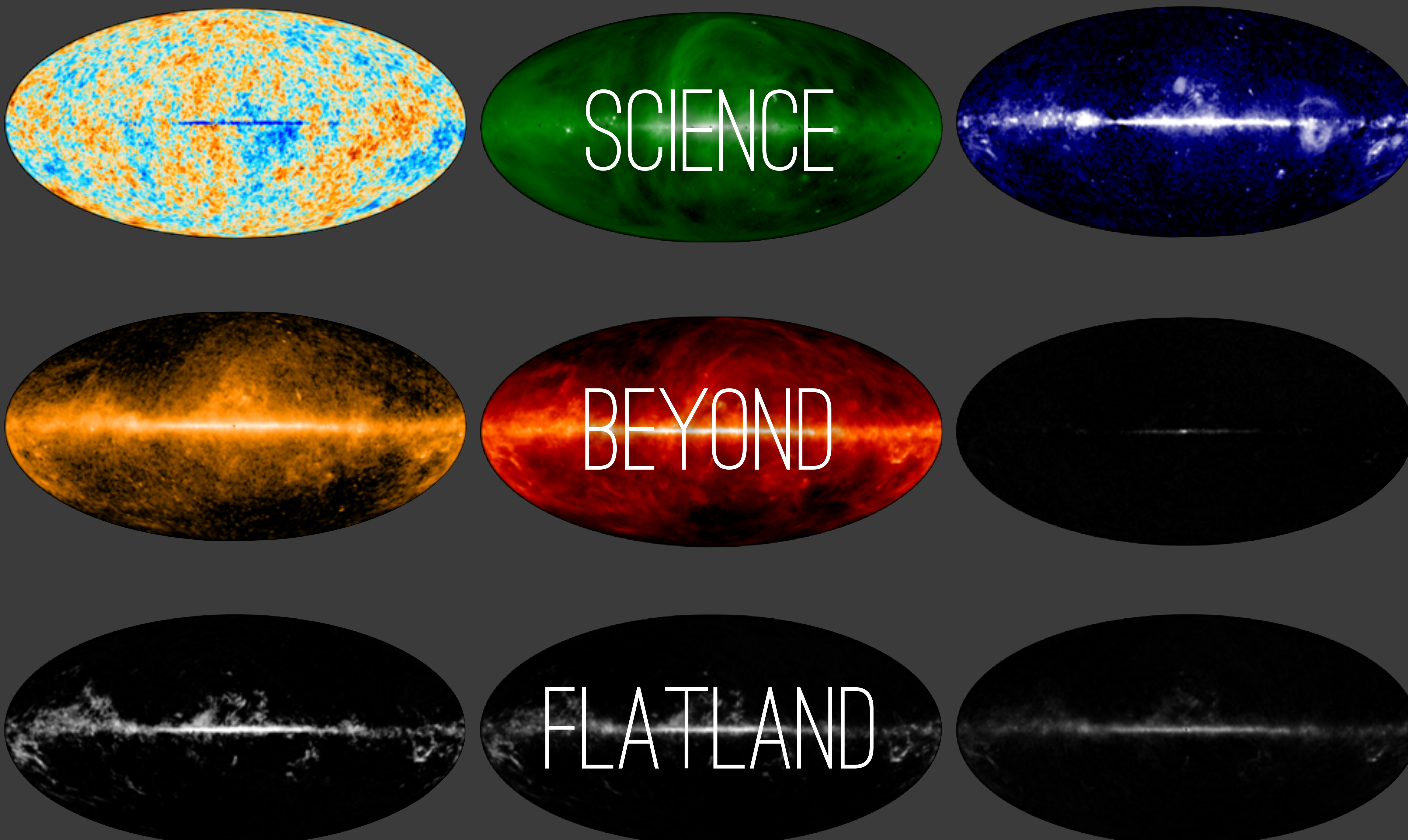
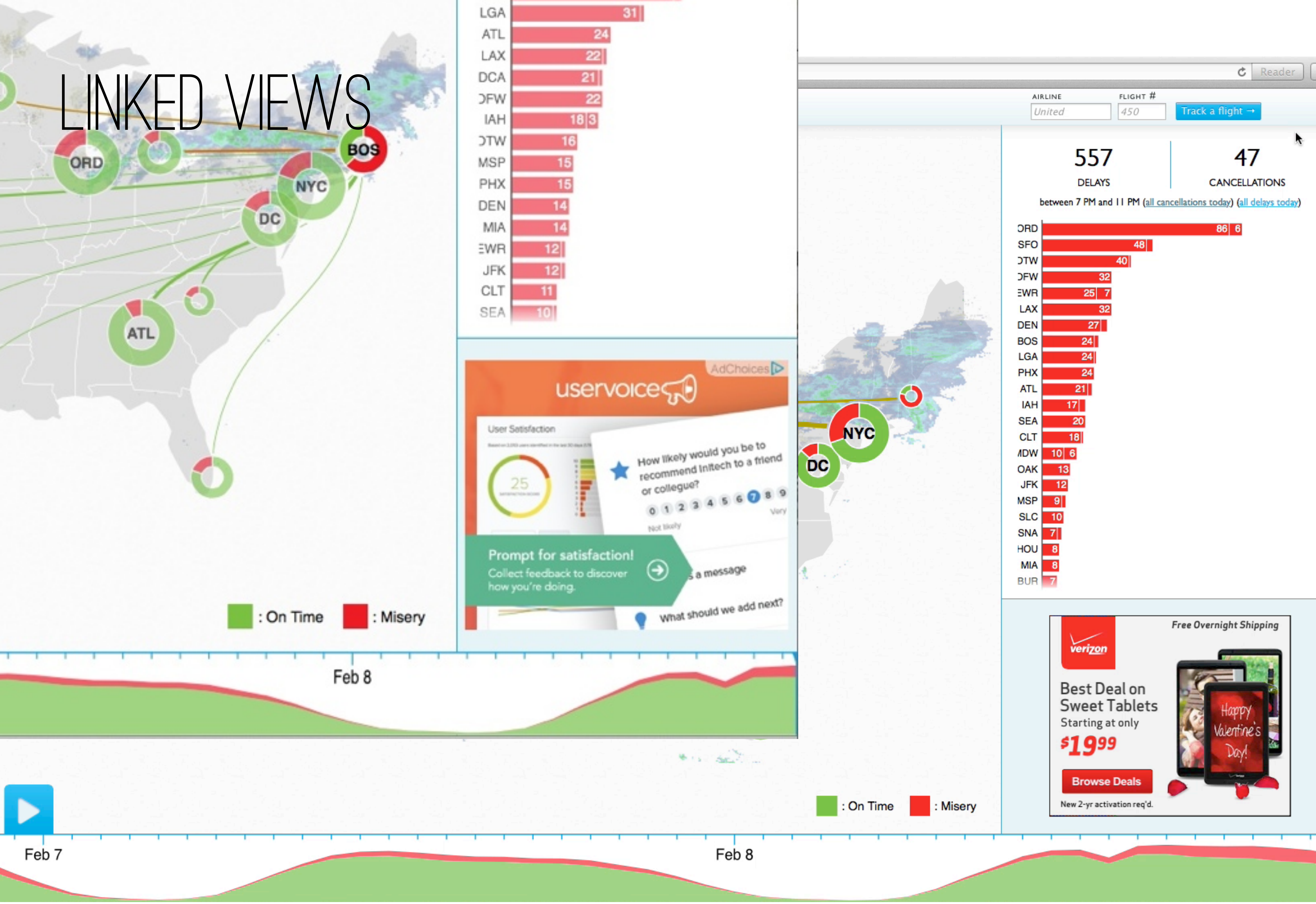
SCIENCE BEYOND FLATLAND



