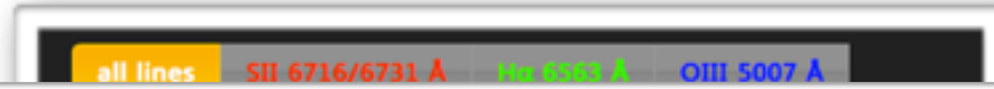
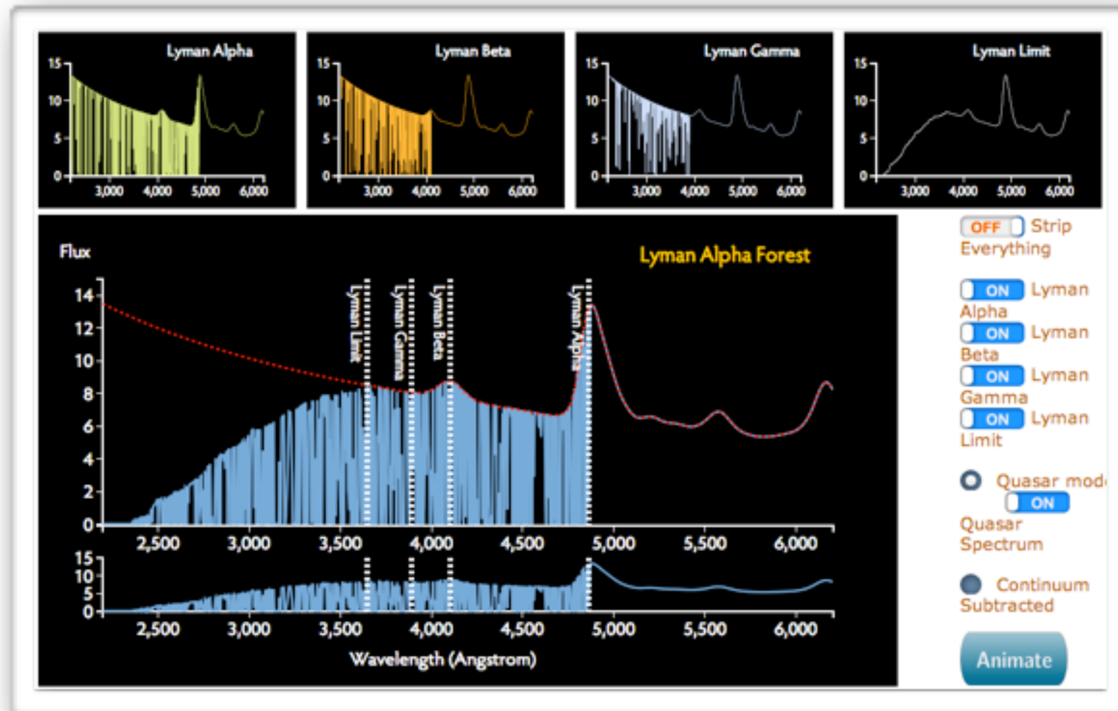
Stephen



Yuan-Sen **Ting**

Interstellar Absorption and the Lyman Alpha Forest

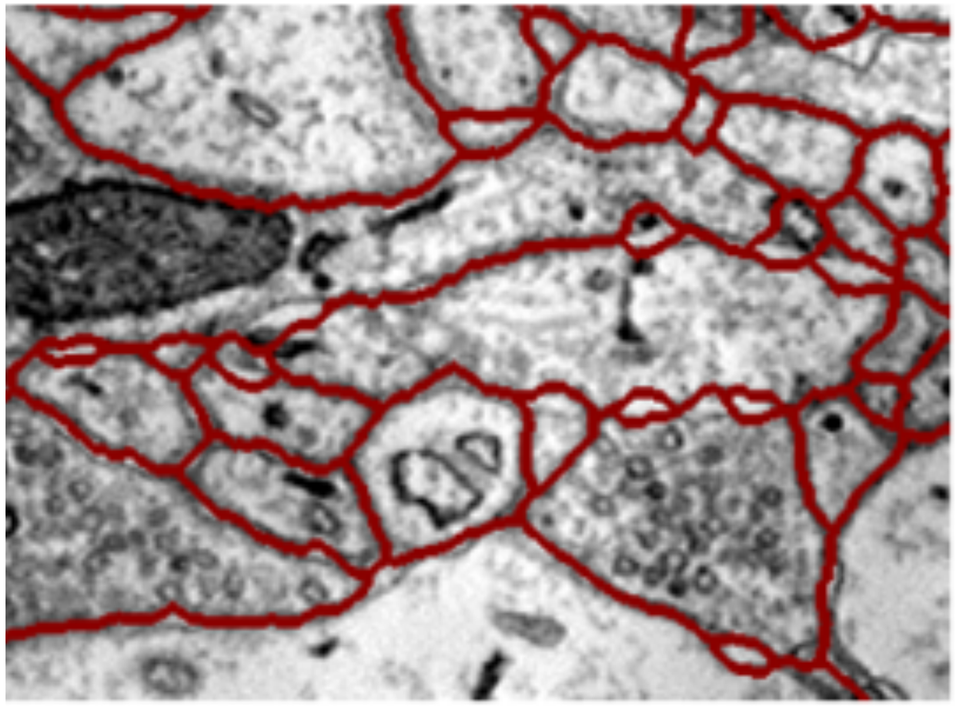


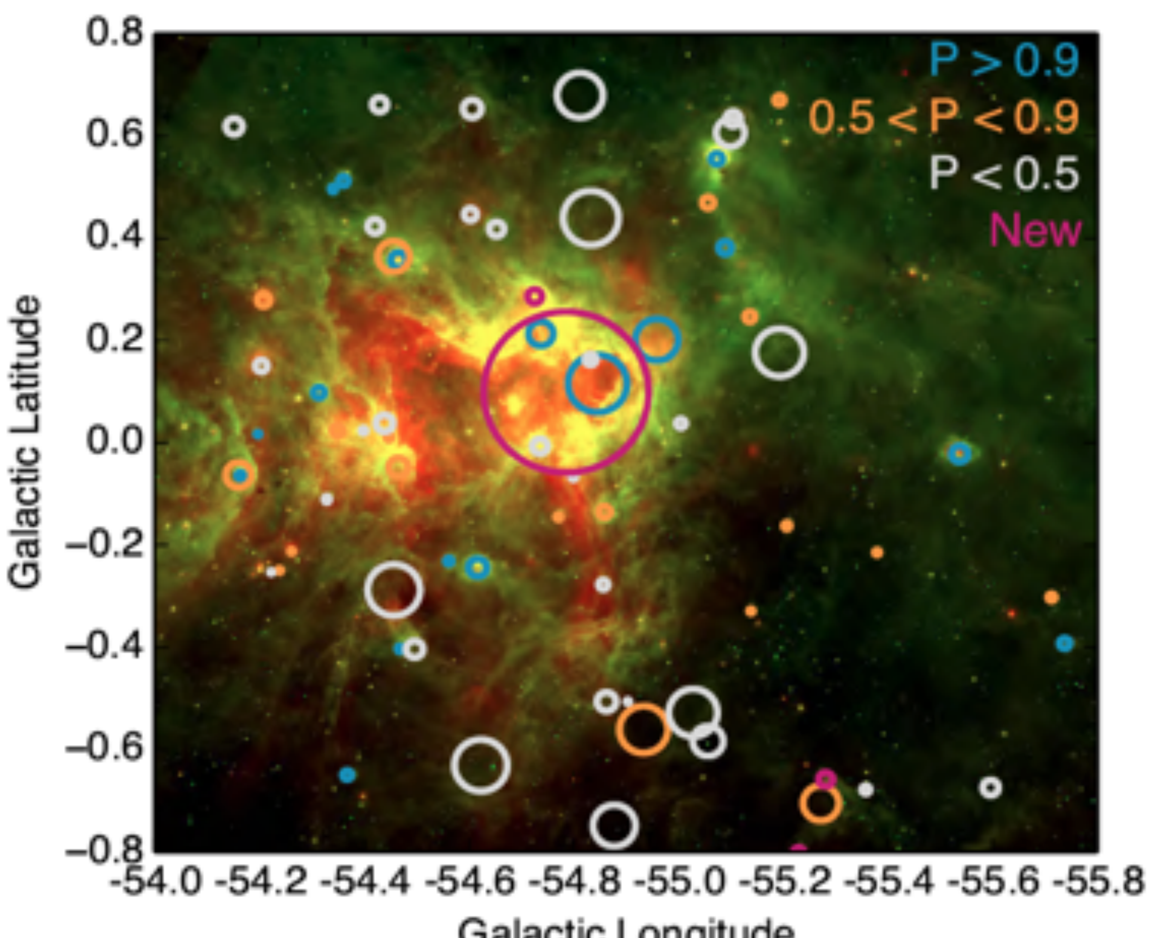
JavaScript https://www.cfa.harvard.edu/~yuan-sen.ting/lyman_alpha.html

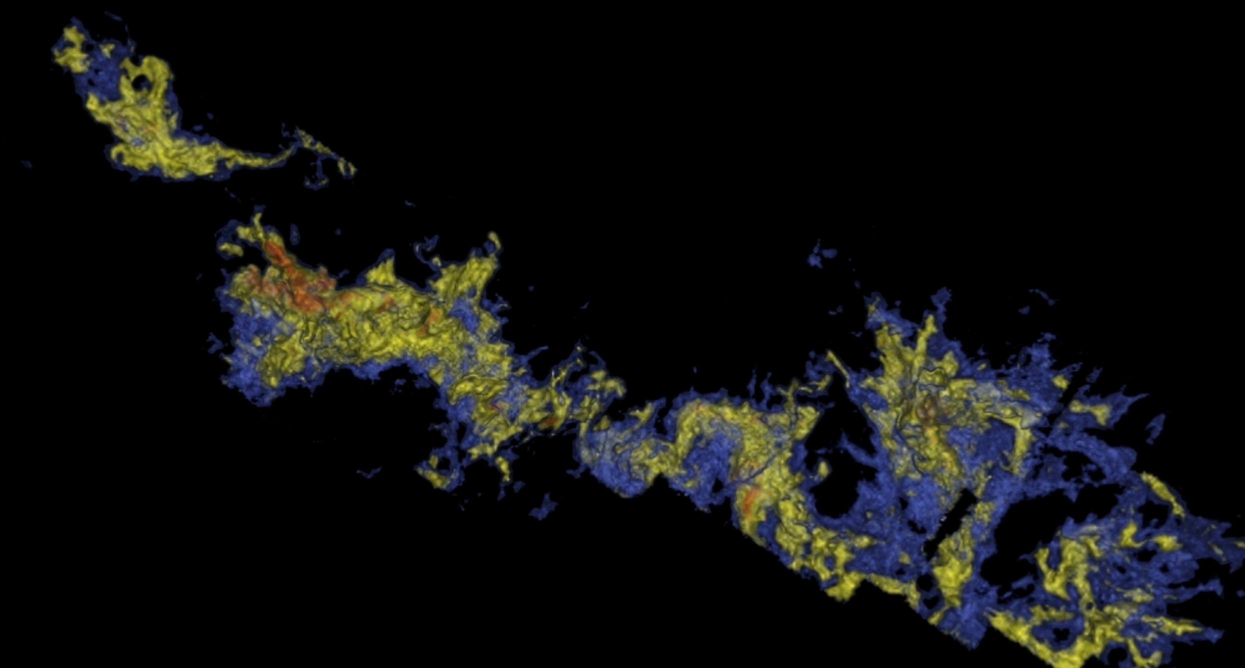
JavaScript http://portillo.ca/nebula/

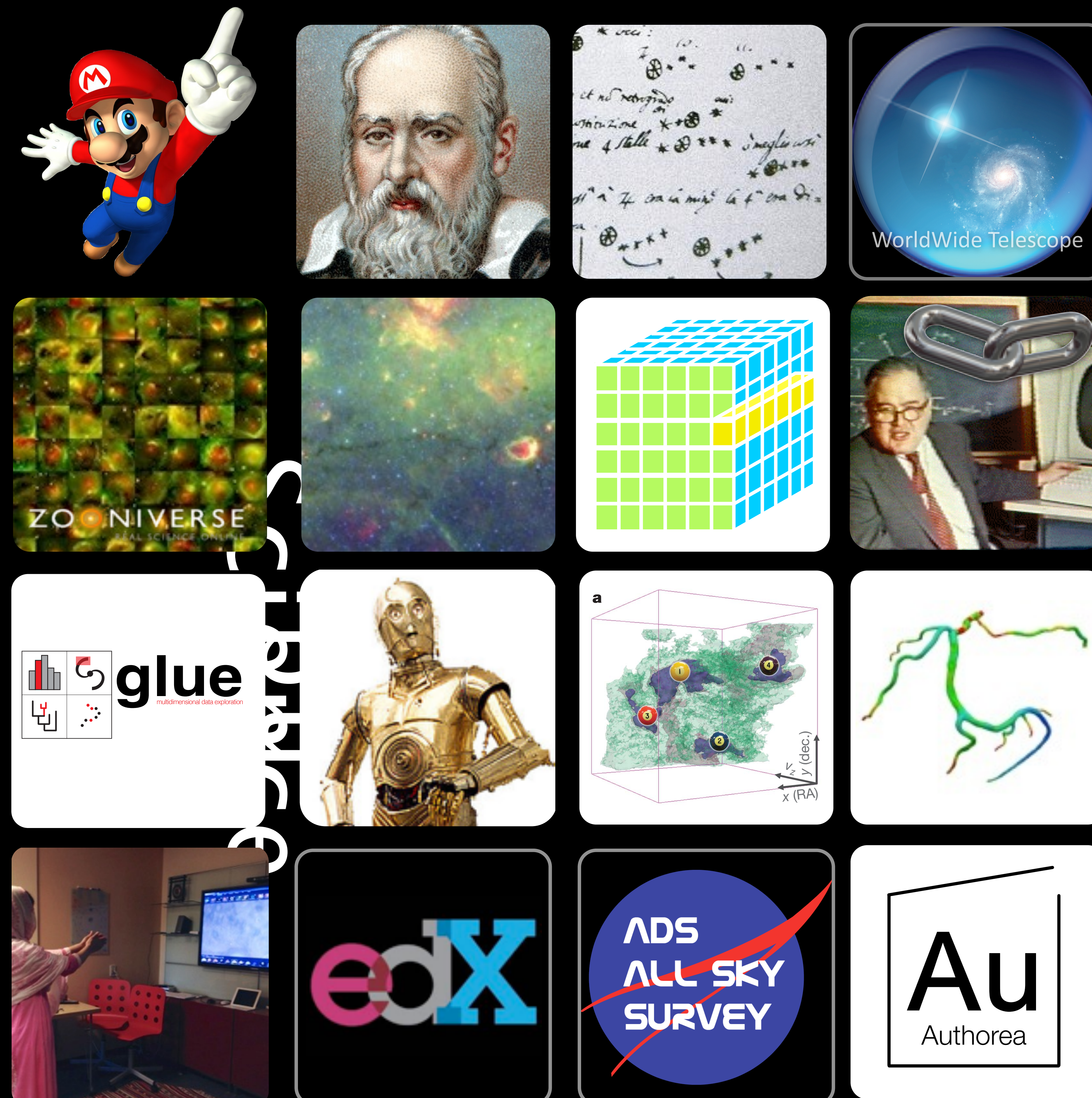
see: A New Approach to Developing Interactive Software Modules through Graduate Education, Sanders, Faesi & Goodman 2013

Science




P > 0.9
0.5 < P < 0.9
P < 0.5
New
Galactic Latitude
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
-54.0 -54.2 -54.4 -54.6 -54.8 -55.0 -55.2 -55.4 -55.6 -55.8
Galactic Longitude





Prof. Alyssa A. Goodman–Harvard-Smithsonian Center for Astrophysics–@aagie

+Herricks High School, Class of 1980

Relative Strengths

Pattern Recognition
Creativity

Calculations

Resolution

Context

Big Data

Wide Data

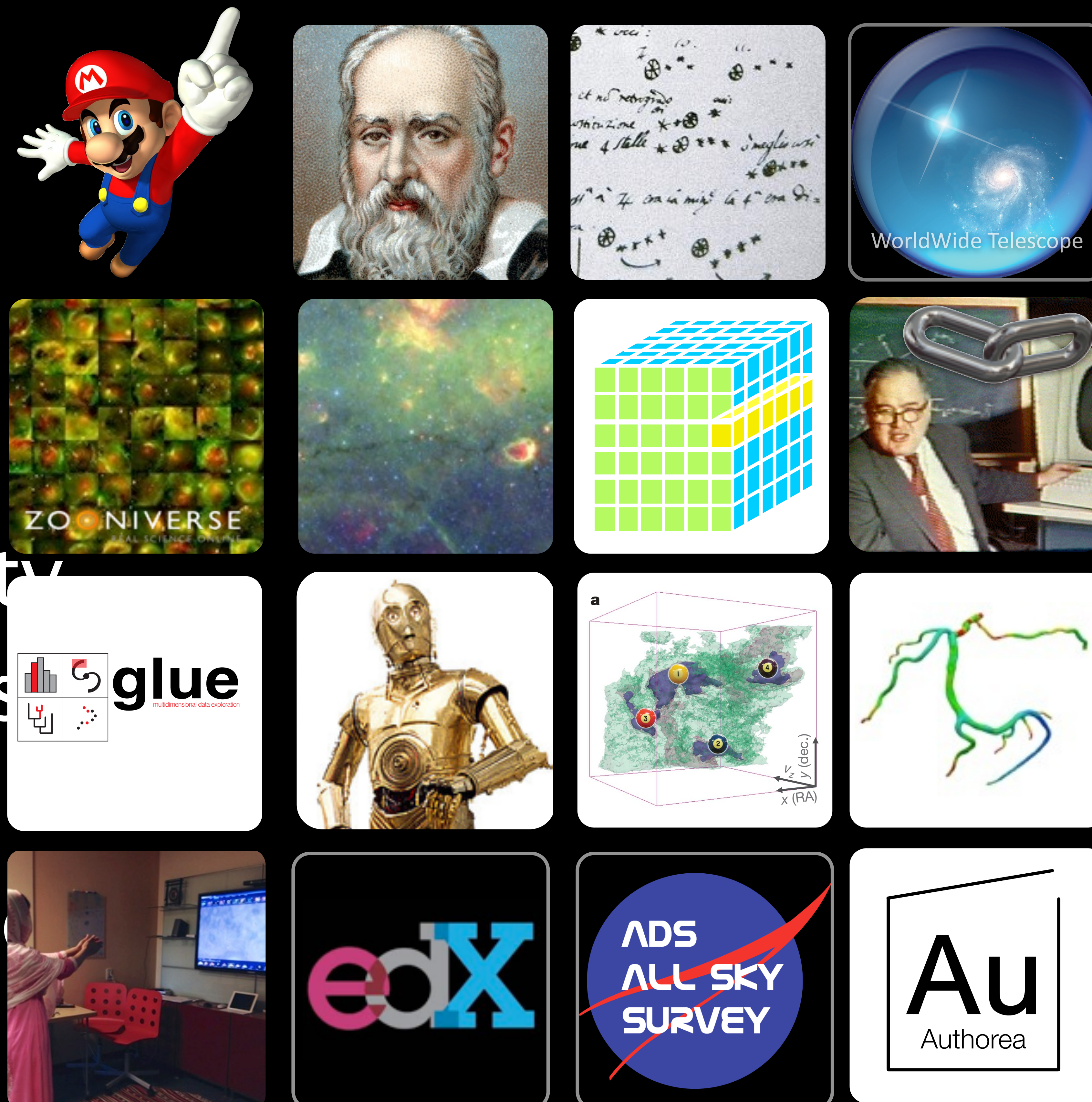
Dimensionality

Linked views

Interaction

Communicati

education

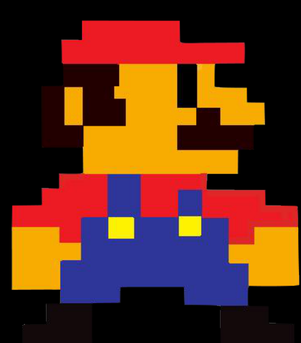


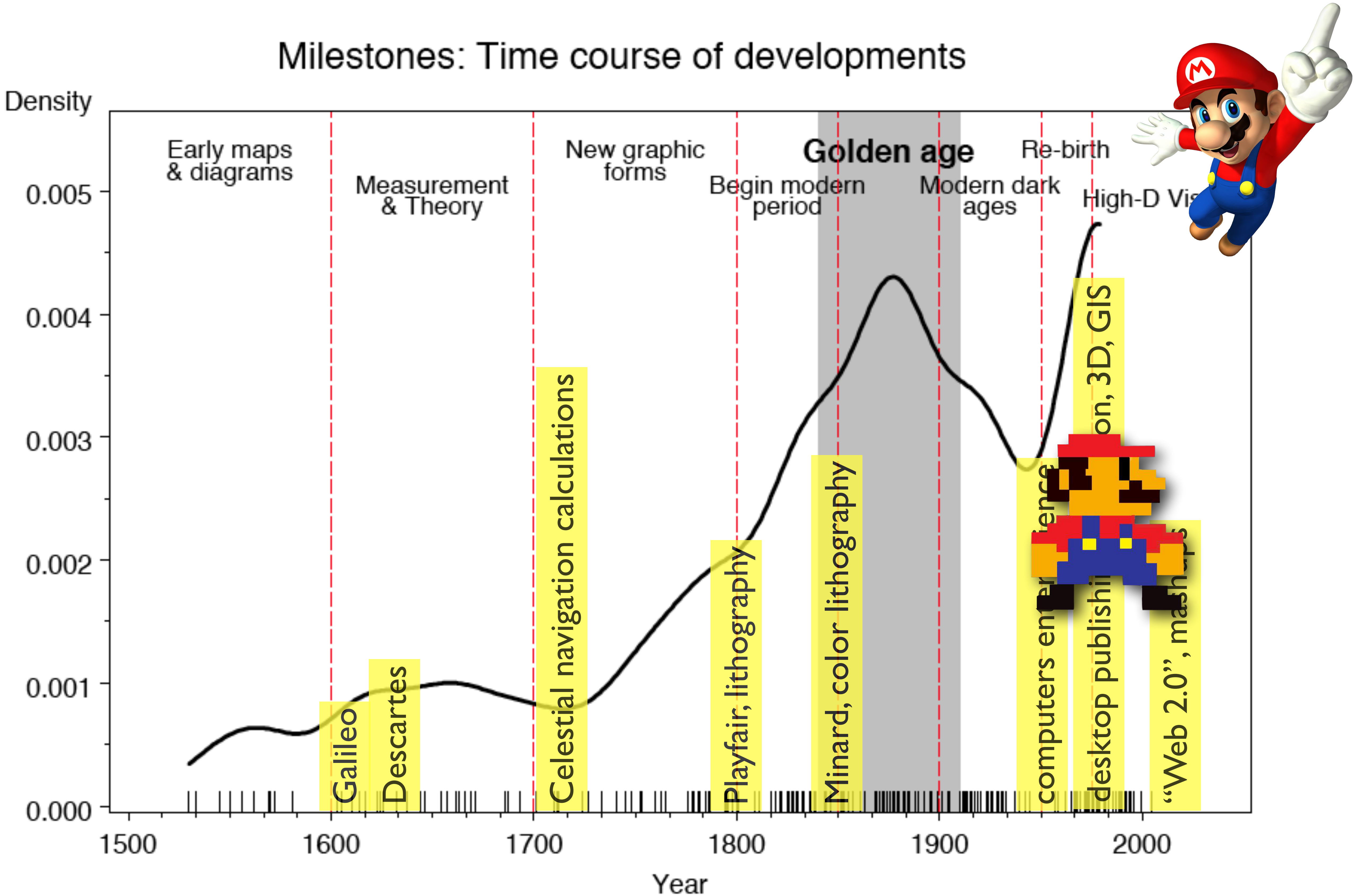
1992

Super Mario Kart: Rainbow Road (1992)

2014

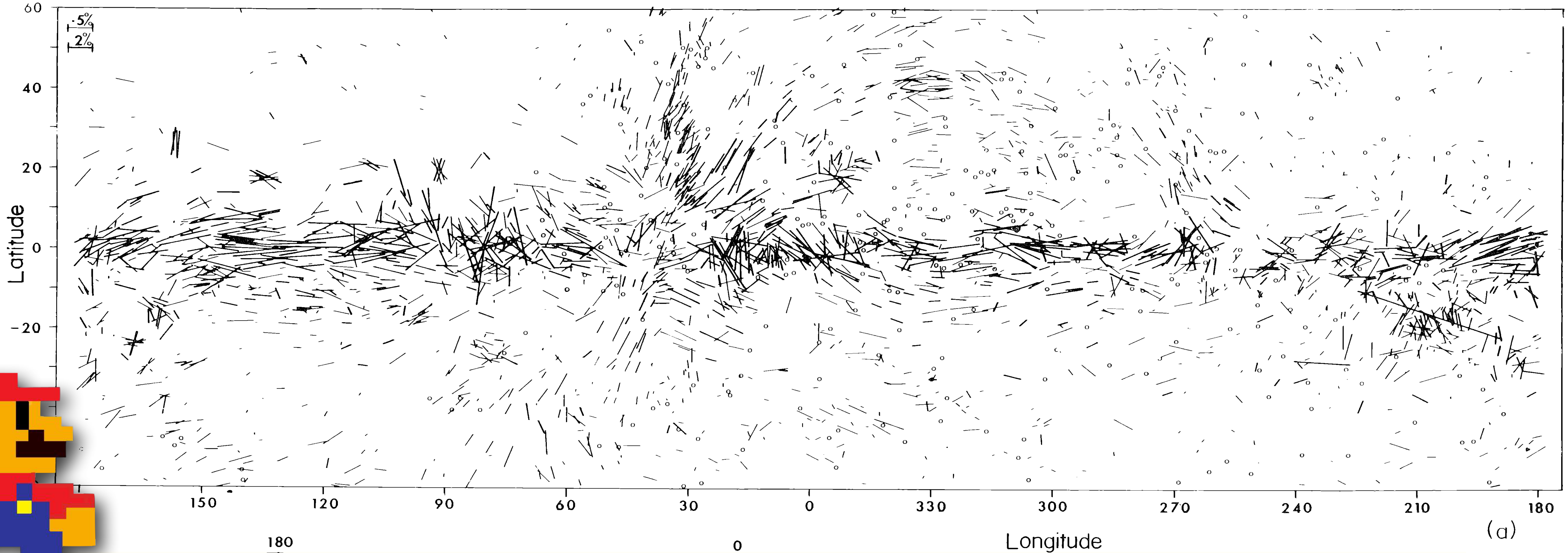
Mario Kart 8: Rainbow Road (2014)



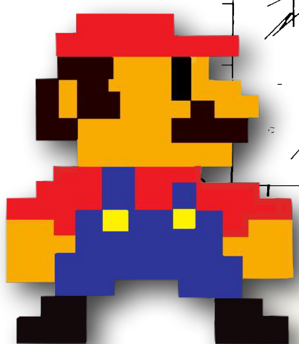


adapted from Friendly, "The Golden Age of Statistical Graphics," *Statistical Science*, 2009

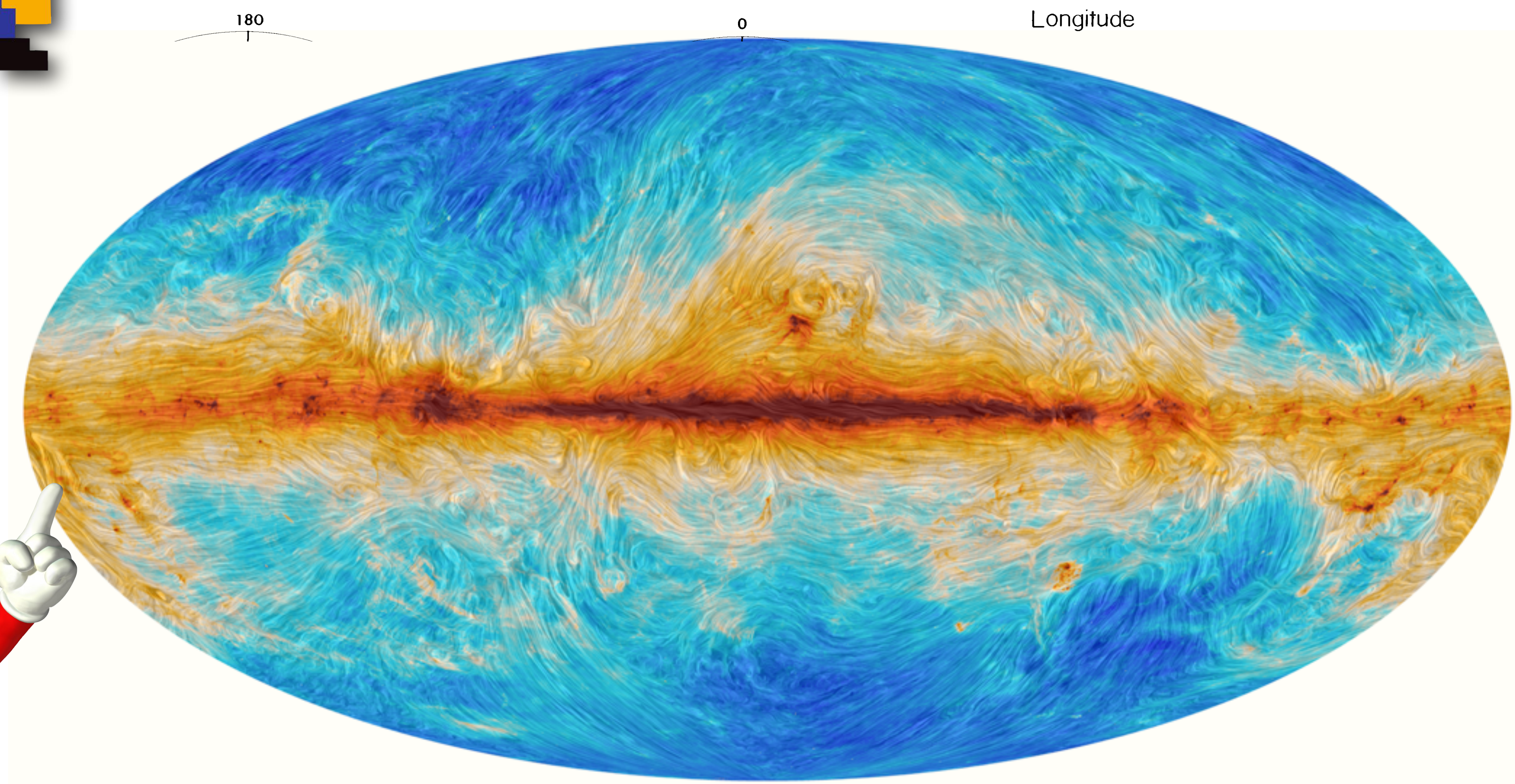
1970



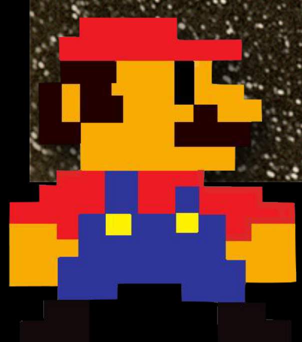
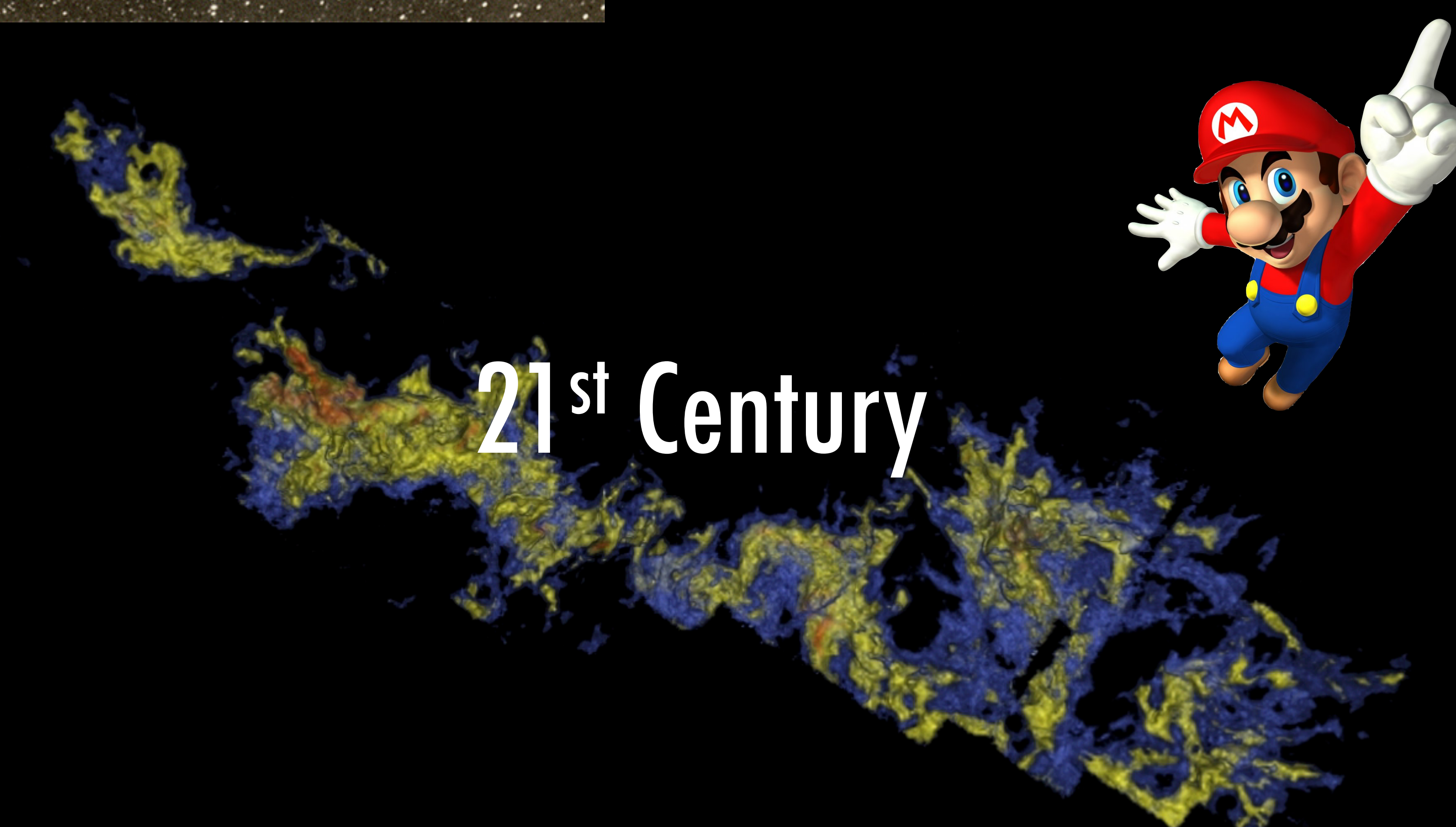
60
40
20
0
-20
Latitude
·5%
2%
150
120
90
60
30
0
330
300
270
240
210
180
Longitude
(a)



