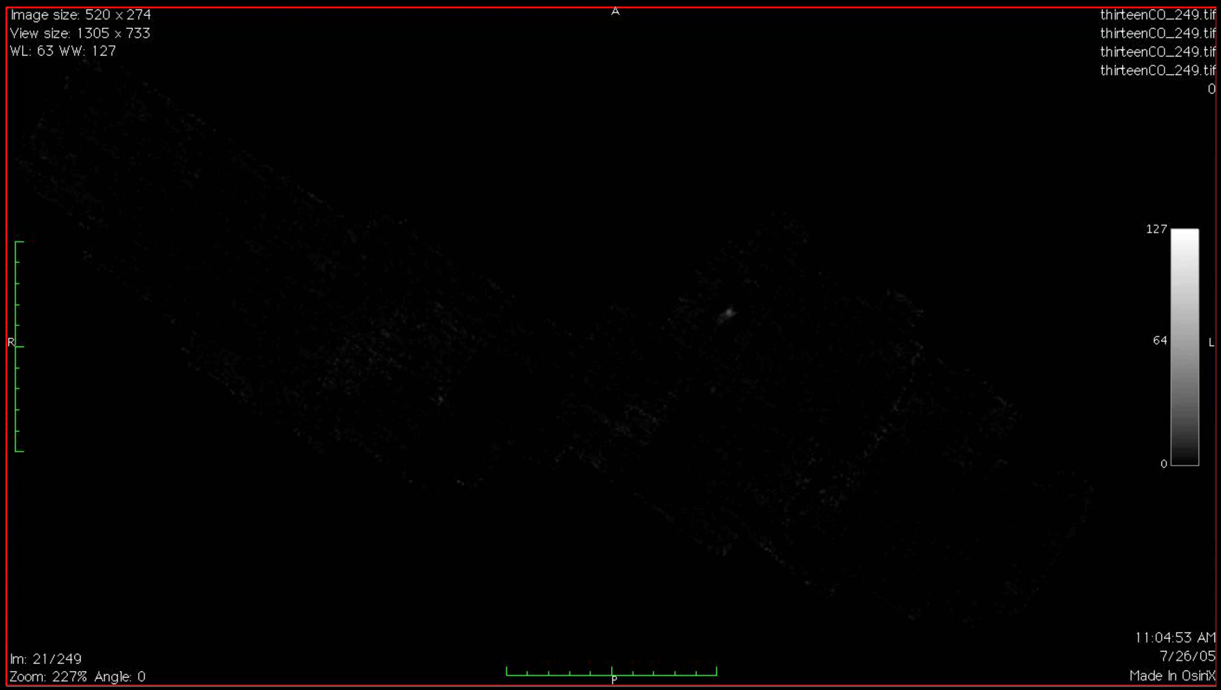
Why AstronomicalMedicine?



"KEITH"

"PERSEUS"

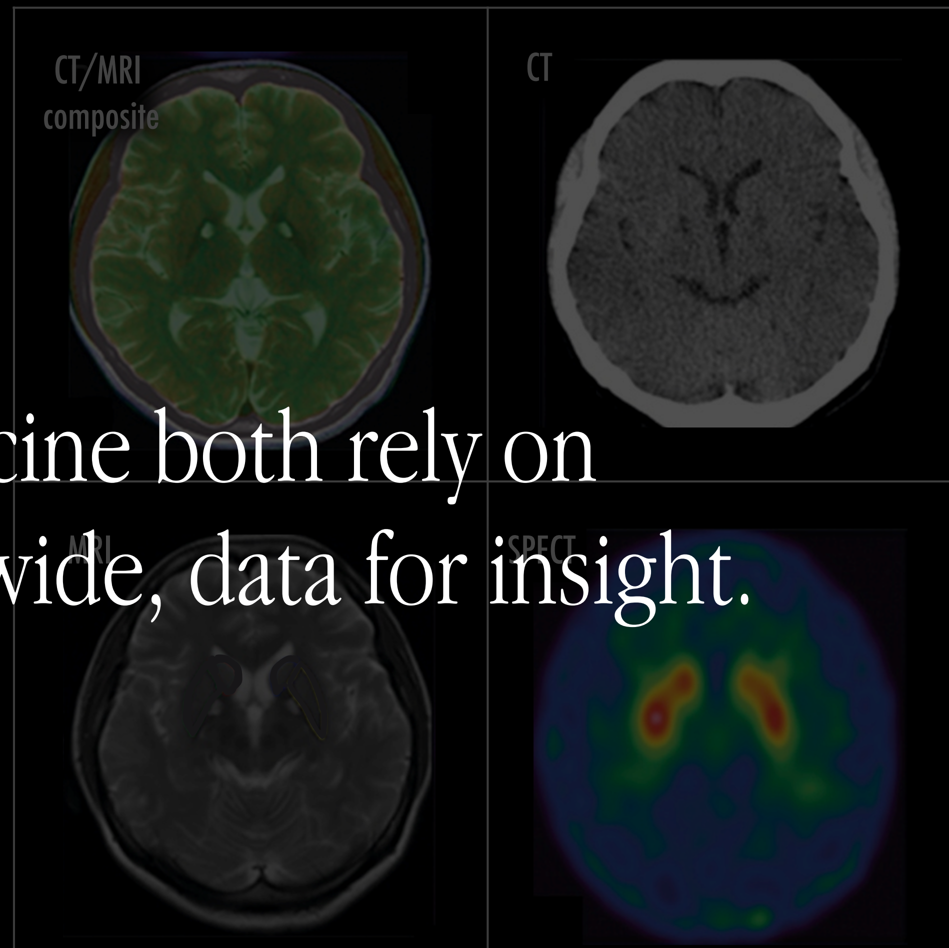




"z" is depth into head

"z" is line-of-sight velocity

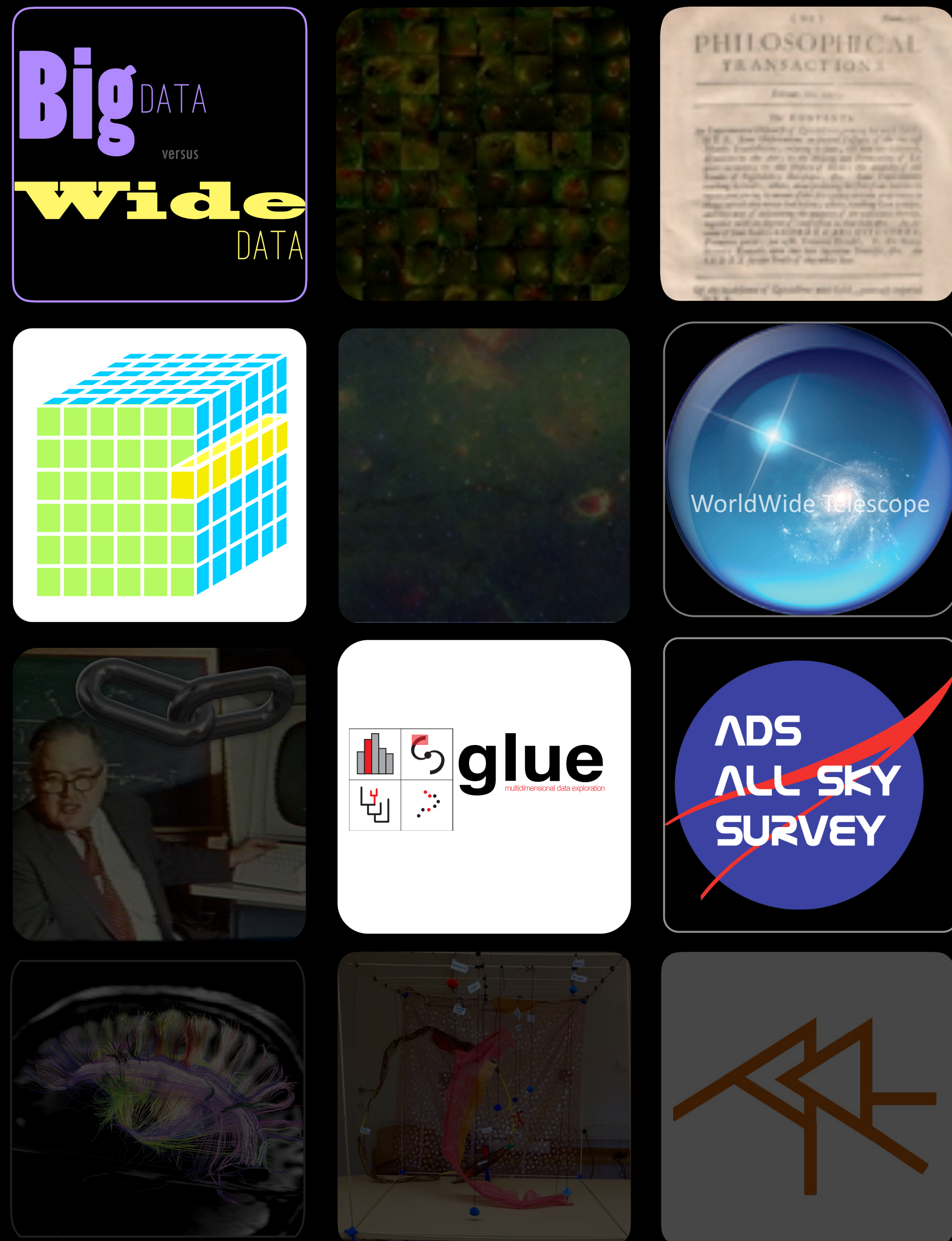
Why AstronomicalMedicine?



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

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

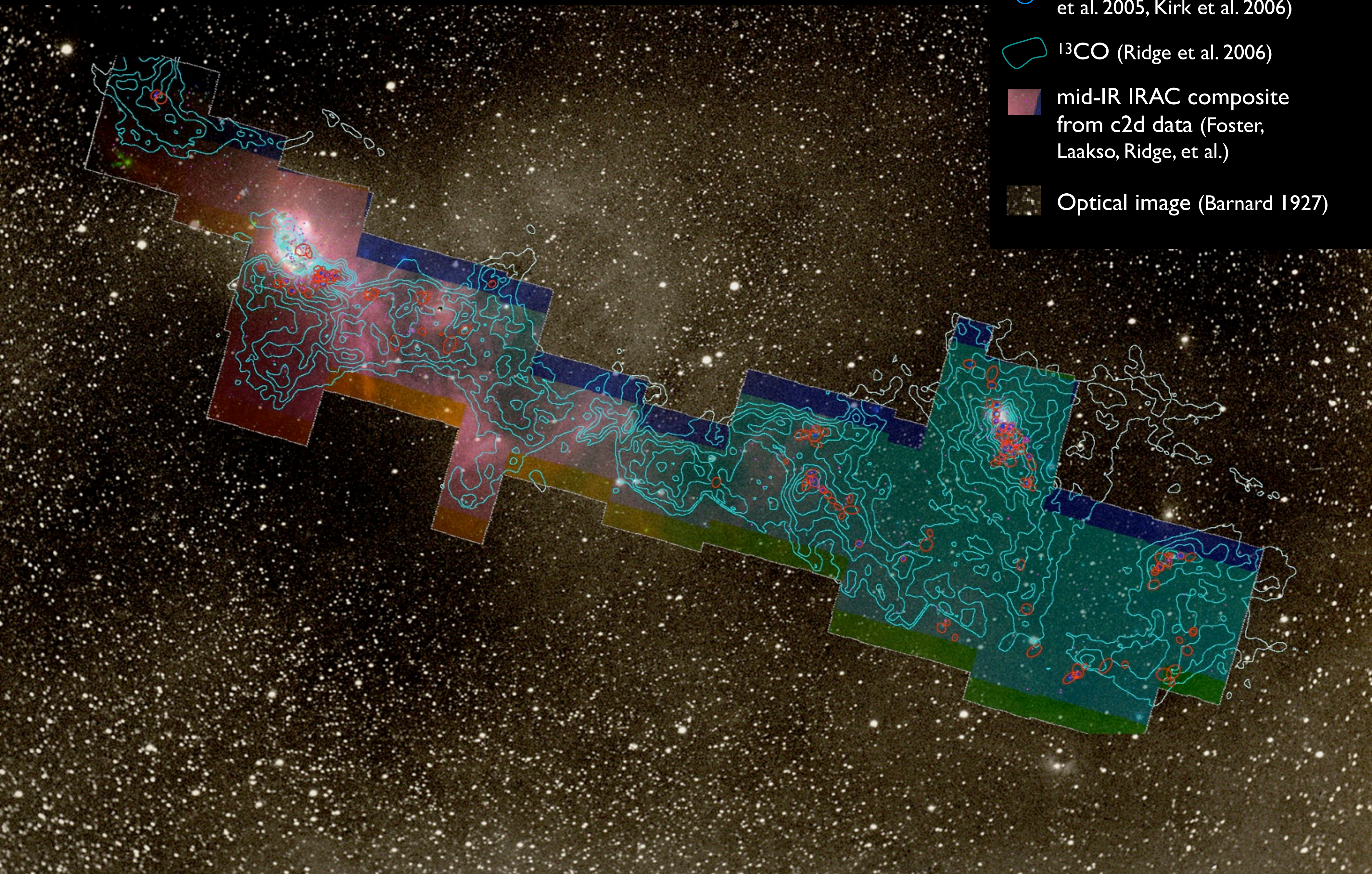
Chang, et al. 2011, brain.oxfordjournals.org/content/134/12/3632


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

WIDE DATA

Big DATA versus Wide DATA

COMPLETE



mm peak (Enoch et al. 2006)

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

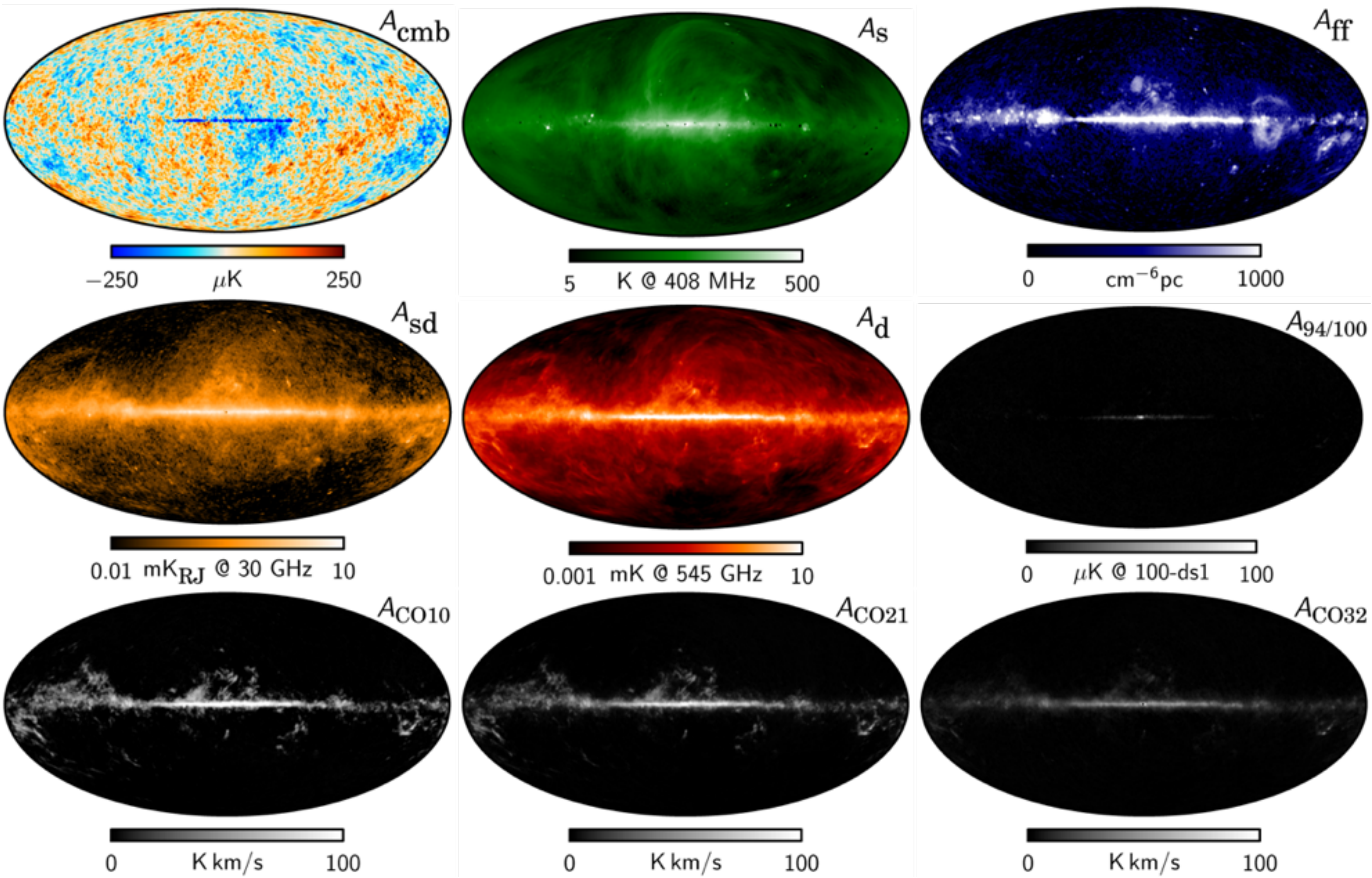
^{13}CO (Ridge et al. 2006)