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

LINKED VIEWS



flightaware.com/miserymap, by David Chouinard

RESOLUTION

CONTEXT

BIG DATA

WIDE DATA

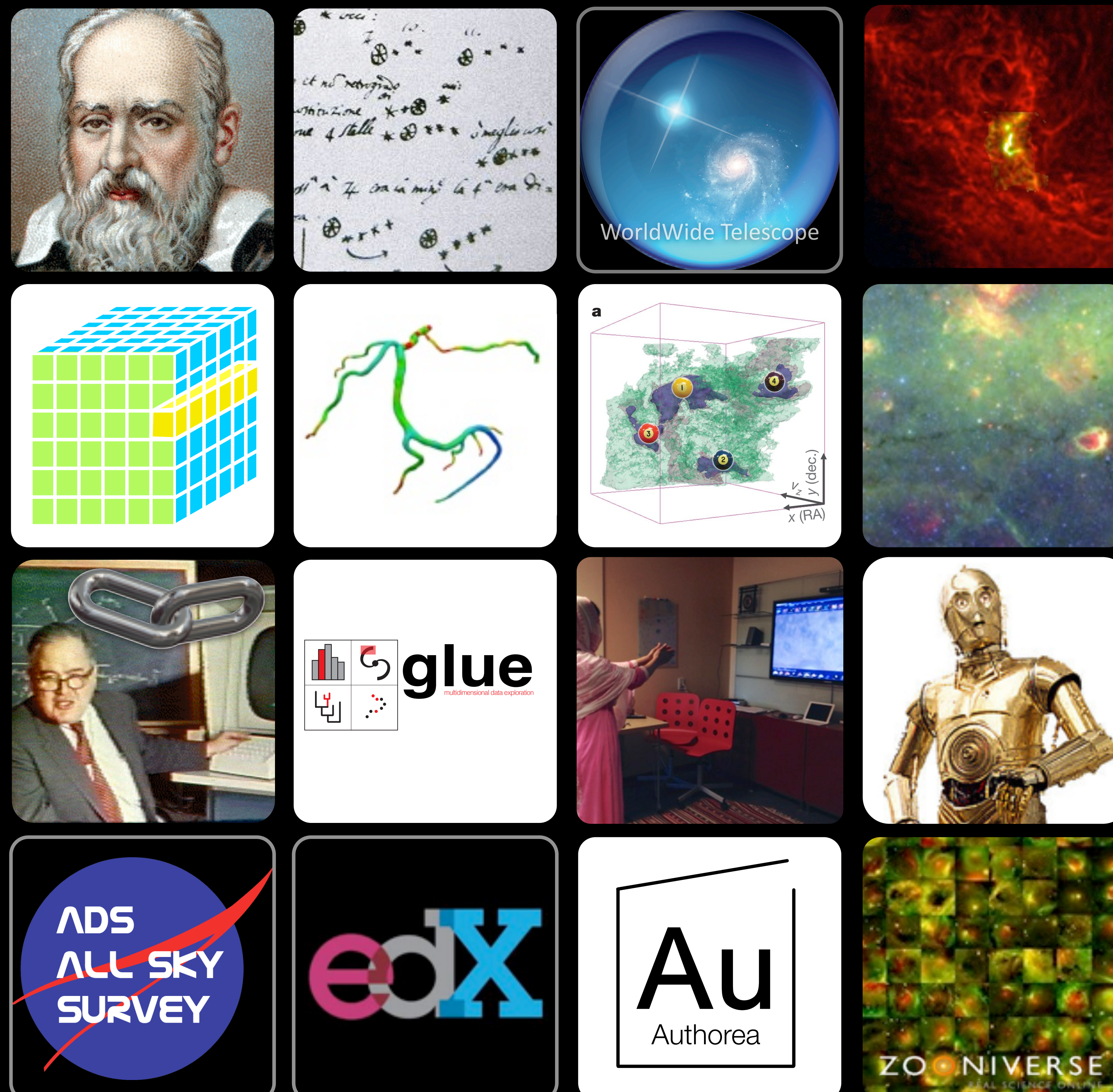
DIMENSIONALITY

LINKED VIEWS

INTERACTION

COMMUNICATION

EDUCATION



RESOLUTION

CONTEXT