2014



180
0


20th Century


21st Century

Resolution

Context

Big Data

Wide Data

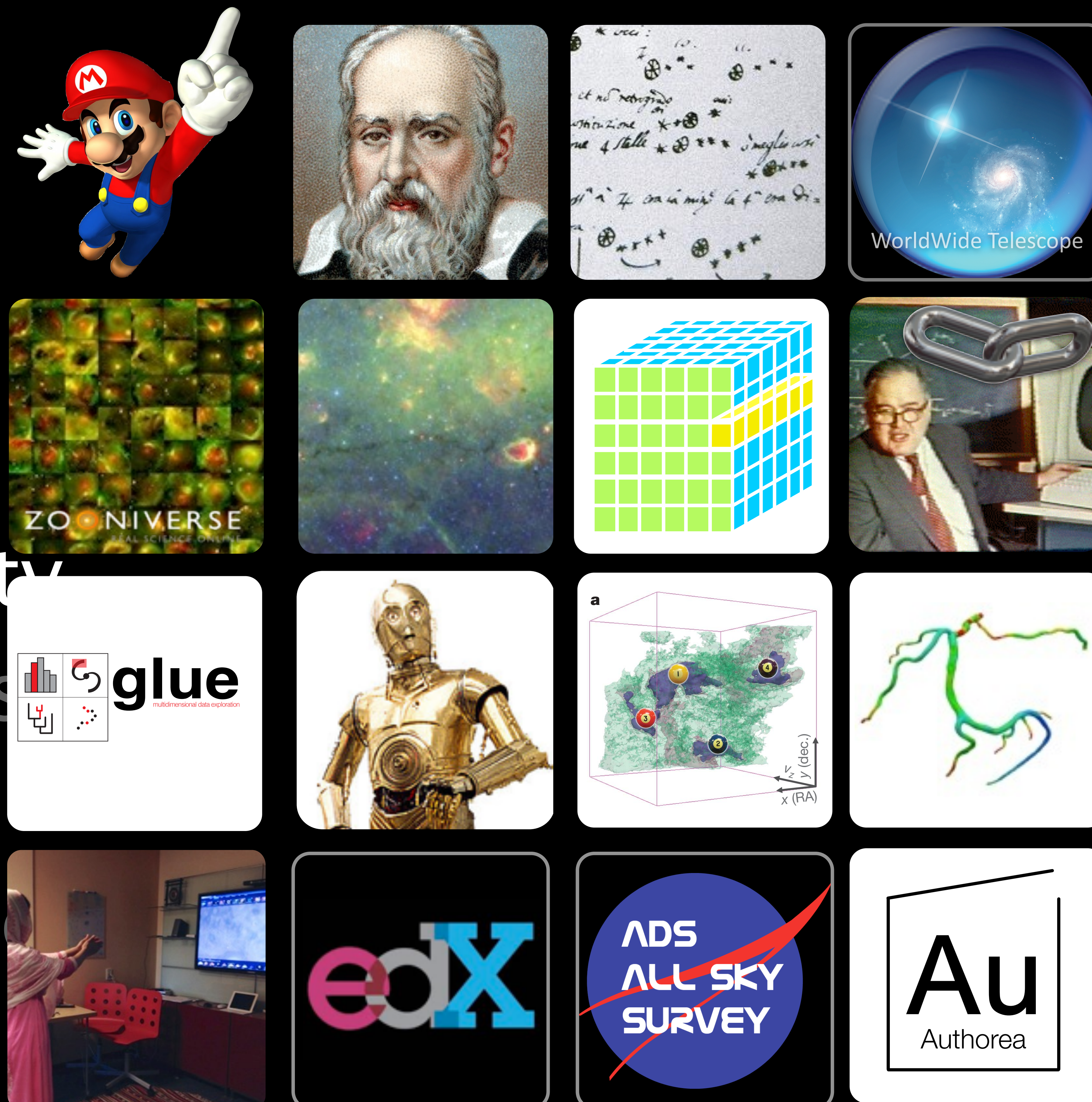
Dimensionality

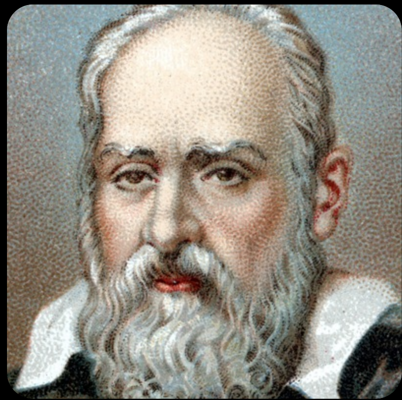
Linked views

Interaction

Communicati

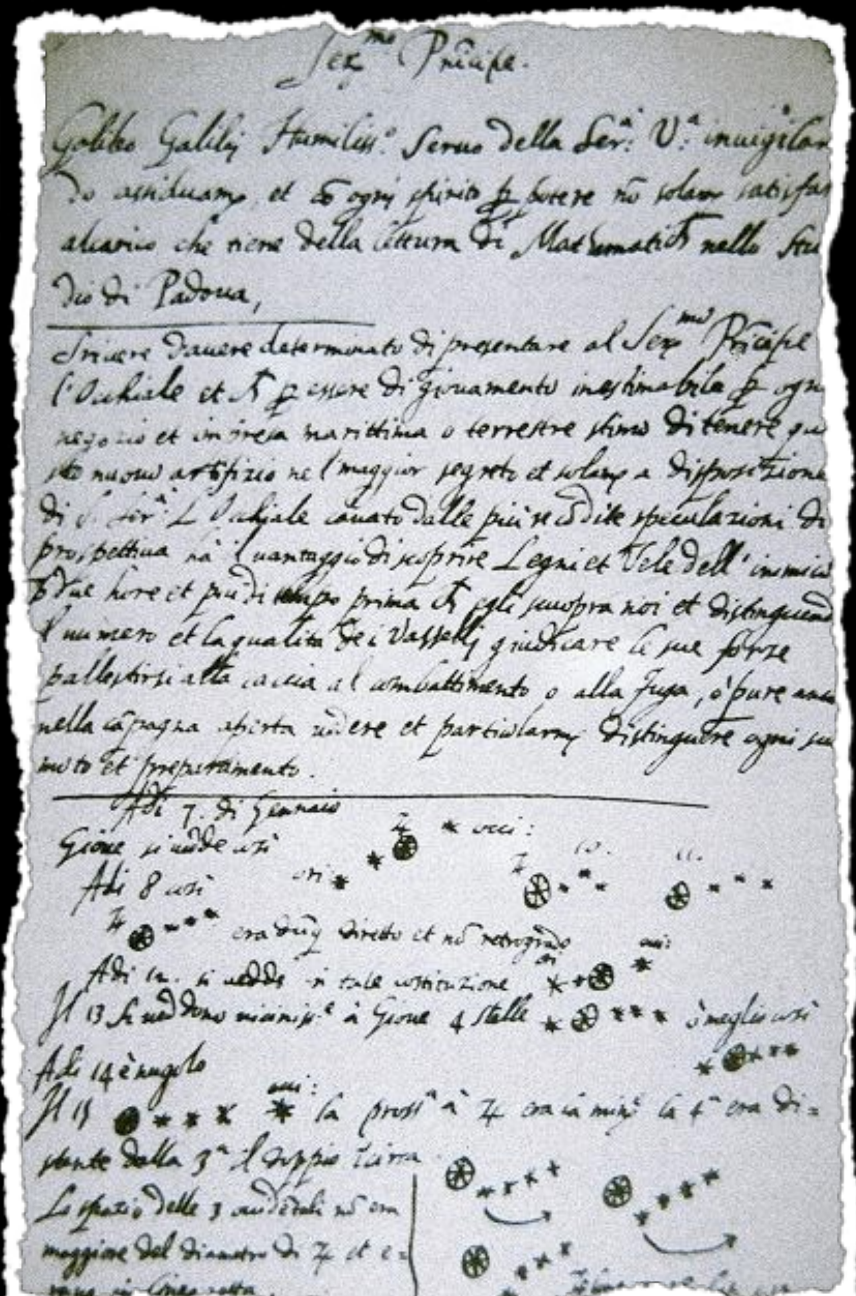
education

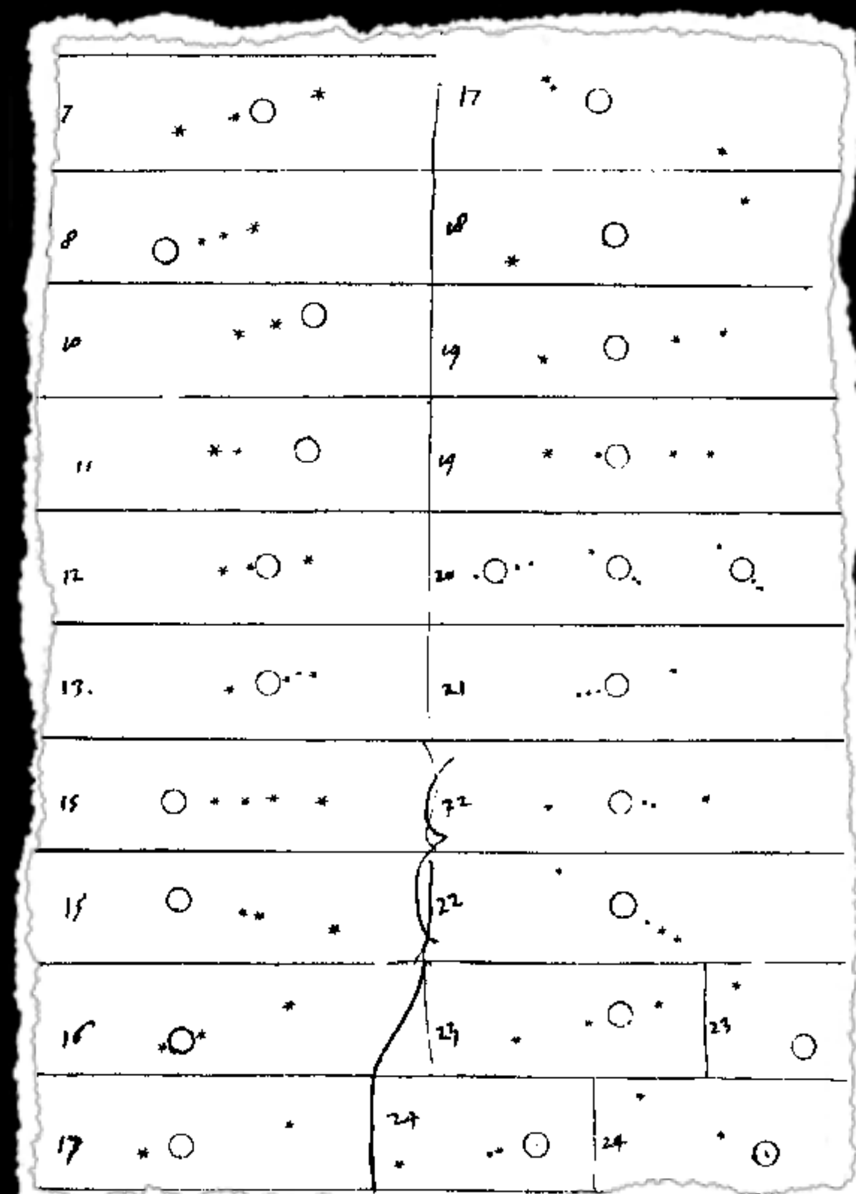


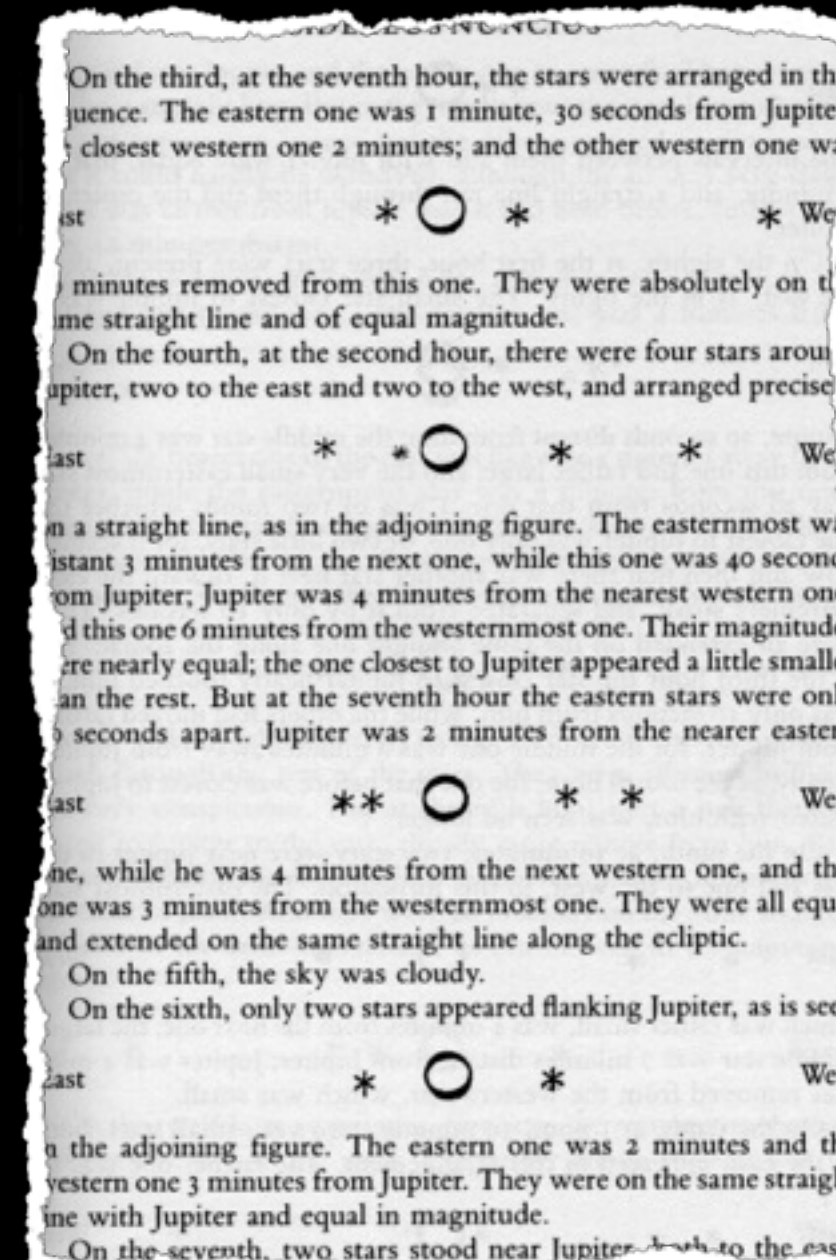


Galileo Galilei

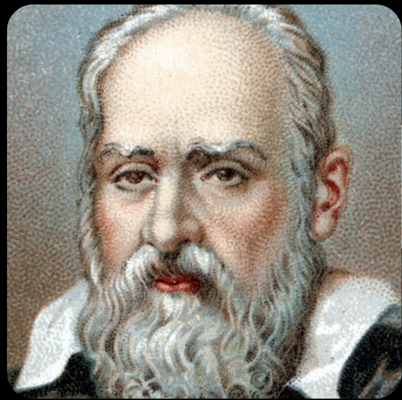
(1564–1642)



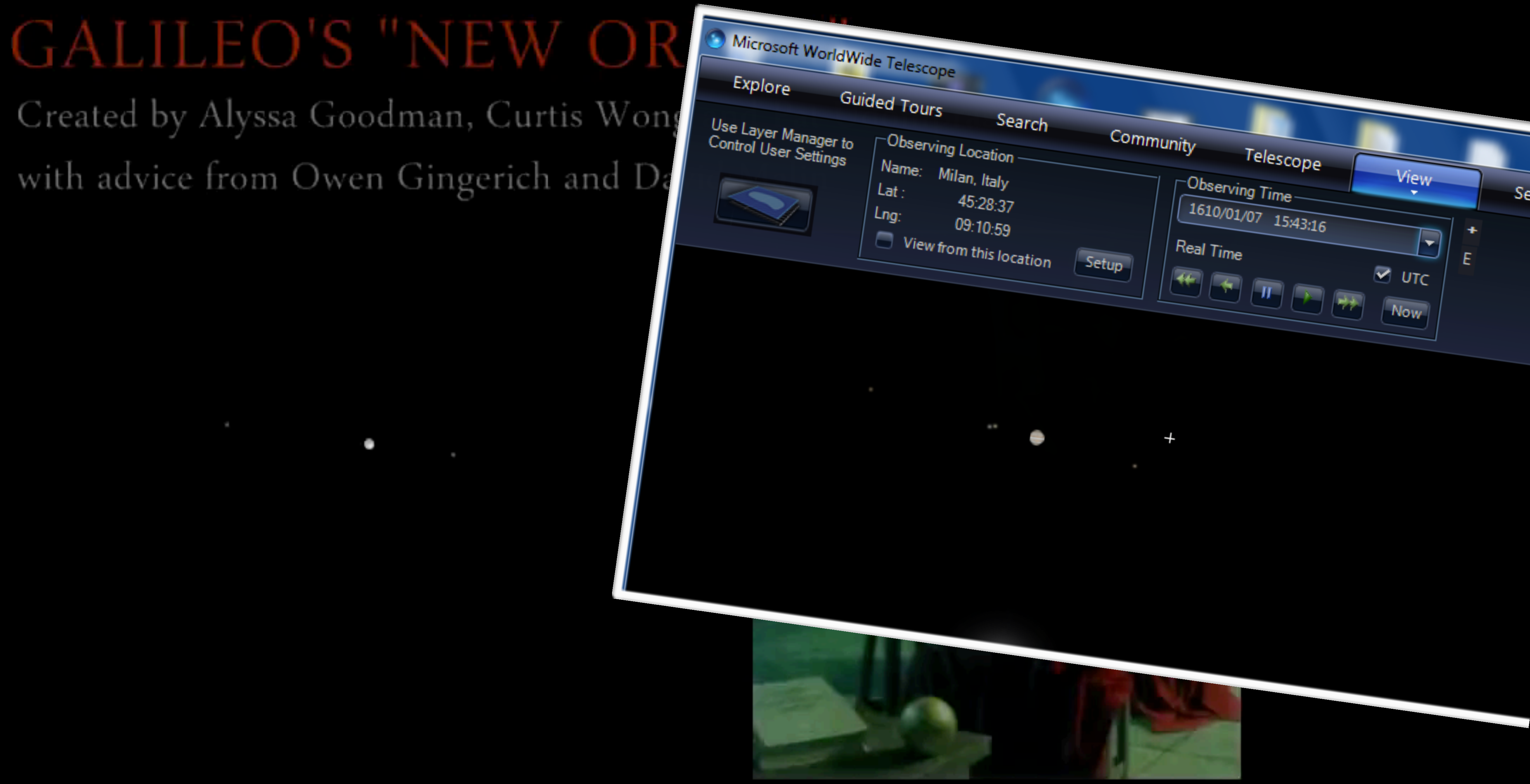



On the third, at the seventh hour, the stars were arranged in thi
juence. The eastern one was 1 minute, 30 seconds from Jupiter
closest western one 2 minutes; and the other western one wa
ast * ◯ * * We
minutes removed from this one. They were absolutely on t
me straight line and of equal magnitude.
On the fourth, at the second hour, there were four stars arou
upiter, two to the east and two to the west, and arranged precise
ast * *◯ * * We
n a straight line, as in the adjoining figure. The easternmost wa
istant 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
ere nearly equal; the one closest to Jupiter appeared a little smalle
an the rest. But at the seventh hour the eastern stars were only
seconds apart. Jupiter was 2 minutes from the nearer easter
ast ** ◯ * * Wes
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 seen
ast * ◯ * Wes
n the adjoining figure. The eastern one was 2 minutes and the
western one 3 minutes from Jupiter. They were on the same straigh
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



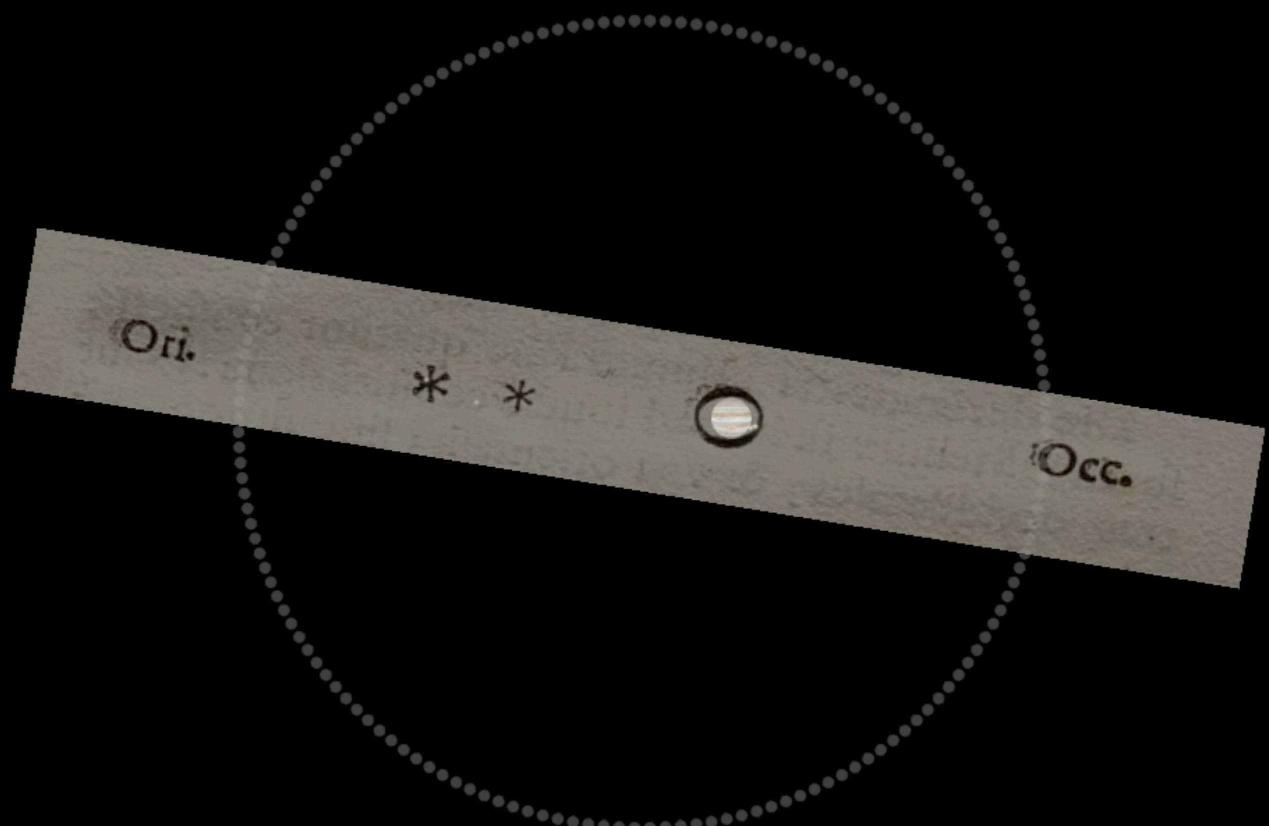
Resolution & Contex



Galileo's New Order, A WorldWide Telescope Tour by Goodman, Wong & Udomprasert 2010
Microsoft Research WWT Software (~now "OpenWWT"): Wong (inventor), Fay (architect), et al.

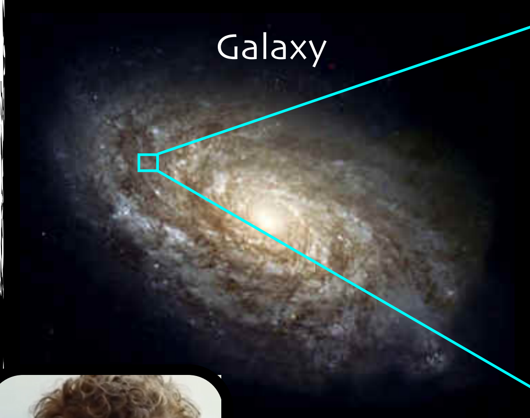
Resolution & Context + Dimensionality

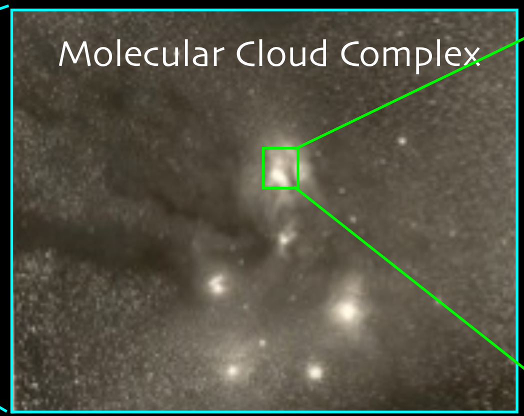
January 11, 1610

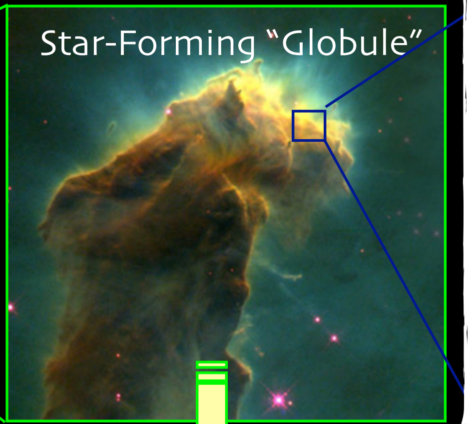


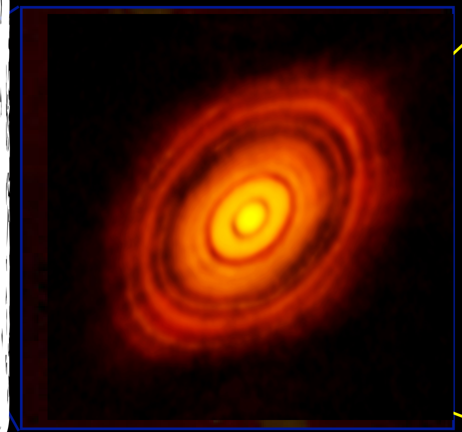
Galileo's New Order, A WorldWide Telescope Tour by Goodman, Wong & Udomprasert 2010
Microsoft Research WWT Software (~now "OpenWWT"): Wong (inventor), Fay (architect), et al.