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

Optical image (Barnard 1927)

WIDE DATA

Big DATA versus Wide DATA



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

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Guided Tours
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View
Settings
Install Windows Client
Use Layer Manager to Control User Settings
Name My Location
Lat 37:47:15
Alt 0 m
Lng -123:35:23
View From This Location
2015/02/11 04:40:33
Real Time
Now
Galactic Plane Mode
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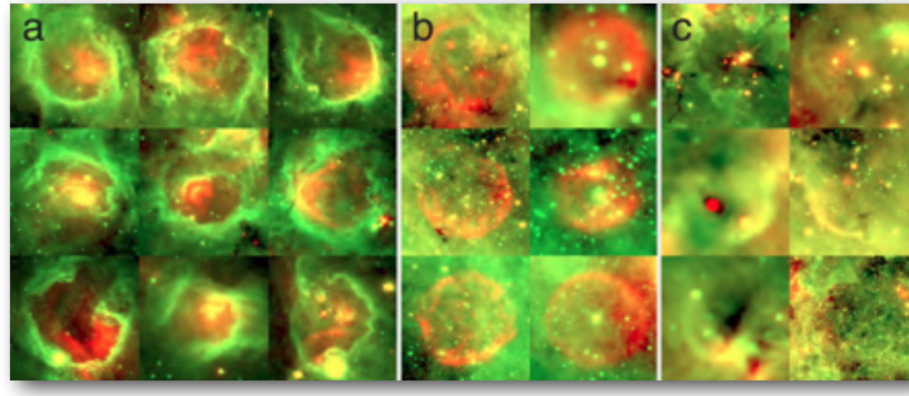
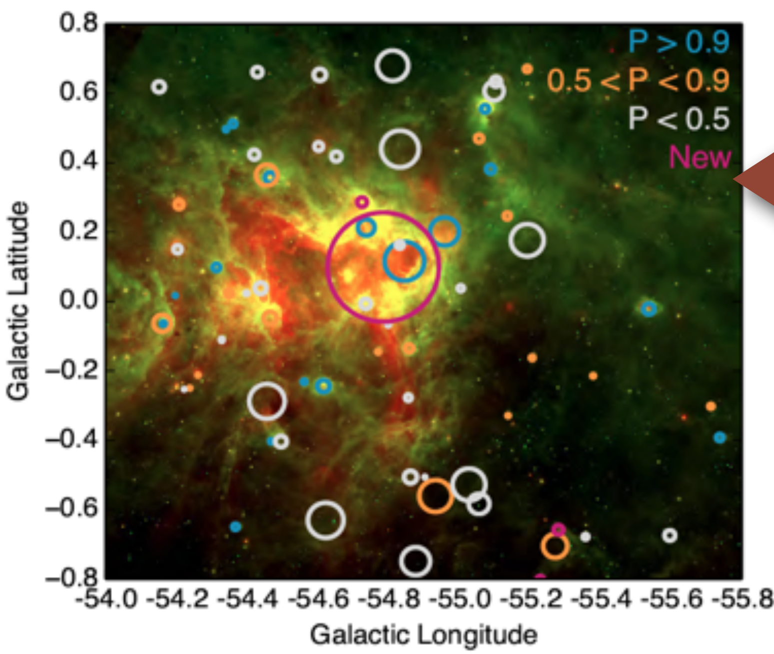
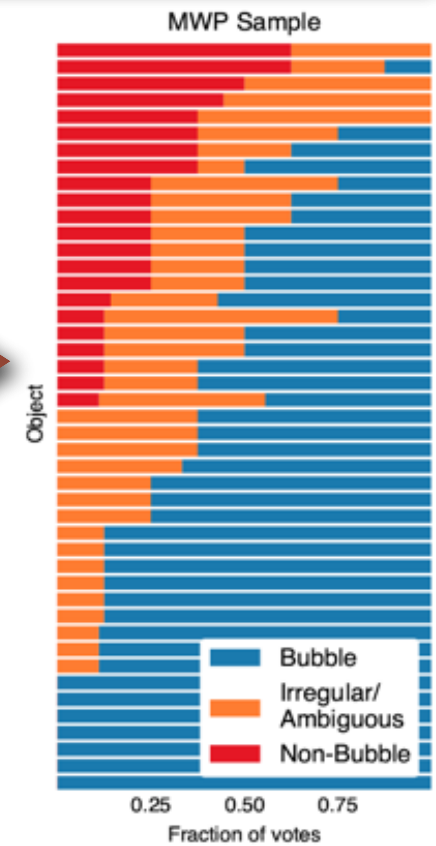
BIG DATA
Look At
Sky
Imagery
Digitized Sky Survey (Color)
Image Crossfade
Tracking
GLIMPSE/MIPSGAL
1 of 3
N
Scorpius
Pismis 24 and
NGC6334
NGC6357
NGC6374
NGC6383
NGC6396
NGC6404
Lesath
Shaula
HR6397
HR6405
RA: 17h28m14s

BIG DATA AND "HUMAN-AIDED COMPUTING"



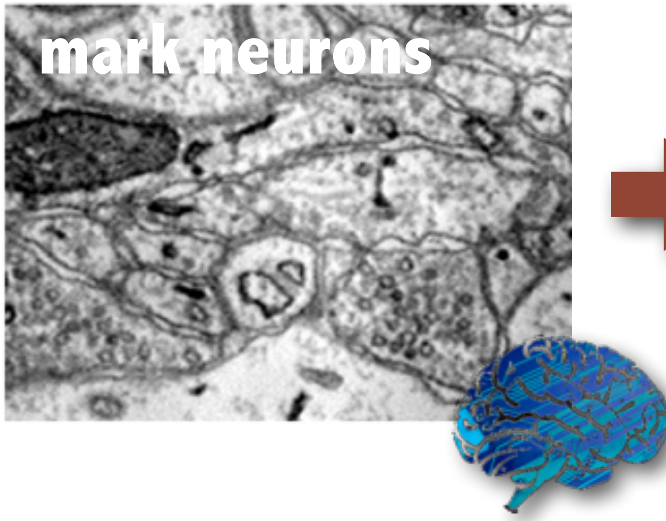
machine-learning algorithm (Brut)



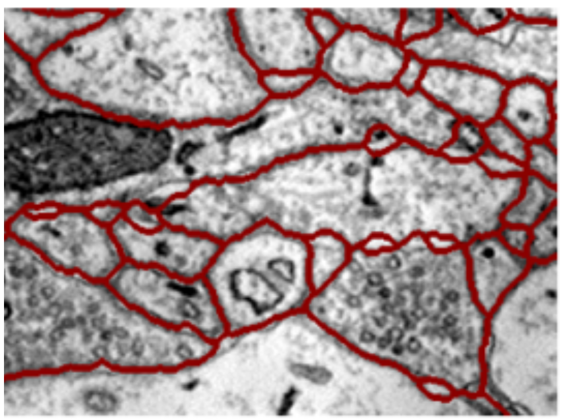


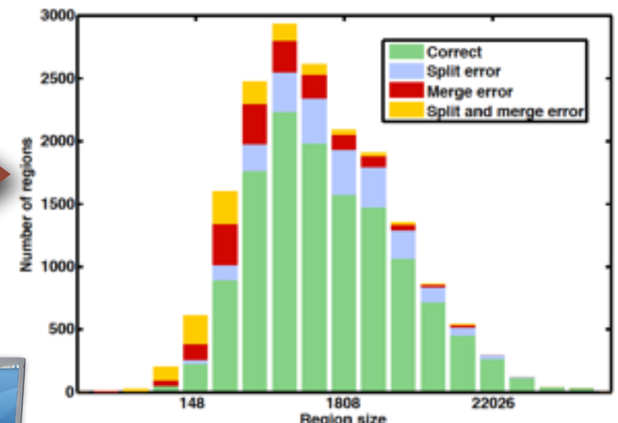
example here from: ***Beaumont****, Goodman, Kendrew, Williams & Simpson 2014; based on* ***Milky Way Project*** *catalog (Simpson et al. 2013), which came from* ***Spitzer/GLIMPSE*** *(Churchwell et al. 2009, Benjamin et al. 2003), cf. Shenoy & Tan 2008 for discussion of HAC;* ***astroml.org*** *for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

BIG DATA AND "HUMAN-AIDED COMPUTING"



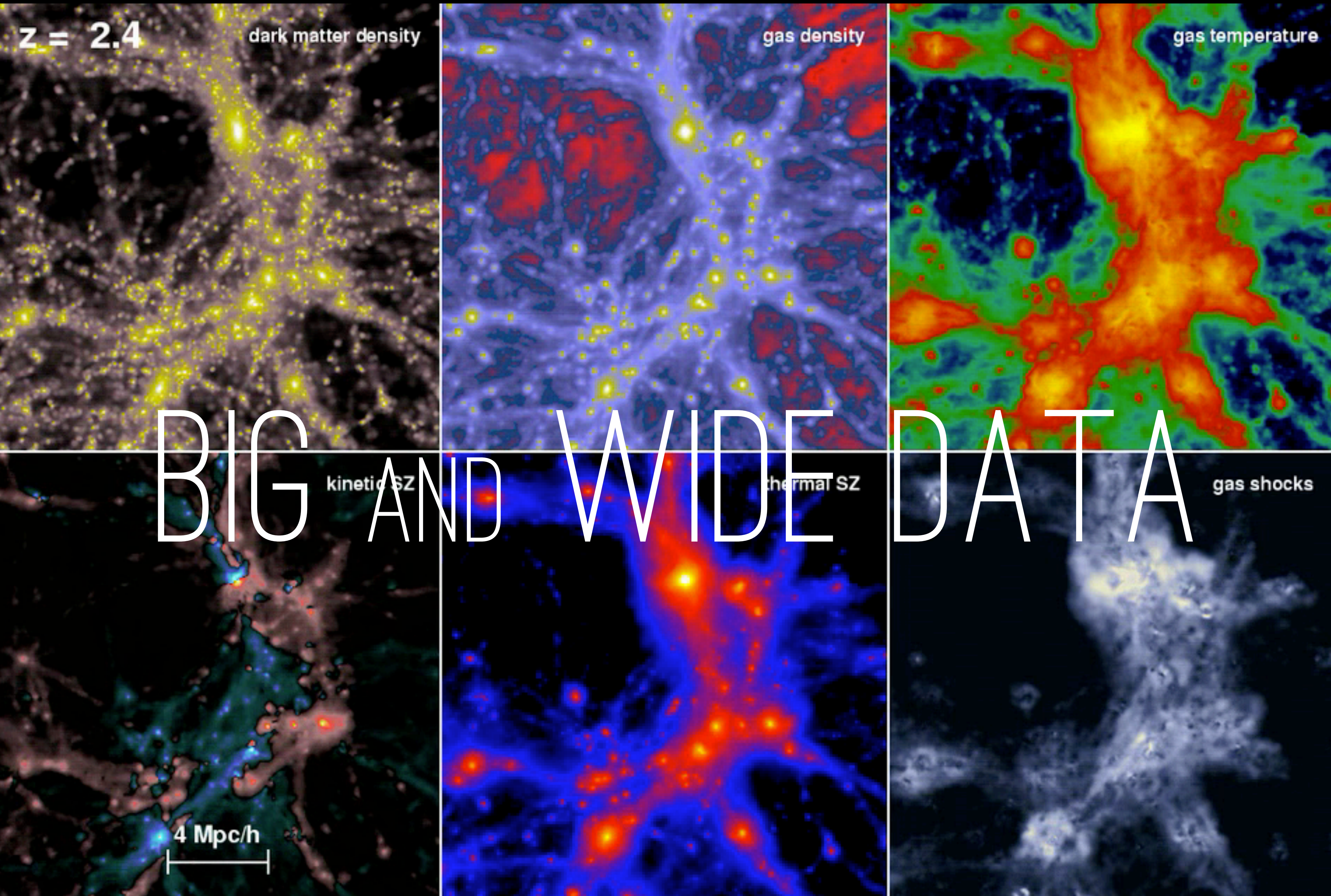
machine-learning algorithm (RF+CRF)