BIG DATA

WIDE DATA

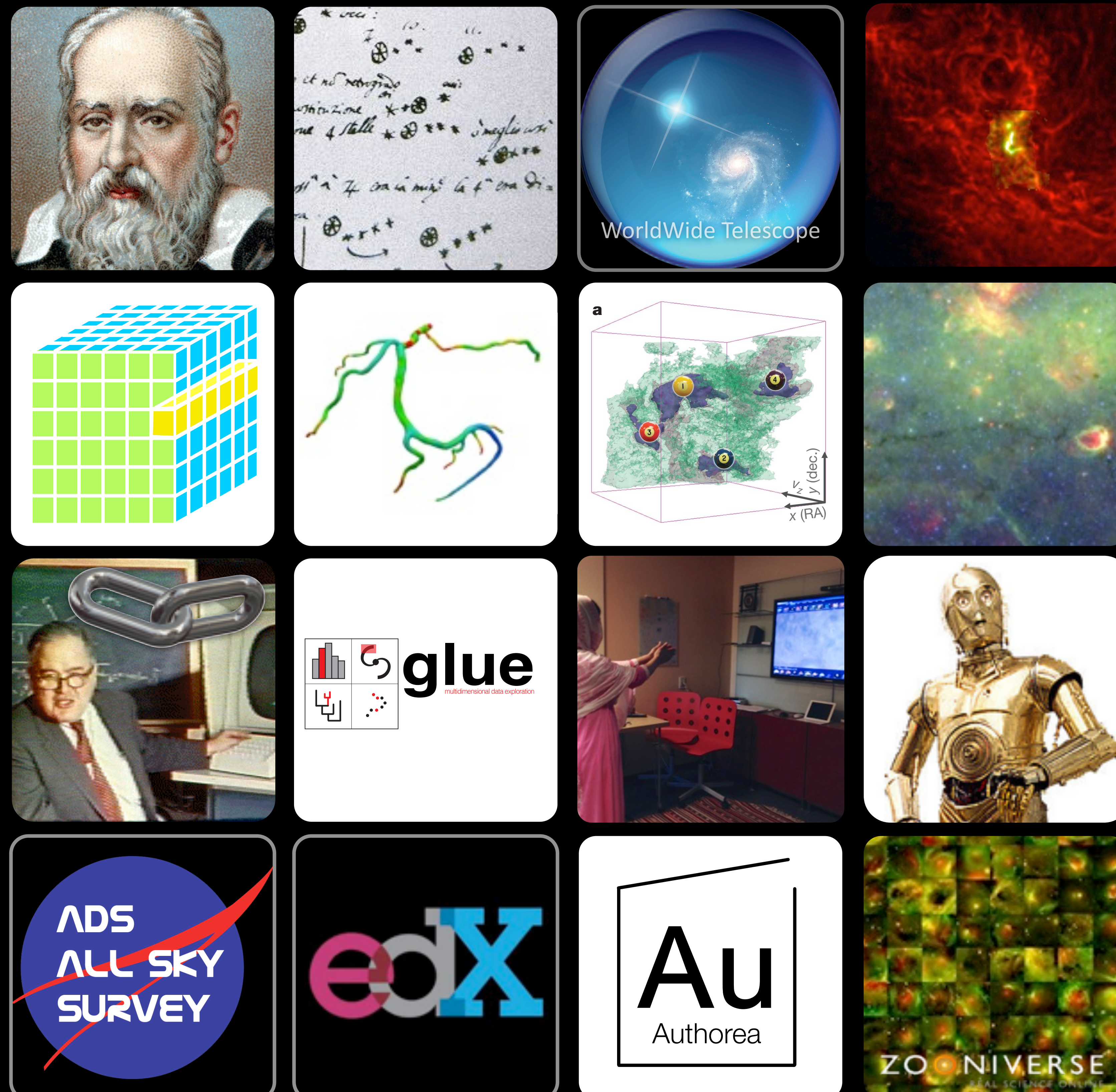
DIMENSIONALITY

LINKED VIEWS

INTERACTION

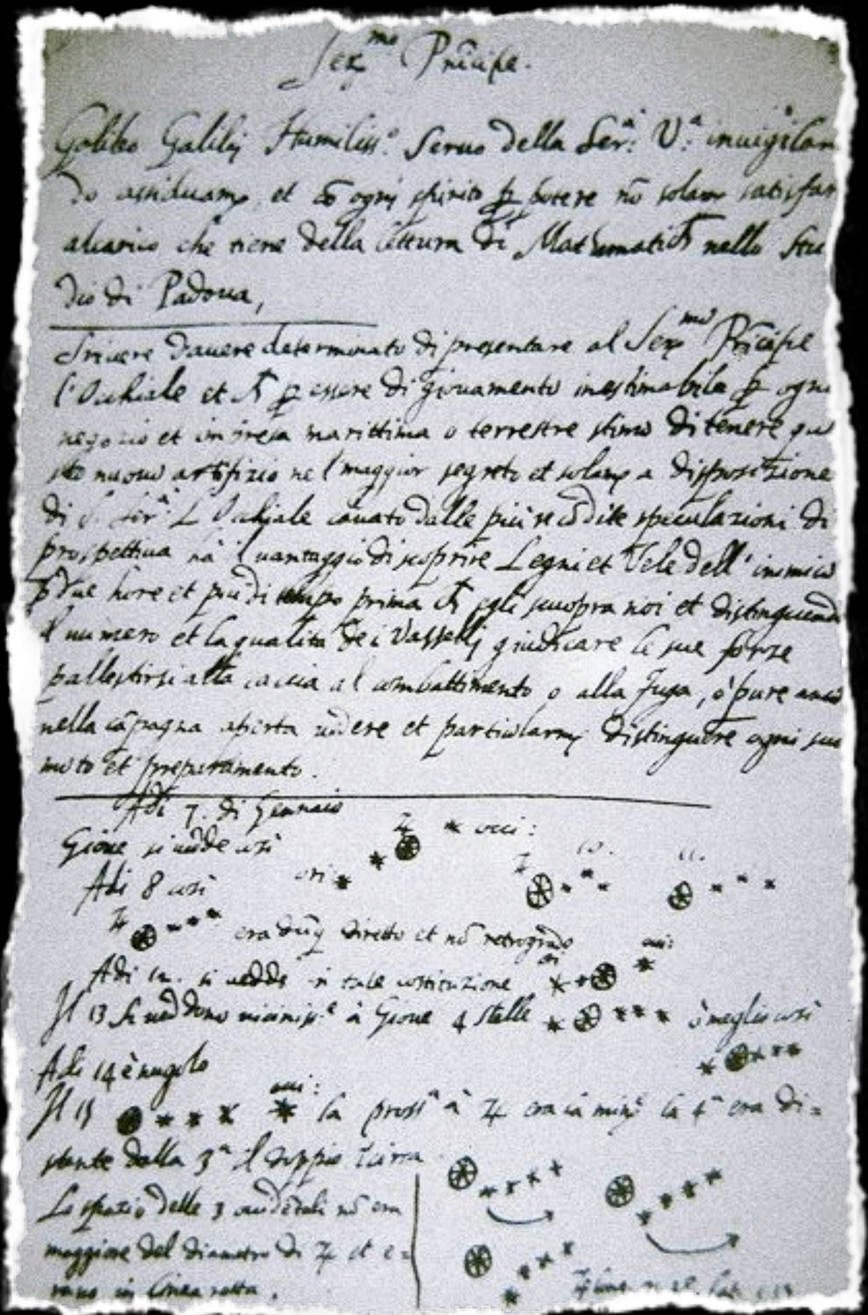
COMMUNICATION

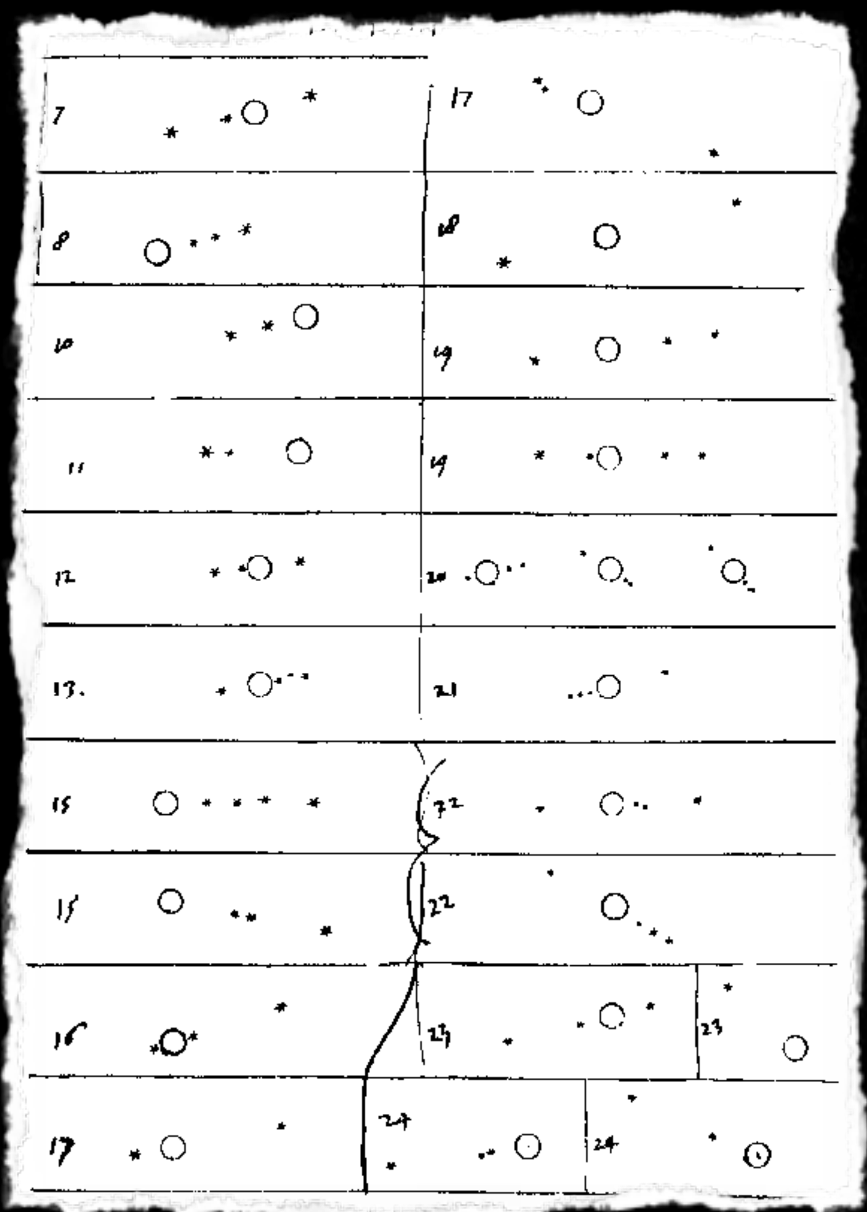
EDUCATION

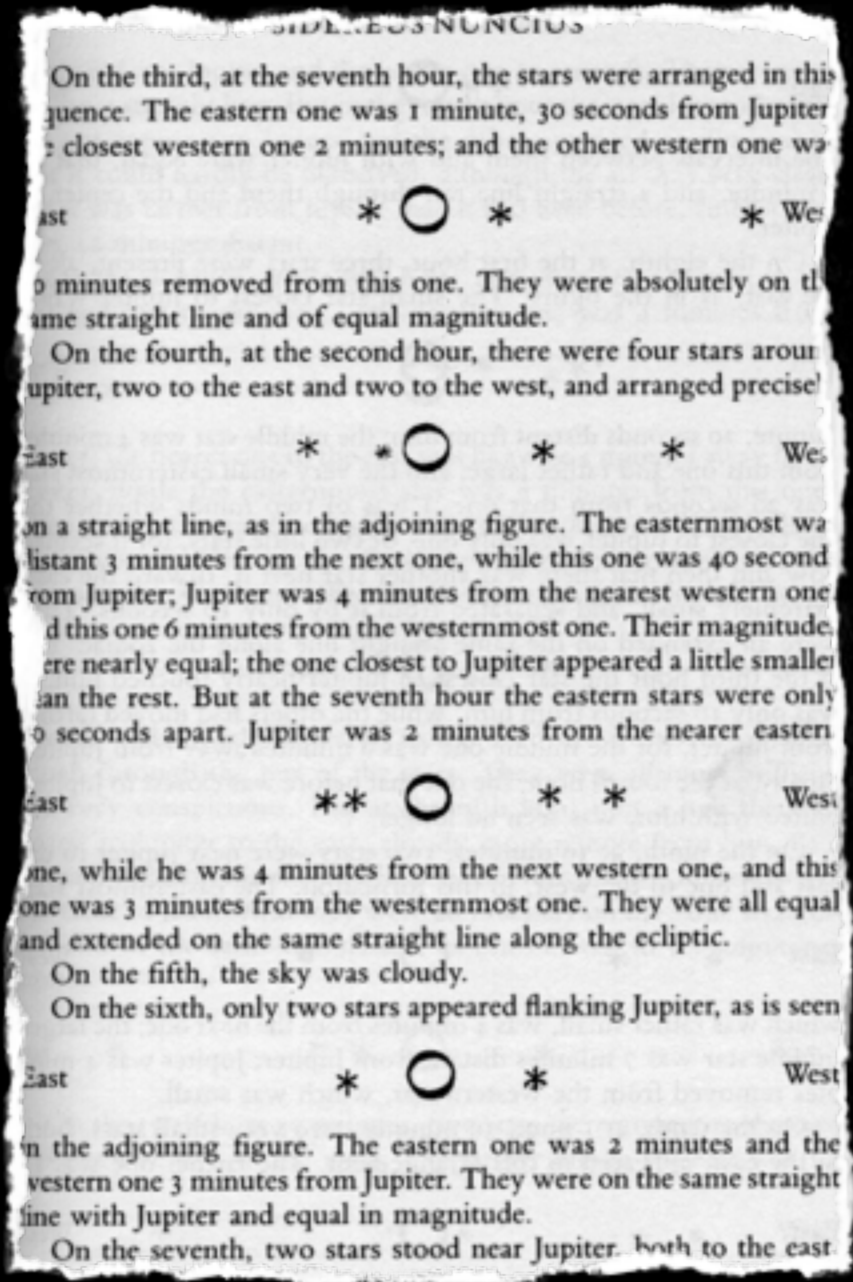


GALILEO GALILEI

(1564-1642)