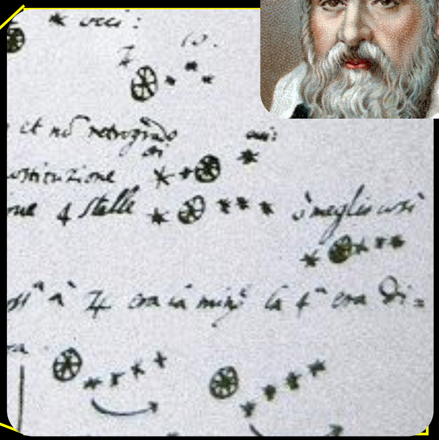
Star & Planet formation in 1 slide

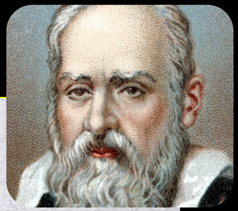


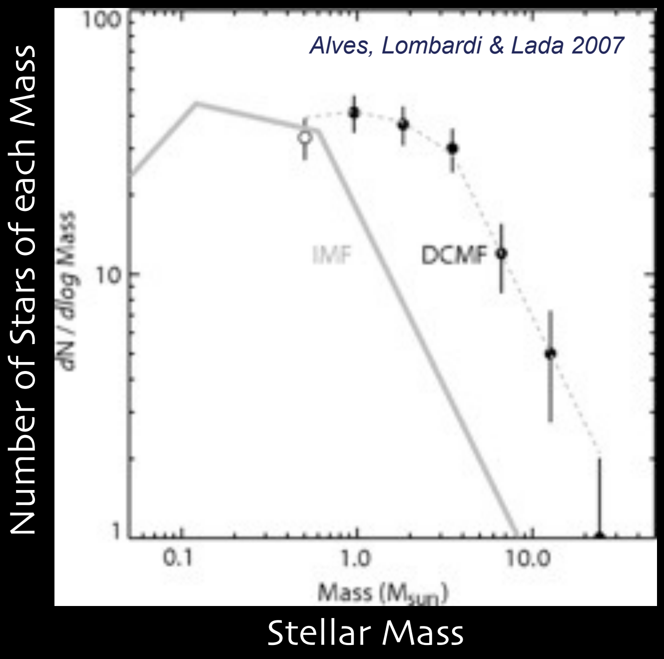


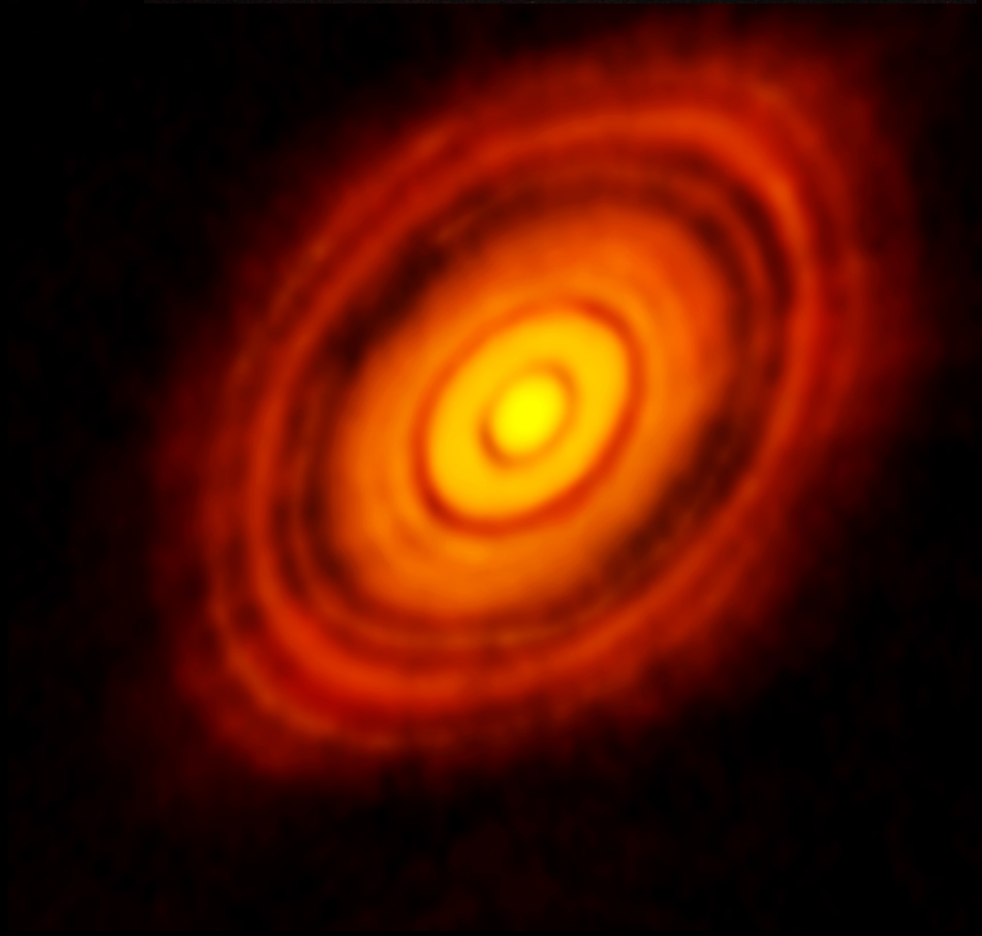












Artist's Rendering 2004

(based on theory & simulations, credit R. Hurt)

Real ALMA data 2014

Resolution

Context

Big Data

Wide Data

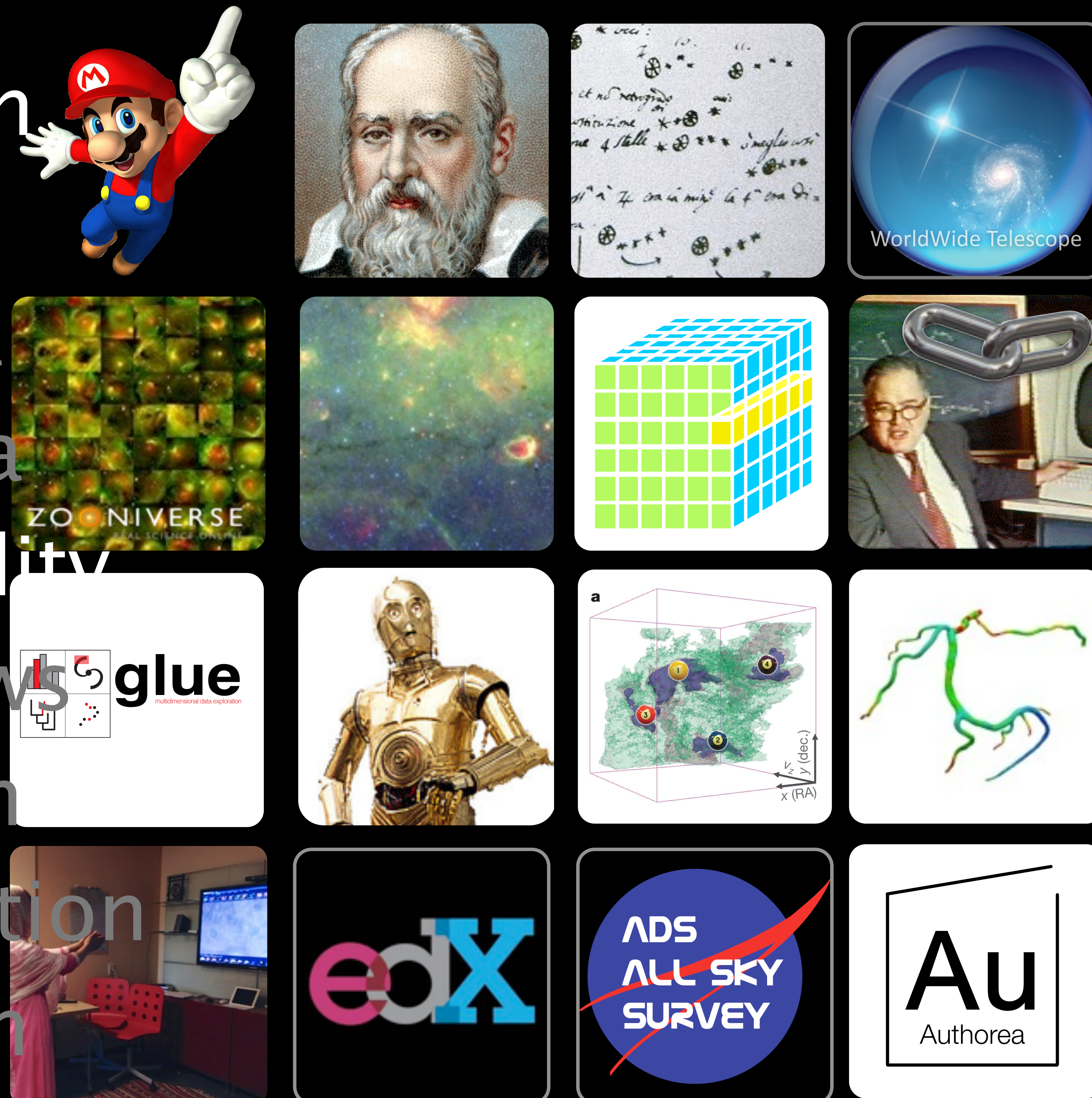
Dimensionality

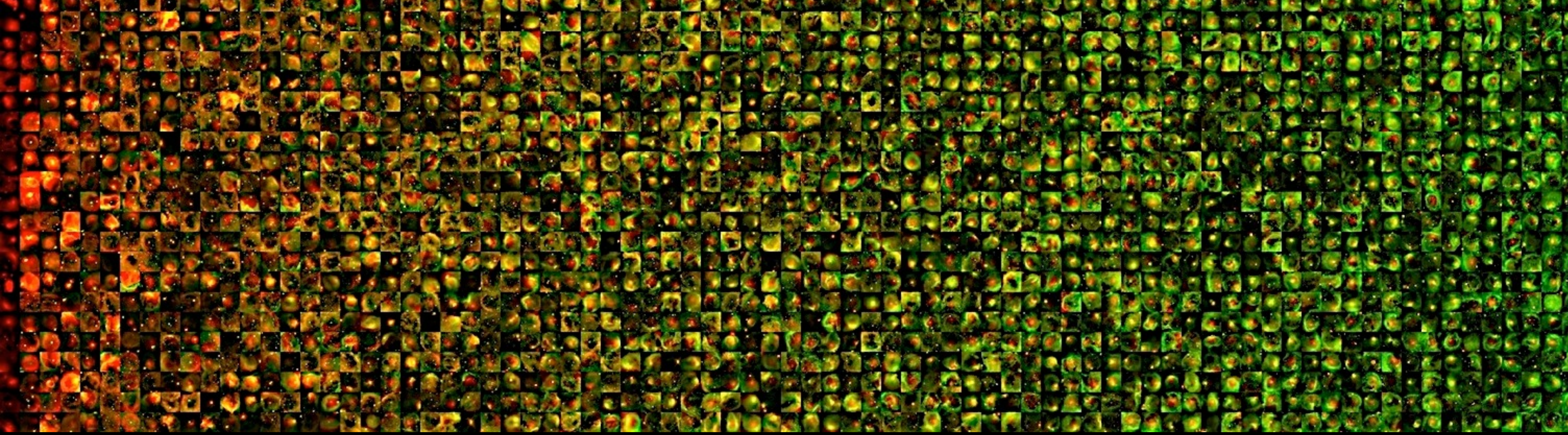
Linked views

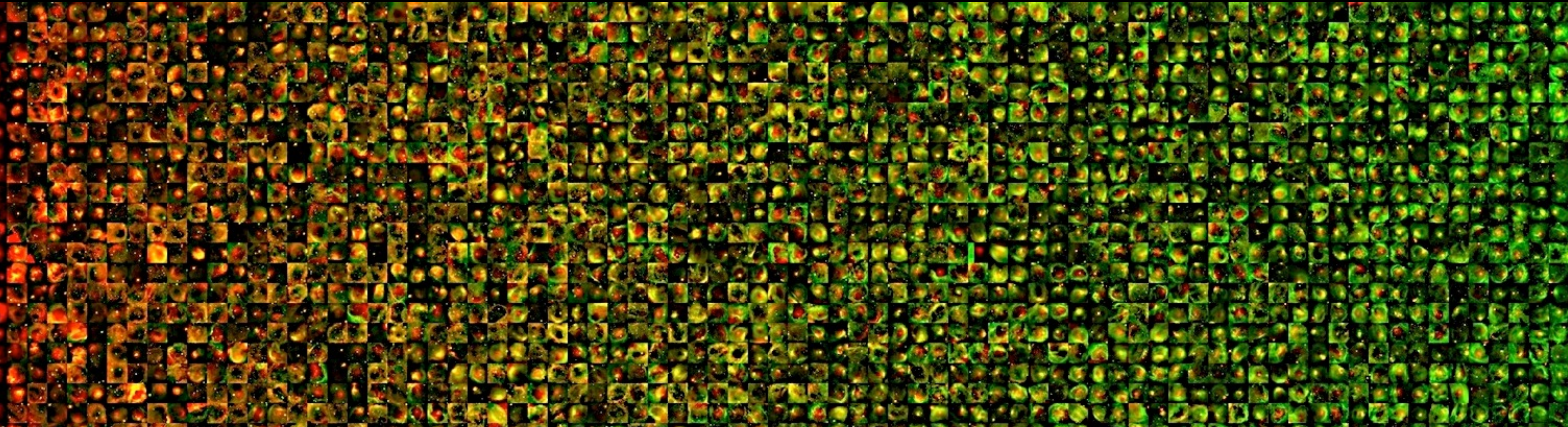
Interaction

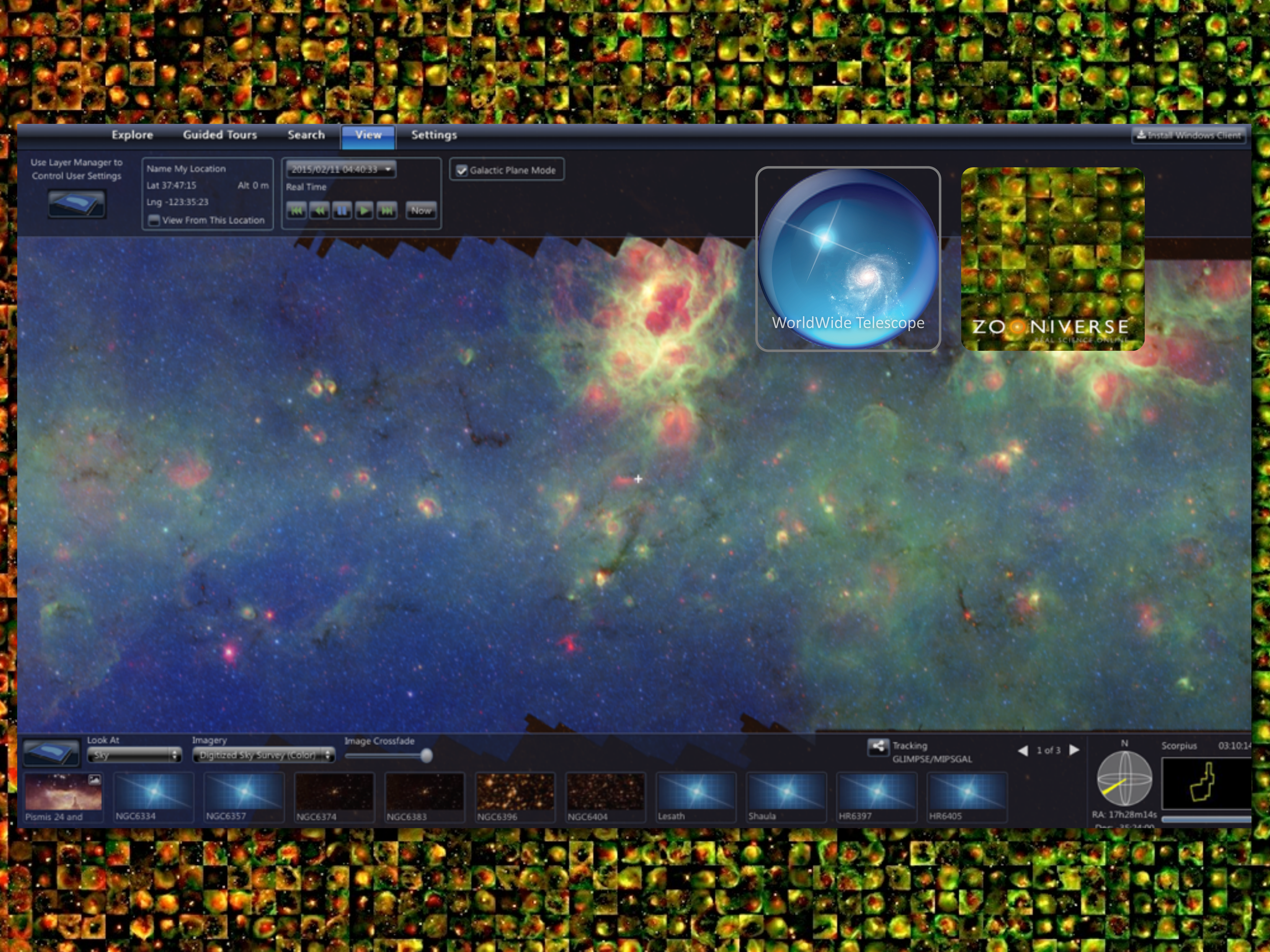
Communication

education

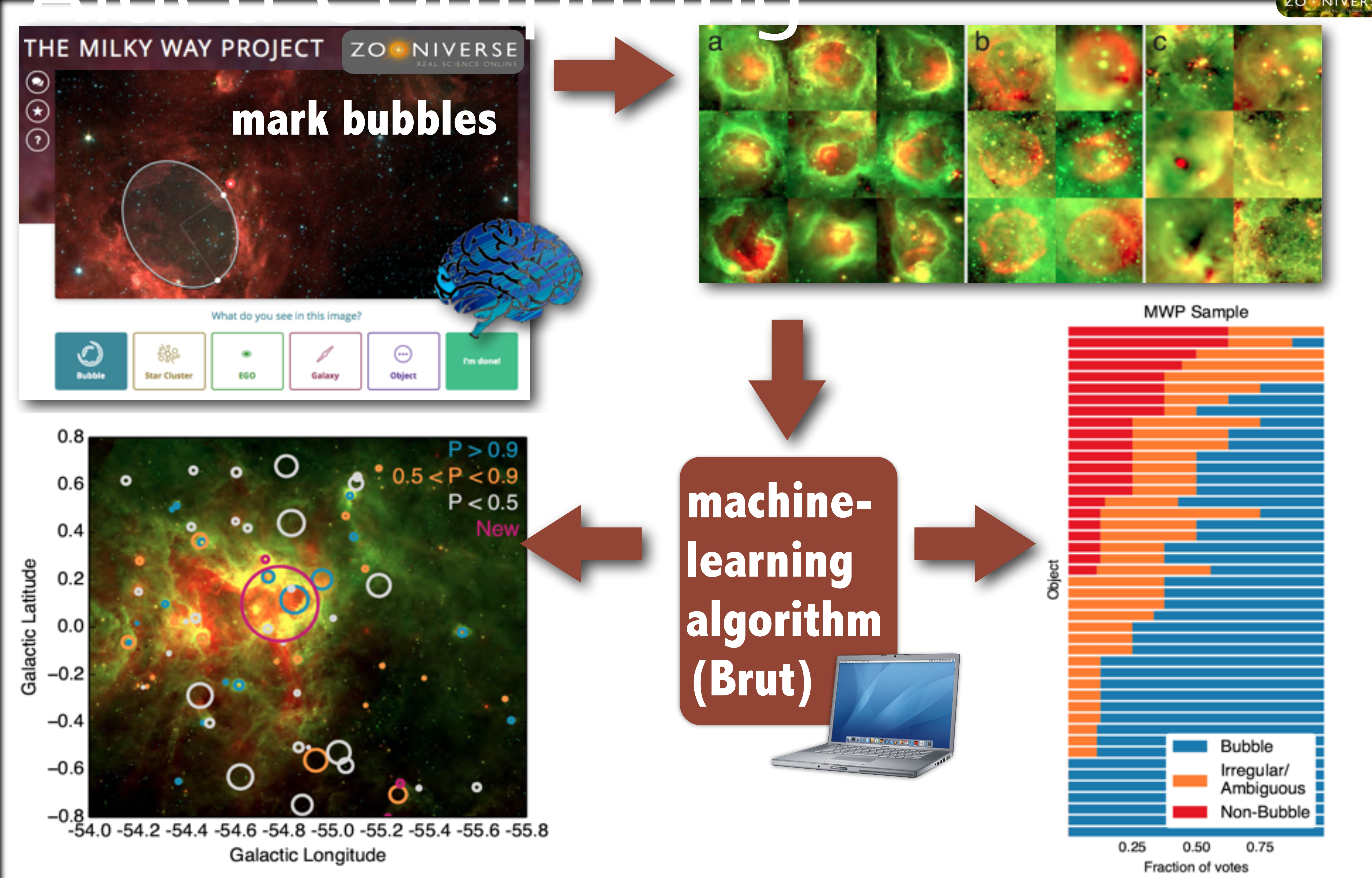






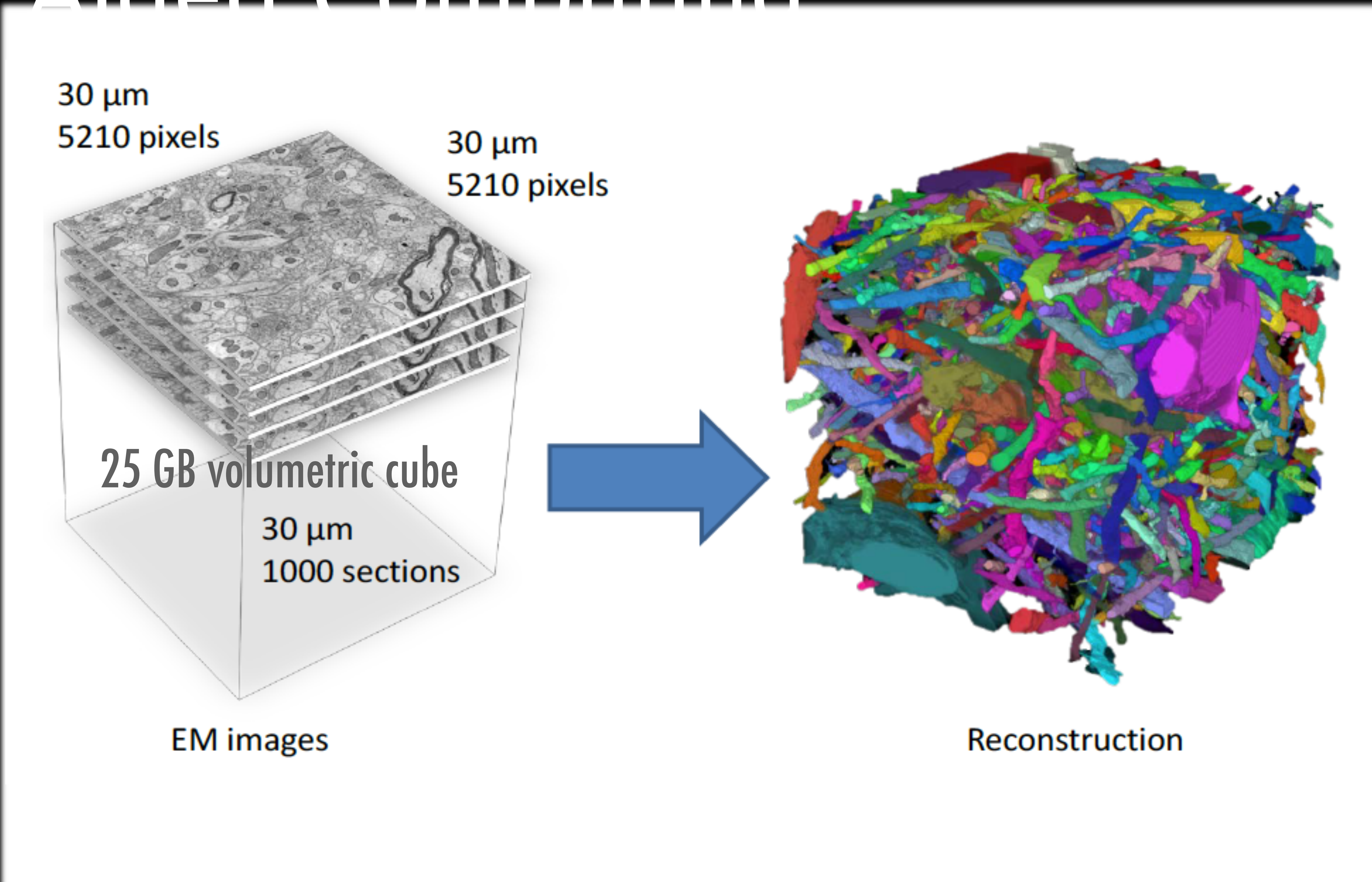

Explore
Guided Tours
Search
View
Settings
Install Windows Client
Use Layer Manager to Control User Settings
Name My Location
Lat 37:47:15
Alt 0 m
Lng -123:35:23
View From This Location
2015/02/11 04:40:33
Real Time
Now
Galactic Plane Mode
WorldWide Telescope
ZOONIVERSE
Look At
Sky
Imagery
Digitized Sky 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"



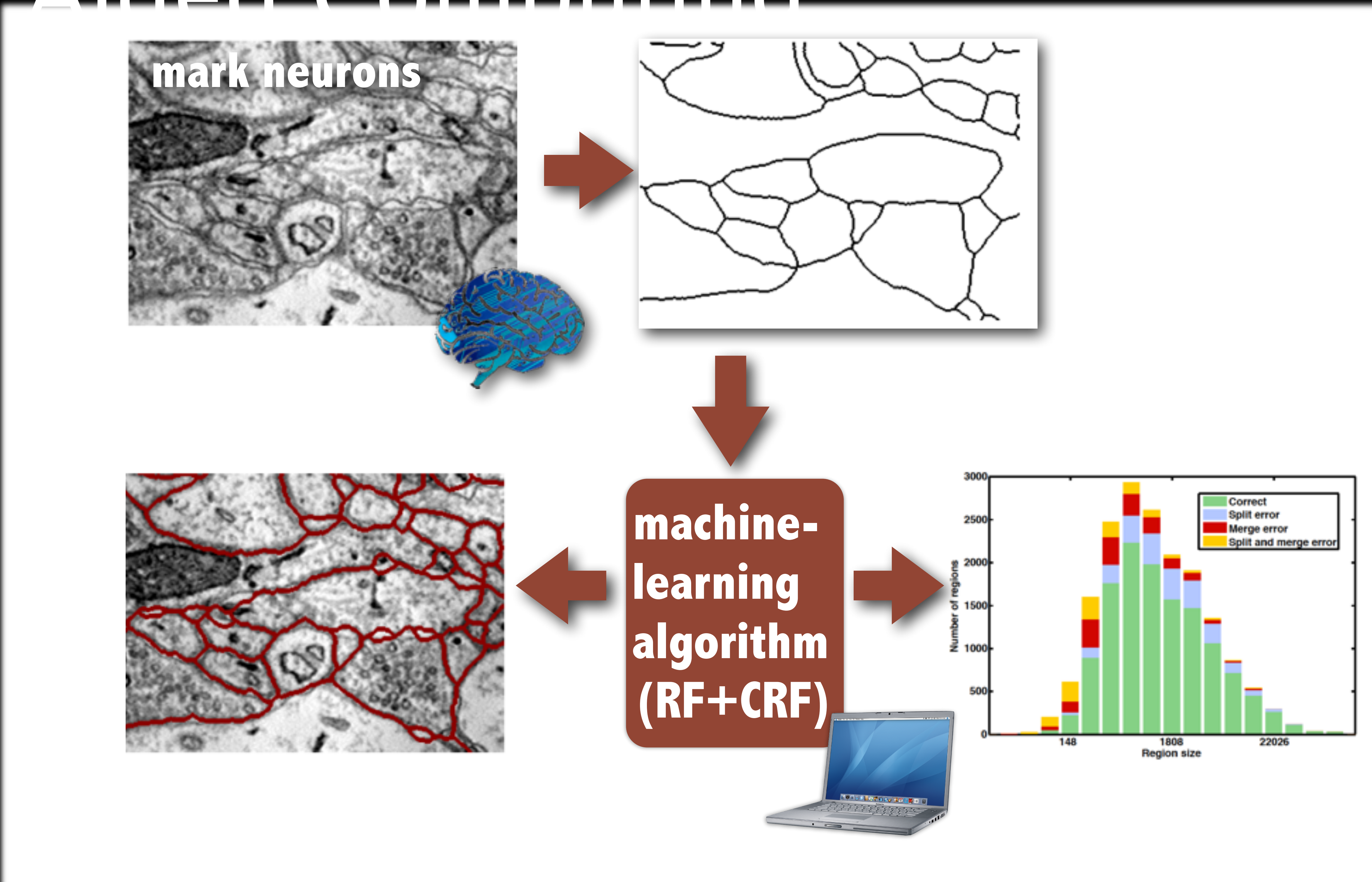
example here from: ***Beaumont****, Goodman, Kendrew, Williams & Simpson 2014; based on* ***Milky Way Project*** *catalog (Simpson et al. 2013), which came from* ***Spitzer/ GLIMPSE*** *(Churchwell et al. 2009, Benjamin et al. 2003), cf. Shenoy & Tan 2008 for discussion of HAC;* ***astroml.org*** *for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

BIG DATA and "Human–Aided Computing"

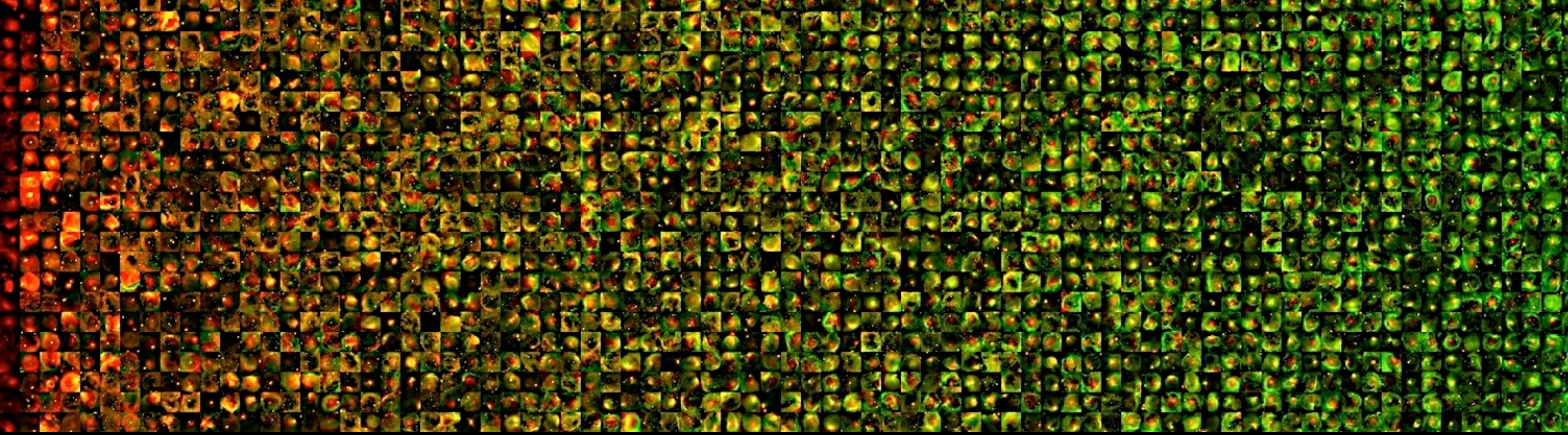


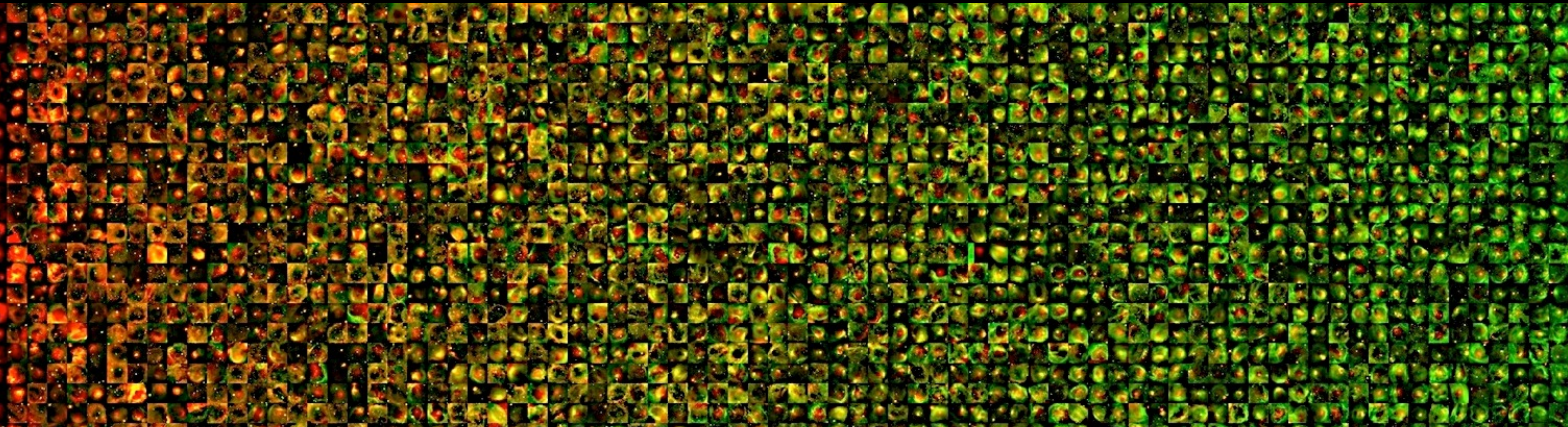
example here from: Kaynig...Lichtman...Pfister et al. 2013, "Large-Scale Automatic Reconstruction of Neuronal Processes from Electron Microscopy Images"; cf. Shenoy & Tan 2008 for discussion of HAC; ***astroml.org*** *for machine learning advice/tools*

BIG DATA and "Human–Aided Computing"