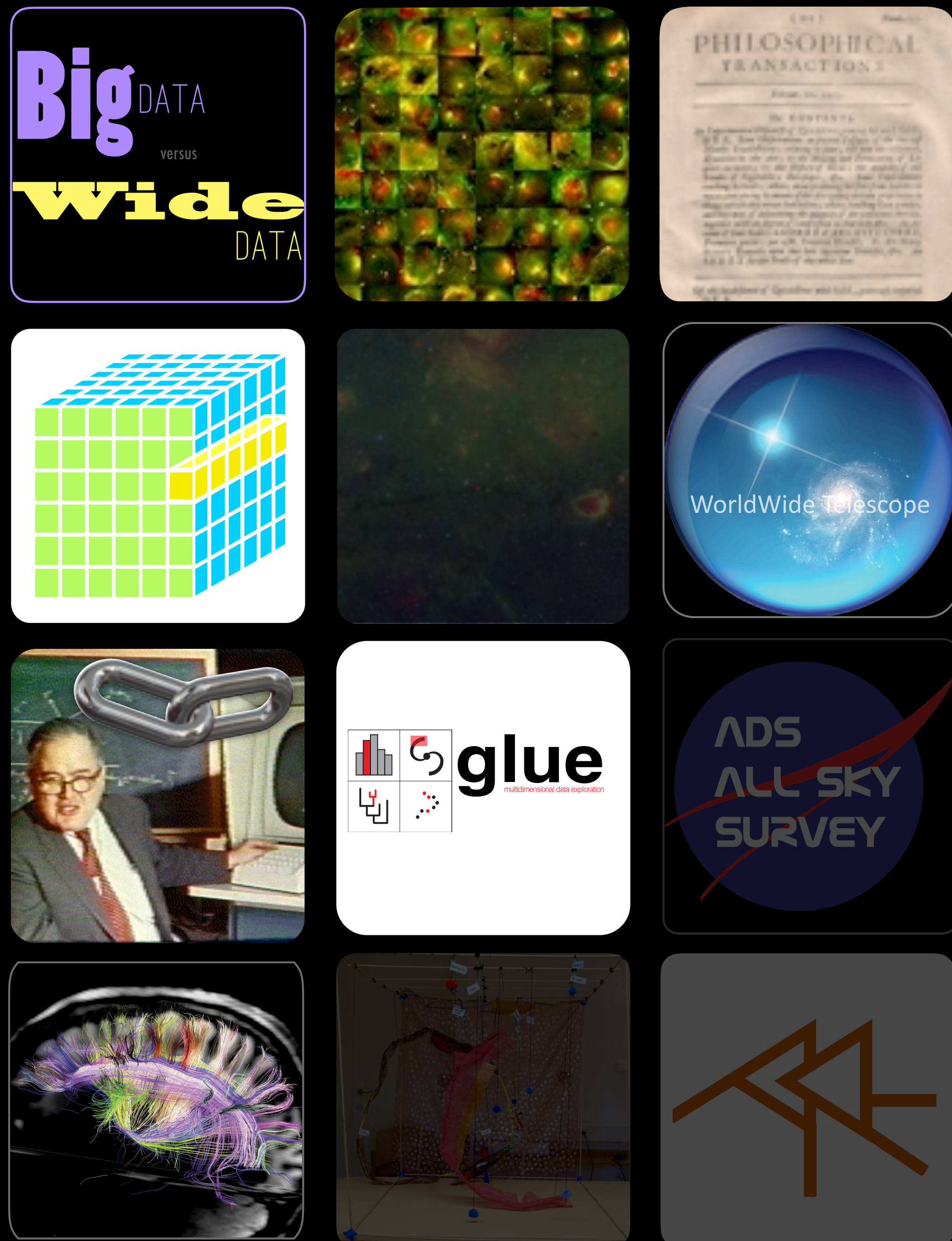


example here from: Kaynig...Lichtman...Pfister et al. 2013, "Large-Scale Automatic Reconstruction of Neuronal Processes from Electron Microscopy Images"; cf. Shenoy & Tan 2008 for discussion of HAC; ***astroml.org*** *for machine learning advice/tools (Note: RF=Random Forest; CRF=Conditional Random Fields.)*

BIG AND WIDE DATA



Movie: Volker Springel, formation of a cluster of galaxies. Millenium Simulation requires 25TB for output.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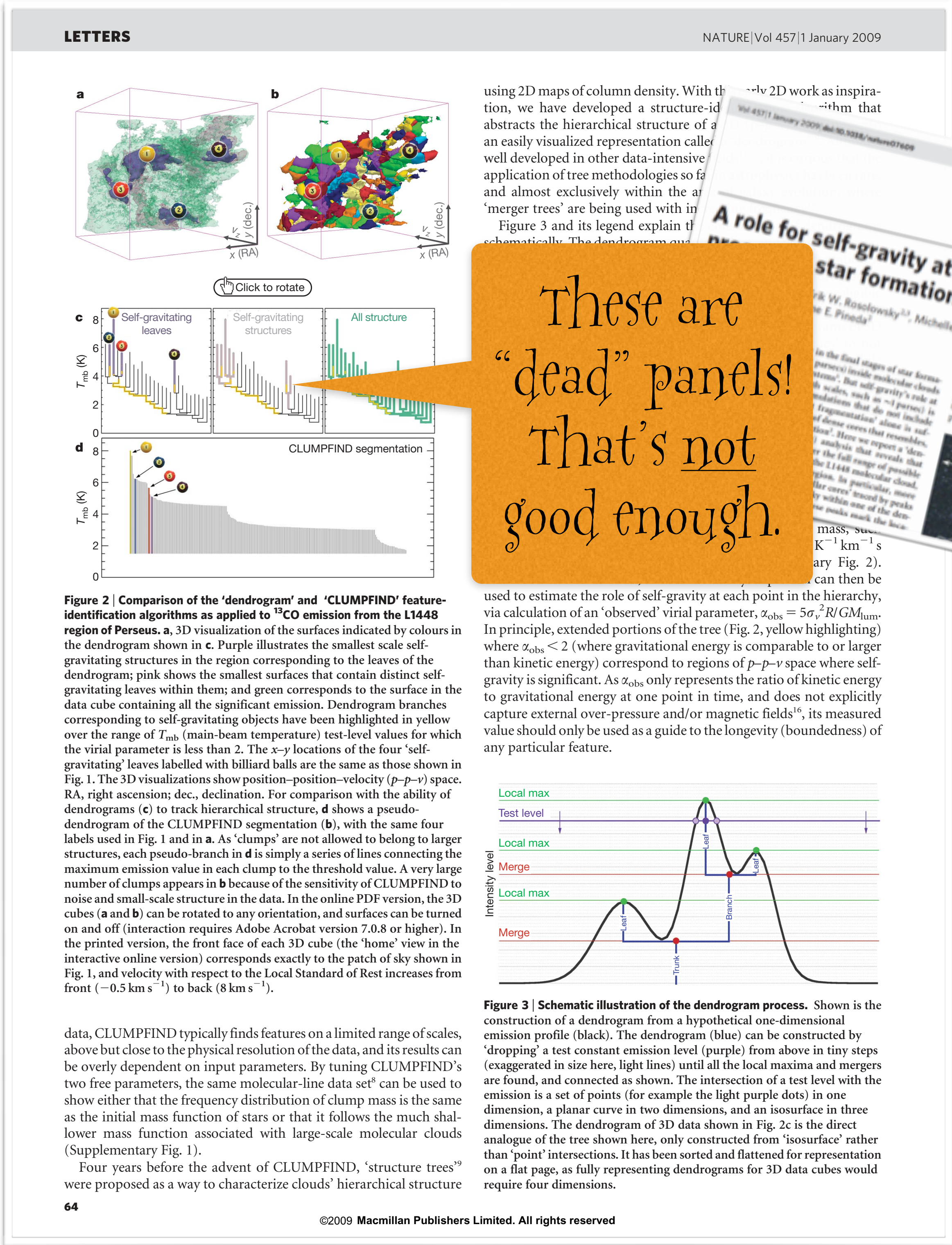
multidimensional data exploration
ADS
ALL SKY
SURVEY

2009

3D PDF

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



a b

x (RA) y (dec.) v_z

Click to rotate

c Self-gravitating leaves | Self-gravitating structures | All structure

T_{mb} (K)

d CLUMPFIND segmentation

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

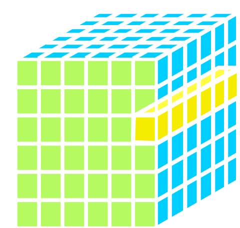
using 2D maps of column density. With th… …rly 2D work as inspiration, we have developed a structure-id… …ithm that abstracts the hierarchical structure of a… an easily visualized representation calle… well developed in other data-intensive… application of tree methodologies so fa… and almost exclusively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

Figure 3 and its legend explain th… schematically. The dendrogram qua…

… mass, su… … $\mathrm{K^{-1}\,km^{-1}\,s}$ … …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.

Local max
Test level
Local max
Merge
Local max
Merge
Intensity level
Leaf
Branch
Trunk

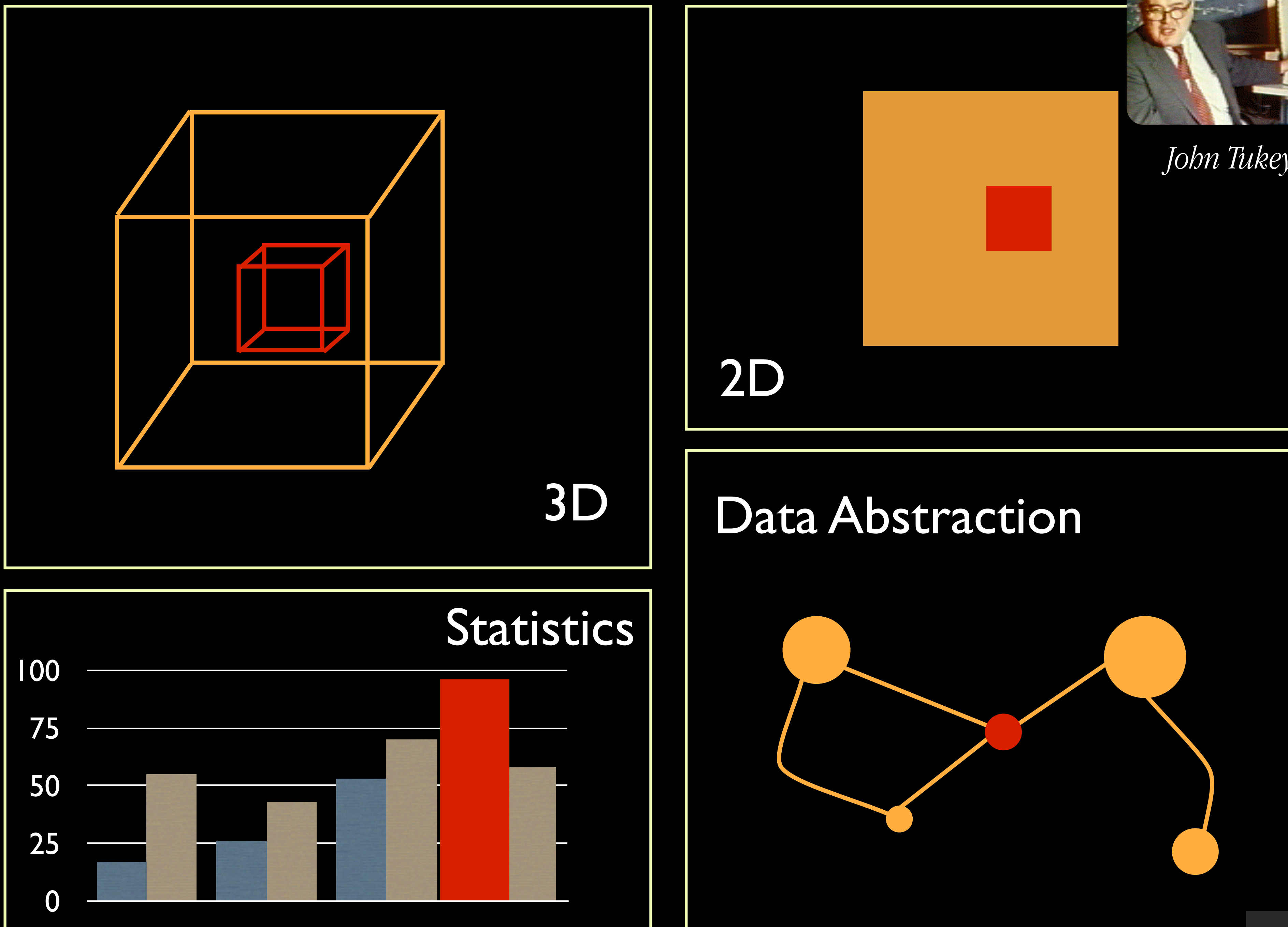
Figure 3 | Schematic illustration of the dendrogram process. Shown is the construction of a dendrogram from a hypothetical one-dimensional emission profile (black). The dendrogram (blue) can be constructed by 'dropping' a test constant emission level (purple) from above in tiny steps (exaggerated in 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