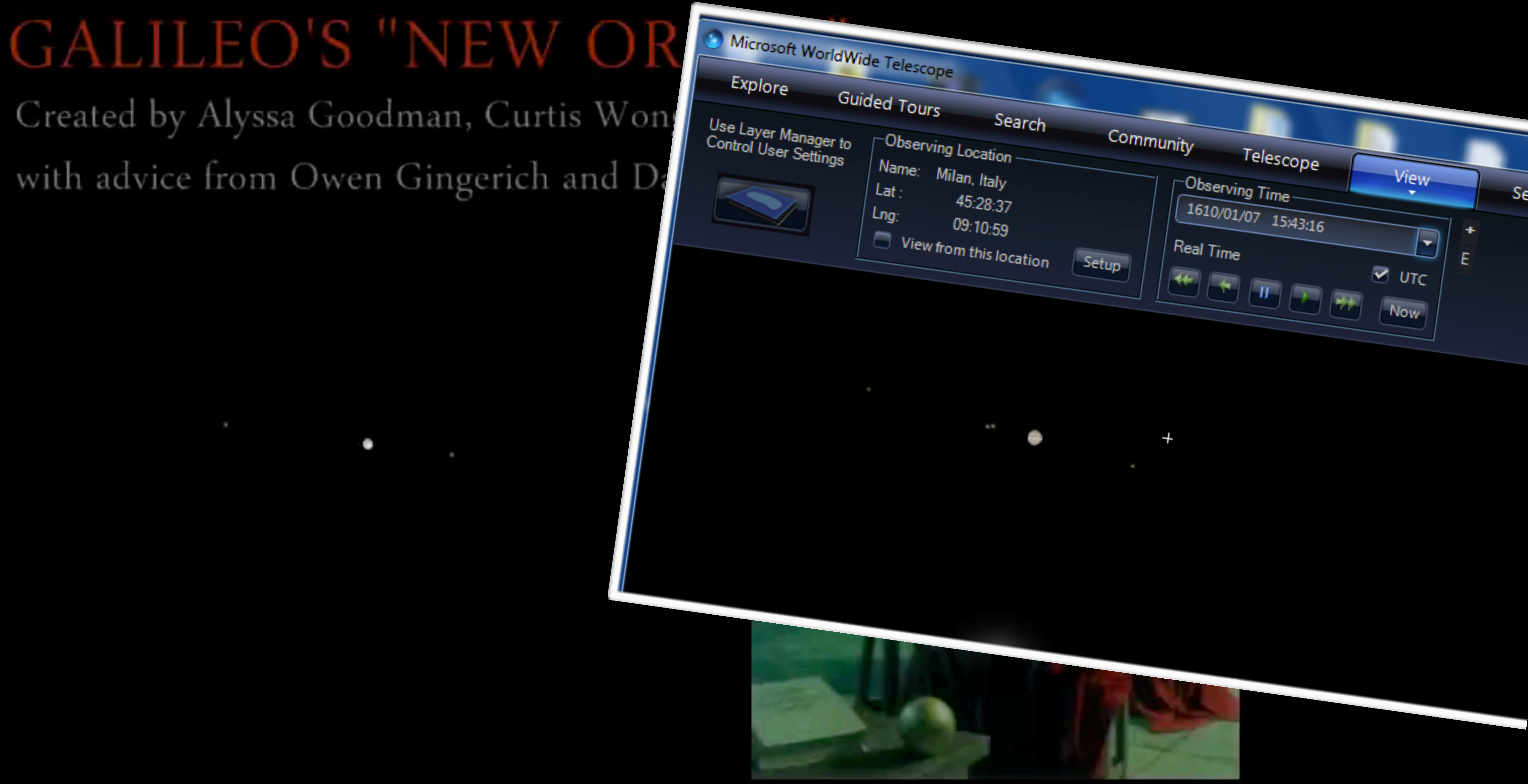






Notes for & re-productions of Siderius Nuncius

RESOLUTION & CONTEXT

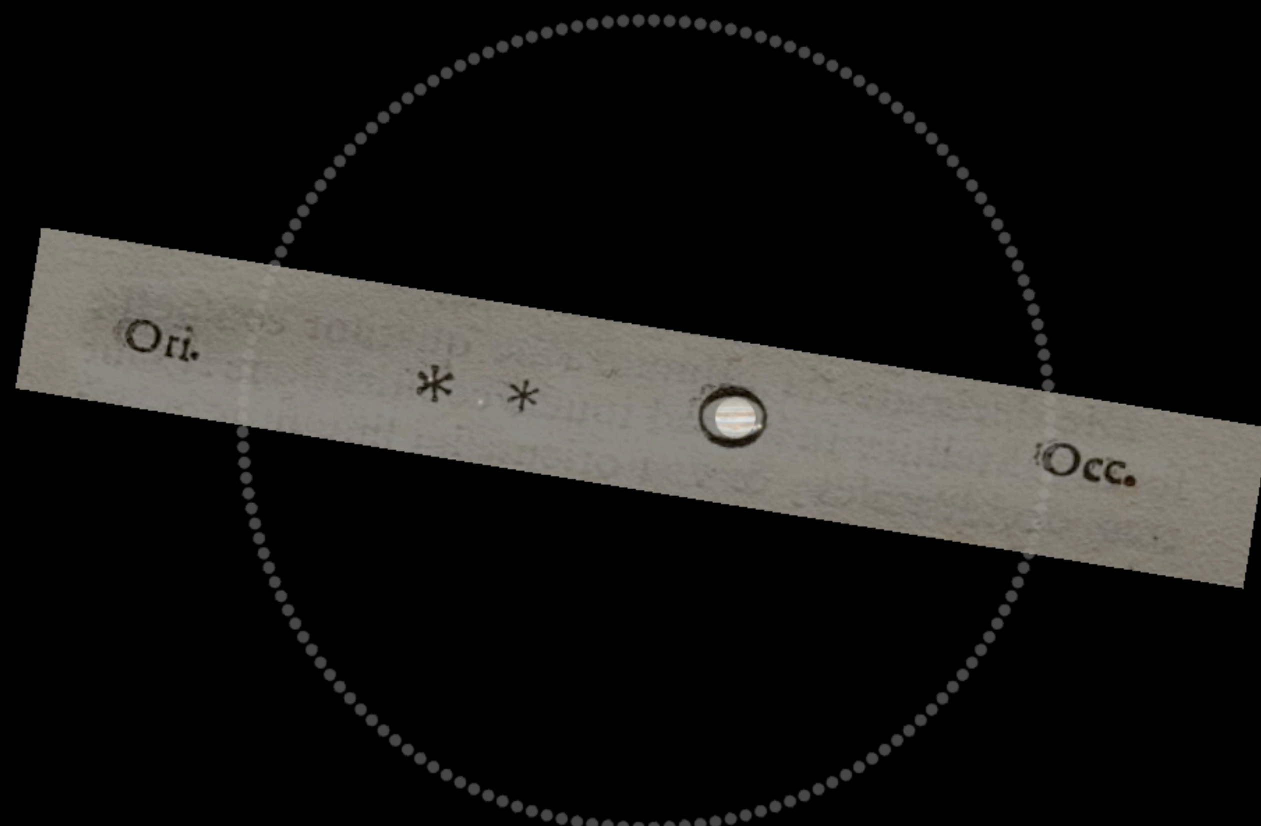


Galileo's New Order, A WorldWide Telescope Tour by Goodman, Wong & Udomprasert 2010
Microsoft Research WWT Software (~now "OpenWWT"): Wong (inventor), Fay (architect), et al.