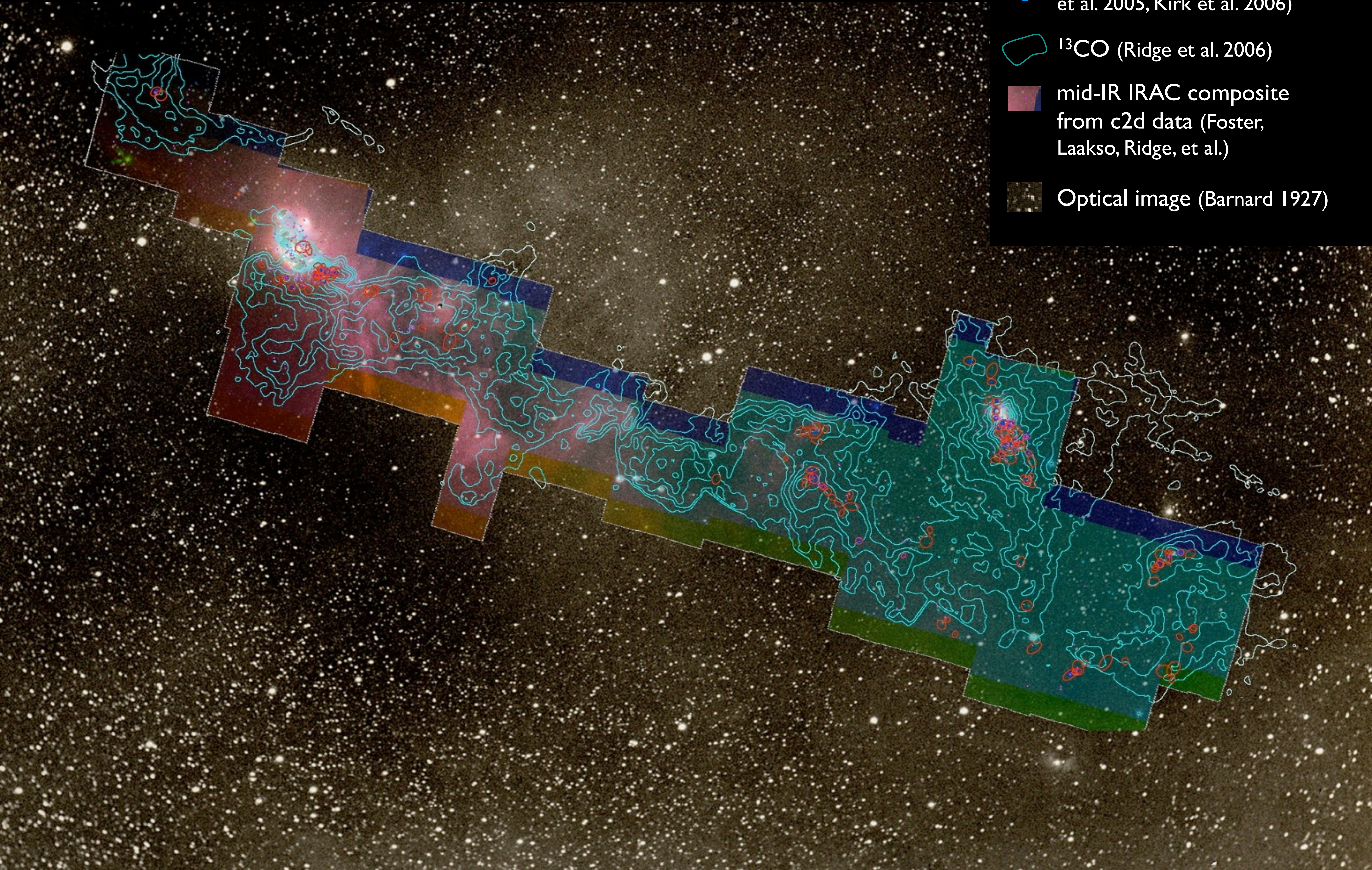
example here from: Kaynig...Lichtman...Pfister et al. 2013, "Large-Scale Automatic Reconstruction of Neuronal Processes from Electron Microscopy Images"; cf. Shenoy & Tan 2008 for discussion of HAC; ***astroml.org*** *for machine learning advice/tools (Note: RF=Random Forest; CRF=Conditional Random Fields.)*

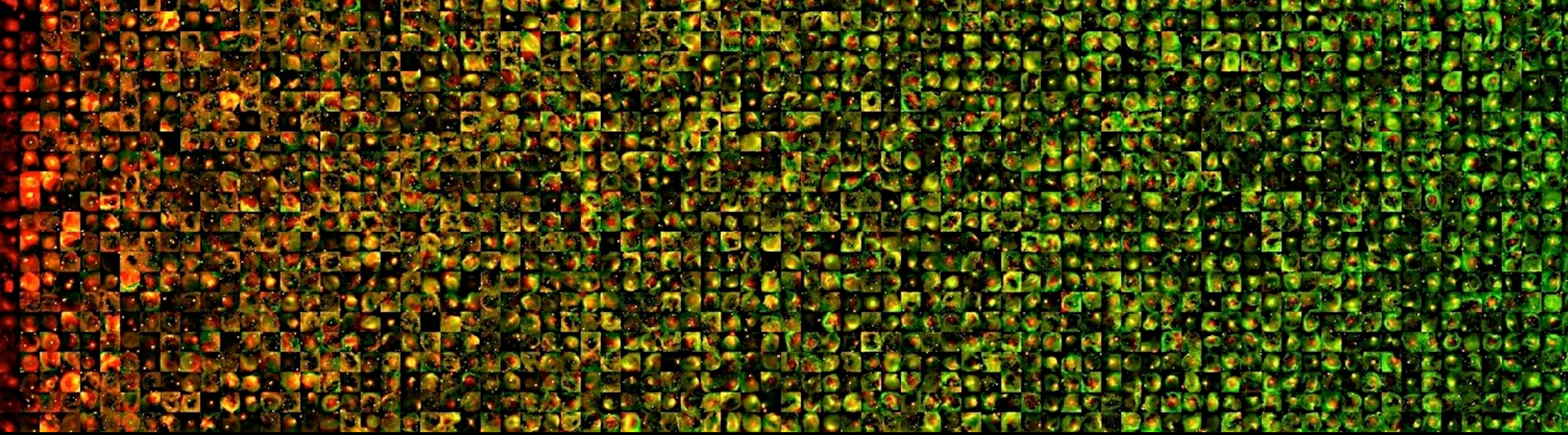


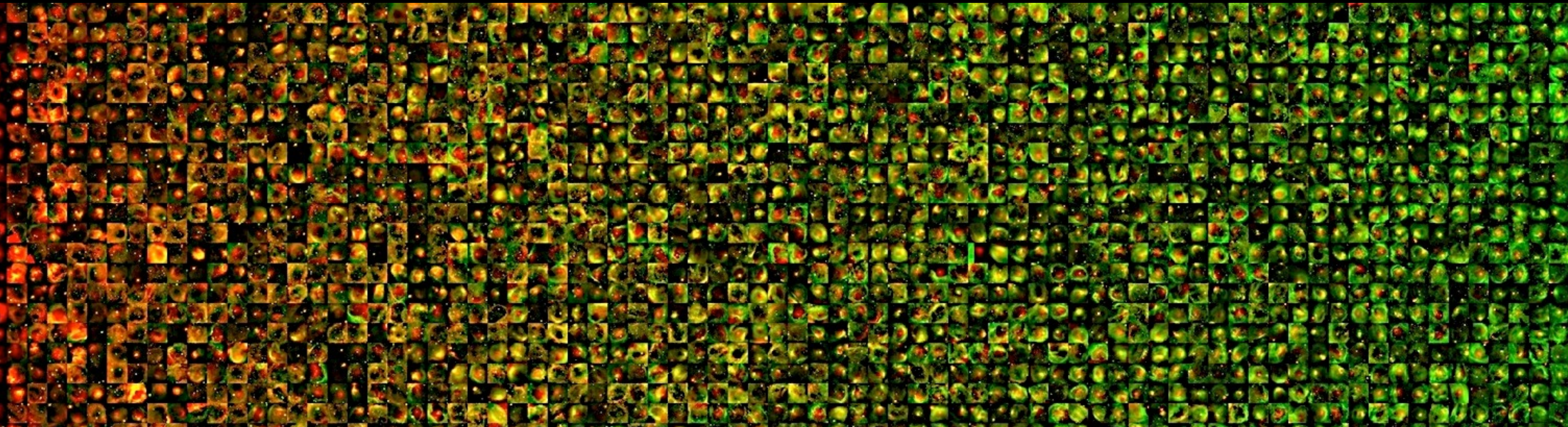


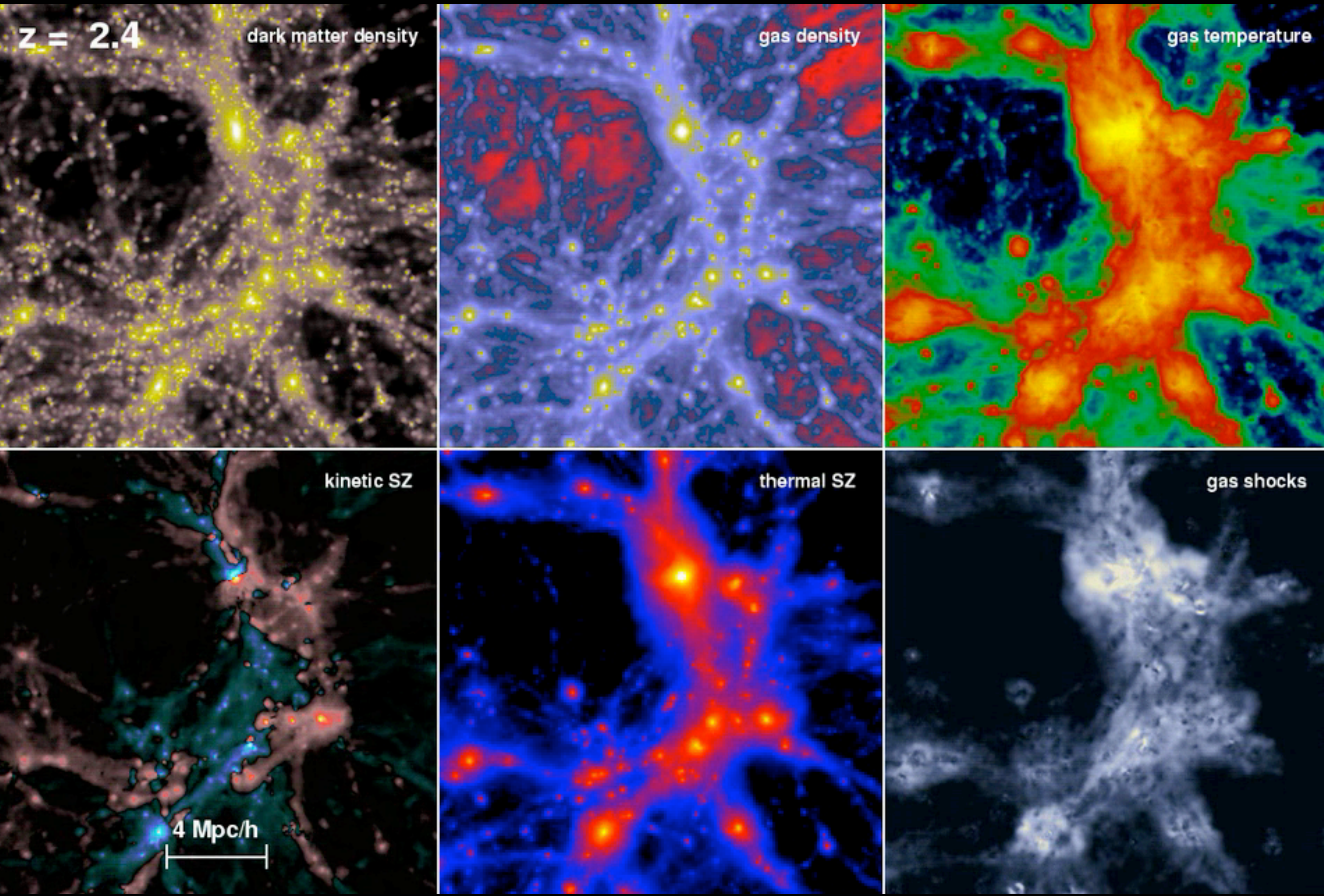
Vide Data

COMPLETE



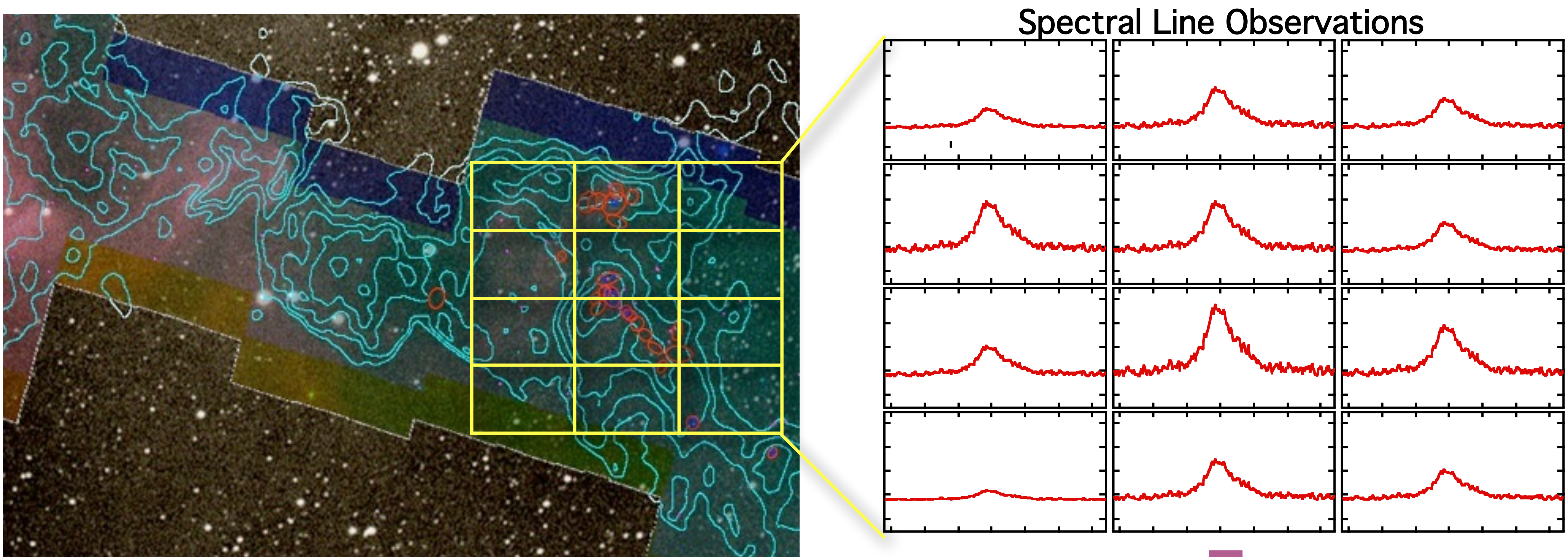


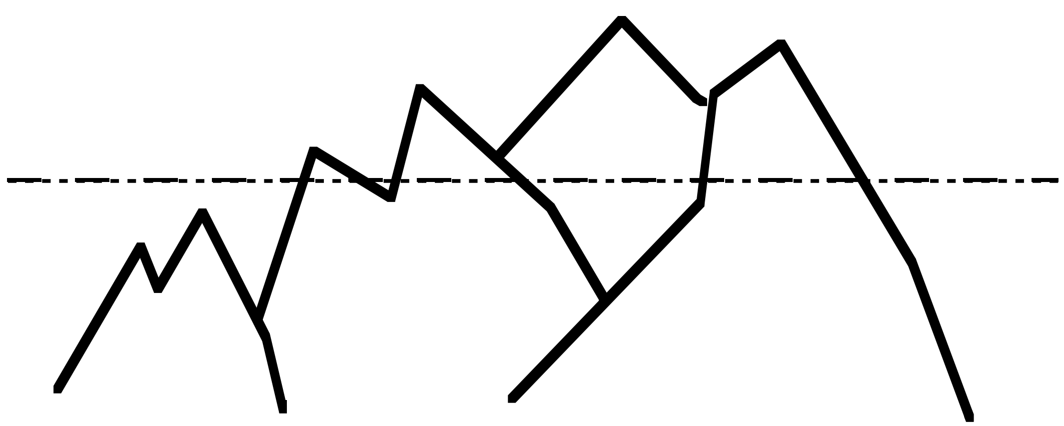




Movie: Volker Springel, formation of a cluster of galaxies. Millenium Simulation requires 25TB for output.

hidden “3D” in Astronom

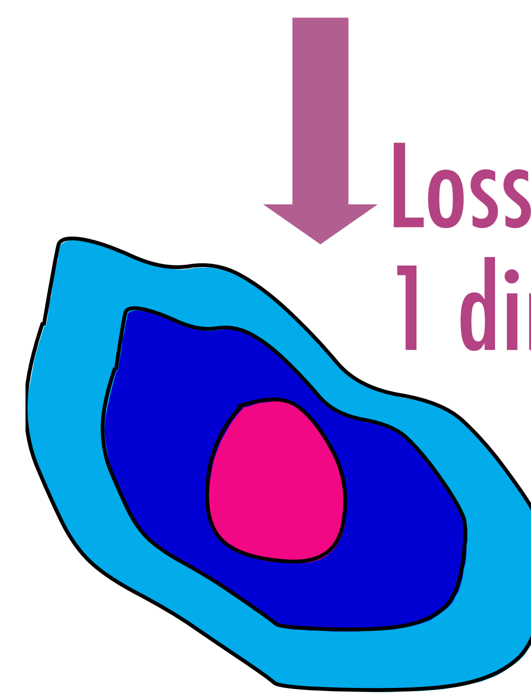




Mountain Range

No loss of information

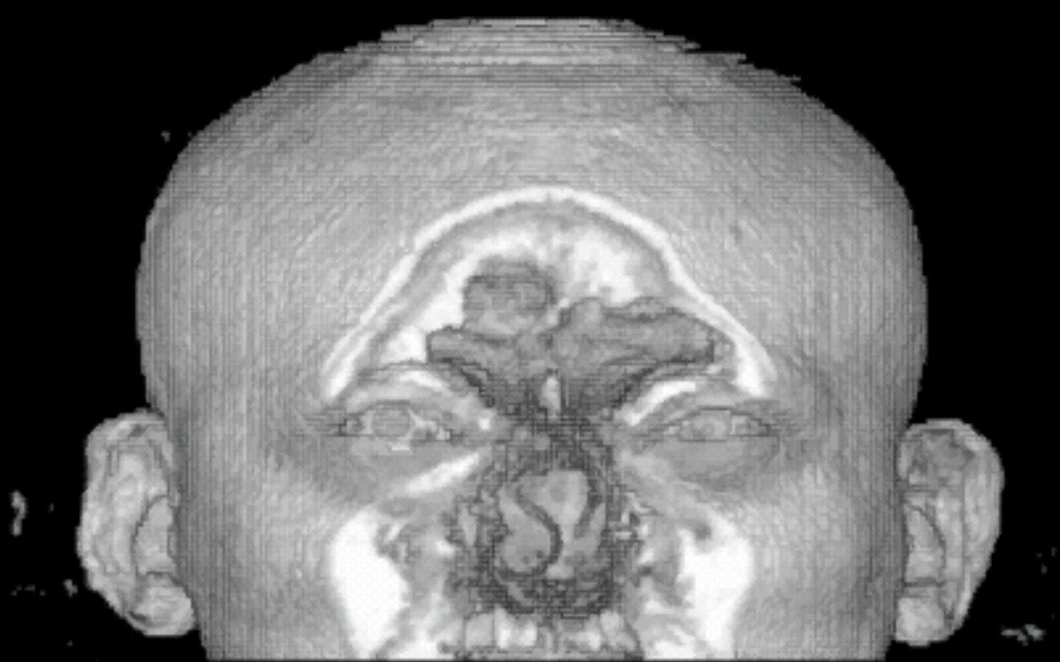
Loss of 1 dimension

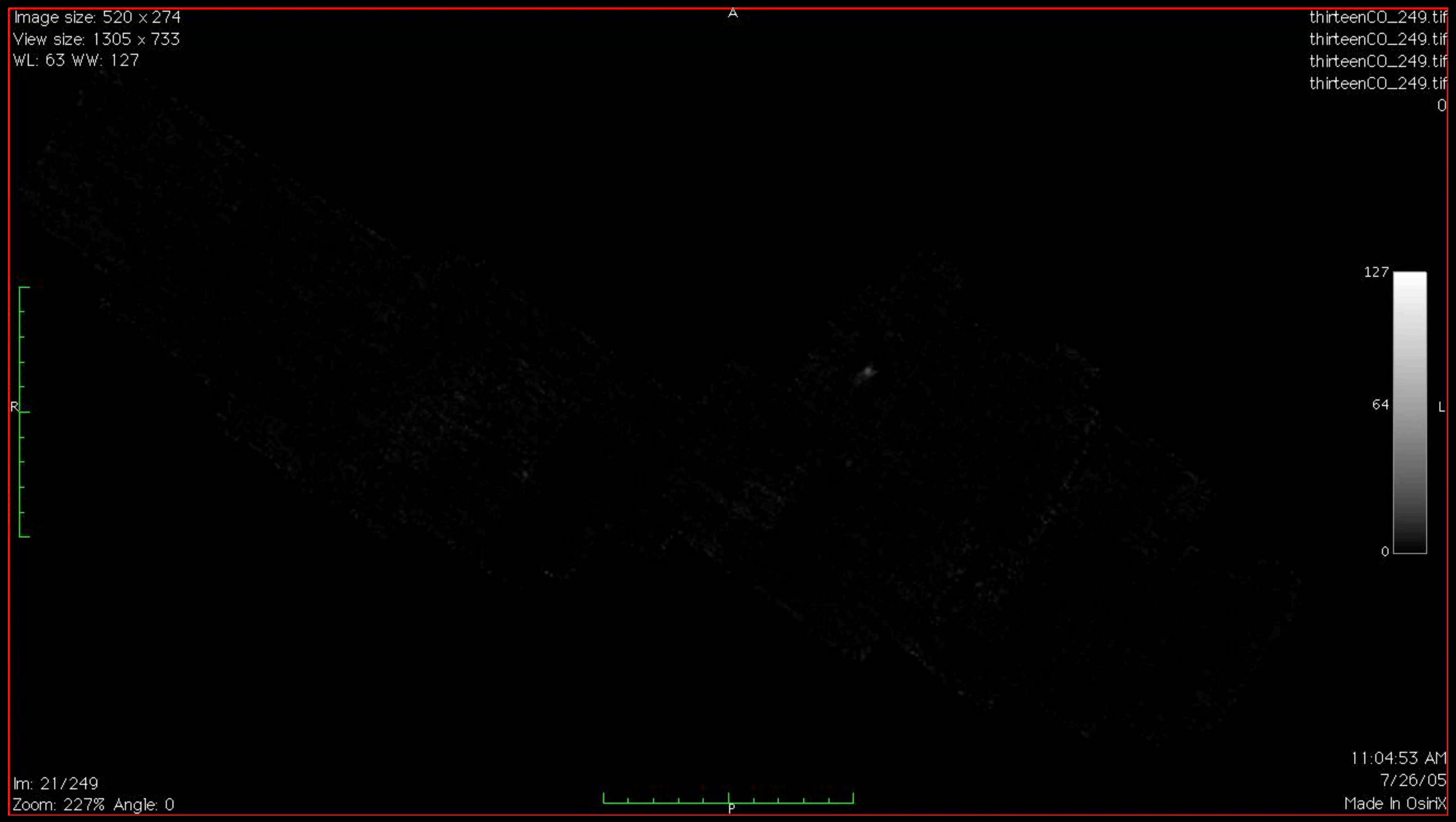


AstronomicalMedicine@IIC

"KEITH"

"PERSEUS"

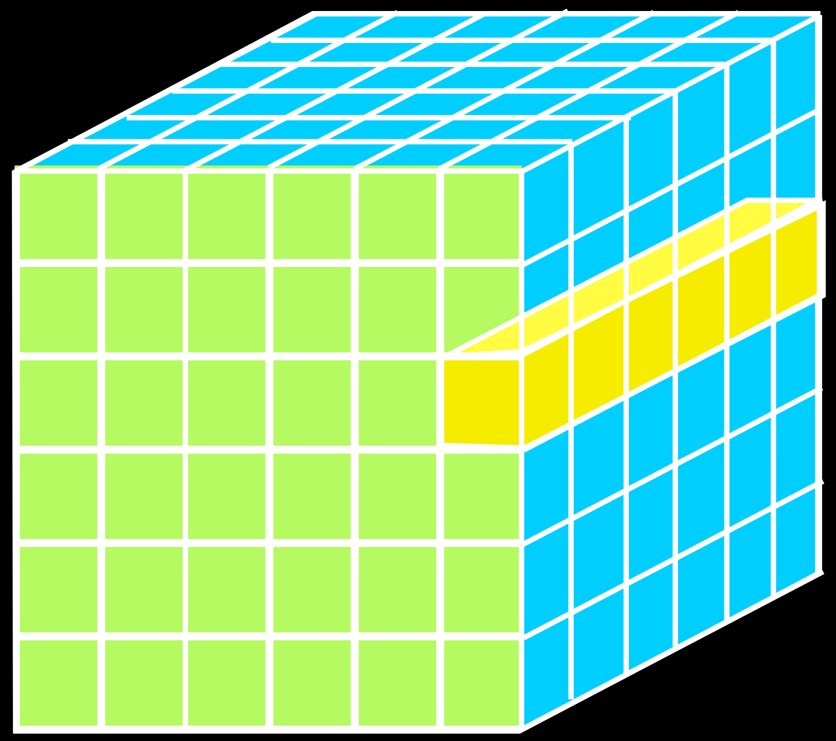




"z" is depth into head

"z" is line-of-sight velocity

(This kind of "series of 2D slices view" is known in the Viz as "the grand tour")



“Data, Dimensions, Display”

1D: Columns = “Spectra”, “SEDs” or “Time Series” (x-y Graphs)
2D: Faces or Slices = “Images”
3D: Volumes = “3D Renderings”, “2D Movies”
4D: Time Series of Volumes = “3D Movies”

Wide Data, "In 3D"

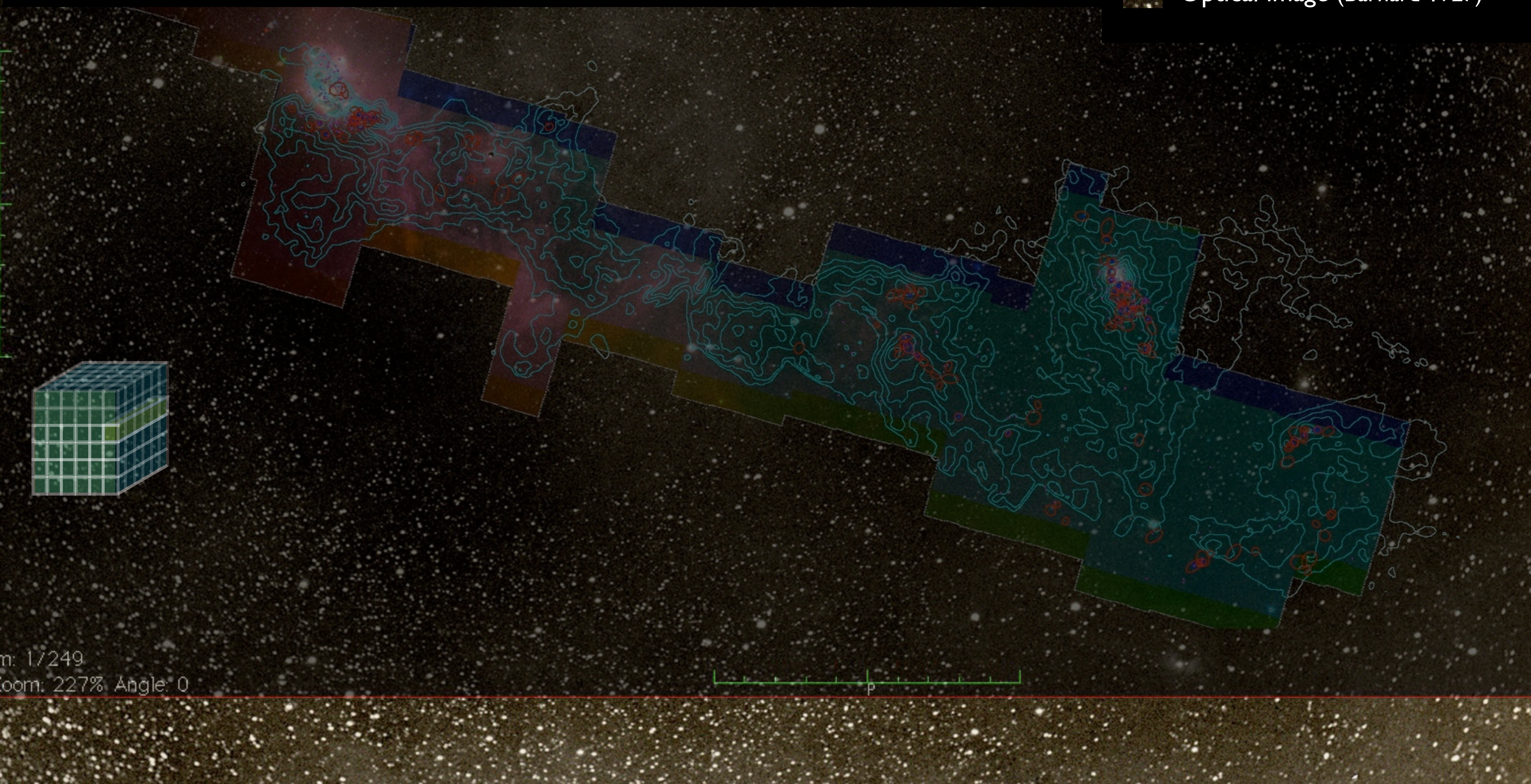
mm peak (Enoch et al. 2006)

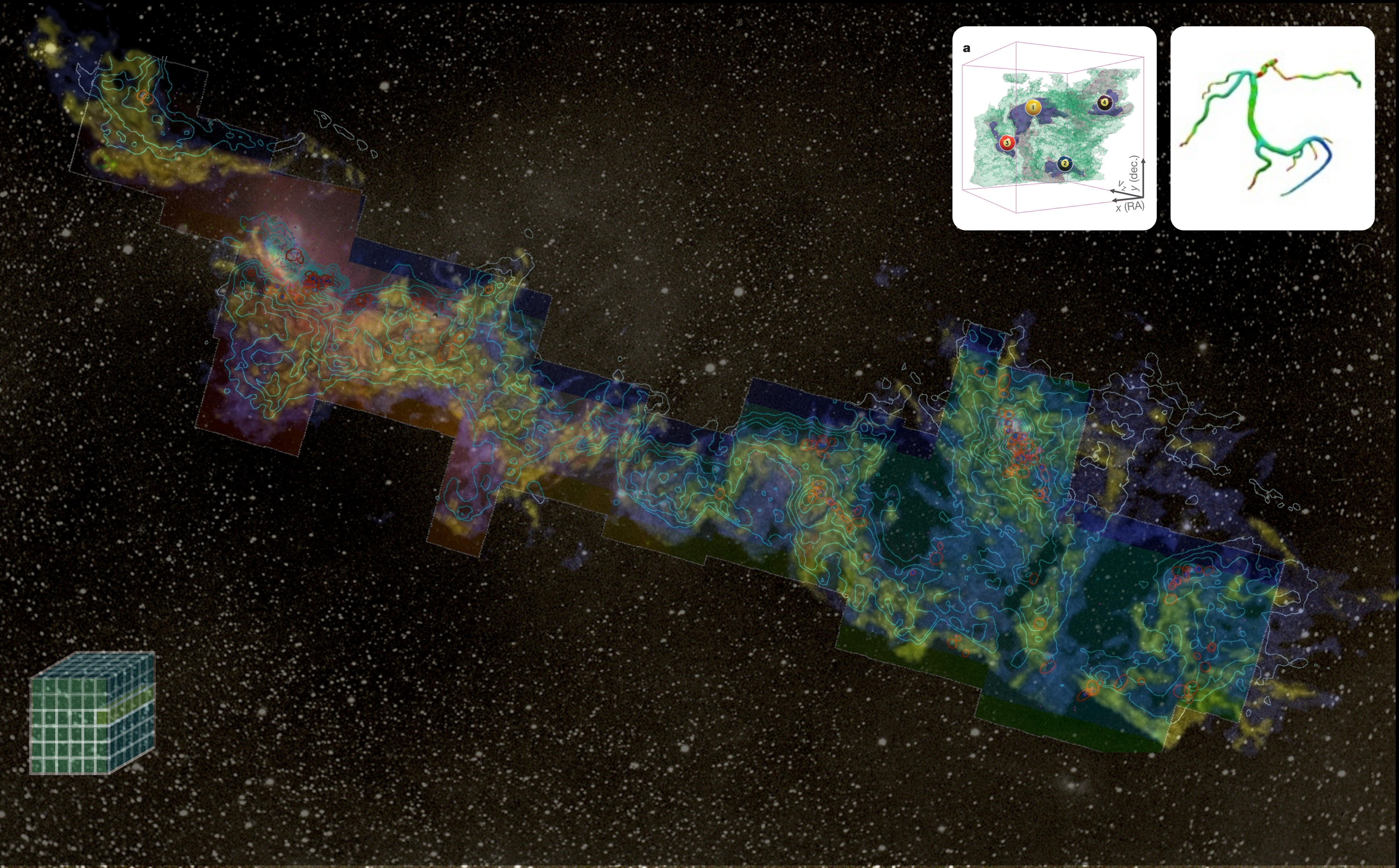
sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)

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

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

Optical image (Barnard 1927)