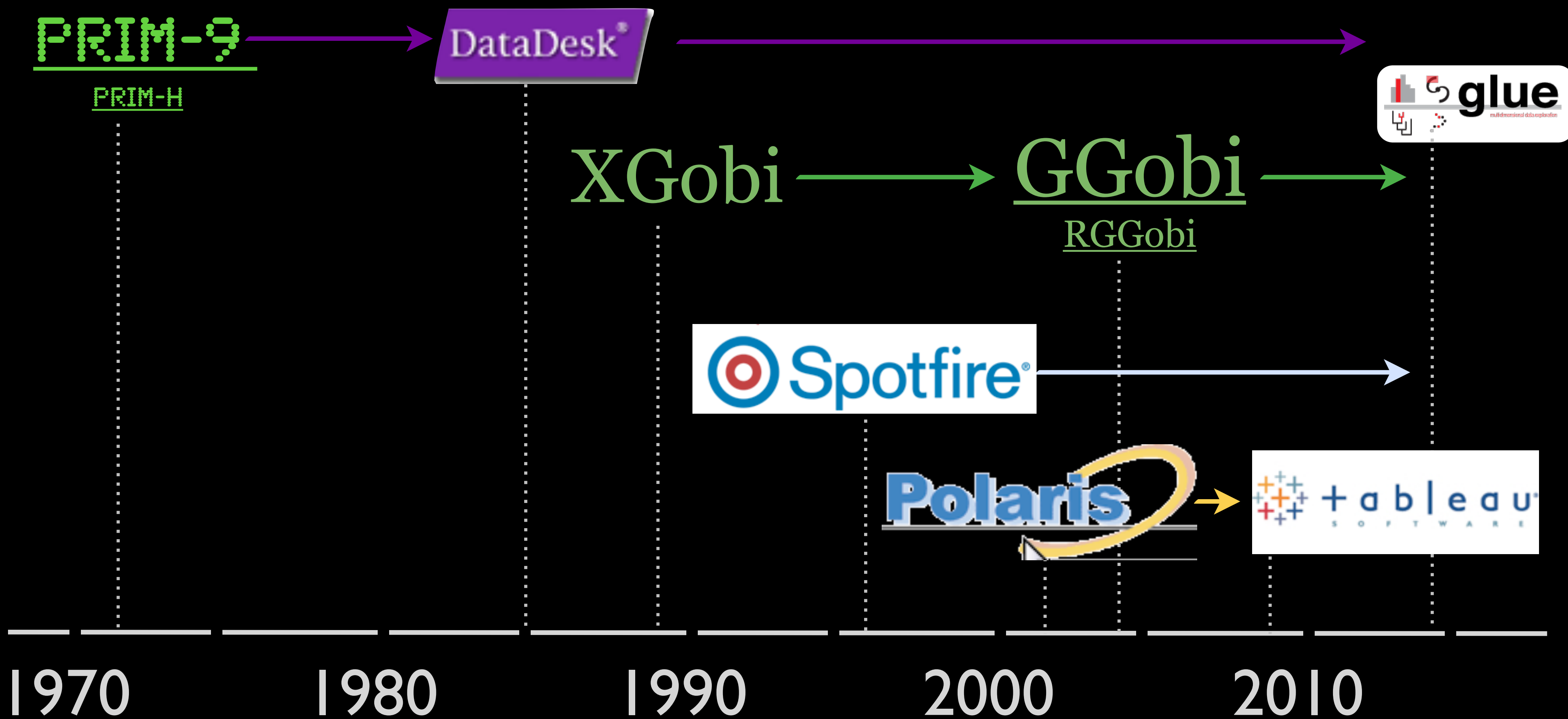
Linked Views of High-dimensional Data

John Tukey



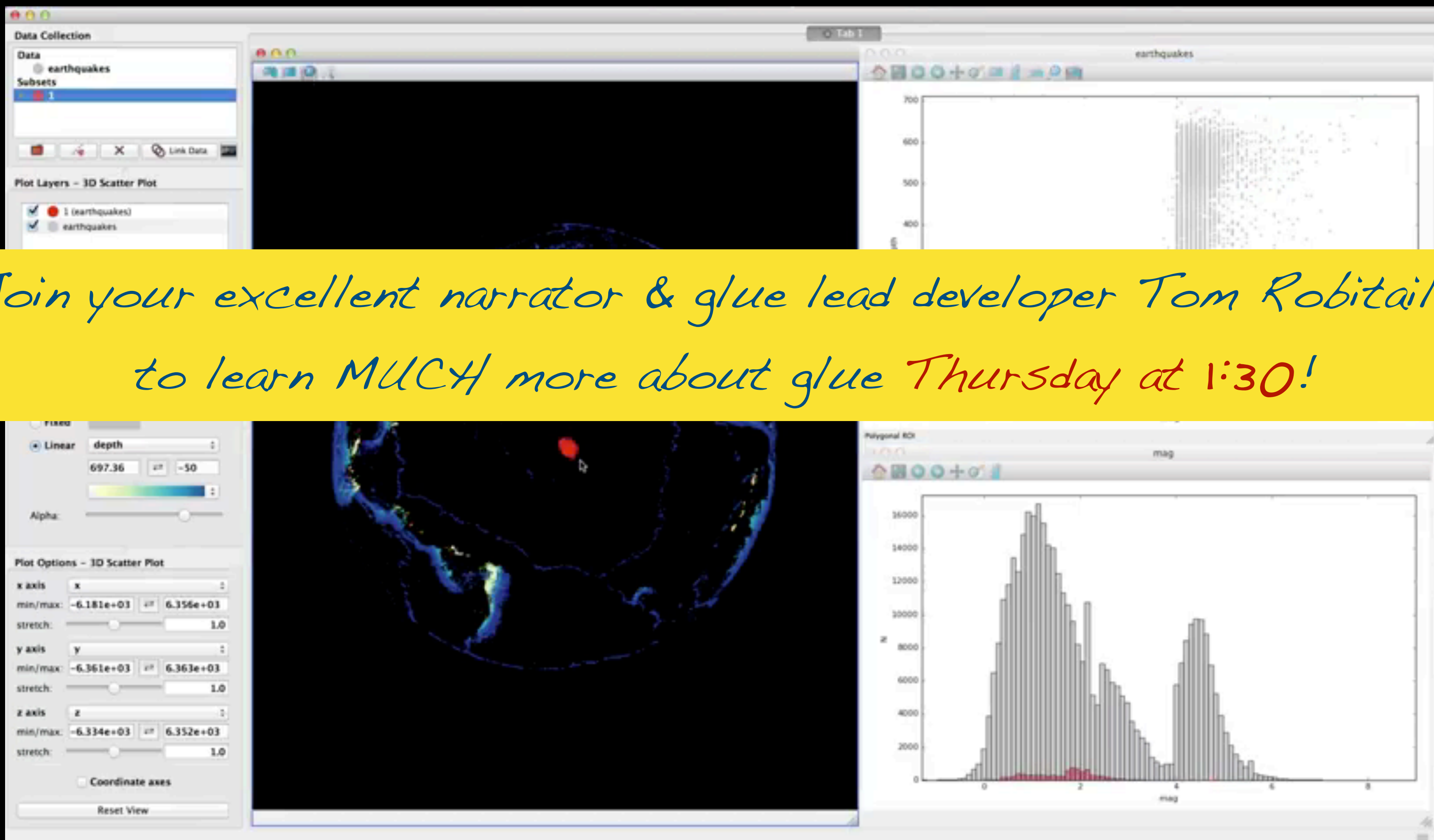
figure, by M. Borkin, reproduced from Goodman 2012, "Principles of High-Dimensional Data Visualization in Astronomy"

JOHN TUKEY'S LEGACY



LINKED VIEWS OF HIGH-DIMENSIONAL DATA (IN PYTHON)

GLUE



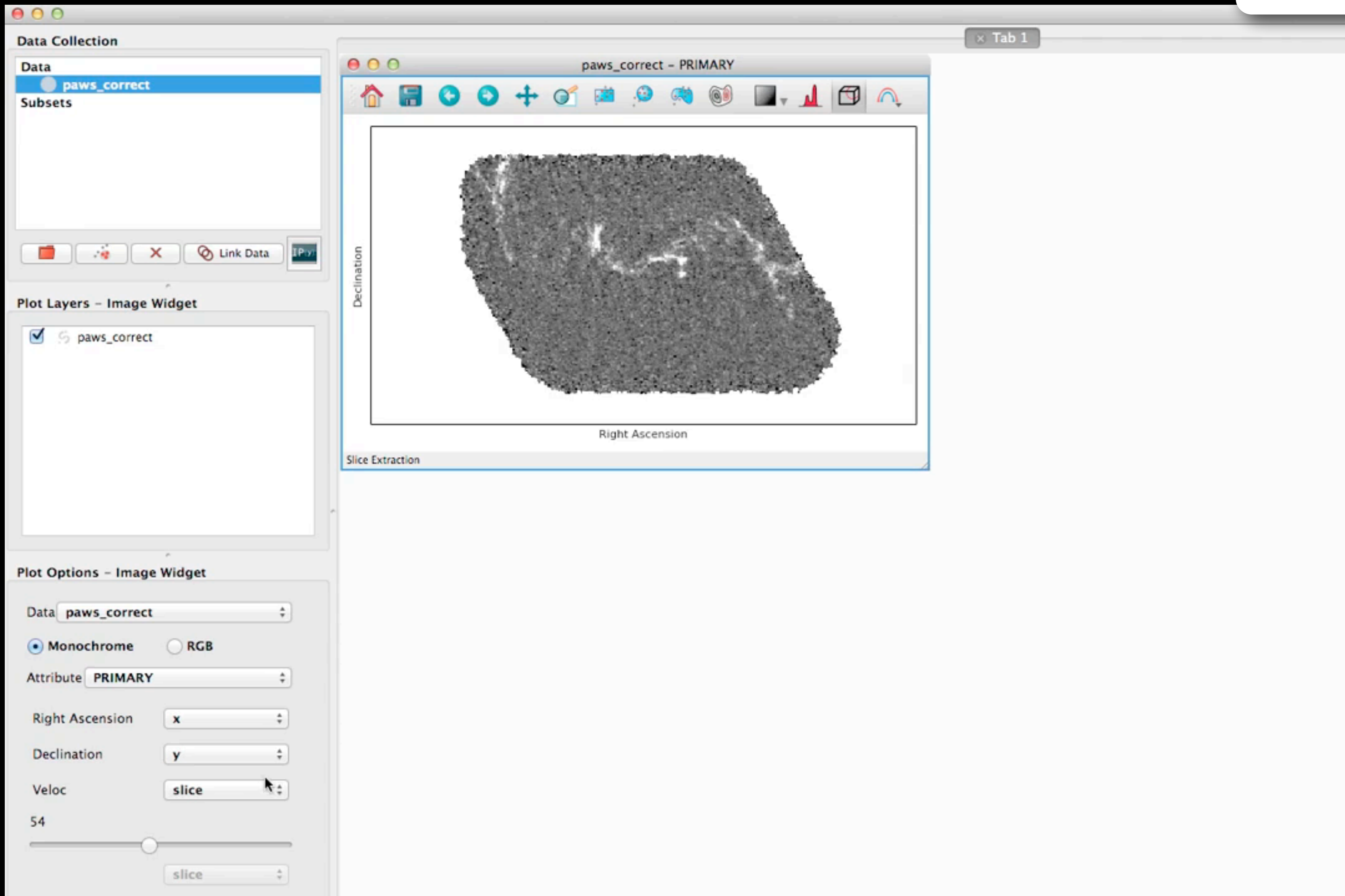
Join your excellent narrator & glue lead developer Tom Robitaille to learn MUCH more about glue Thursday at 1:30!

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

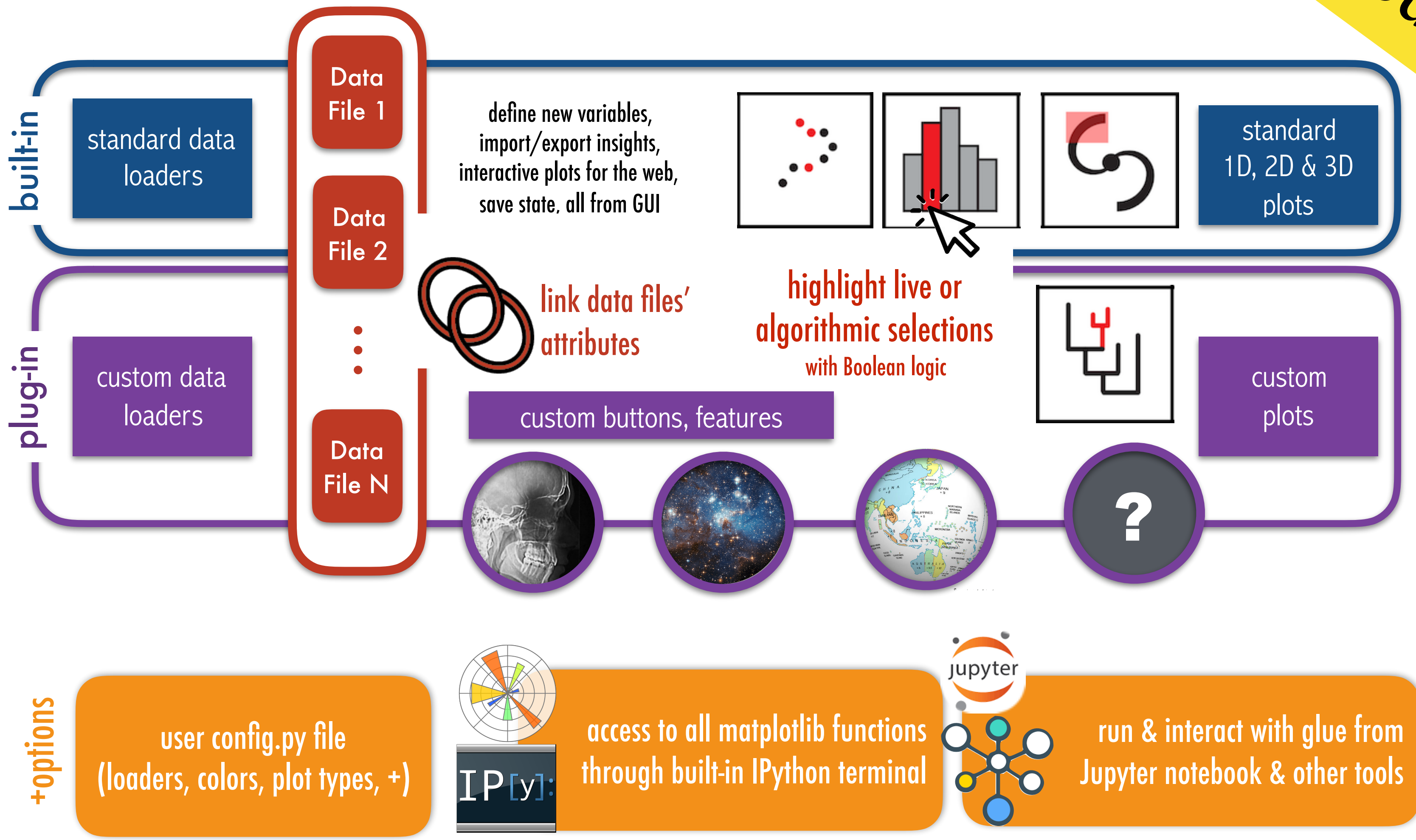


video by Chris Beaumont, glue developer

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

glue

multidimensional data exploration



glueviz.org

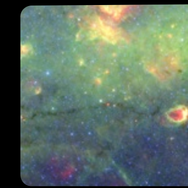
What is visualization (and all this software) for?

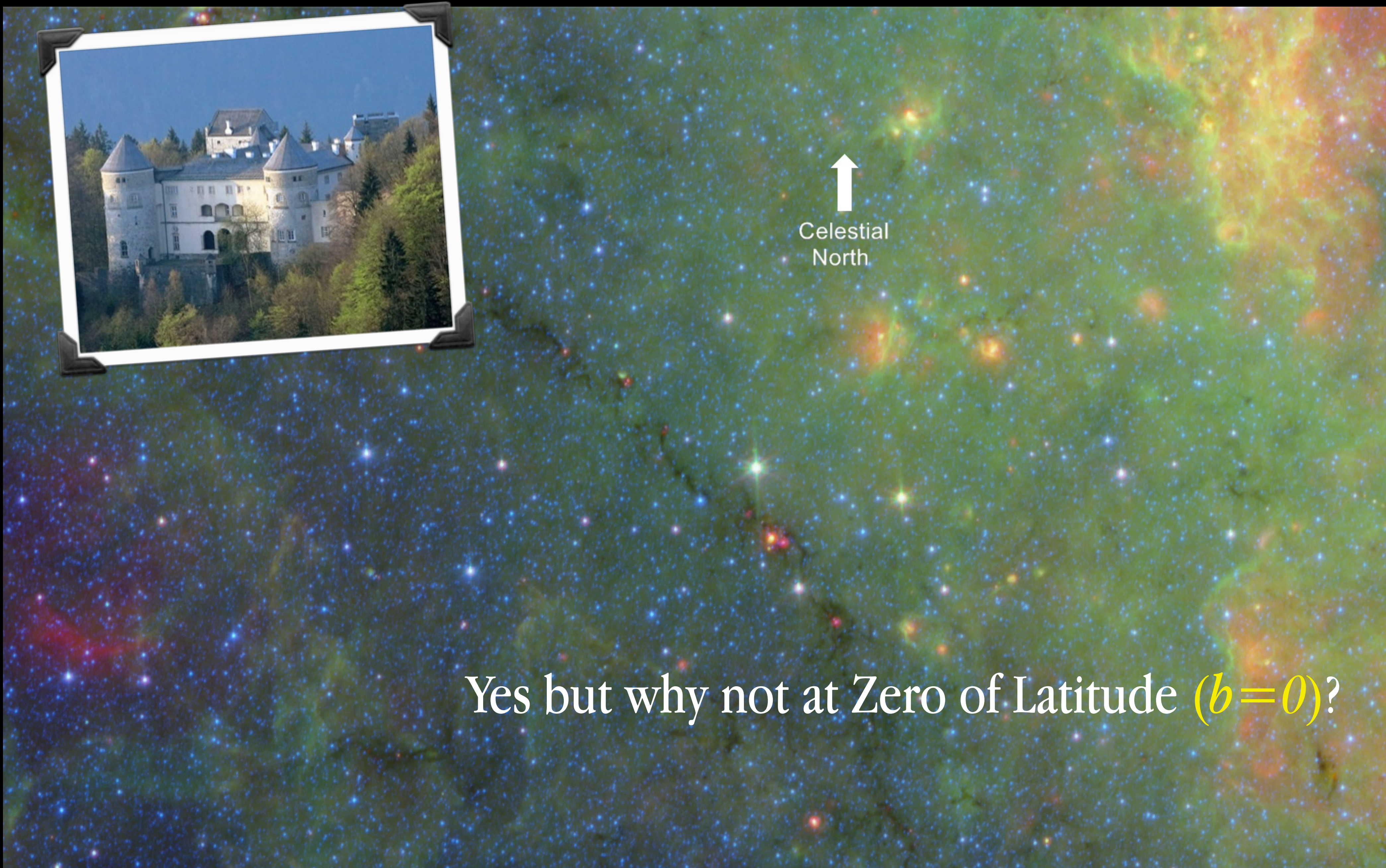
INSIGHT

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

“Is Nessie Parallel to the Galactic Plane?”