RESOLUTION & CONTEXT + DIMENSIONALITY

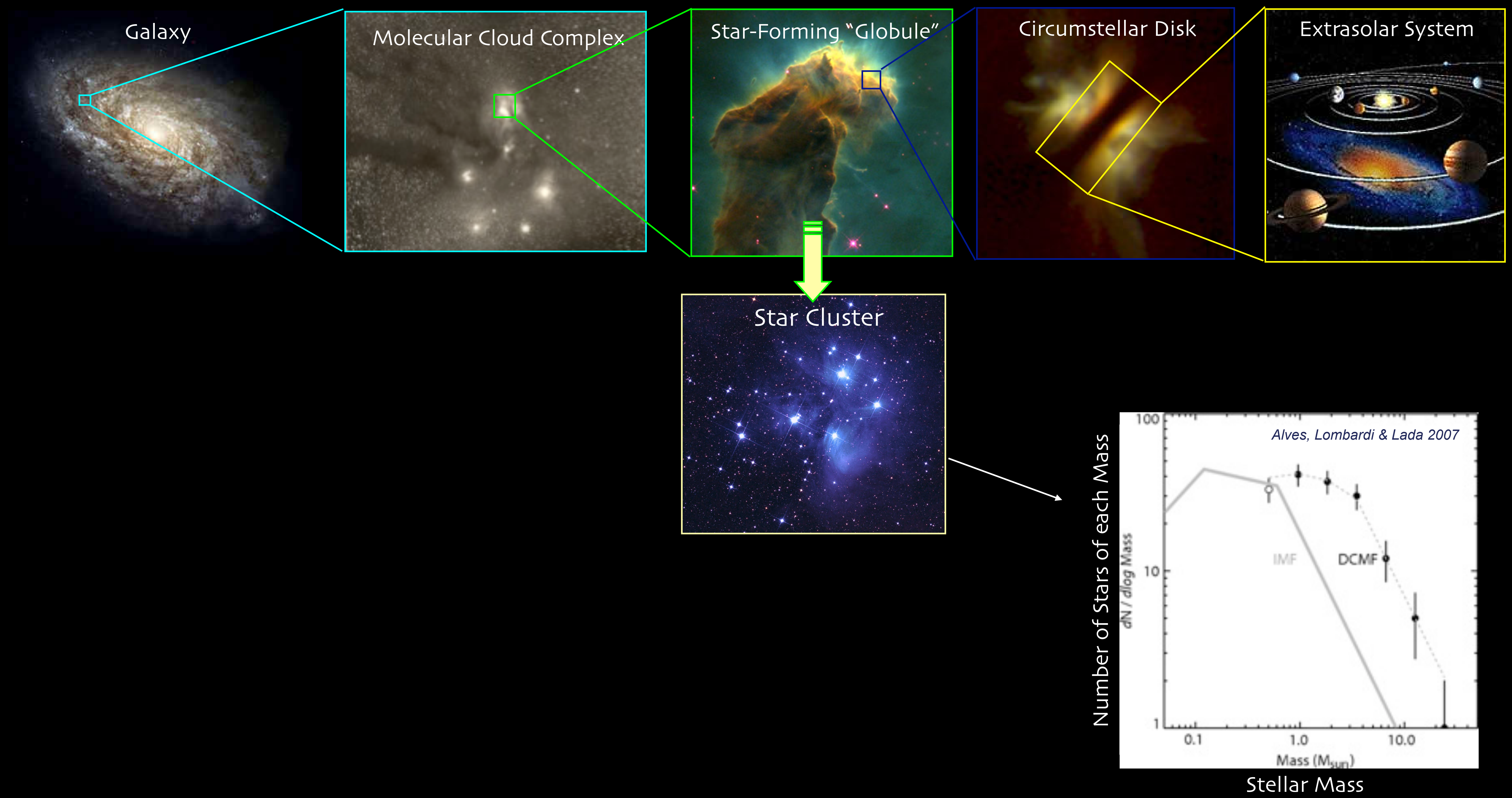
WorldWide Telescope

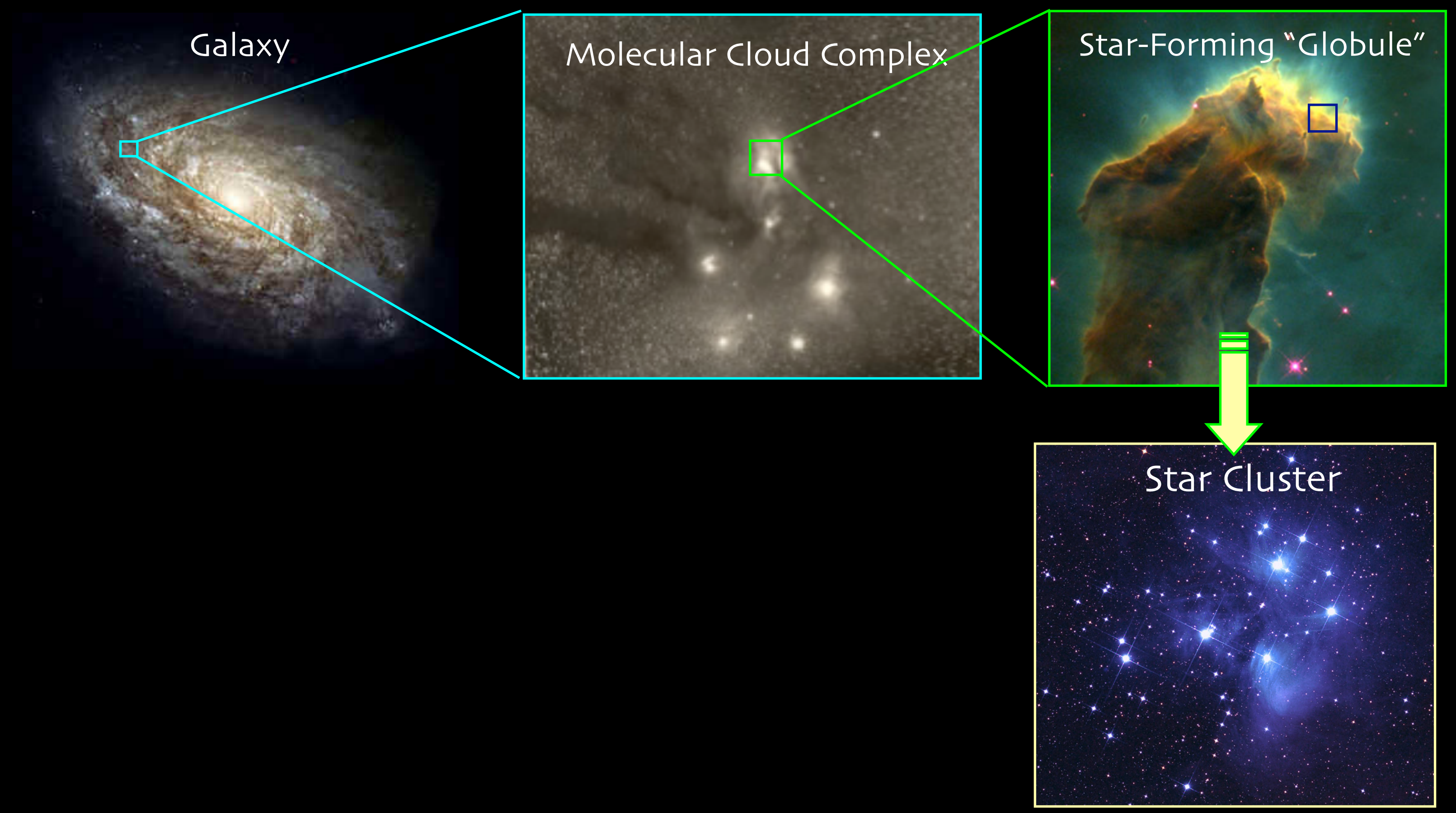
January 11, 1610



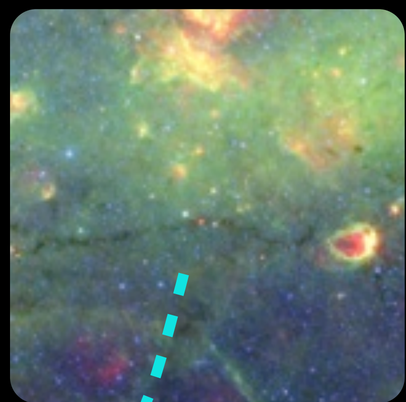
Galileo's New Order, A WorldWide Telescope Tour by Goodman, Wong & Udomprasert 2010
Microsoft Research WWT Software (~now "OpenWWT"): Wong (inventor), Fay (architect), et al.