3D Viz made with VolView

AstronomicalMedicine@IIC

COMPLETE

Resolution

Context

Big Data

Wide Data

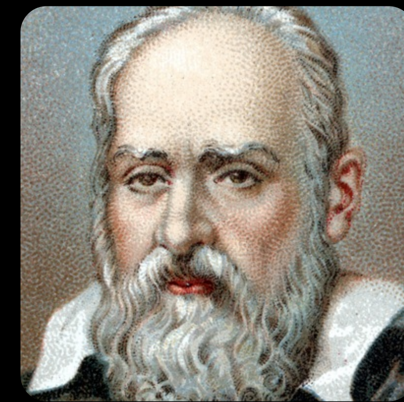
Dimensionality

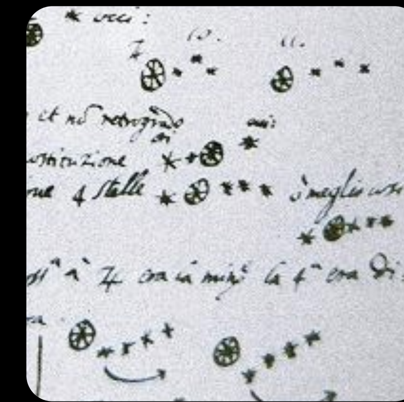
Linked views

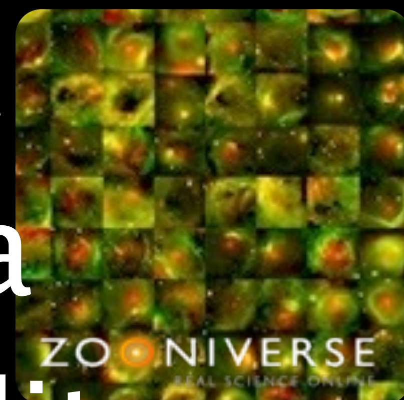
Interaction

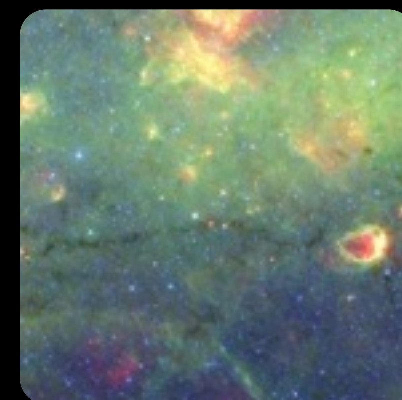
Communication

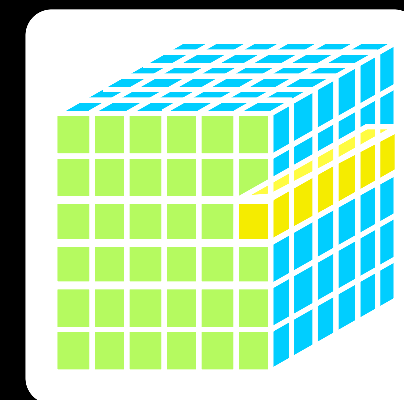
education

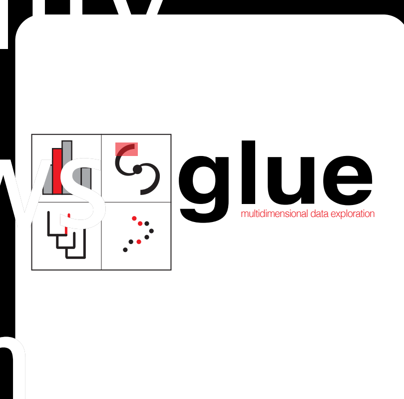


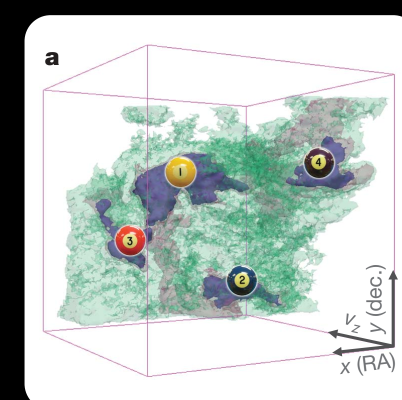


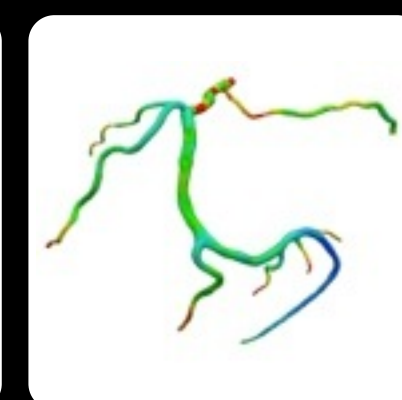


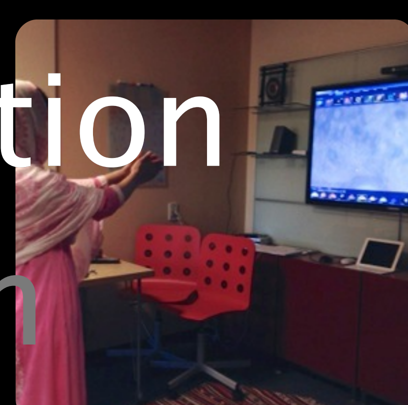






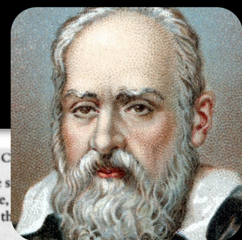


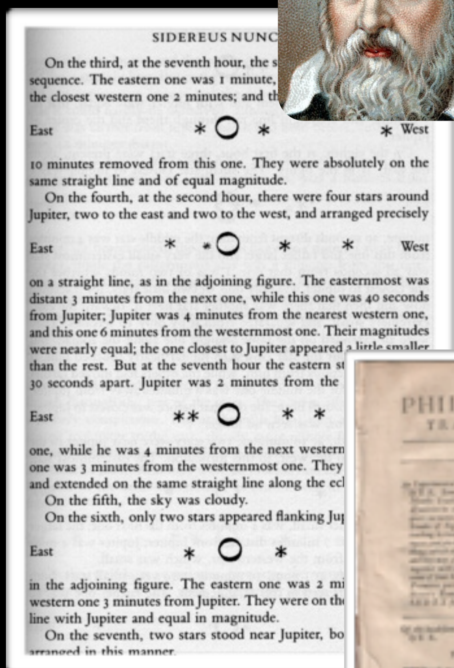




scholarly Communication

1610





SIDEREUS NUNC

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sequence. The eastern one was 1 minute,
the closest western one 2 minutes; and th

East * O * * West

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East * *O * * West

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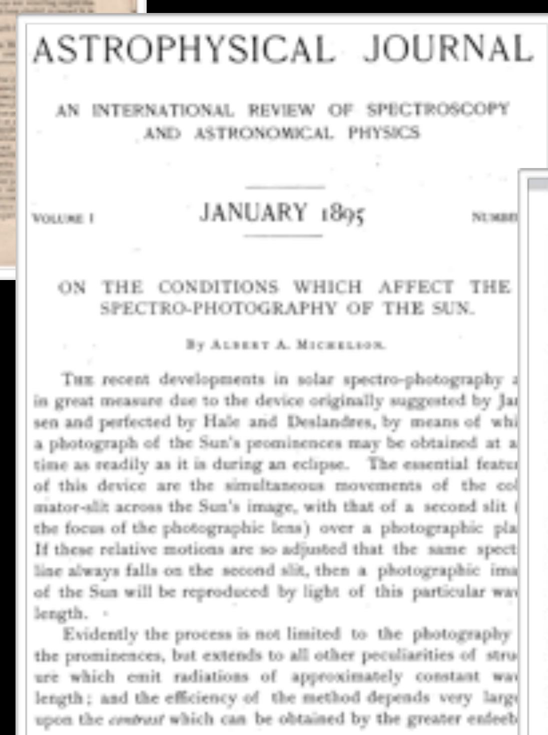
1665

PHILOSOPHICAL TRANSACTIONS

1895



ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

VOLUME I JANUARY 1895 NUMBE

ON THE CONDITIONS WHICH AFFECT THE SPECTRO-PHOTOGRAPHY OF THE SUN.

By Albert A. Michelson.

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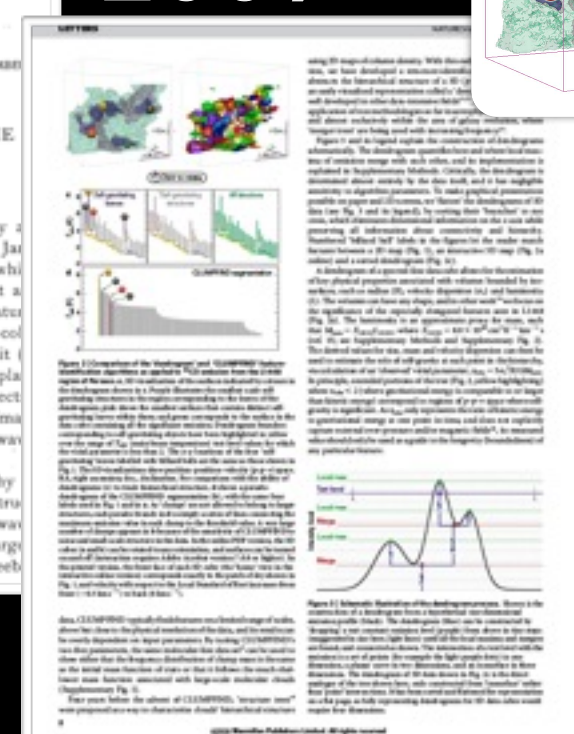
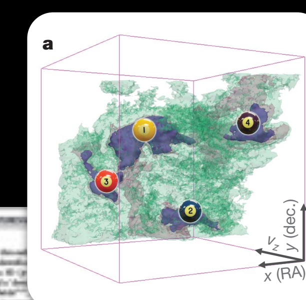
2009





2009

3D PDF

interactivity in a "Paper"

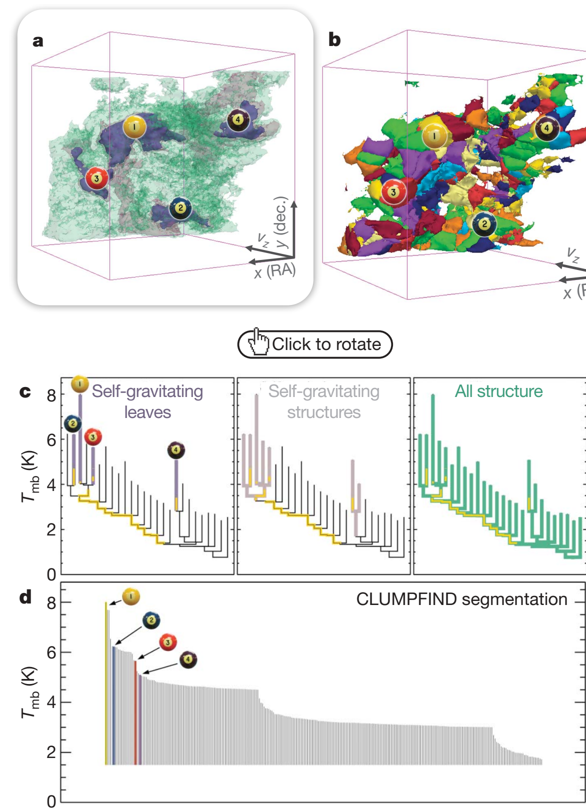


Figure 2 | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. a, 3D visualization of the surfaces indicated by colours in the dendrogram shown in **c**. Purple illustrates the smallest scale self-gravitating 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 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 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 screen… 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), ve… (L). The volumes can have any shape, and in… 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, $\alpha_{obs} = 5\sigma_v^2 R / GM_{lum}$. 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.

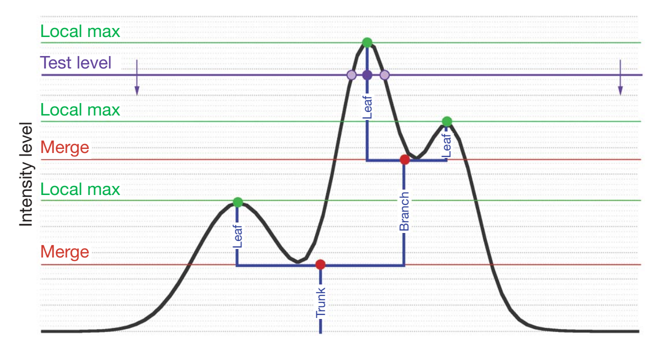
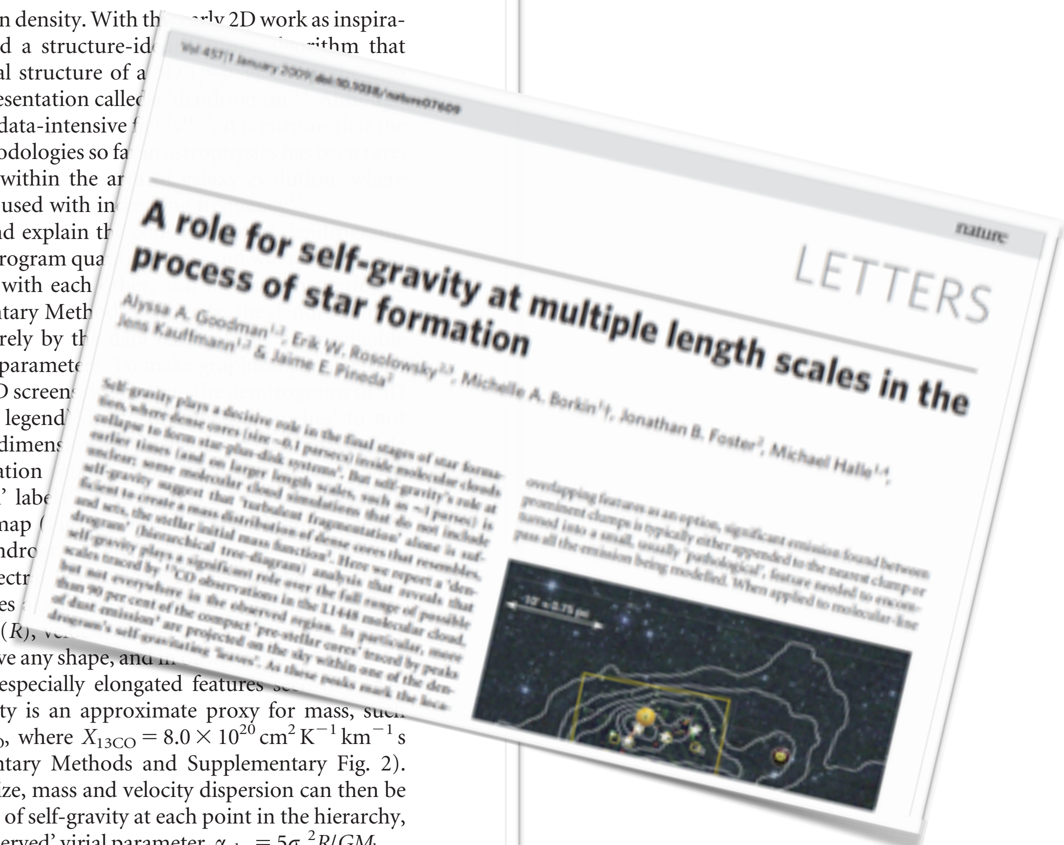
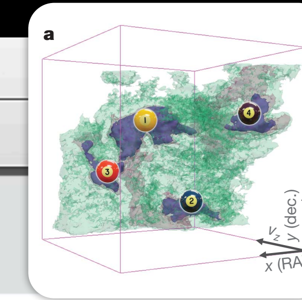


Figure 3 | Schematic illustration of the dendrogram process. Shown is the construction of a dendrogram from a hypothetical one-dimensional emission profile (black). The dendrogram (blue) can be constructed by 'dropping' a test constant emission level (purple) from above in tiny steps (exaggerated in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

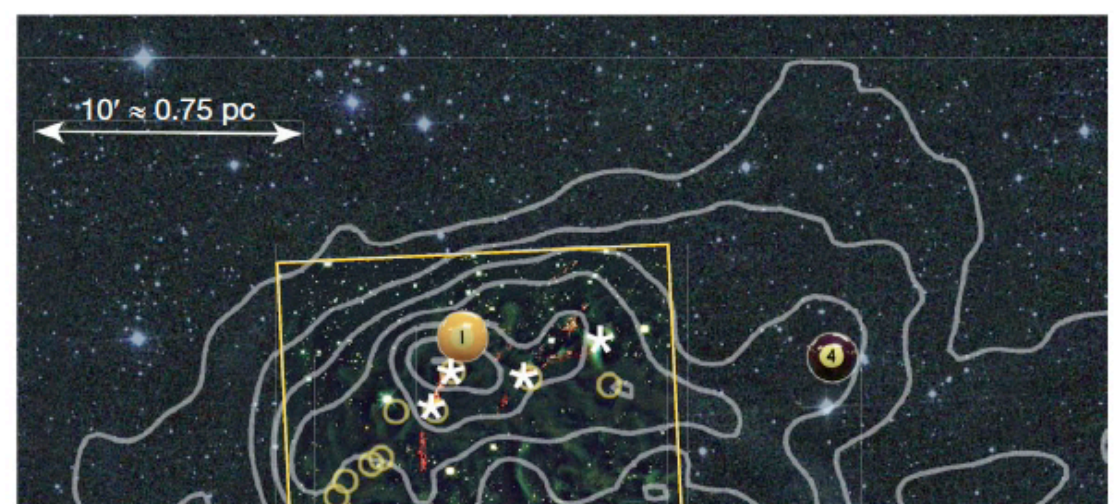
LETTERS

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

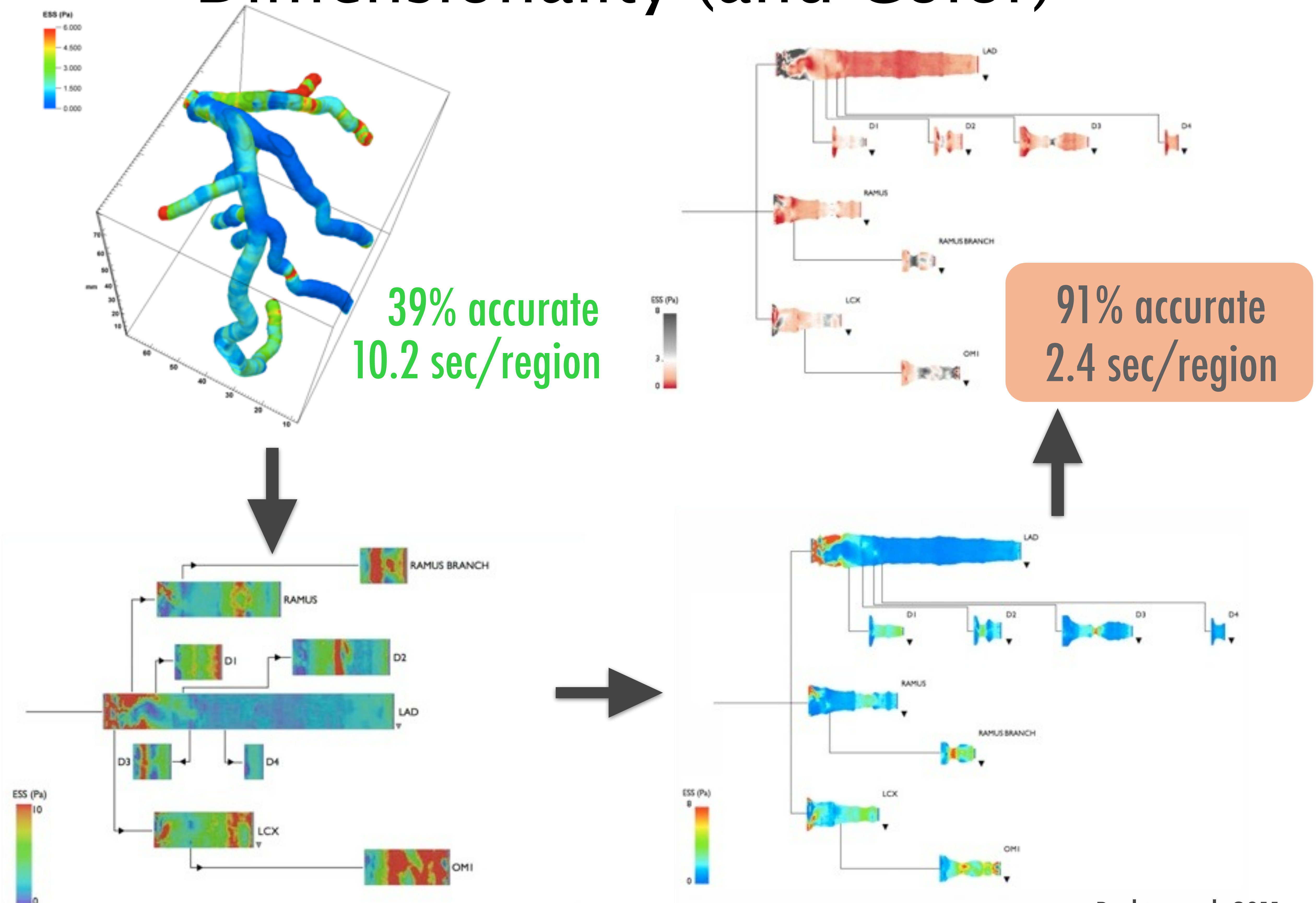
Alyssa A. Goodman[1,2], Erik W. Rosolowsky[2,3], Michelle A. Borkin[1]†, Jonathan B. Foster[2], Michael Halle[1,4], Jens Kauffmann[1,2] & Jaime E. Pineda[2]

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

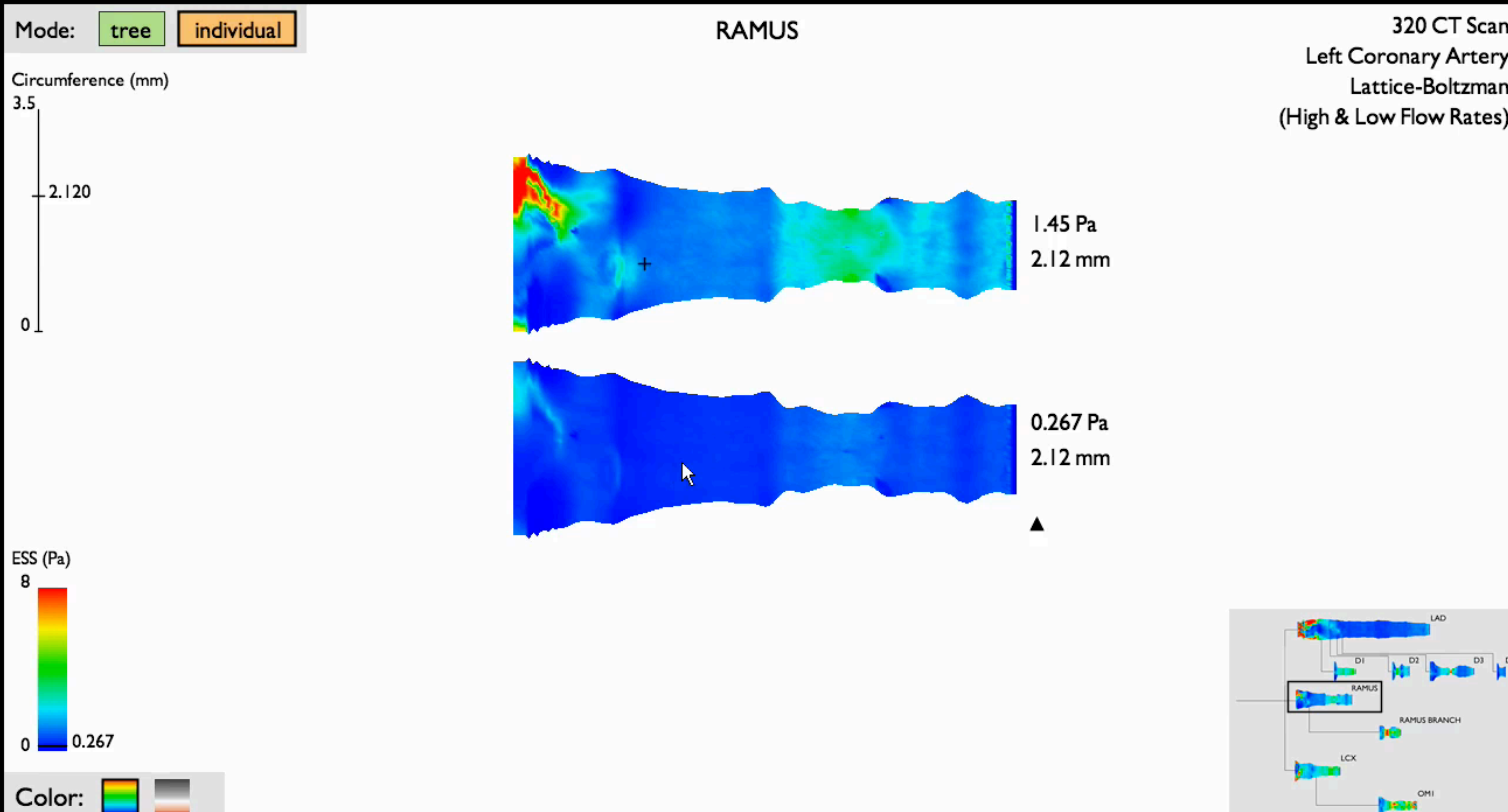


Dimensionality (and Color)



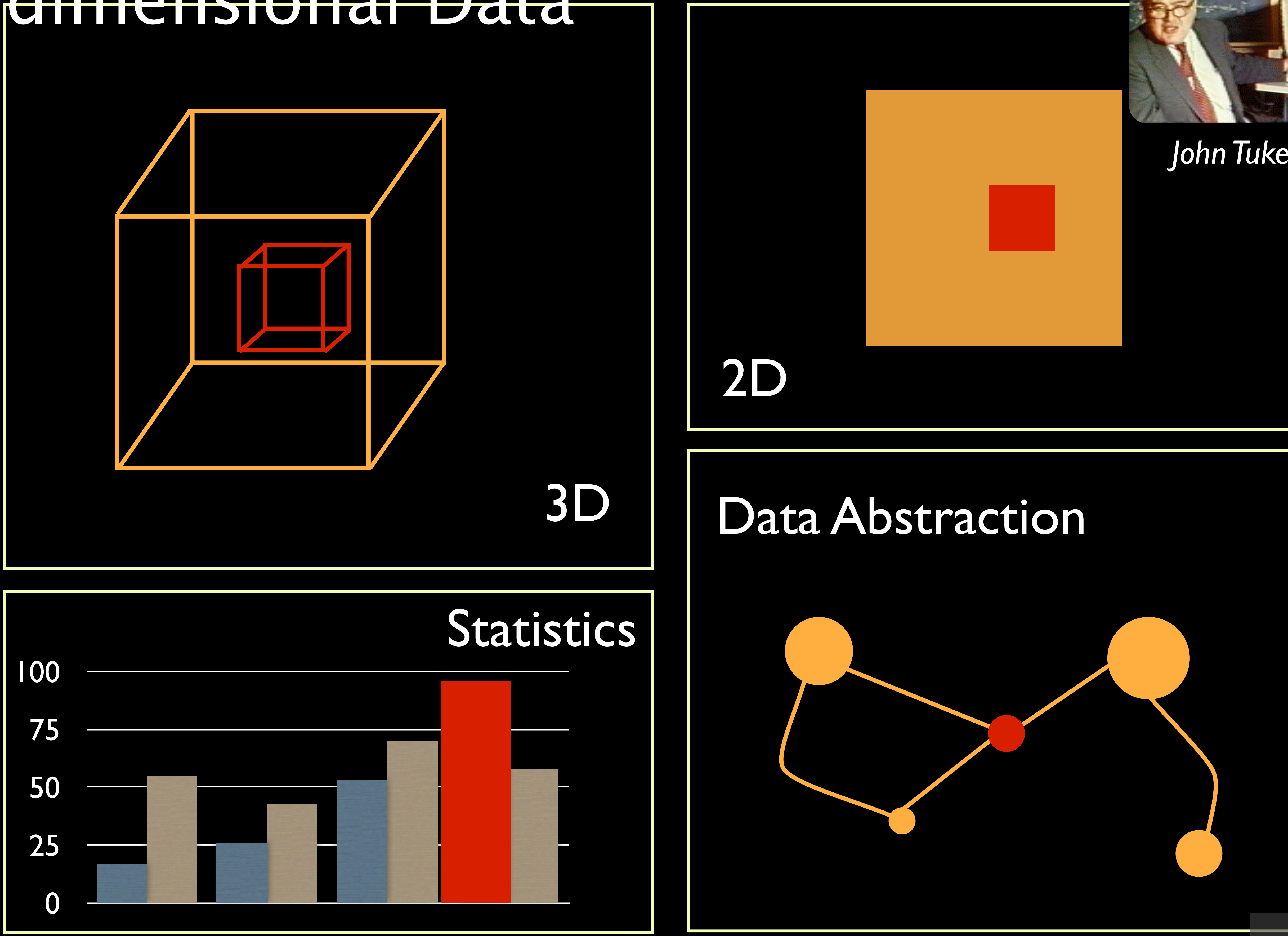
Borkin et al. 2011
cf. colorbrewer2.org

Dimensionality (and Color) +INTERACTION



Borkin et al. 2011

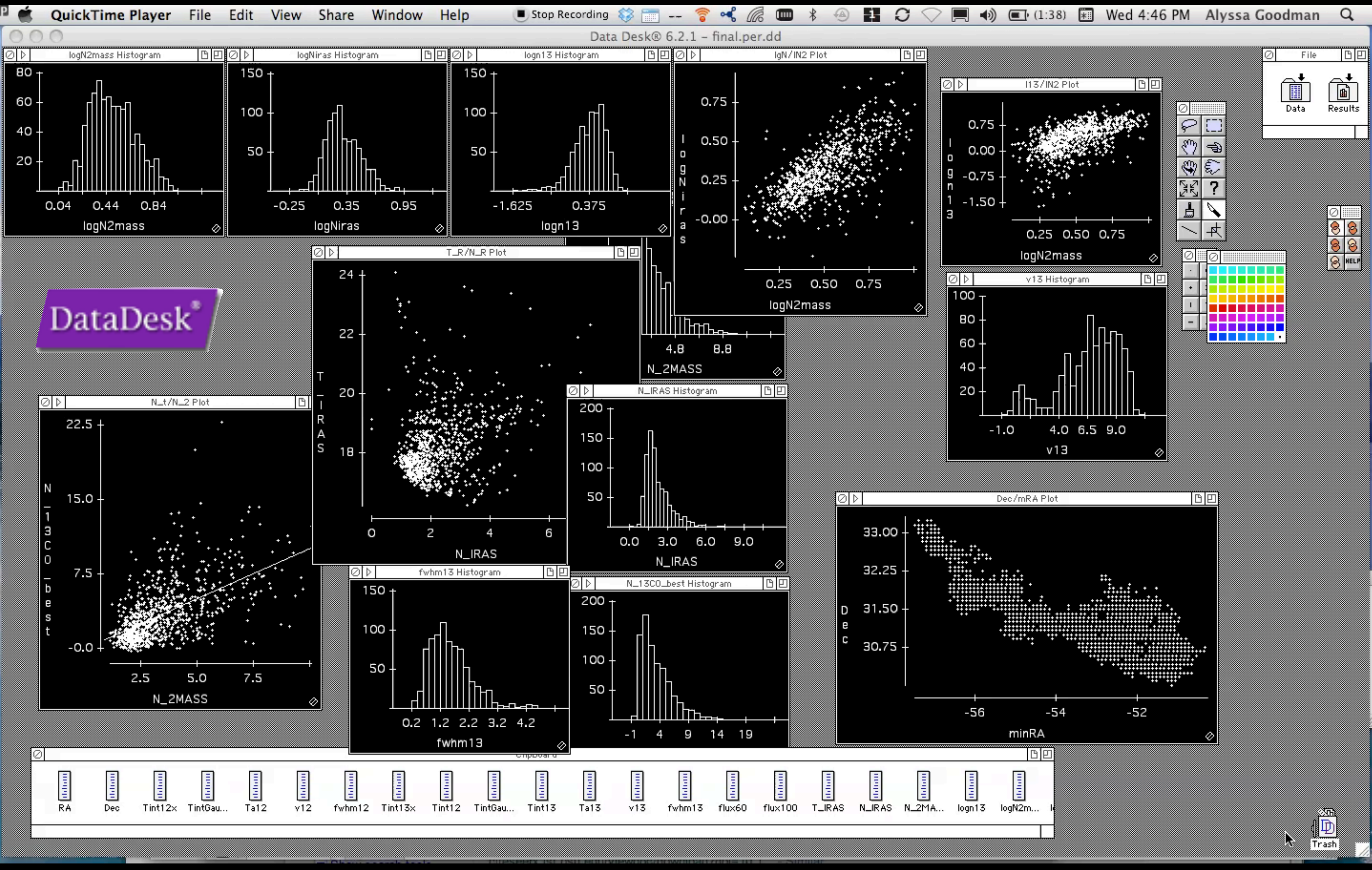
Linked Views of High-dimensional Data



John Tukey

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

DataDesk (est. 1986)