-A. Burkert, 2012

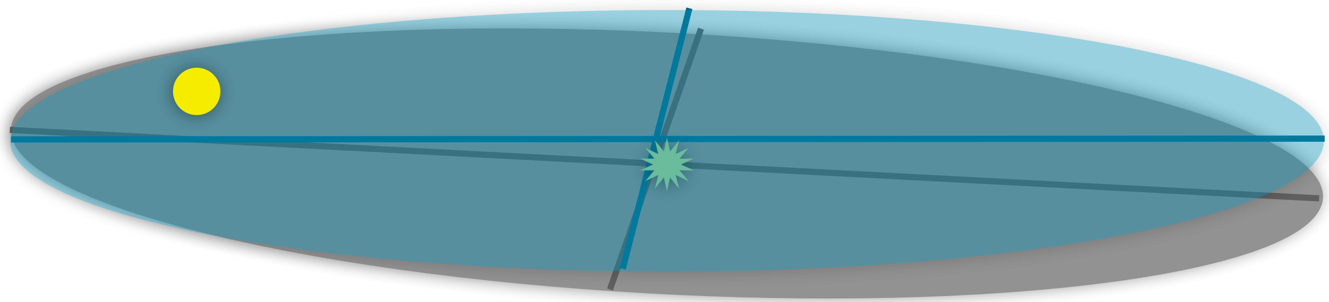




Yes but why not at Zero of Latitude *($b=0$)*?

Where are we, really?

"IAU Milky Way", est. 1959



True Milky Way, modern

The equatorial plane of the new co-ordinate system must of necessity pass through the sun. It is a fortunate circumstance that, within the observational uncertainty, both the sun and Sagittarius A lie in the mean plane of the Galaxy as determined from the hydrogen observations. If the sun had not been so placed, points in the mean plane would not lie on the galactic equator.

[Blaauw et al. 1959]

Sun is ~25 pc "above" the IAU Milky Way Plane

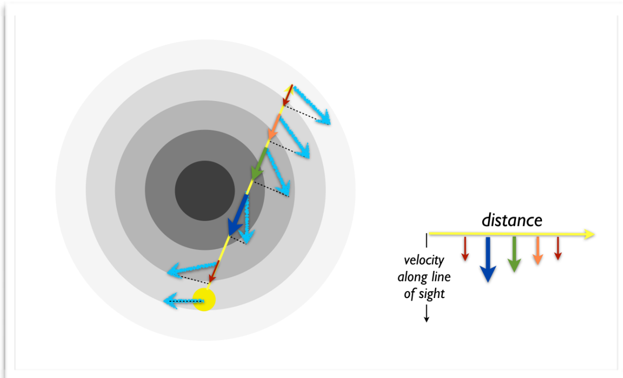
+

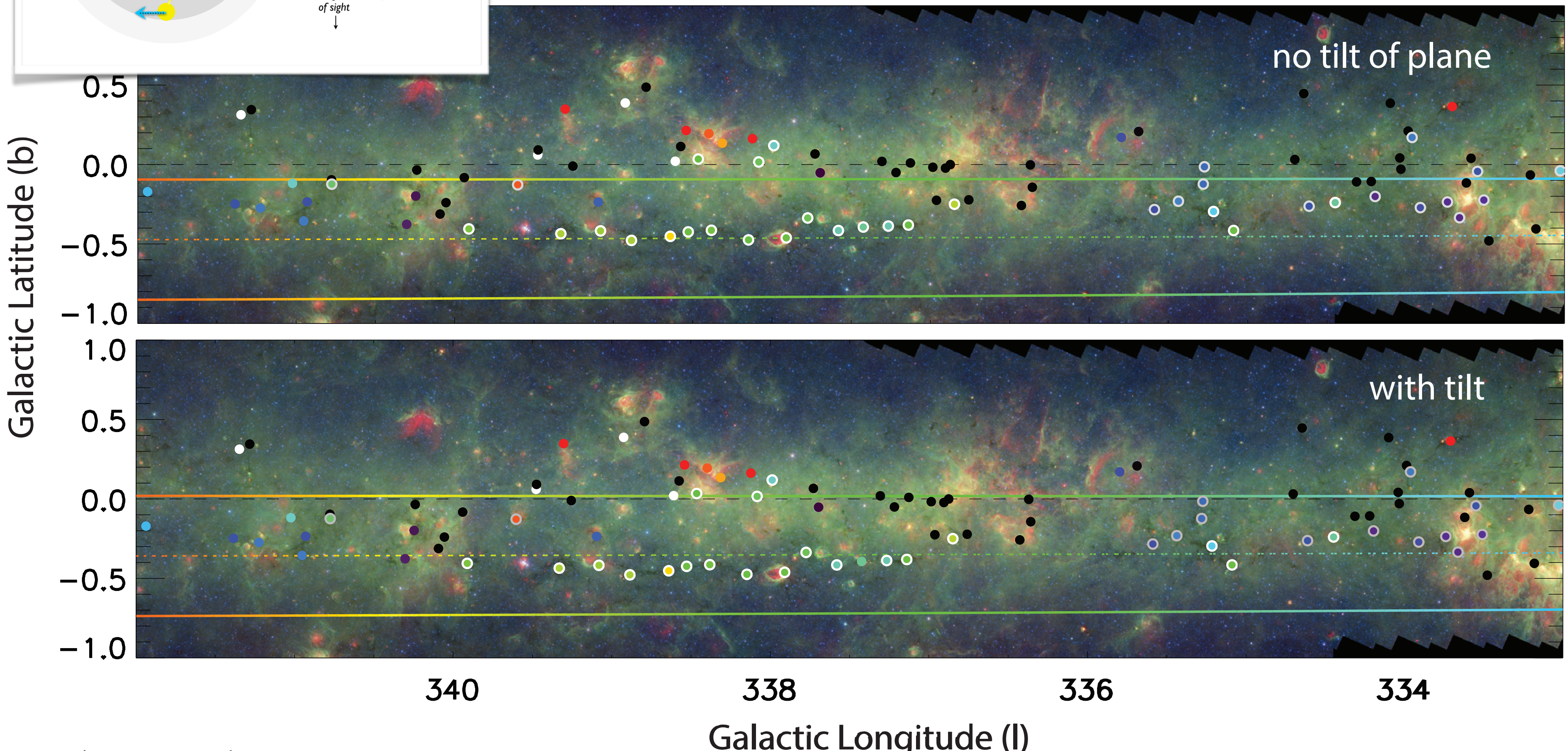
Galactic Center is ~7 pc offset from the IAU Milky Way Center

=

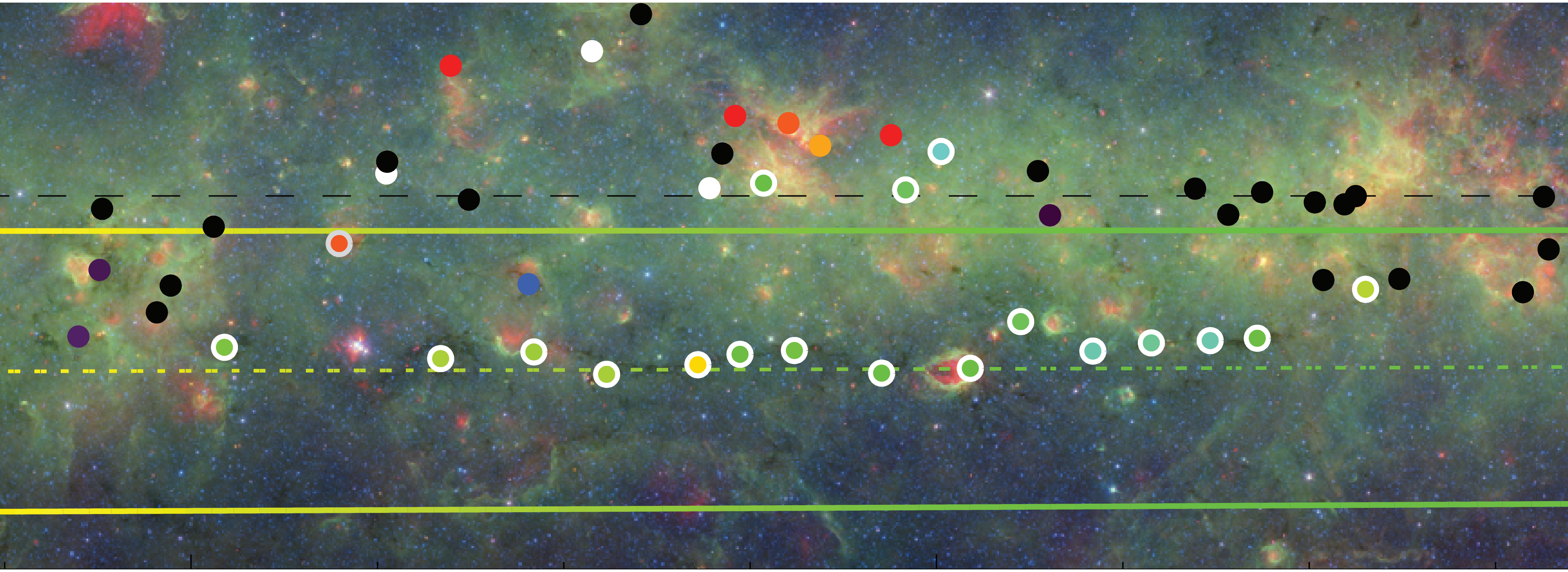
The **Galactic Plane is not quite where you'd think it is** when you look at the sky

In the plane! And at distance of spiral arm!





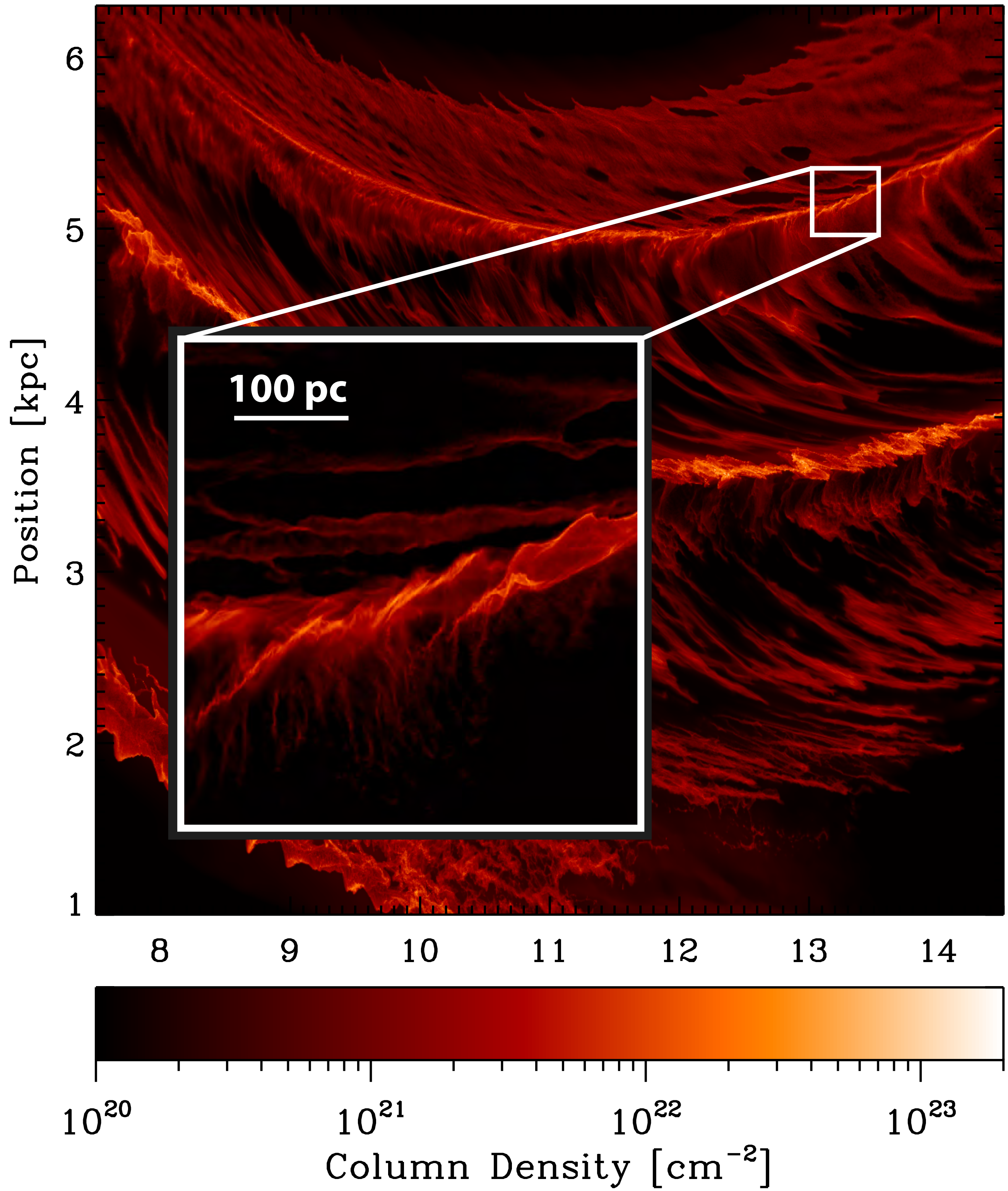
Goodman et al. 2014



...eerily precisely...