STAR & PLANET FORMATION IN 1 SLIDE

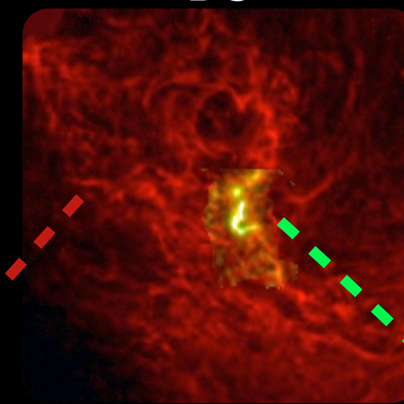


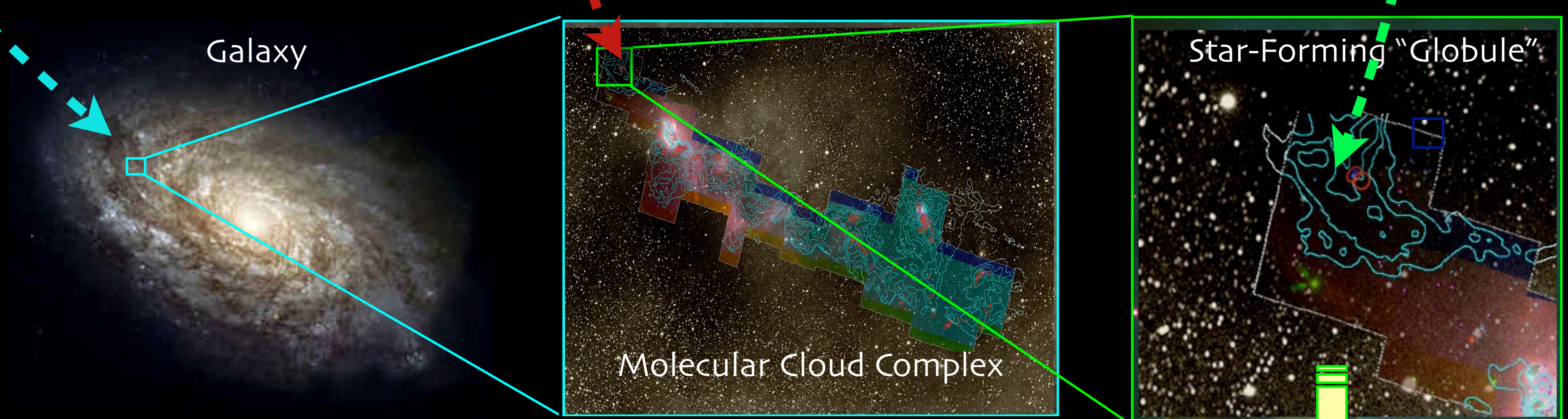

Galaxy
Molecular Cloud Complex
Star-Forming "Globule"
Star Cluster

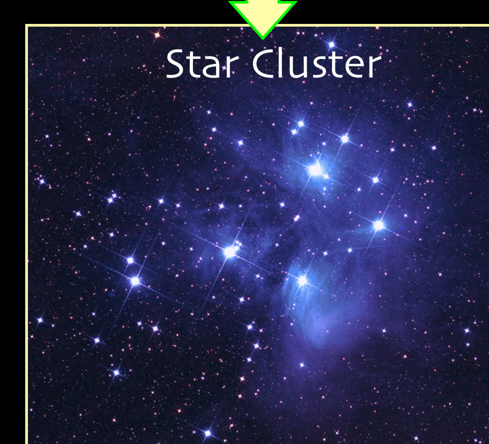
"Nessie"



"B5"