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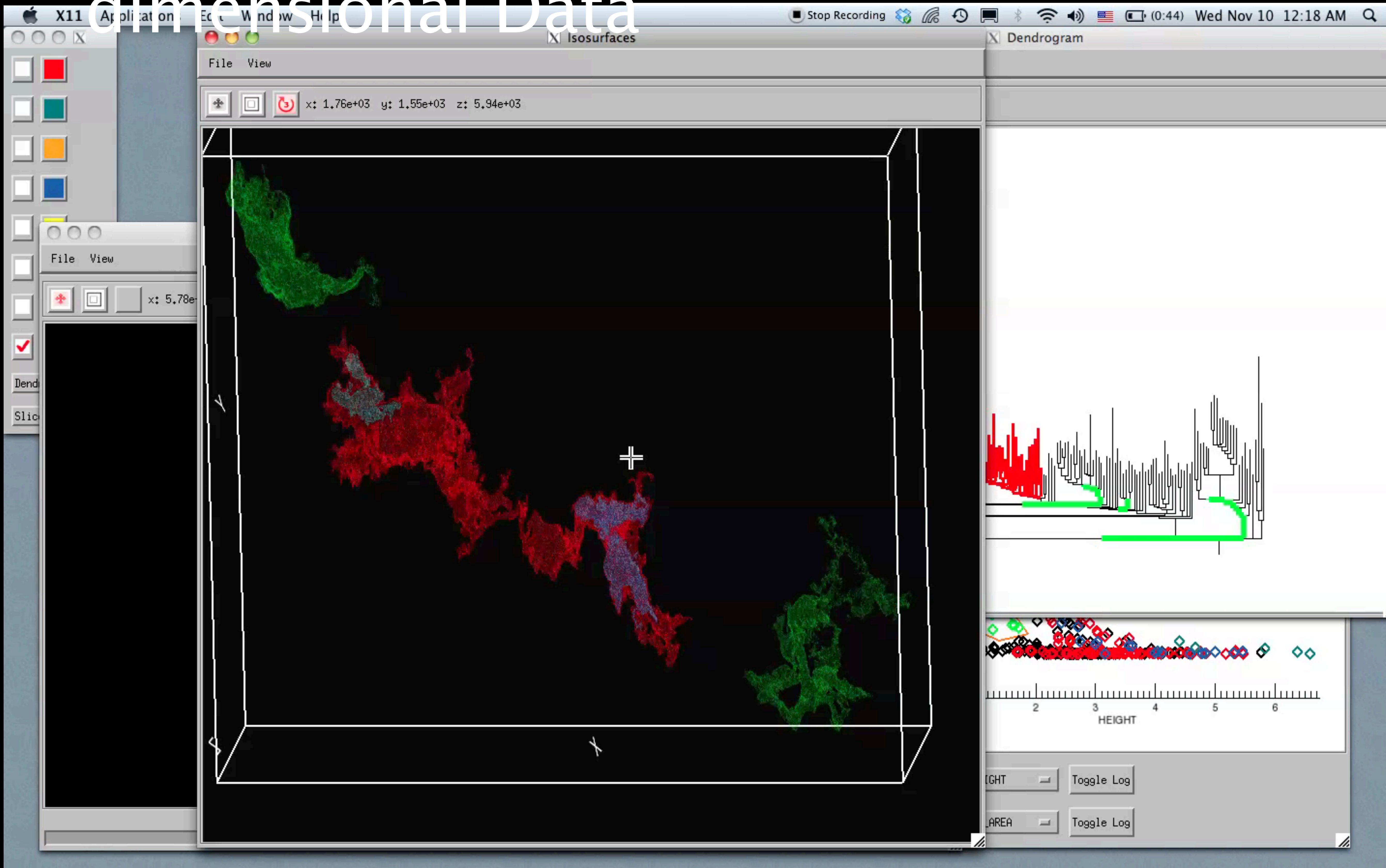
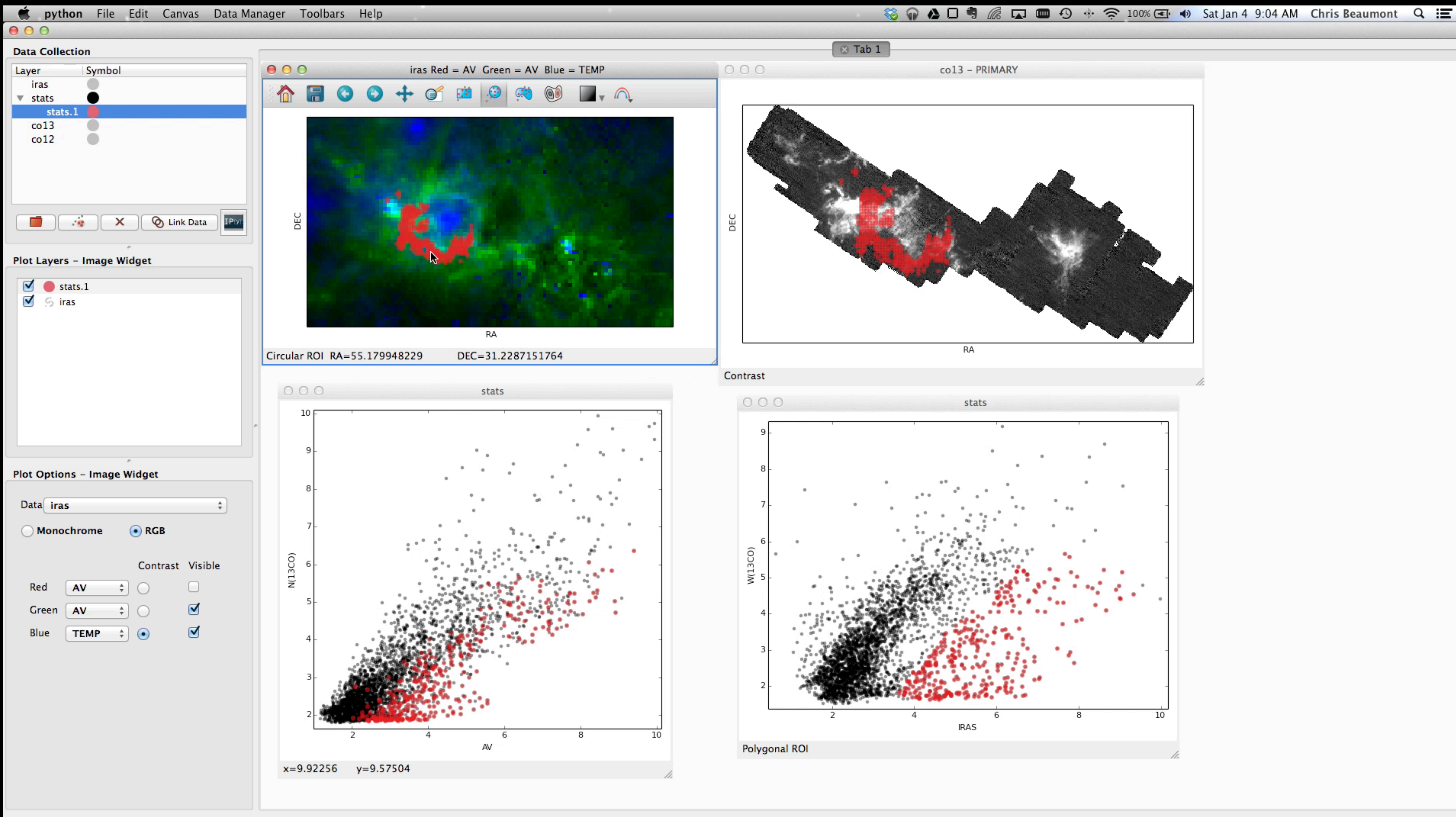


Video & implementation: Christopher Beaumont, Harvard→Counsyl;
inspired by AstroMed work of Douglas Alan, Michelle Borkin, AG, Michael Halle, Erik Rosolowsky

Linked Views of High-dimensional Data (in Python)

Glue

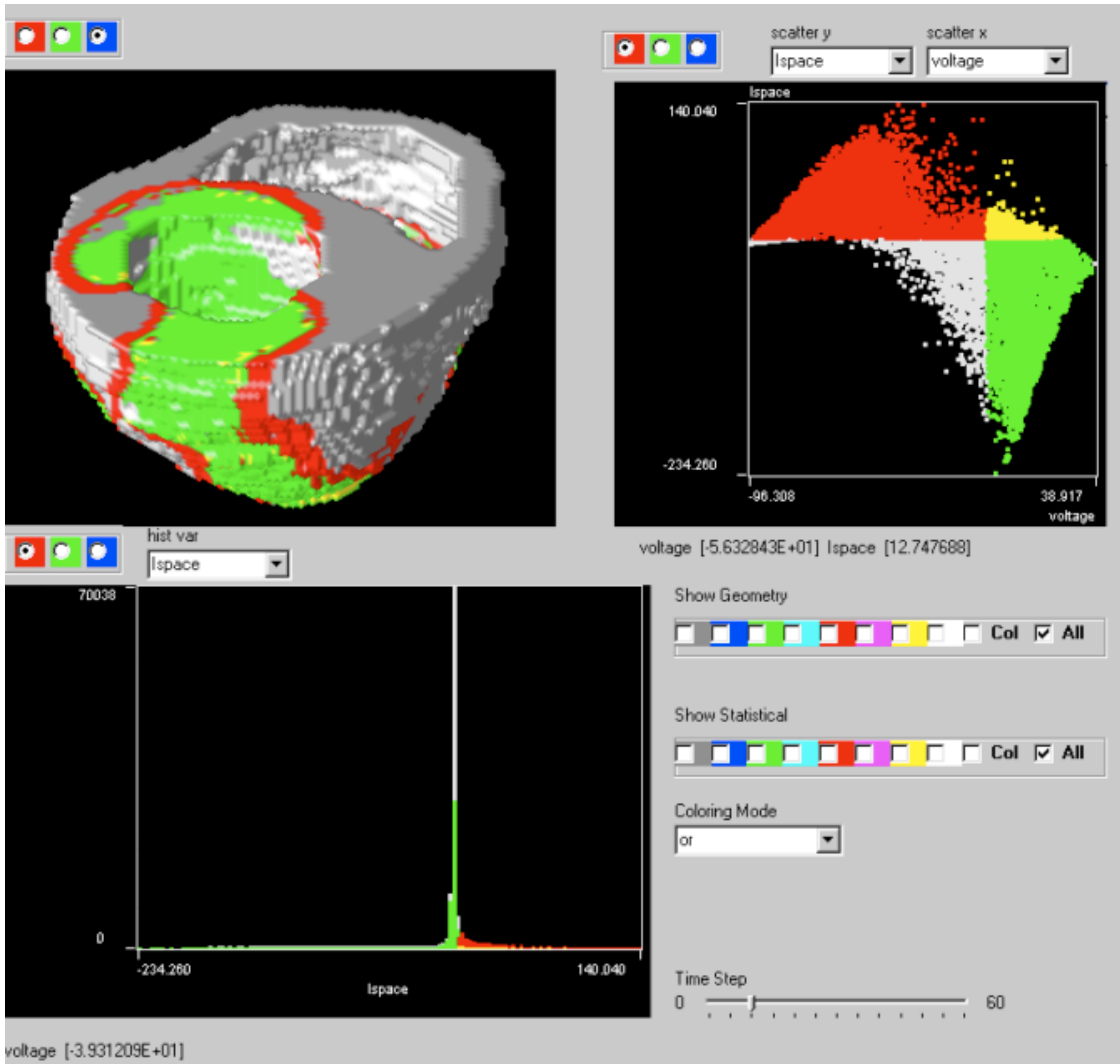


Christopher Beaumont, w/A. Goodman, T. Robitaille & M. Borkin

WEAVE: A System for Visually Linking 3-D and Statistical Visualizations, Applied to Cardiac Simulation and Measurement Data

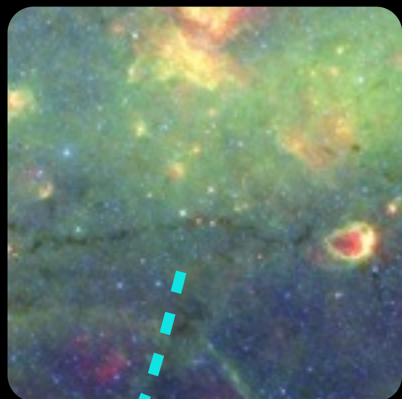
D.L. Gresh and B.E. Rogowitz*
IBM T.J. Watson Research Center

R.L. Winslow, D.F. Scollan, and C.K. Yung †
Department of Biomedical Engineering, Johns Hopkins University School of Medicine

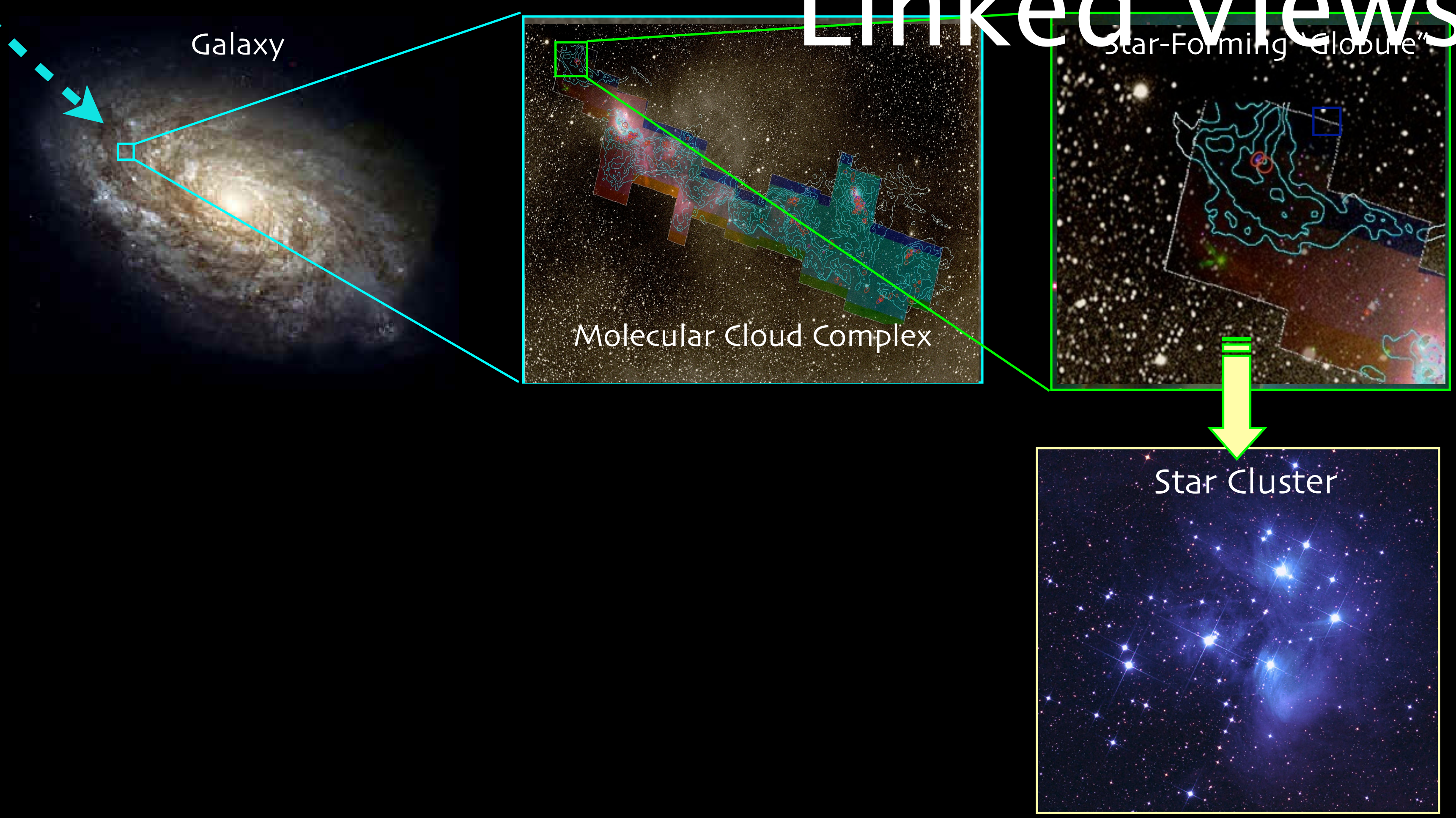


screenshot from Gresh et al. 2000; reproduced as shown in Goodman 2012

"Nessie"

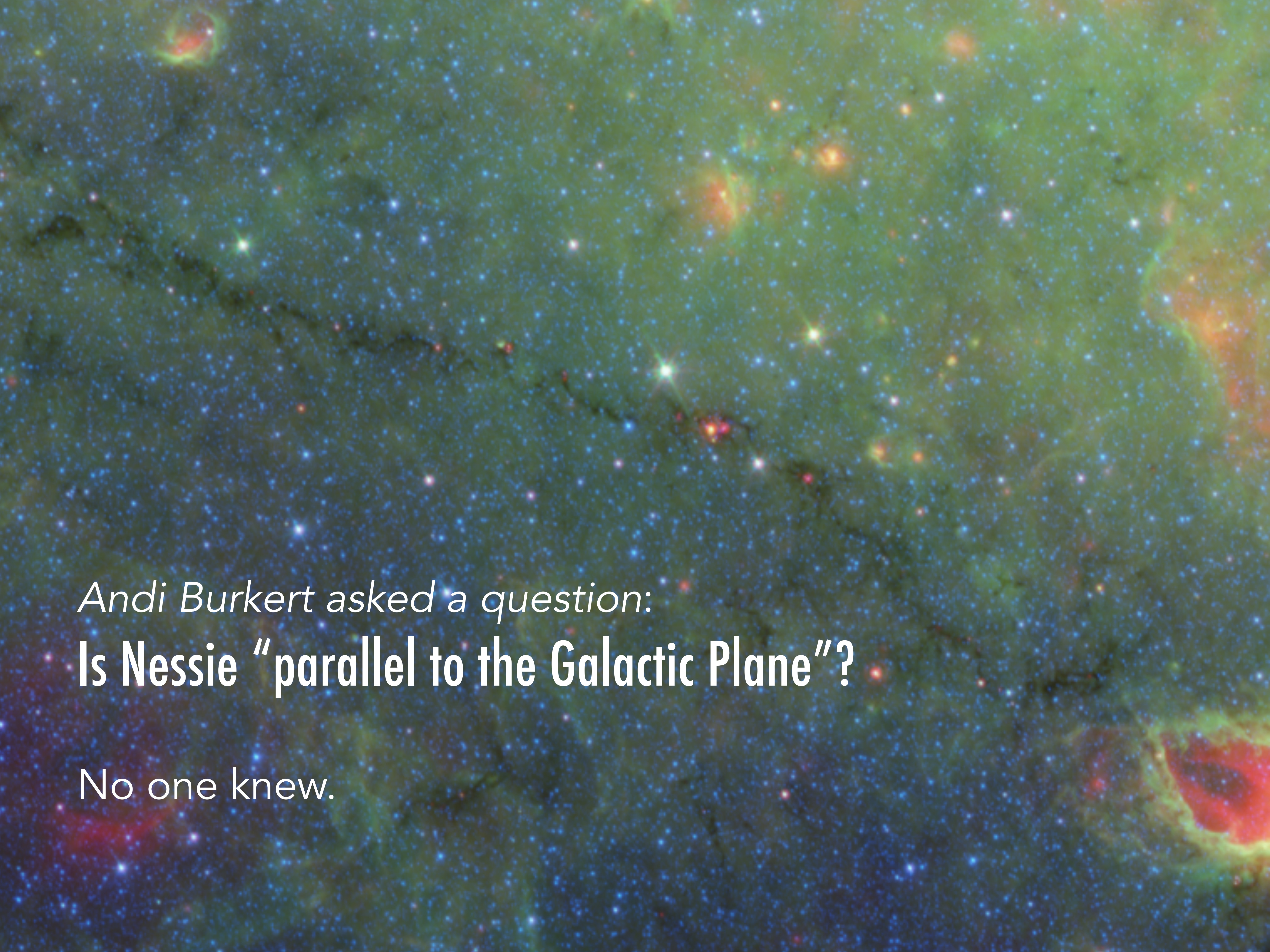


Nessie's story of Resolution, Context, Big Data, Wide Data, Dimensionality, and Linked Views



Once upon a time (2012), in an enchanted castle (in Bavaria)

...at a conference about
"The Early Phases of Star Foration"



Andi Burkert asked a question:

Is Nessie “parallel to the Galactic Plane”?

No one knew.

e Milky Way

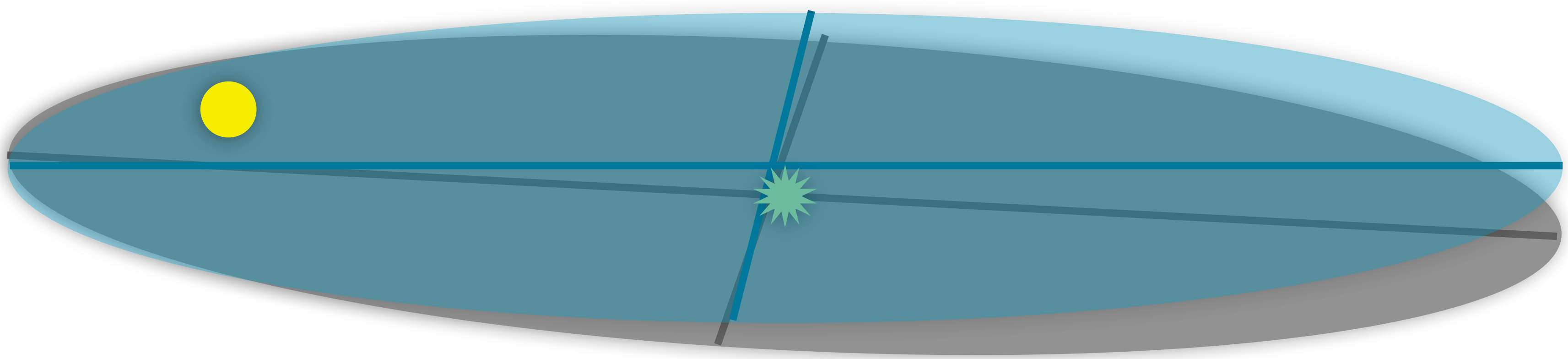
"Galactic Plane"

The Milky Way
(Artist's Conception)

“Is Nessie Parallel to the Galactic Plane?”

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 ~75 light years "above" the IAU Milky Way Plane

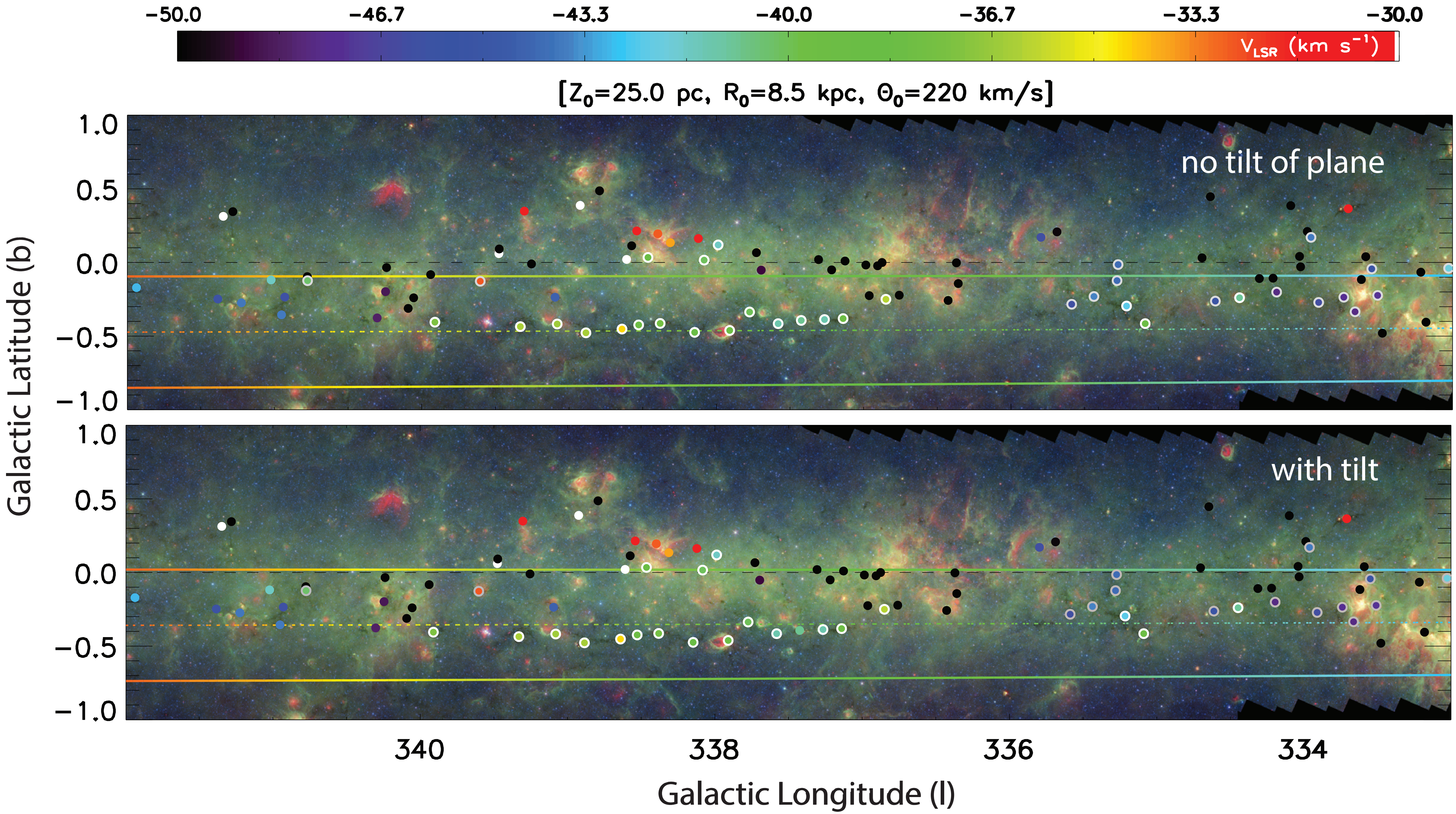
+

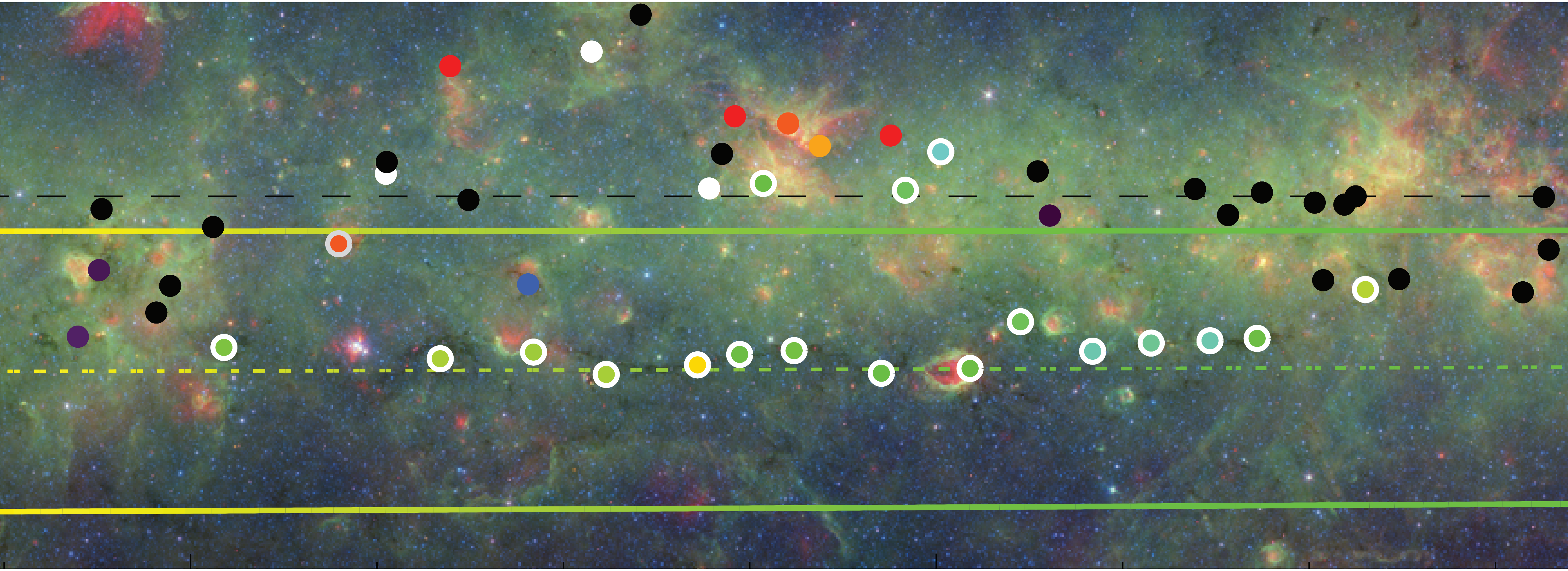
Galactic Center is ~20 light years offset from the IAU Milky Way Center

=

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!



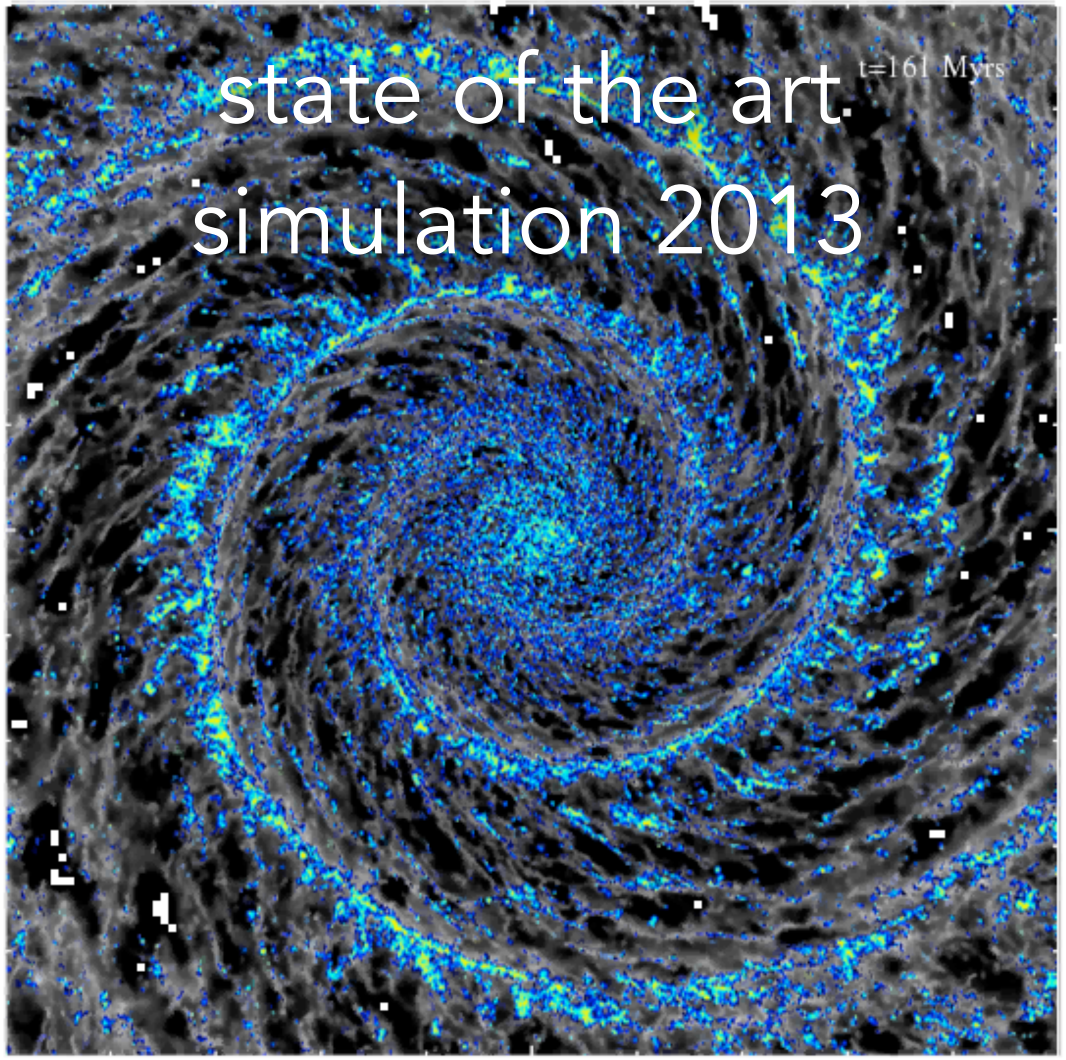


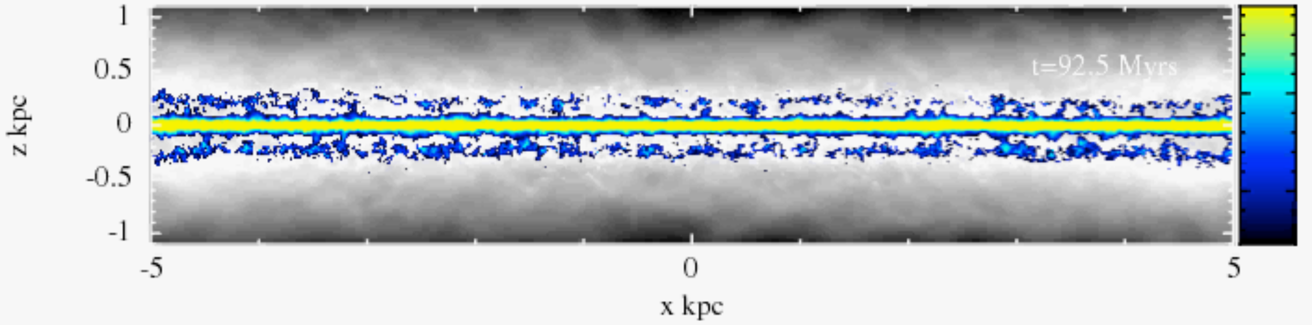
...eerily precisely...