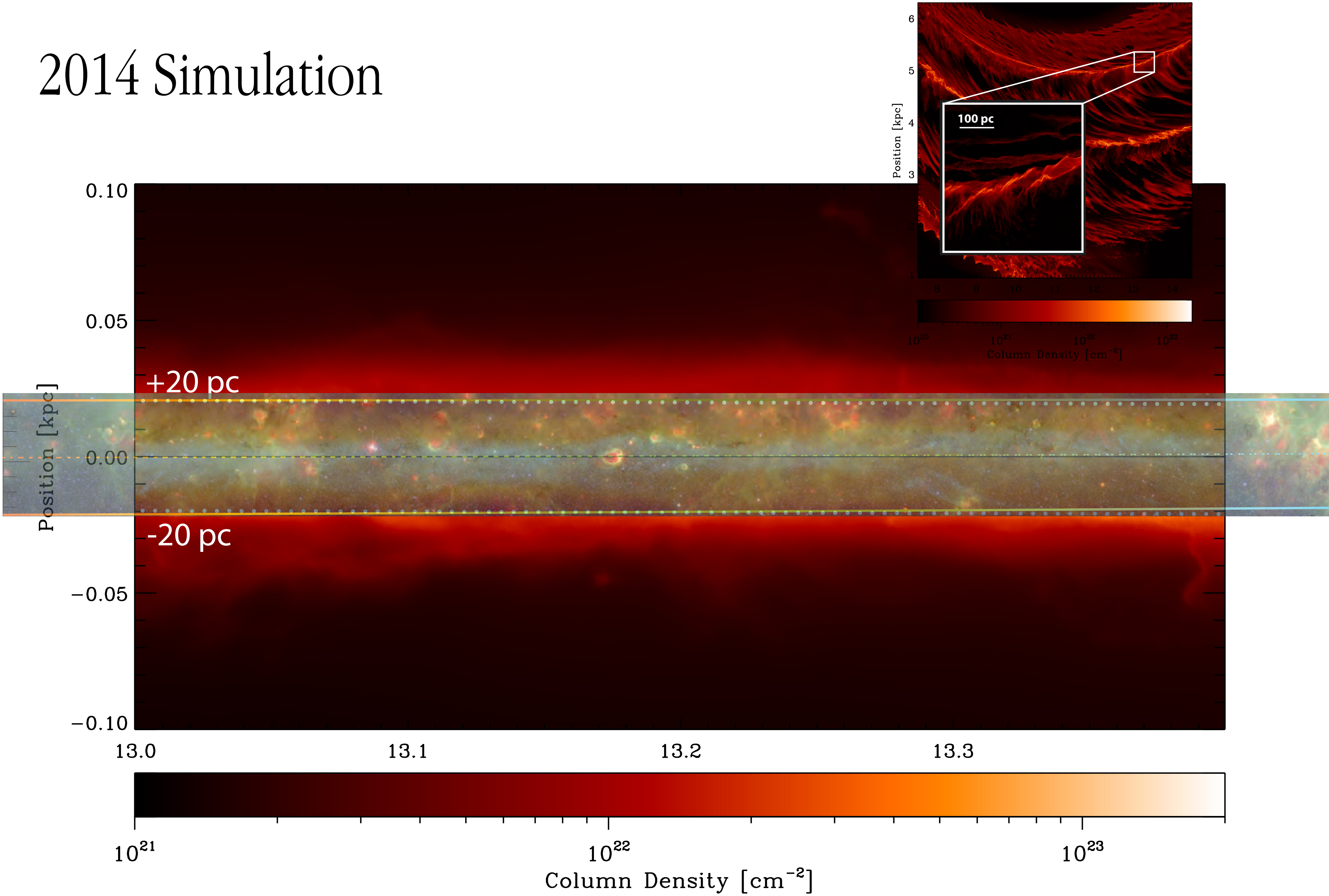
Goodman et al. 2014

2014 Simulation



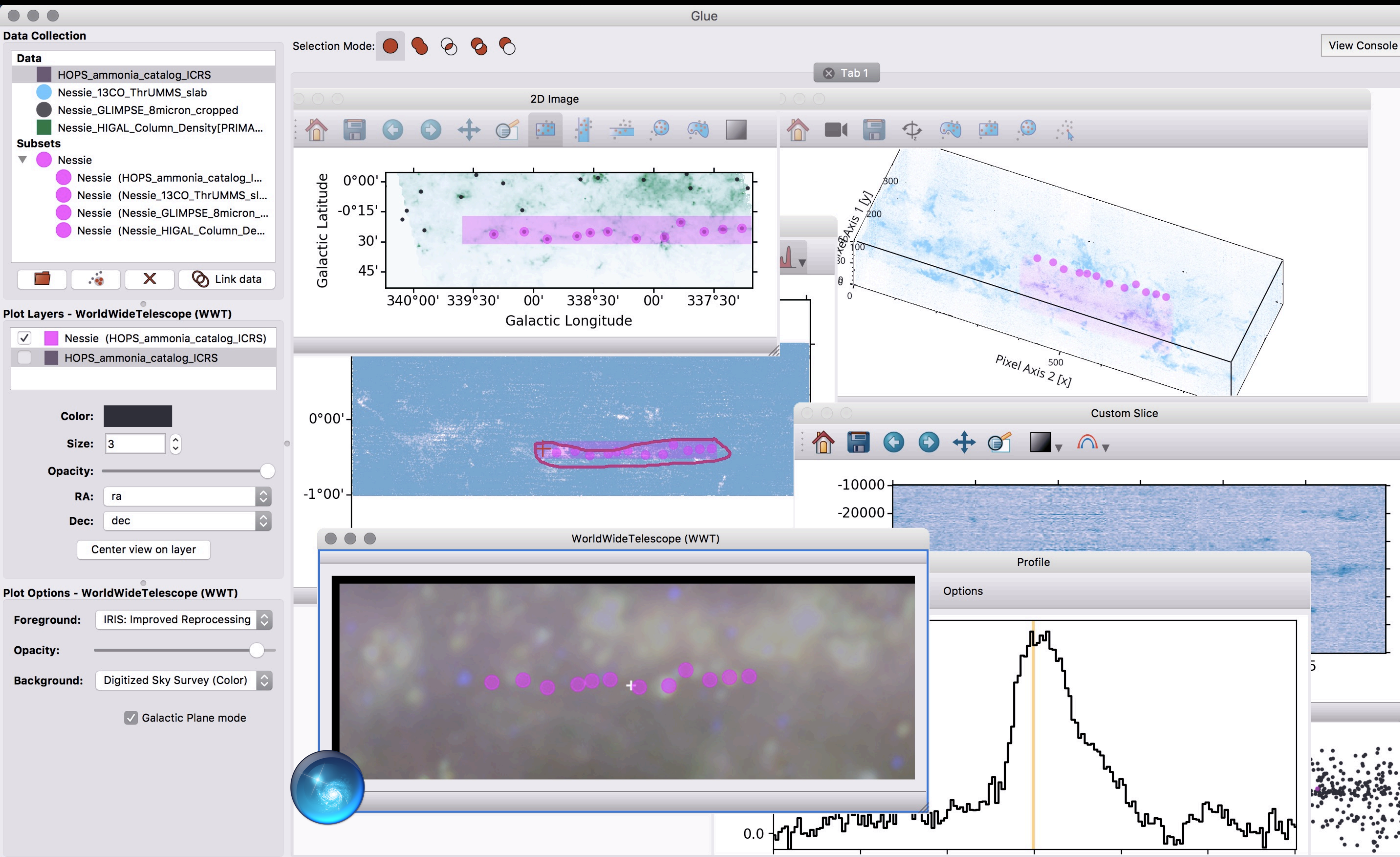
Smith et al. 2014, using AREPO

2014 Simulation

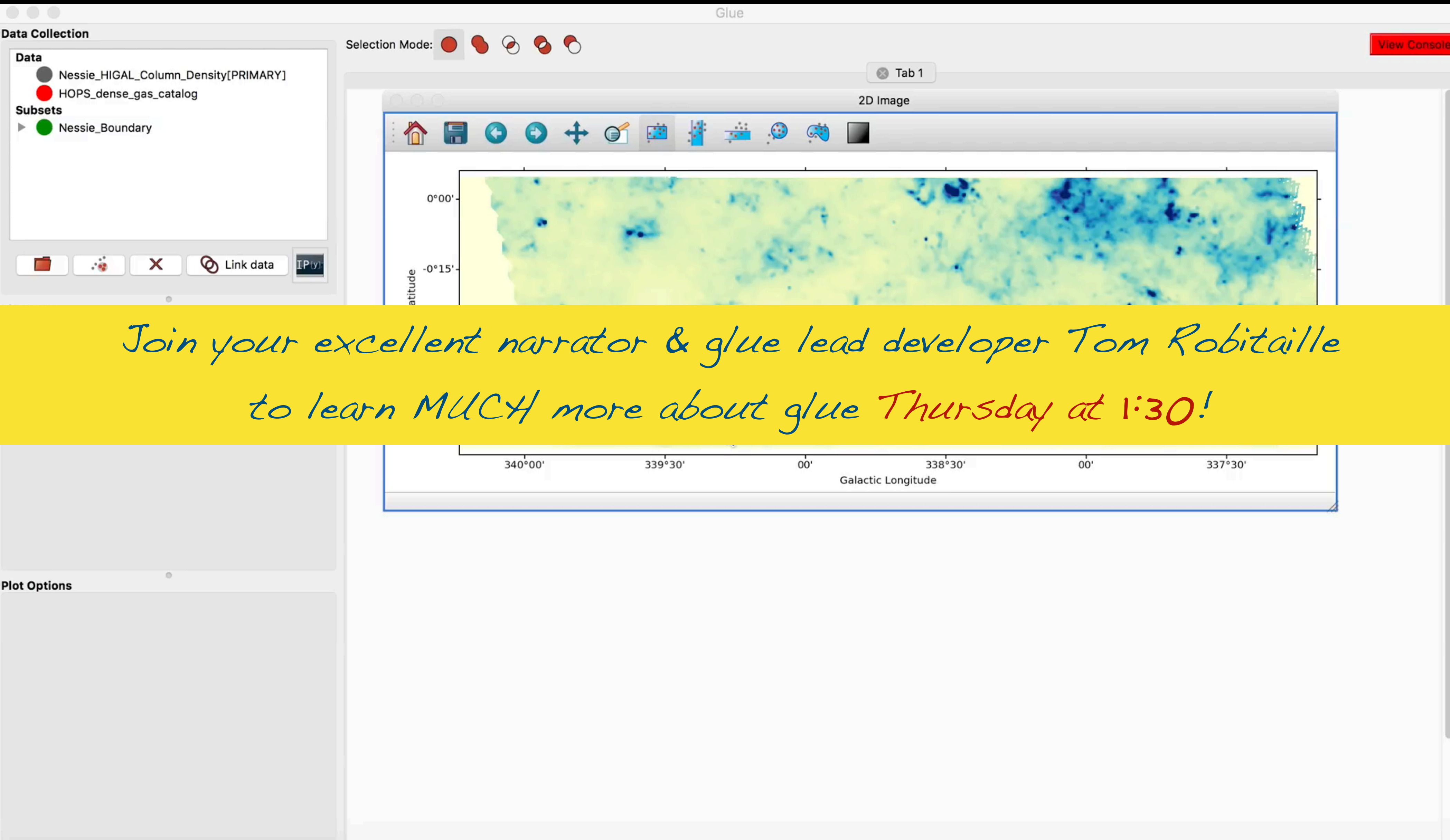


Smith et al. 2014, using AREPO (hydro+chemistry, imposed potential, no B-fields, no local (self-)gravity, no feedback)