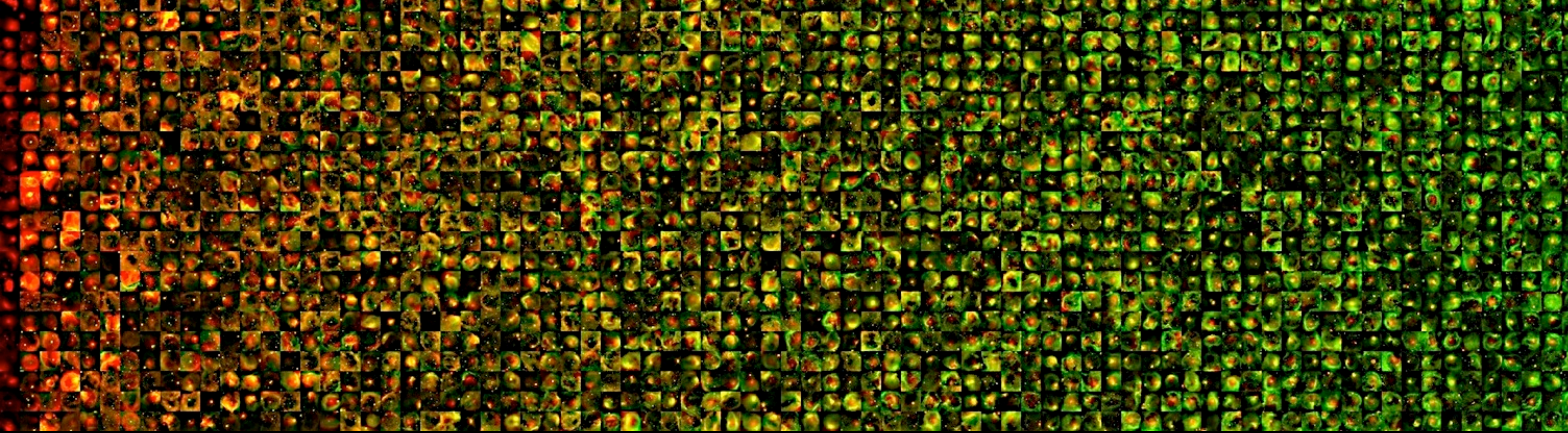




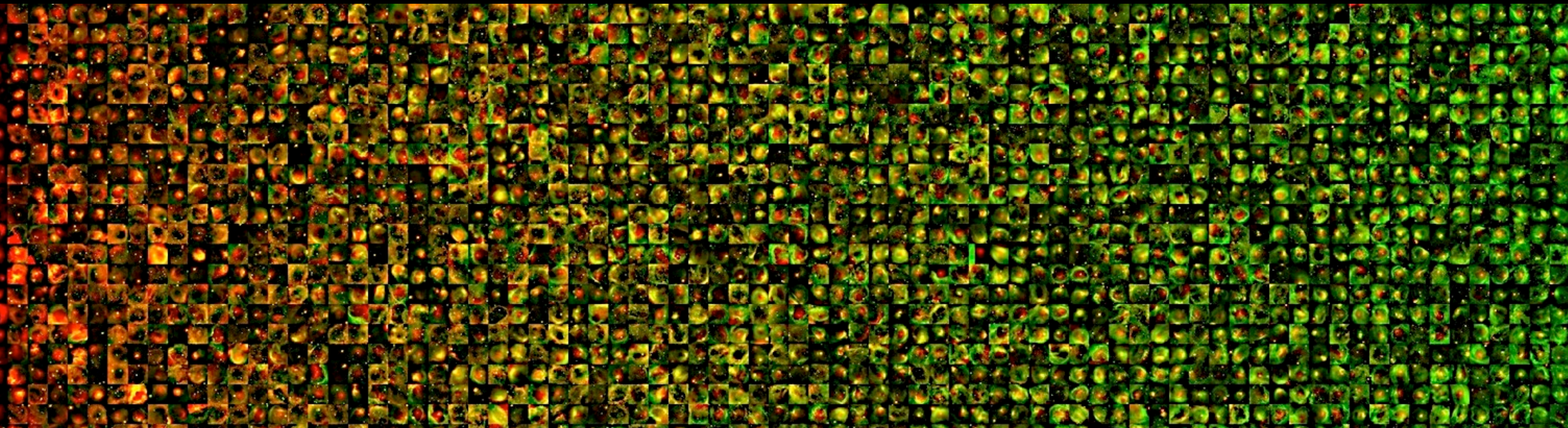


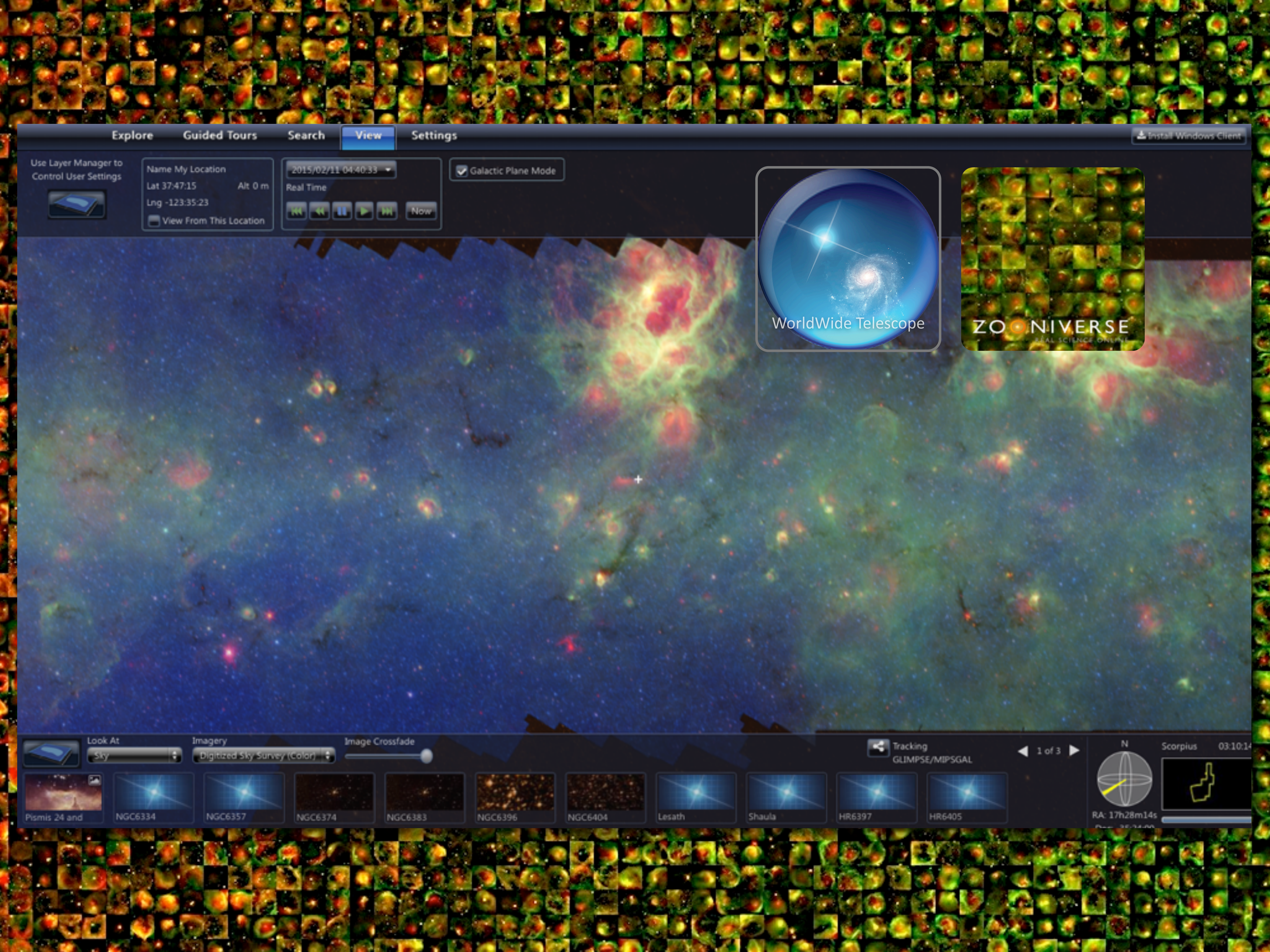
"RESOLUTION & CONTEXT"