How do we know the velocities?

A full 3D skeleton?

(flipped) image of IC342 from Jarrett et al. 2012; WISE Enhanced Resolution Galaxy Atlas

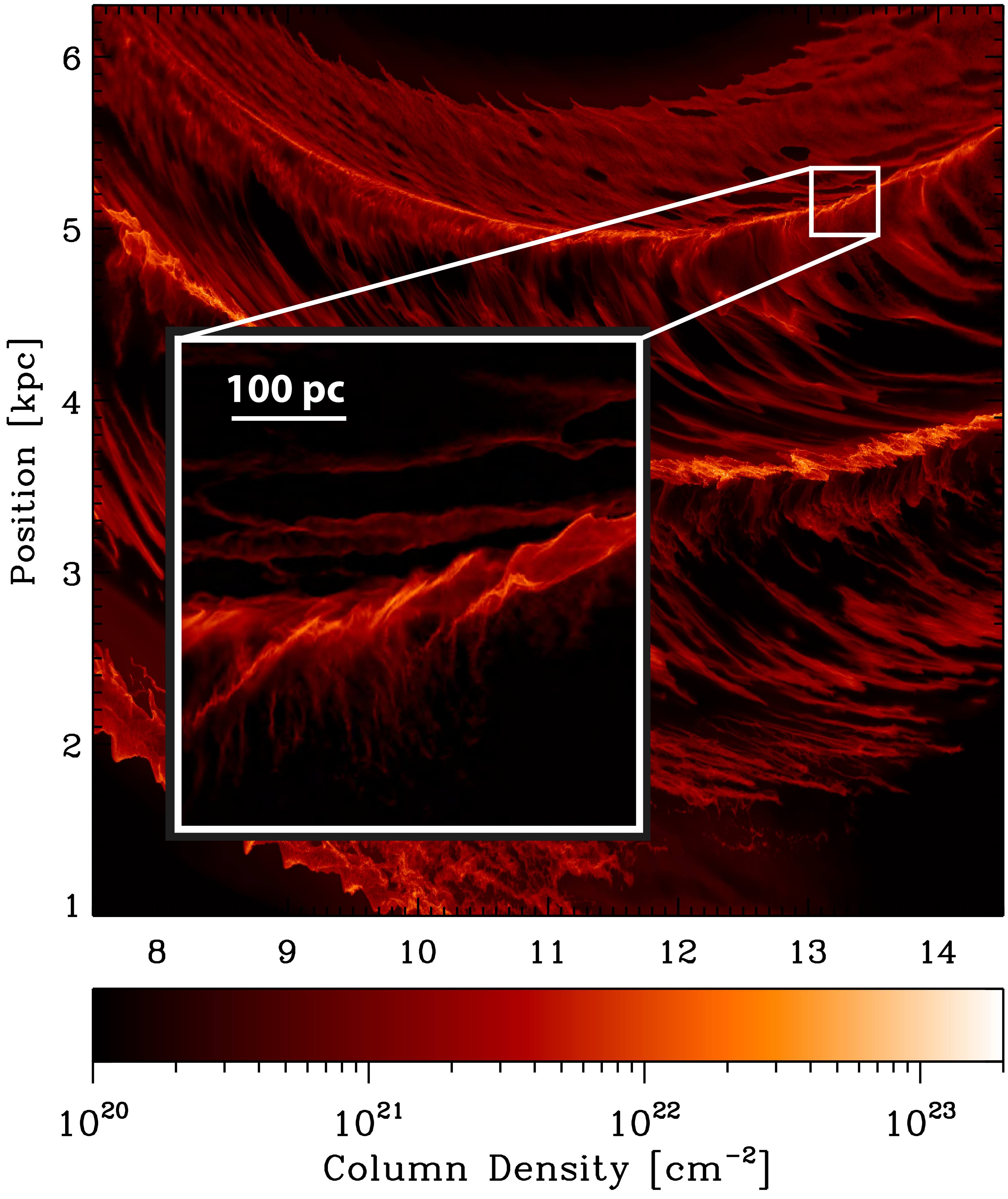




simulations courtesy Clare Dobbs

New!

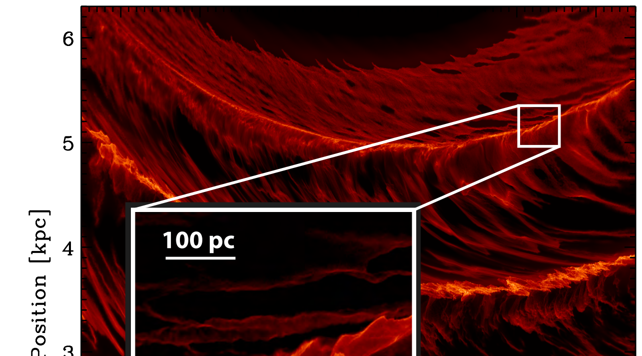
2014 Simulation

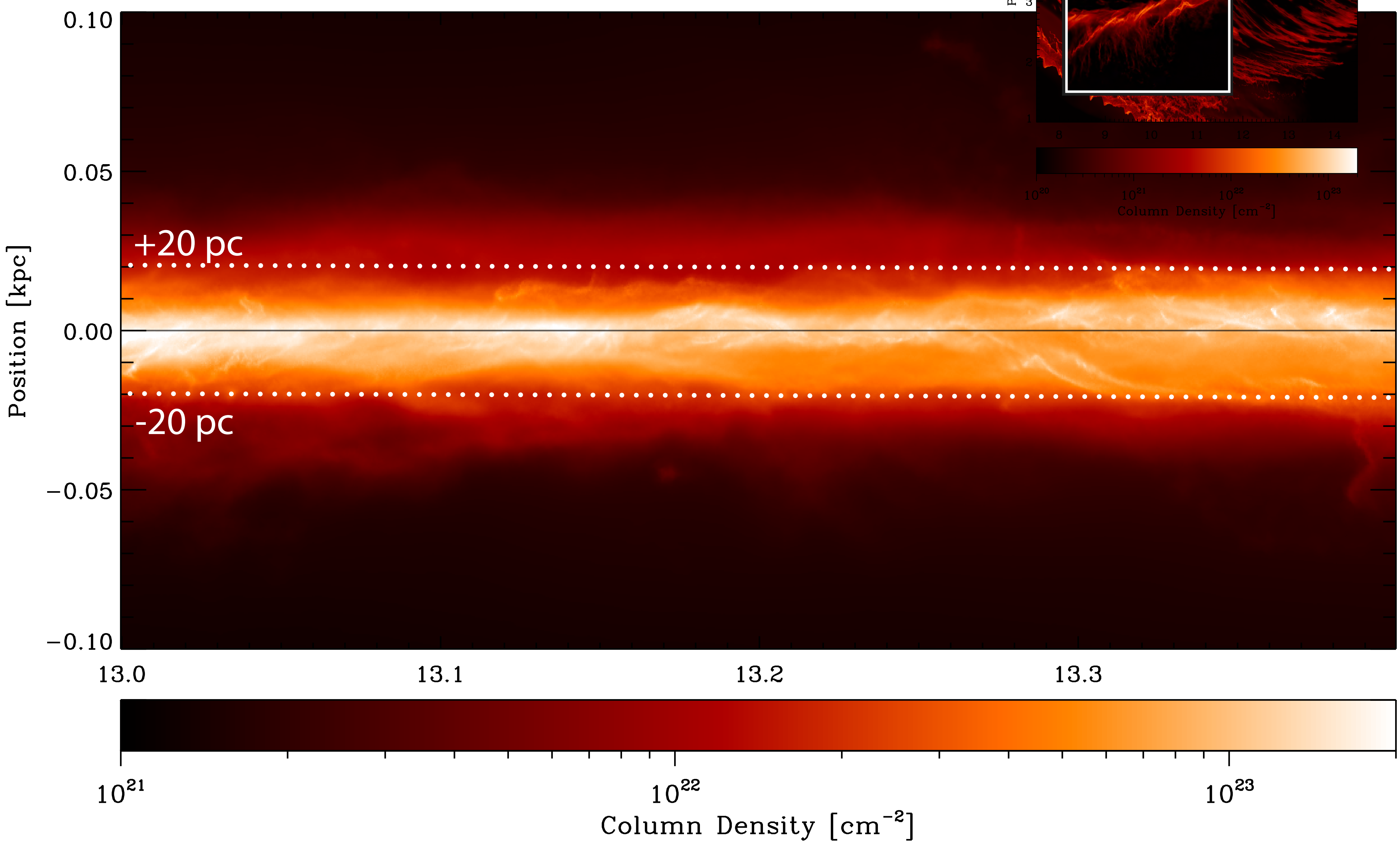


Smith et al. 2014, using AREPO

New!

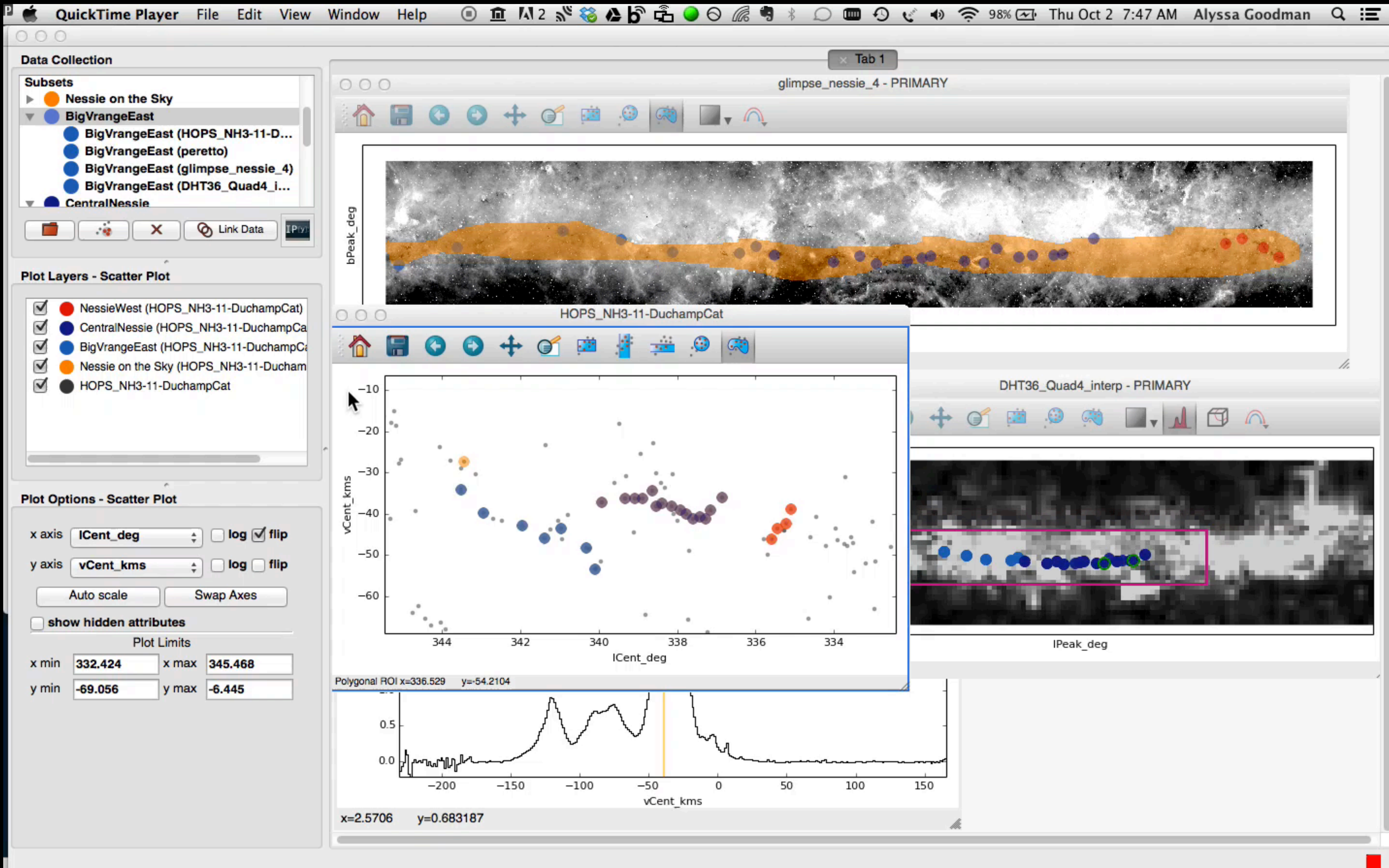
2014 Simulation



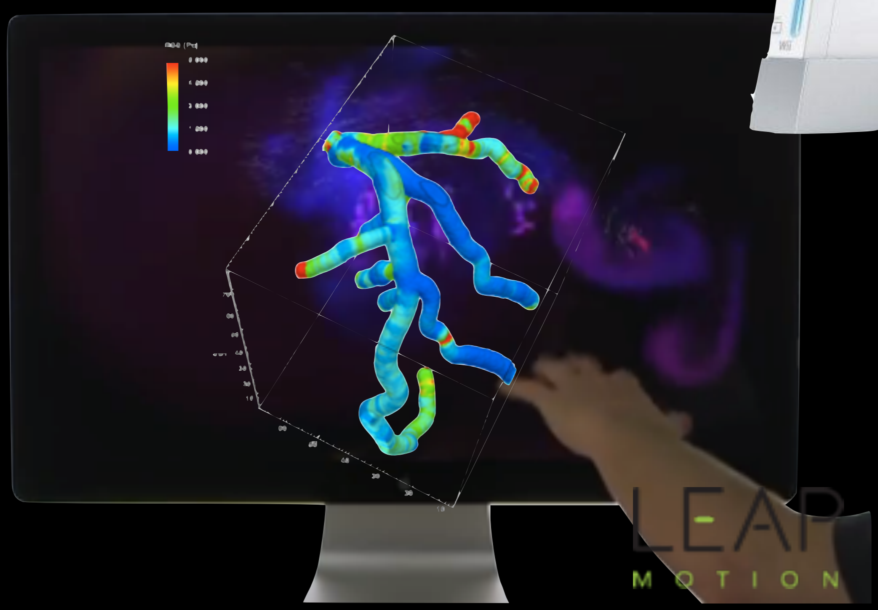


Smith et al. 2014, using AREPO

Nessie in Glue

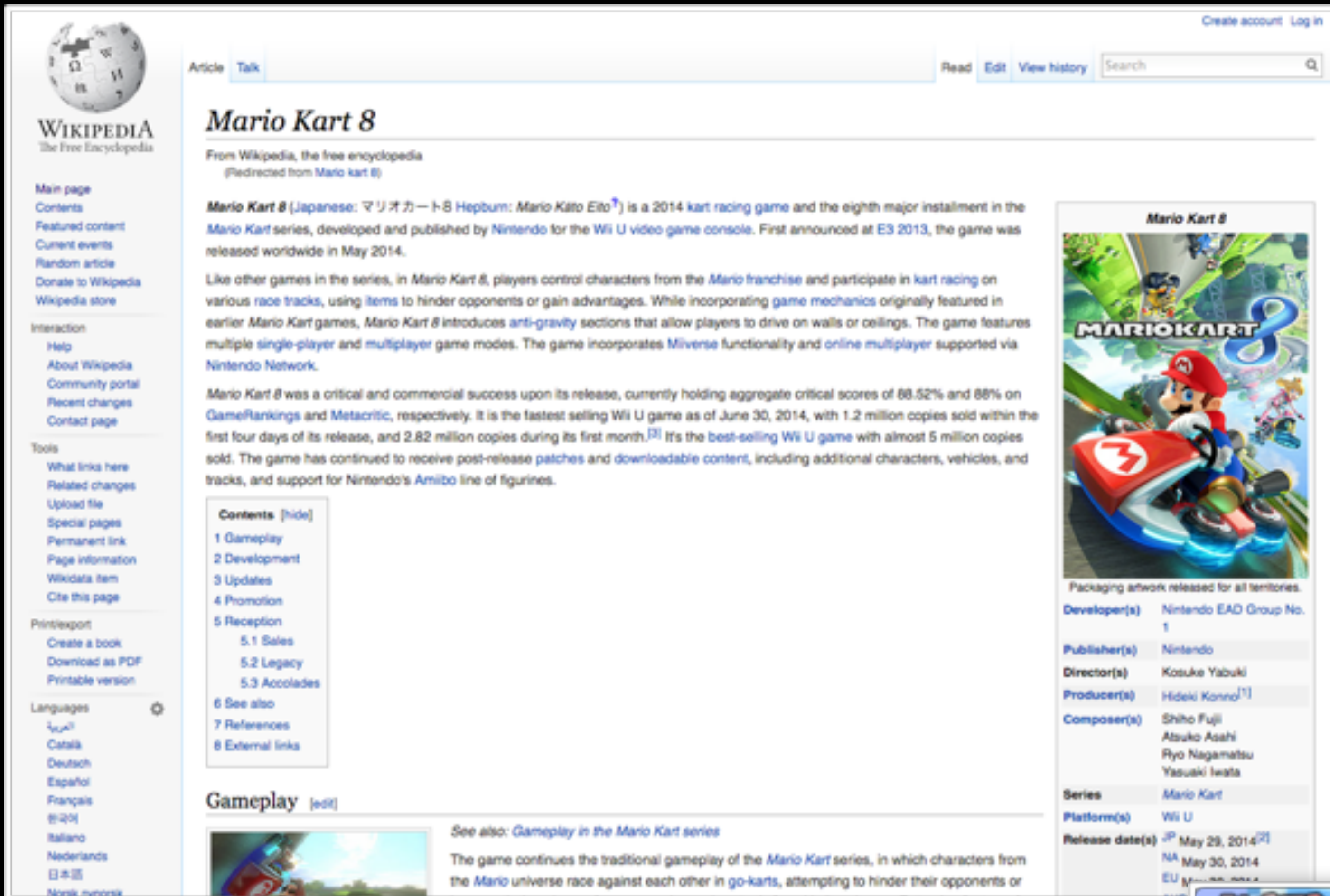


(BUT) Selection in 3D is an unsolved problem



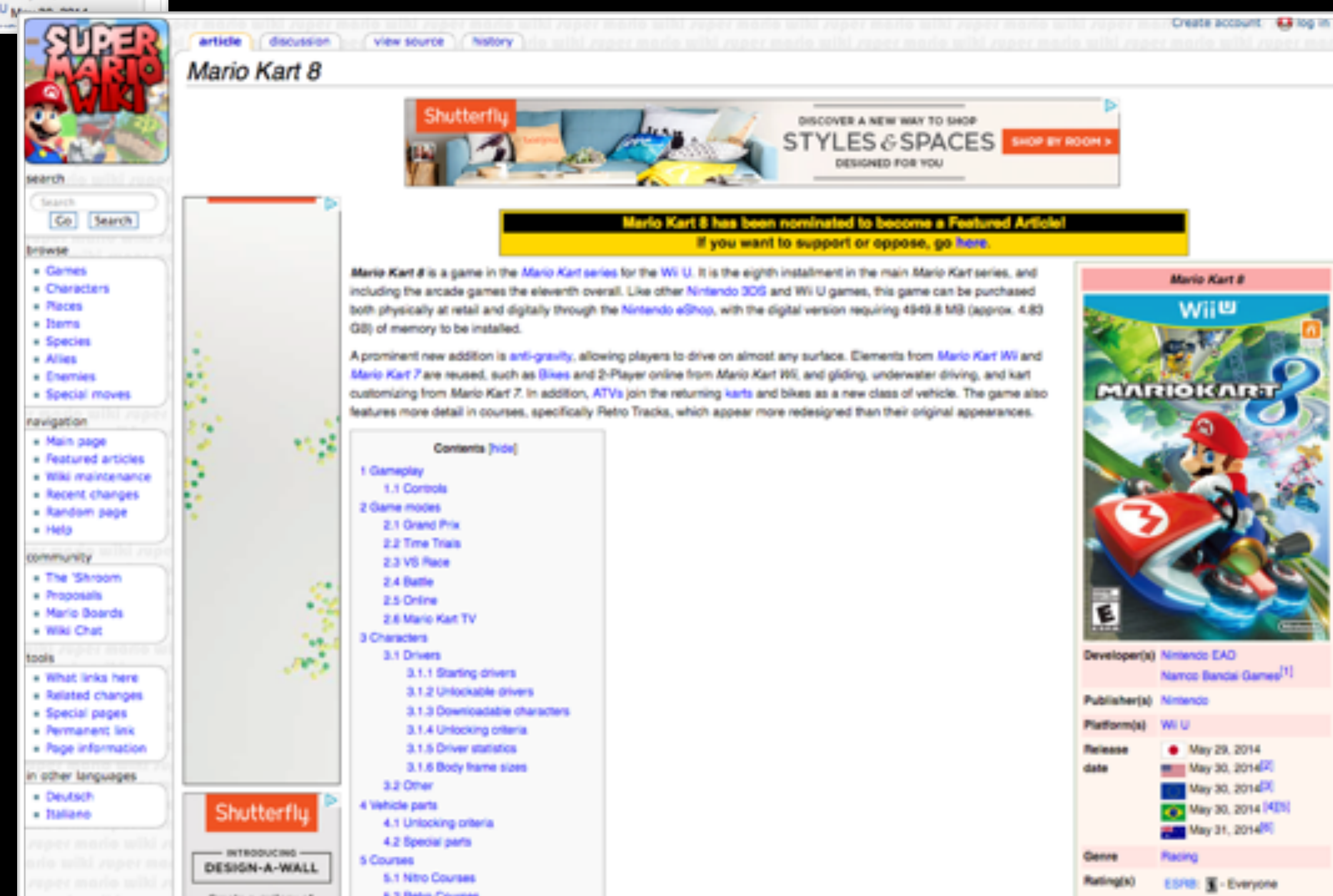
John Tukey's warning:
"details of control can
make or break such a system"

Microsoft HoloLens



en.wikipedia.org/wiki/Mario_Kart_8

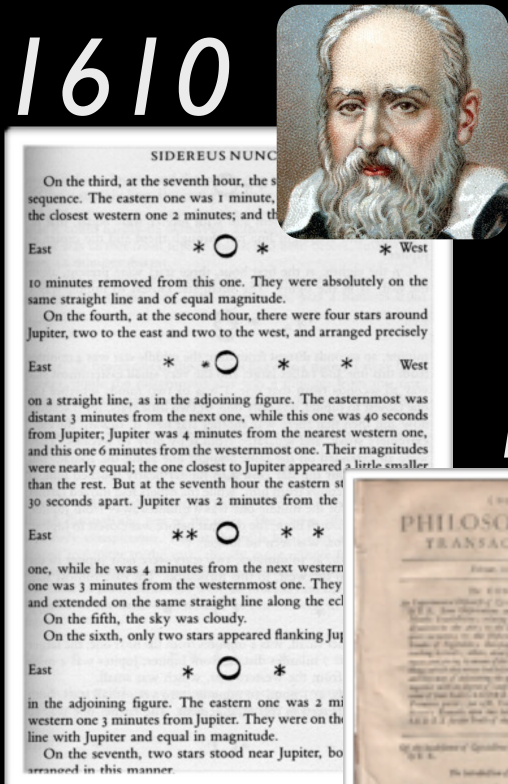
open collaboration and communication



www.mariowiki.com/Mario_Kart_8

scholarly Communication

1610


SIDEREUS NUNC

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East * O * * West

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East * *O * * West

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East * O *

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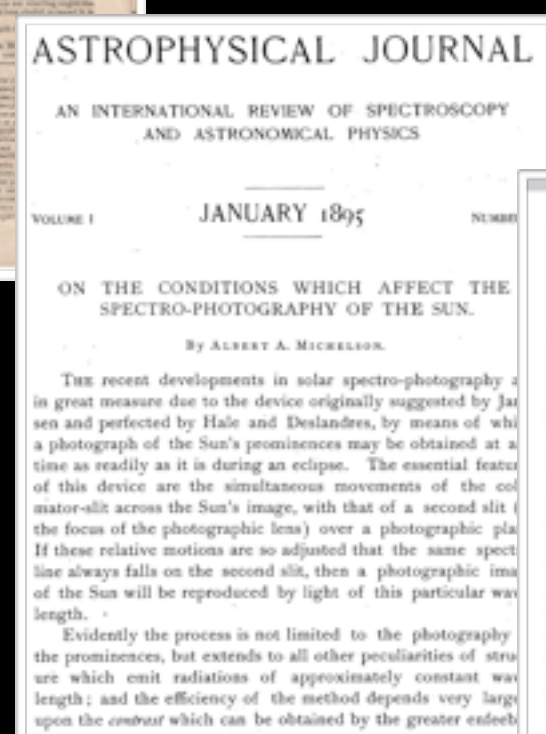
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VOLUME I JANUARY 1895 NUMBE

ON THE CONDITIONS WHICH AFFECT THE SPECTRO-PHOTOGRAPHY OF THE SUN.

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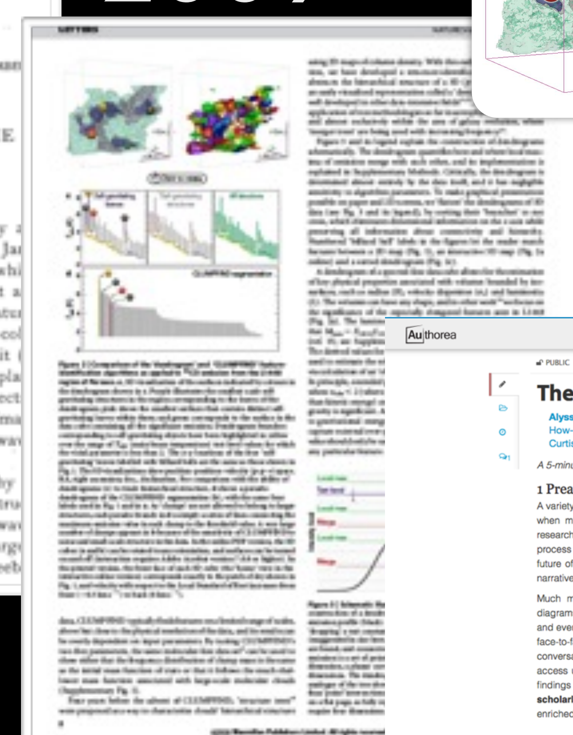
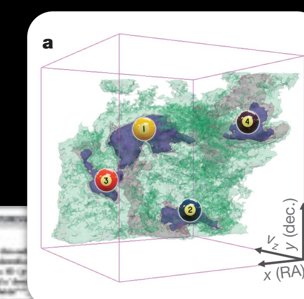
2009





2015

glue

Au
Authorea

Au
Authorea

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The "Paper" of the Future

3

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.

0

Konrad Hinsen 3 days ago · Public
Many good suggestions, but if the goal is "long-lasting rich records of scientific discourse", a more careful and critical attitude towards electronic artifacts is appropriate. I do see it concerning videos, but not a word on the much more critical situation in software. Archiving source code is not sufficient: all the dependencies, plus the complete build environment, would have to be conserved as well to make things work a few years from now. An "executable figure" in the form of an IPython notebook wil...
more

Merce Crosas 3 days ago · Public
Konrad, good points; this has been a concern for the community working on reproducibility. Regarding data repositories, Dataverse handles long-term preservation and access of data files in the following way: 1) for some data files that the repository recognizes (such as R Data, SPSS, STATA), which depend on a statistical package, the system converts them into a preservation format (such as a tab/CSV format). Even though the original format is also saved and can be accessed, the new preservation format gua...
more

Konrad Hinsen 1 day ago · Public
That sounds good. I hope more repositories will follow the example of Dataverse. Figshare in particular has a very different attitude, encouraging researchers to deposit as much as possible. That's perhaps a good strategy to change habits, but in the long run it could well backfire when people find out in a few years that 90% of those deposits have become useless.

Christine L. Borgman 4 months ago · Private
"publications"

d3po/Authorea: Peek, Price-Whelan, Pepe, Beaumont, Borkin, Newton; PoF: Goodman, Peek; WWT: Wong, Fay et al.; Astrometry.net: Hogg, Lang, Roweis et al.