NESSIE IN GLUE+WWT



NESSIE IN GLUE+WWT



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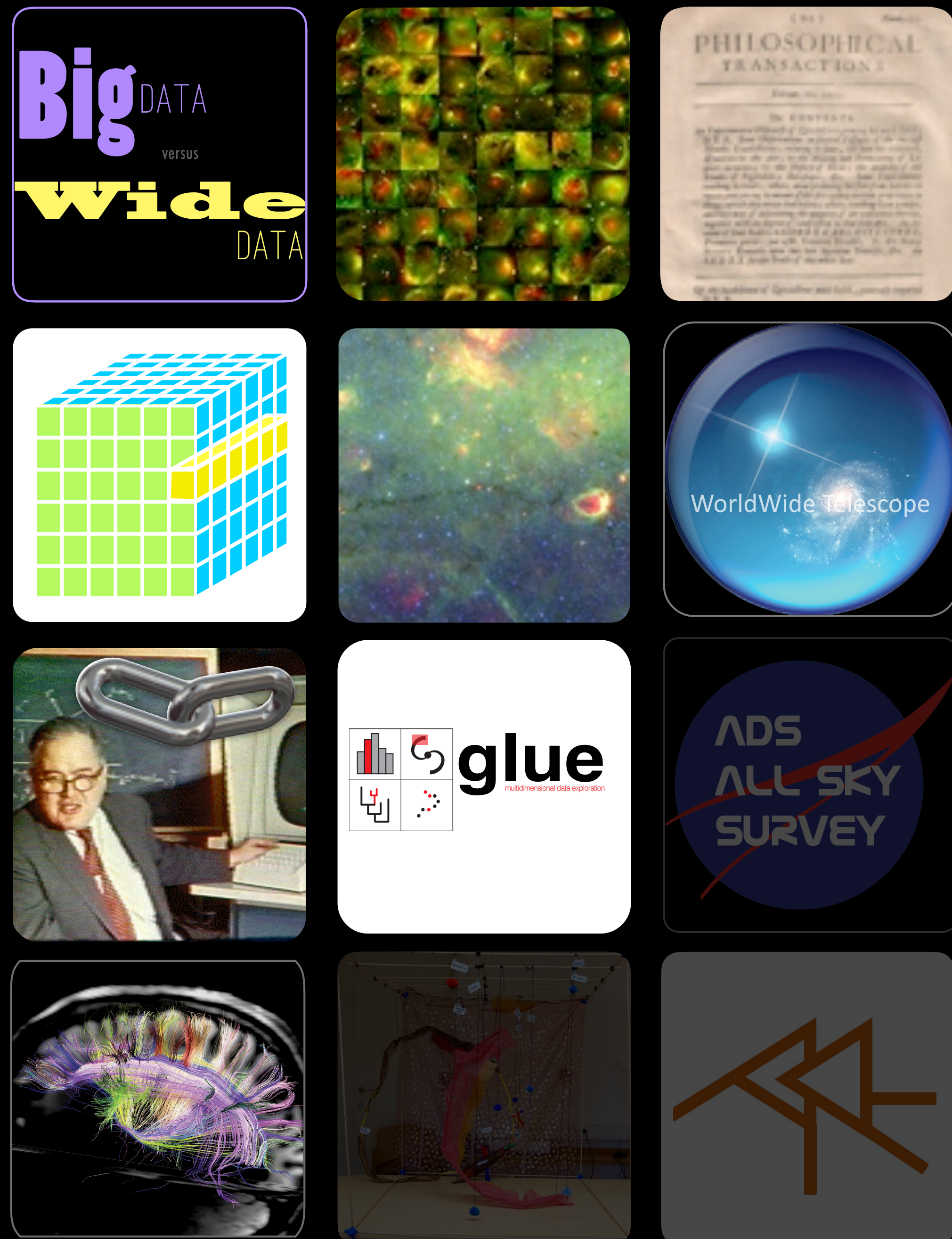
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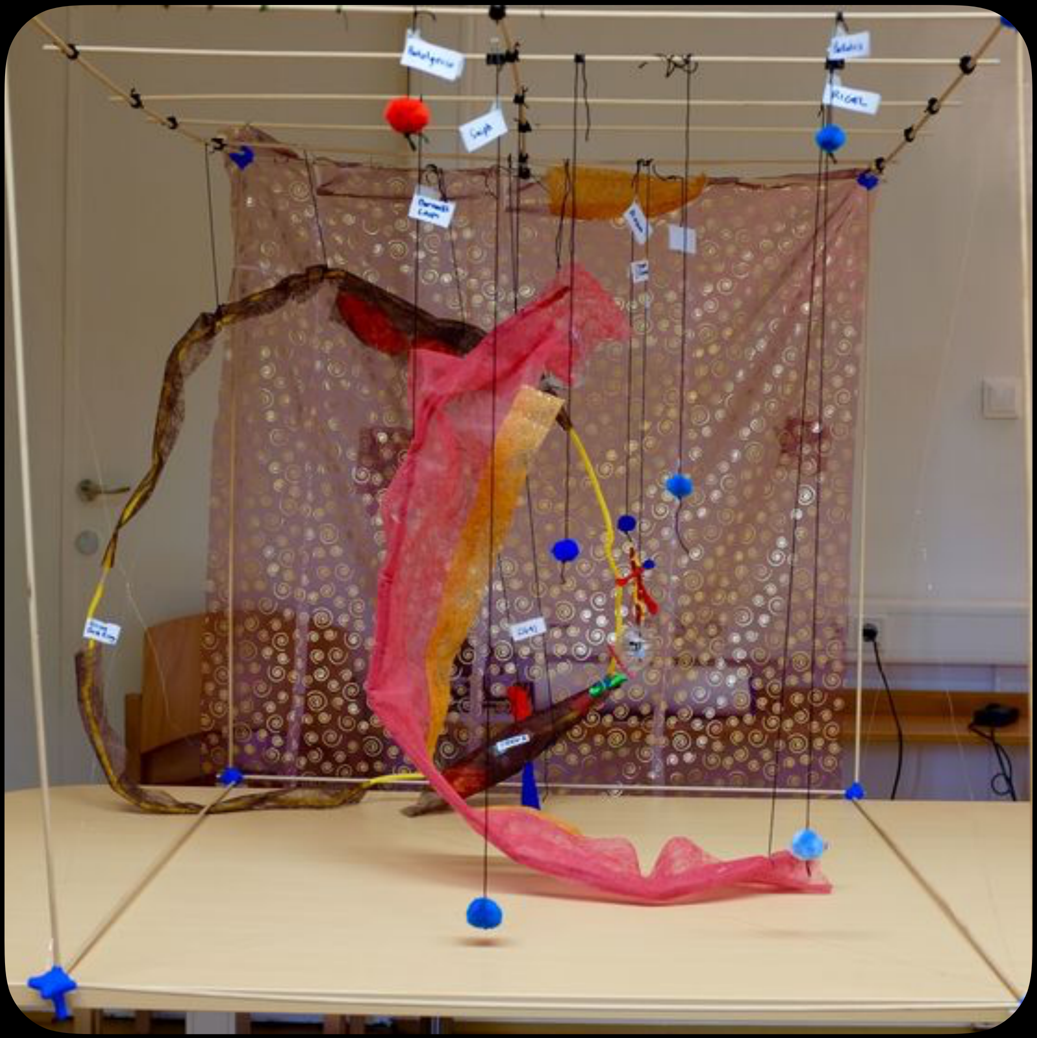
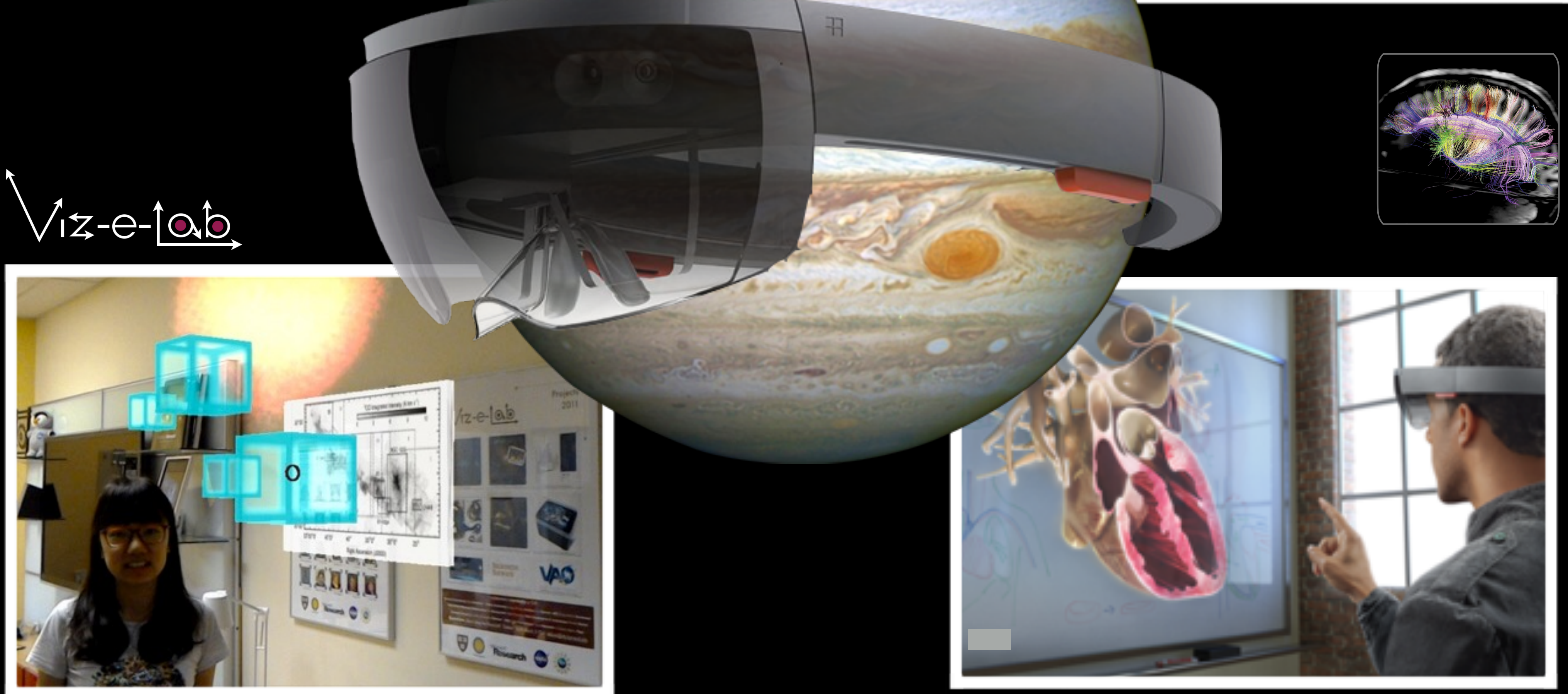
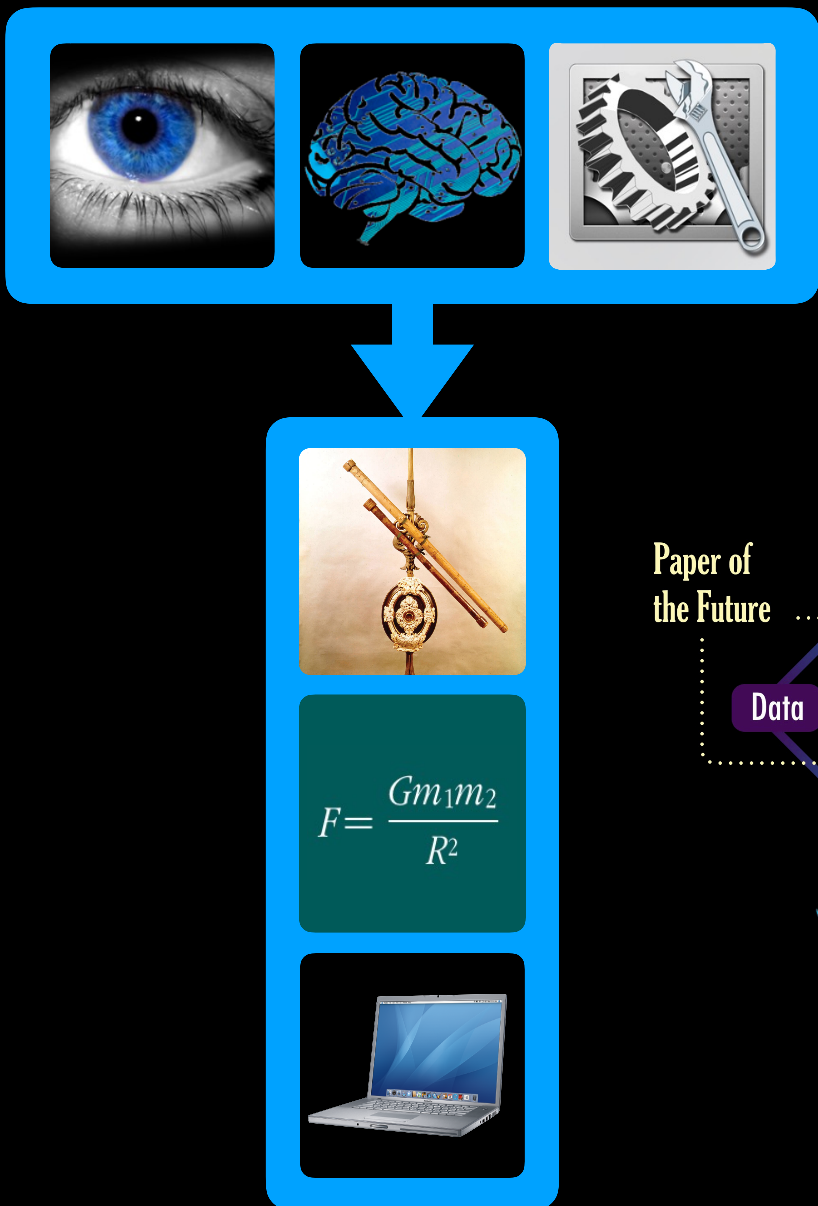
The challenge of 3D Selection

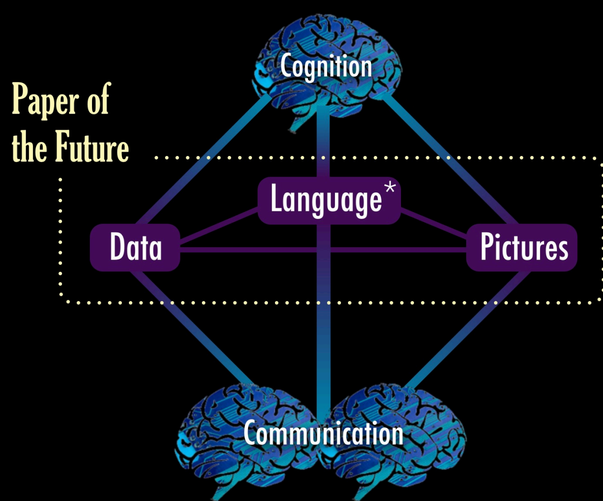


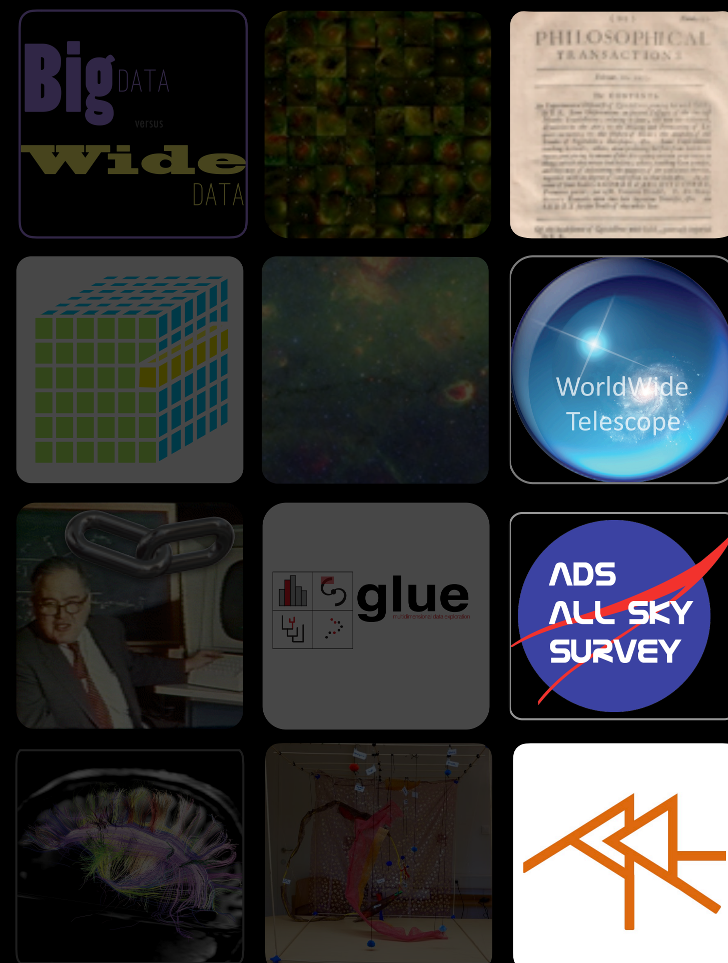
A state-of-the-art 3D model of the stars & gas near the Orion nebula, created at Orion (un)plugged, Vienna, 2015.
Expert builders (~20 total) include: Joao Alves, John Bally, Alyssa Goodman & Eddie Schlafly. (cf. "Image & Meaning" workshops by Felice Frankel)
YouTube video explanation; WWT Tour

The challenge of 3D Selection




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


Paper of
the Future
Cognition
Language*
Data
Pictures
Communication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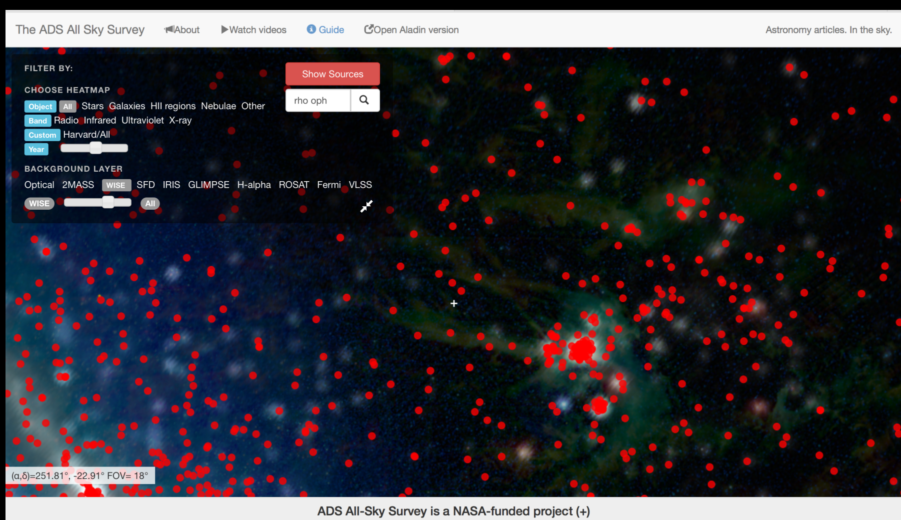
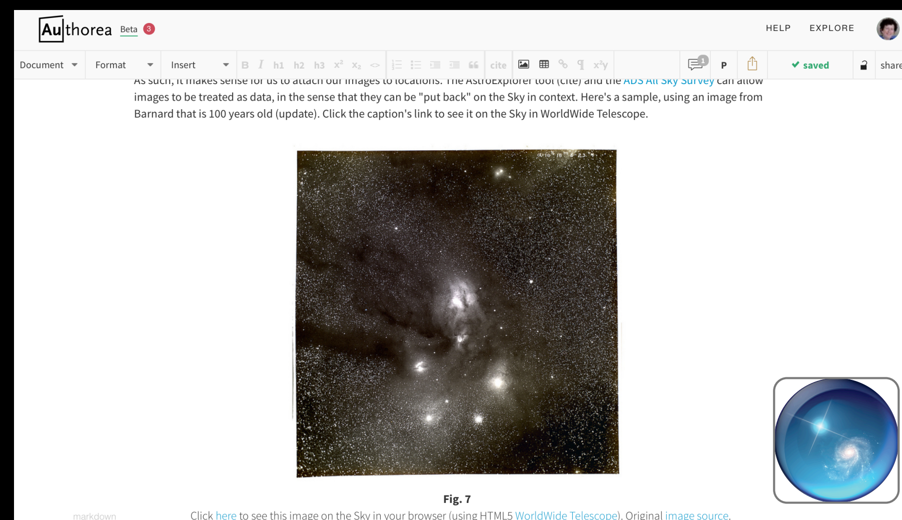
Literature as (a filter for) Data





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!