Astrometry.net glue

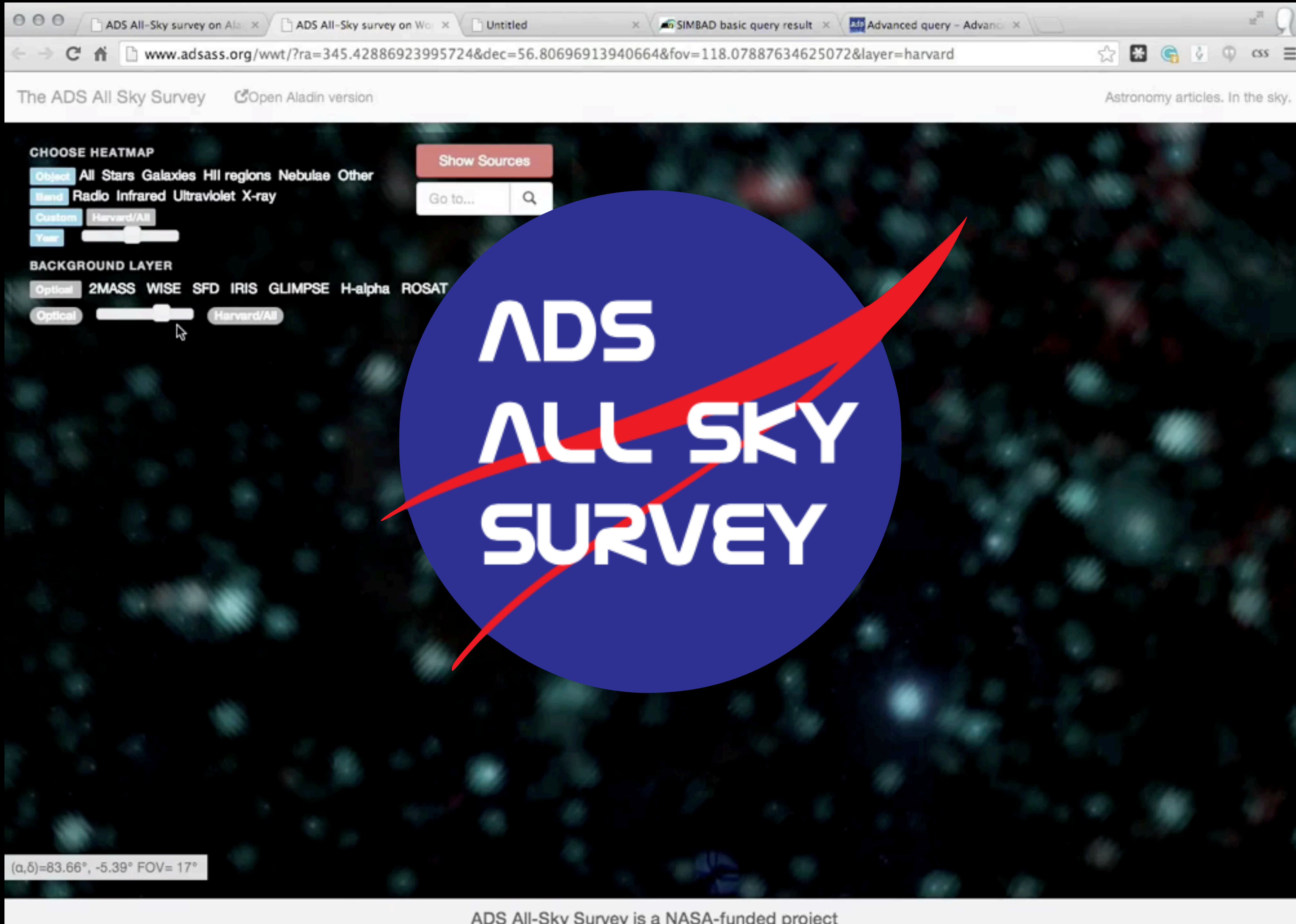
[video, demos]

Communication: Literature as a filter for (BIG) Data

ADS
ALL SKY
SURVEY

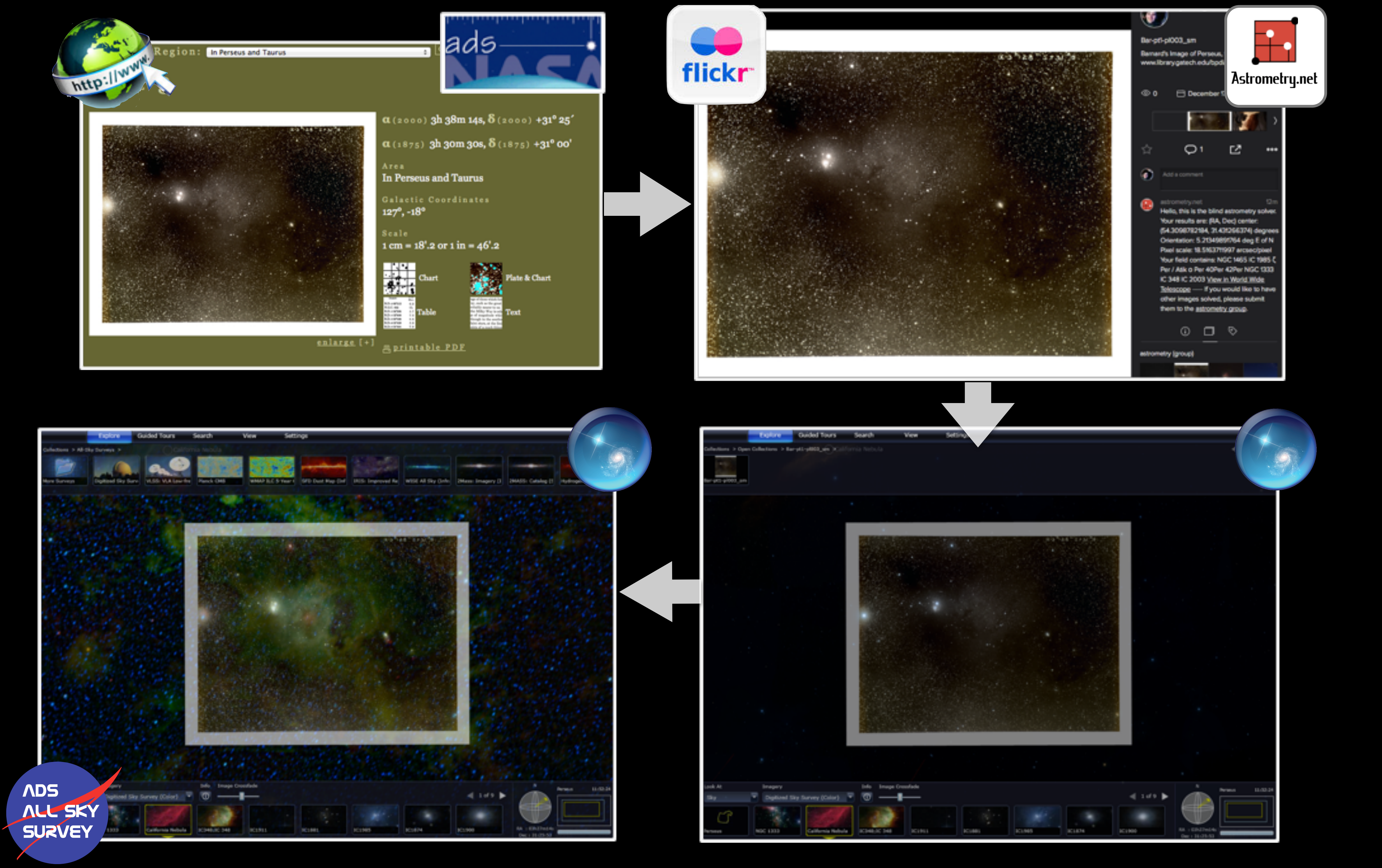
View in Aladin • View in WorldWide Telescope • Demo Videos

[Demo]



WorldWide Telescope: ADS All-Sky Survey

adsass.org



WorldWide Telescope: ADSASS/oldAstronomy

flickr.com/groups/astrometry/

Resolution

Context

Big Data

Wide Data

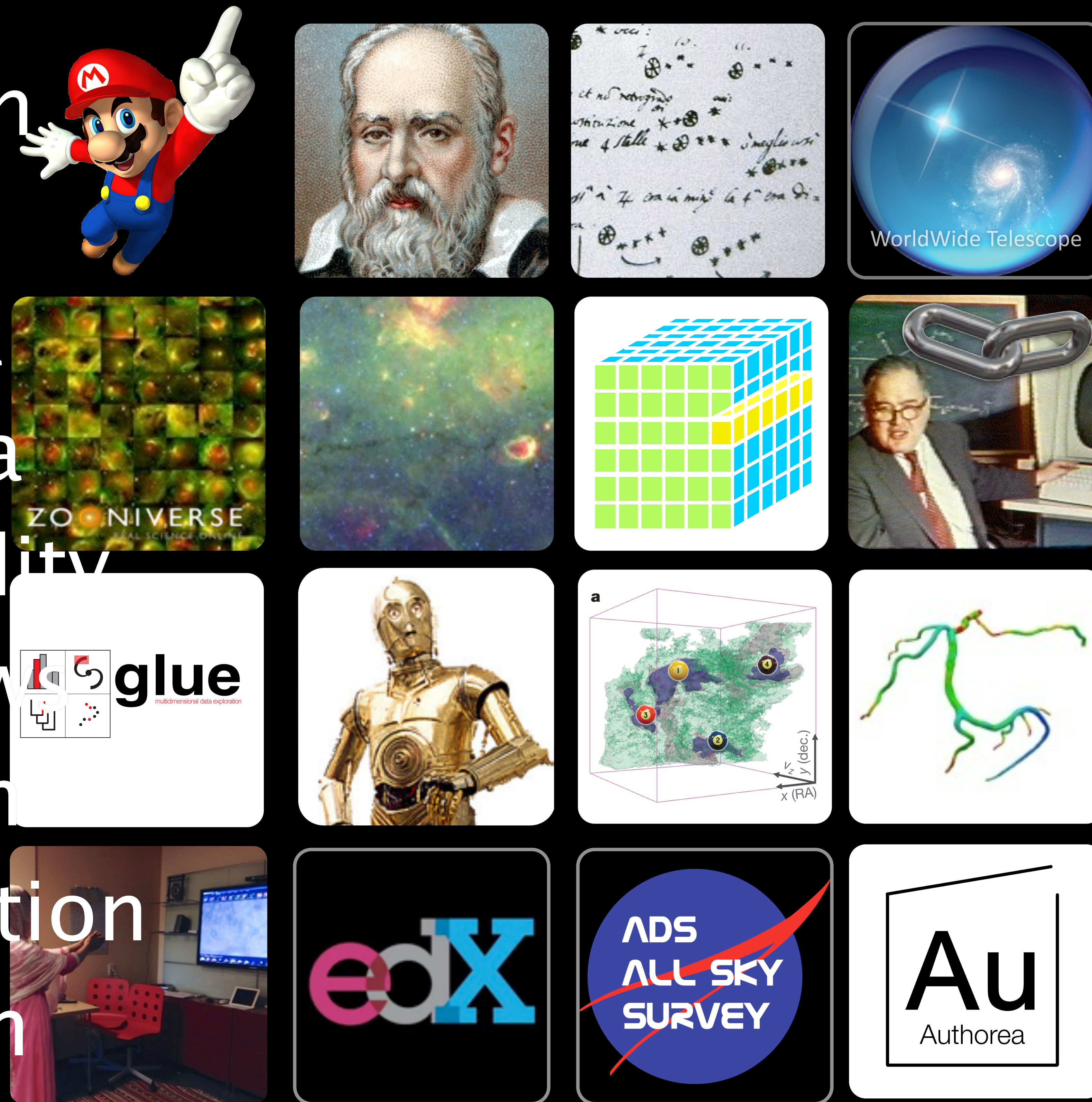
Dimensionality

Linked views

Interaction

Communication

education

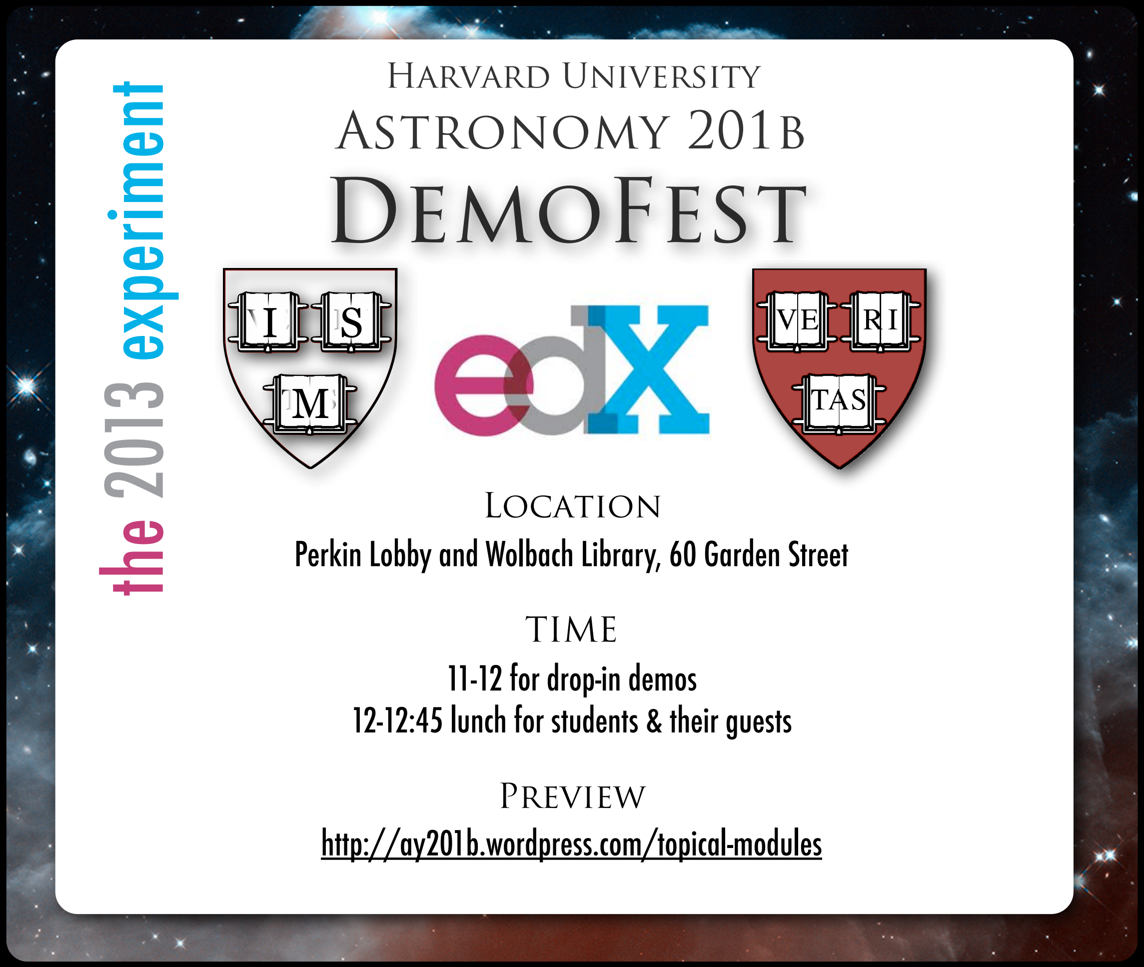


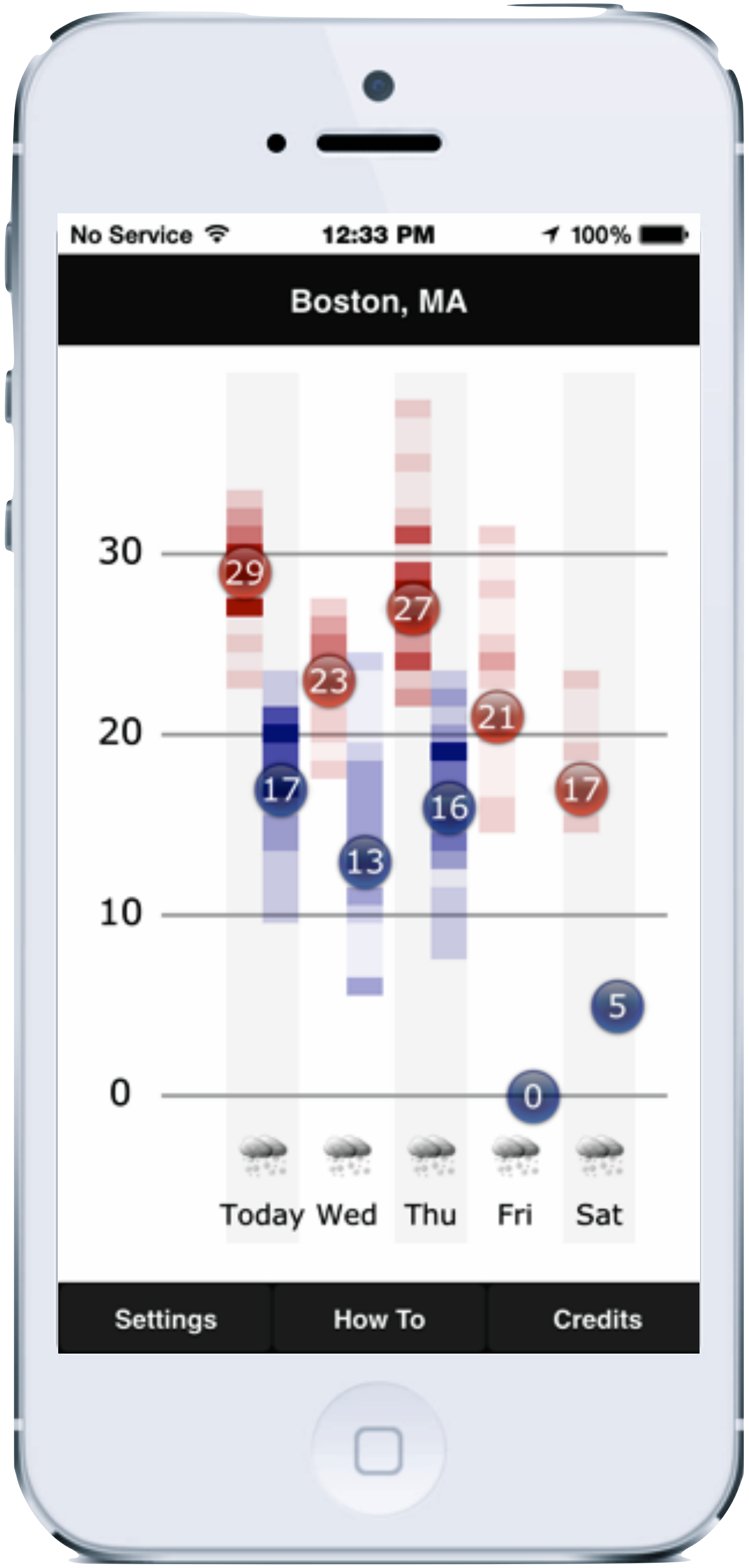
Education: Visualization→ new Ways to learn

WorldWide Telescope Ambassadors

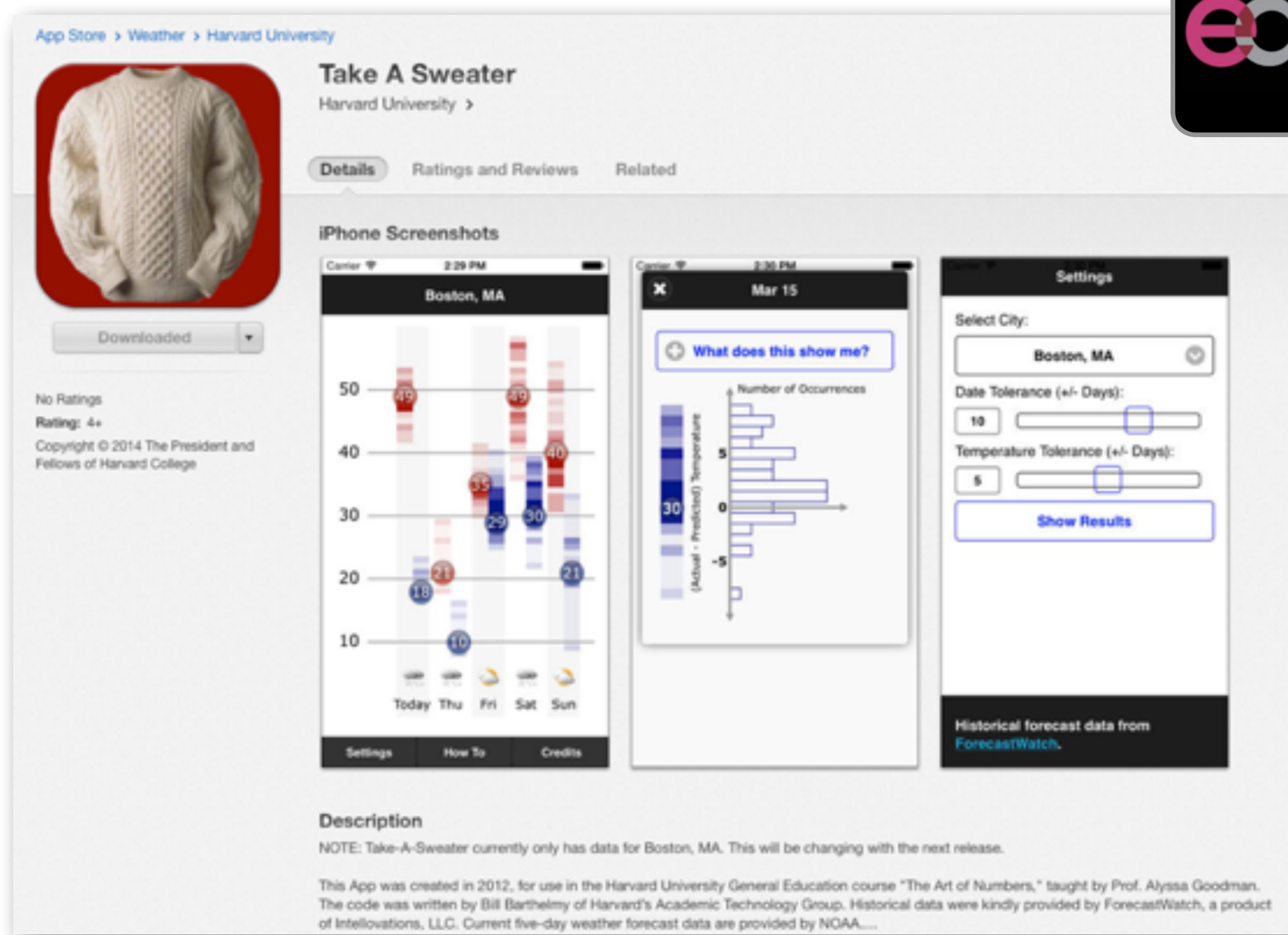
wwtambassadors.org

Higher Ed



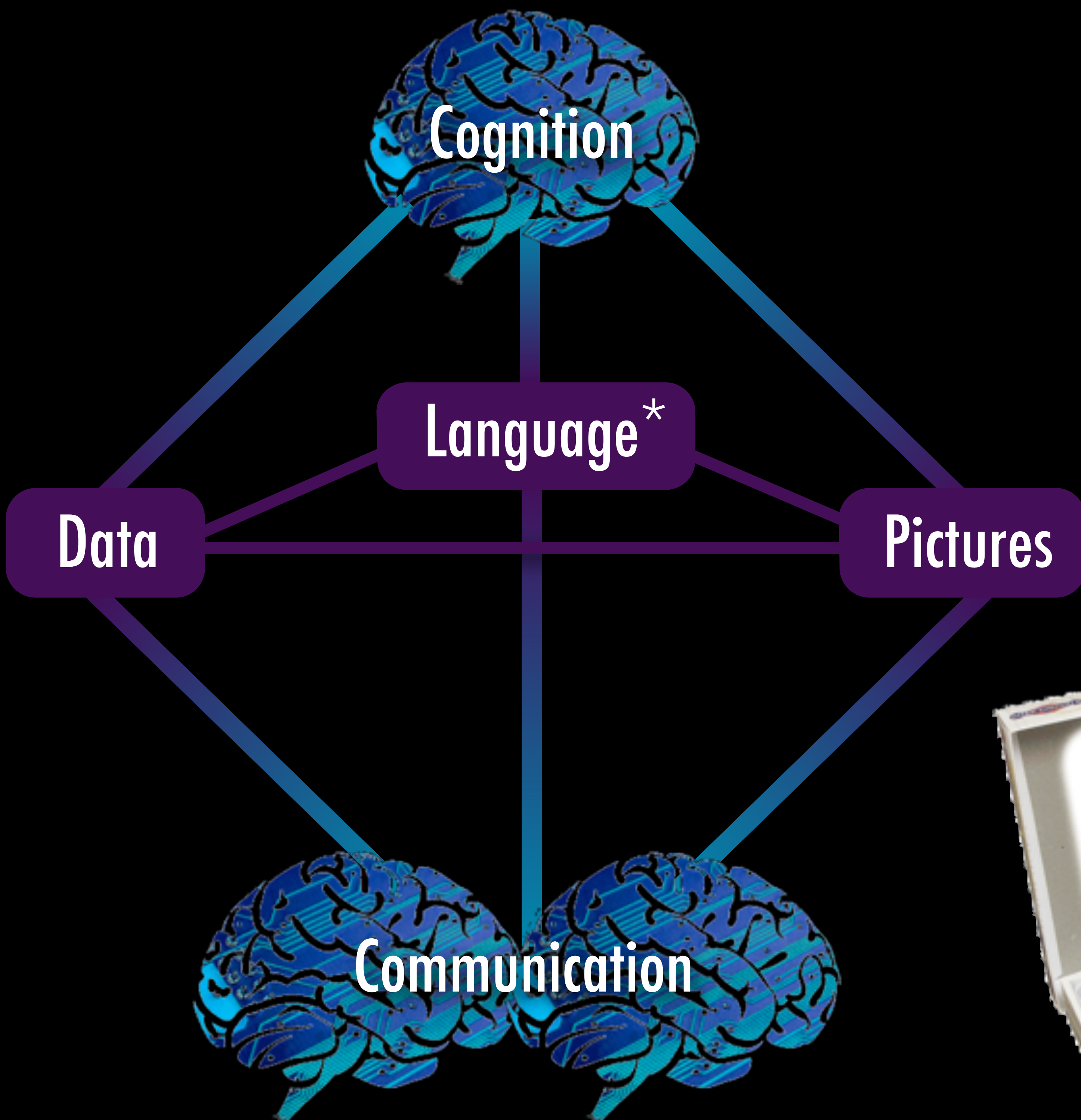


PredictionX



takeasweater.com, and "TakeASweater" in the Apple App Store

The future is about **Integ**



python™
SciPy
IP[y]: IPython Interactive Computing
astropy
A Community Python Library for Astronomy
JavaScript
d3.js
plotly
HTML

CFA NASA ADS HARVARD LIBRARY

John G. Wolbach Library and Information Center

Harvard-Smithsonian Center for Astrophysics
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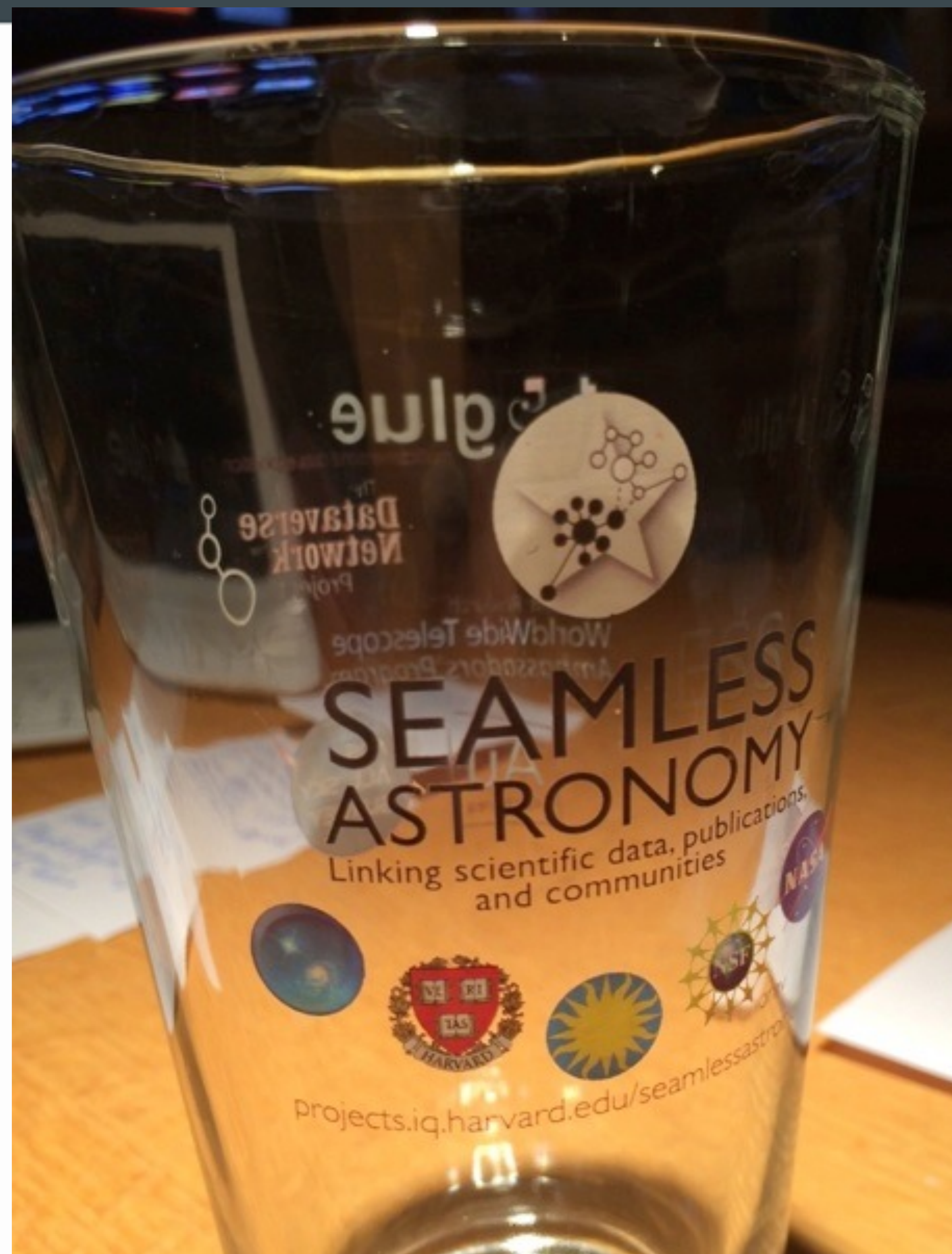

SEARCH LITERATURE

- Quick Links
- Journals & Proceedings
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- Astronomy Resources
- Astronomical Newsletters
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ask me about the "Library of the Future," at Harvard...

Resolution

Context

Big Data

Wide Data

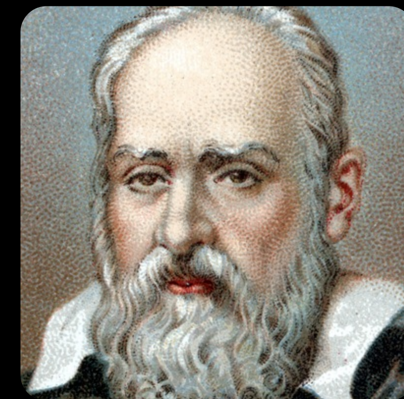
Dimensionality

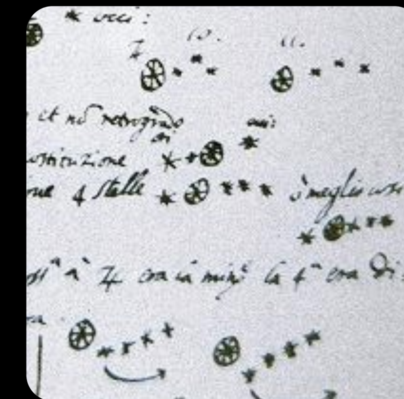
Linked views

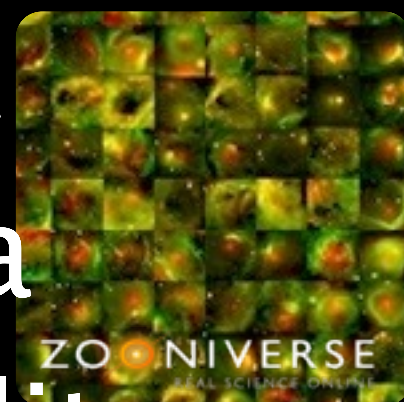
Interaction

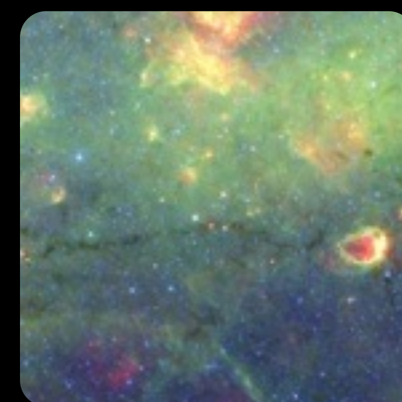
Communication

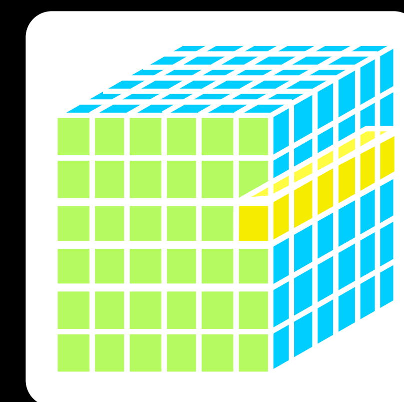
education





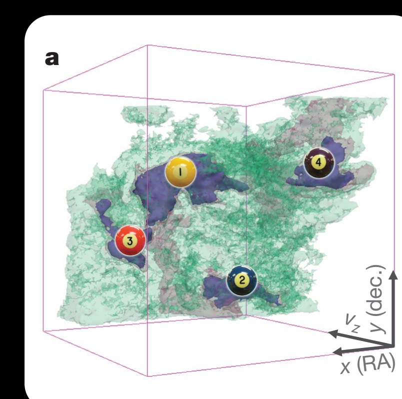


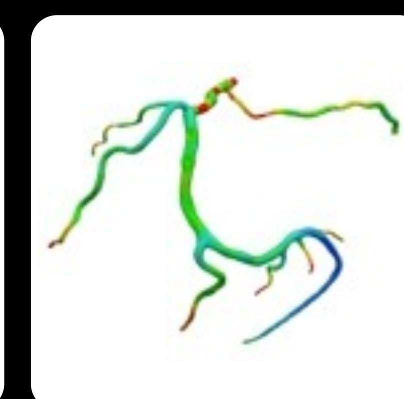




glue

multidimensional data exploration





edX

ADS ALL SKY SURVEY

Au

Authorea

More?

projects.iq.harvard.edu/
seamlessastronomy/
presentations