ADS All-Sky Survey & Astronomy Rewind

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

1. Images Extracted from Journal Articles

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

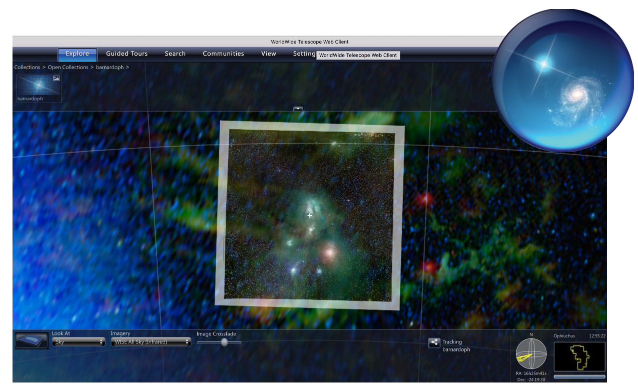
ZOONIVERSE

3. "Solved" images returned to ADS & Astronomy Image Explorer

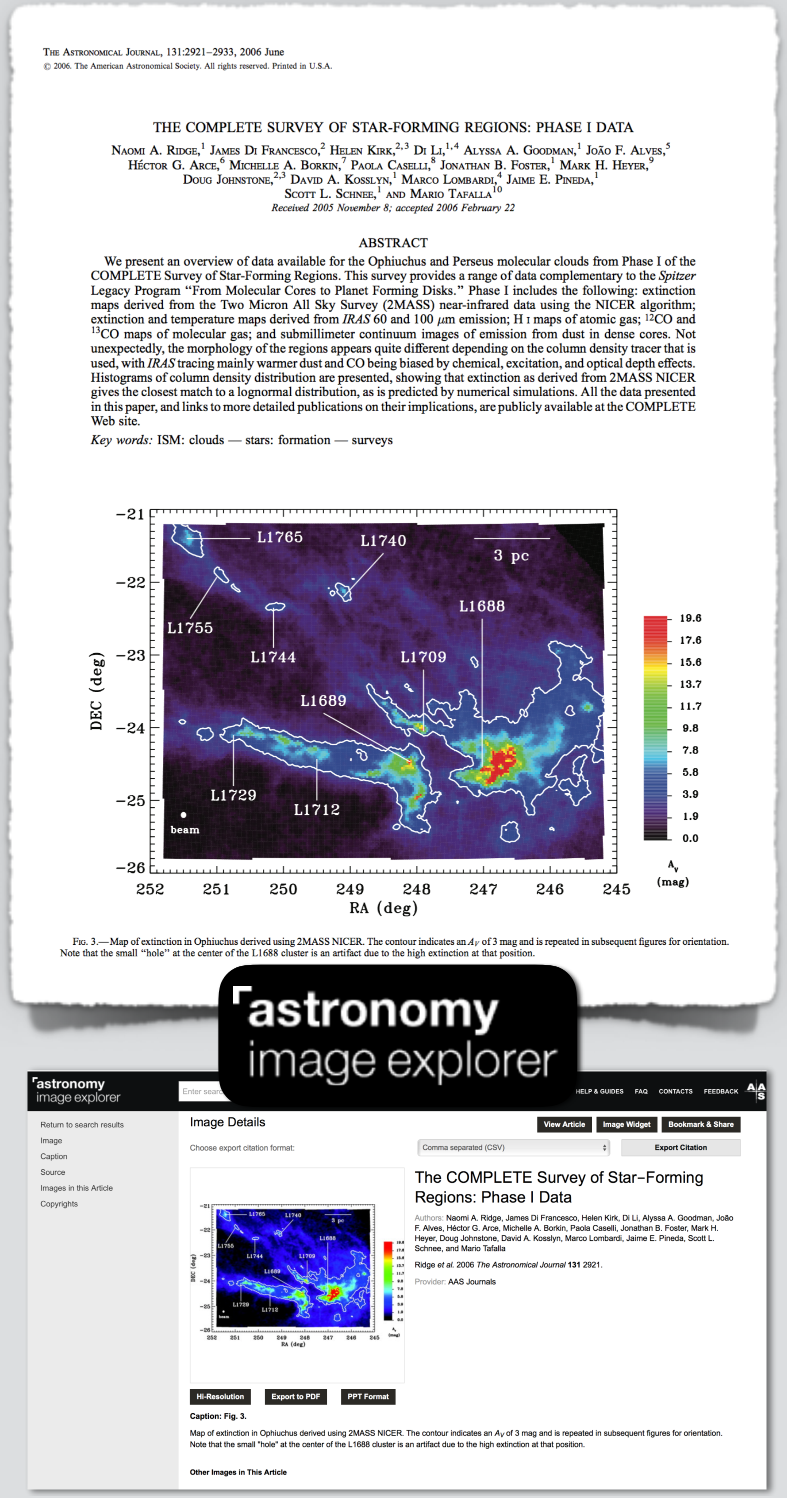
astrophysics data system

astronomy image explorer

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



ADS	click entries on the timeline to try out services	WorldWide Telescope	Zooniverse	Astrometry.net	ADS All Sky Survey	Astronomy Image Explorer	Astronomy Rewind
1992		2008	2009	2011	2014	2014	2017



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

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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. This survey provides a range of data complementary to the *Spitzer* Legacy Program "From Molecular Cores to Planet Forming Disks." Phase I includes the following: extinction maps derived from the Two Micron All Sky Survey (2MASS) near-infrared data using the NICER algorithm; extinction and temperature maps derived from *IRAS* 60 and 100 μm emission; H I maps of atomic gas; ^{12}CO and ^{13}CO maps of molecular gas; and submillimeter continuum images of emission from dust in dense cores. Not unexpectedly, the morphology of the regions appears quite different depending on the column density tracer that is used, with *IRAS* tracing mainly warmer dust and CO being biased by chemical, excitation, and optical depth effects. Histograms of column density distribution are presented, showing that extinction as derived from 2MASS NICER gives the closest match to a lognormal distribution, as is predicted by numerical simulations. All the data presented in this paper, and links to more detailed publications on their implications, are publicly available at the COMPLETE Web site.

Key words: ISM: clouds — stars: formation — surveys

Fig. 3.—Map of extinction in Ophiuchus derived using 2MASS NICER. The contour indicates an A_V of 3 mag and is repeated in subsequent figures for orientation. Note that the small "hole" at the center of the L1688 cluster is an artifact due to the high extinction at that position.

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**.

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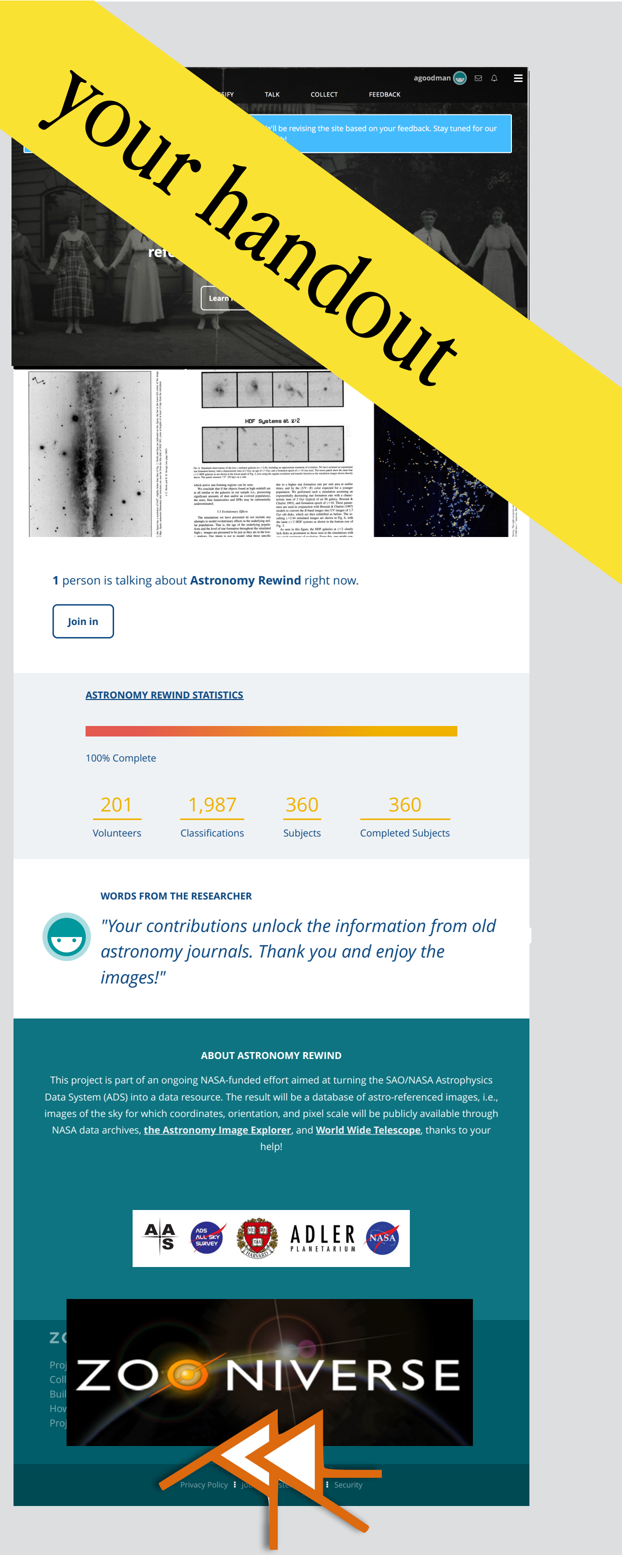

Seeing the Sky

Visualization & Astronomers

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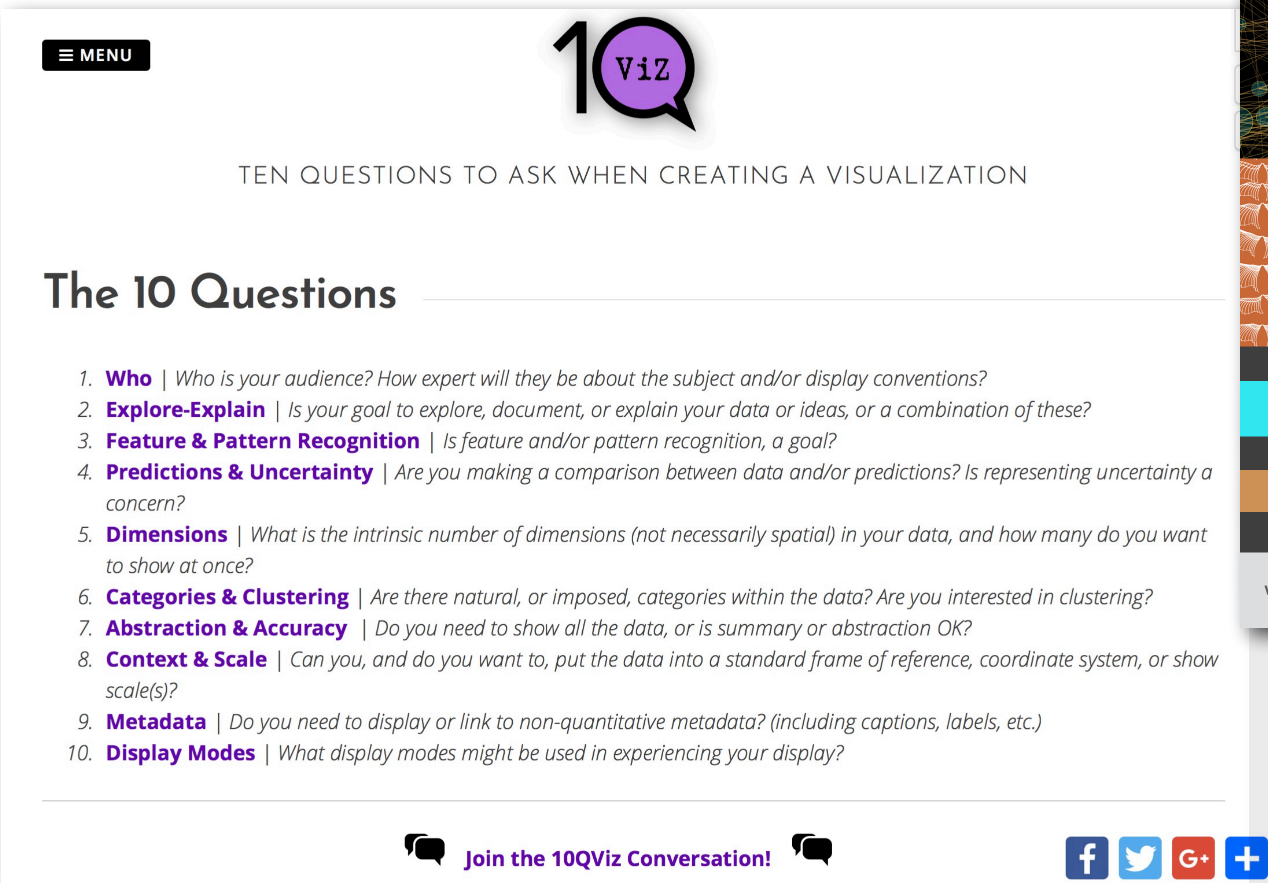
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10 Viz

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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?*
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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?*

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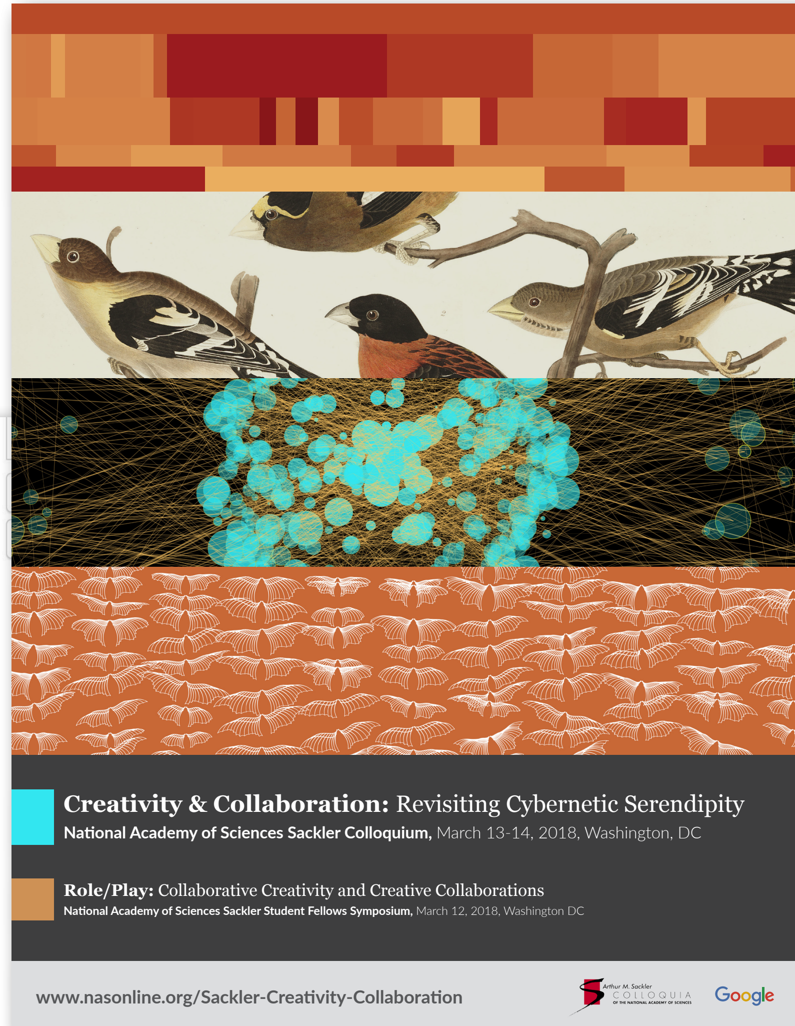

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