(+ DIMENSIONALITY)



BIG DATA, WIDE DATA





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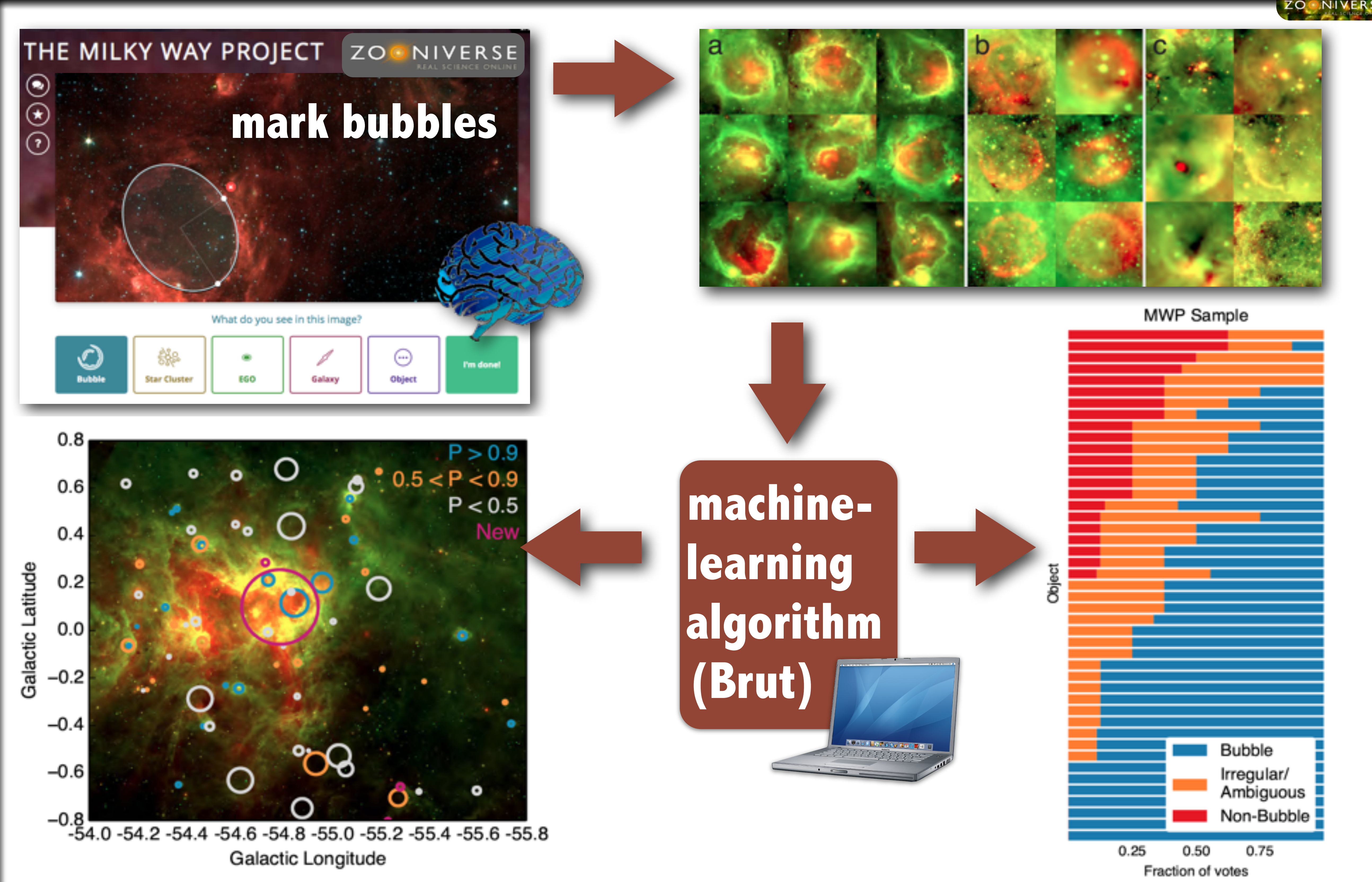
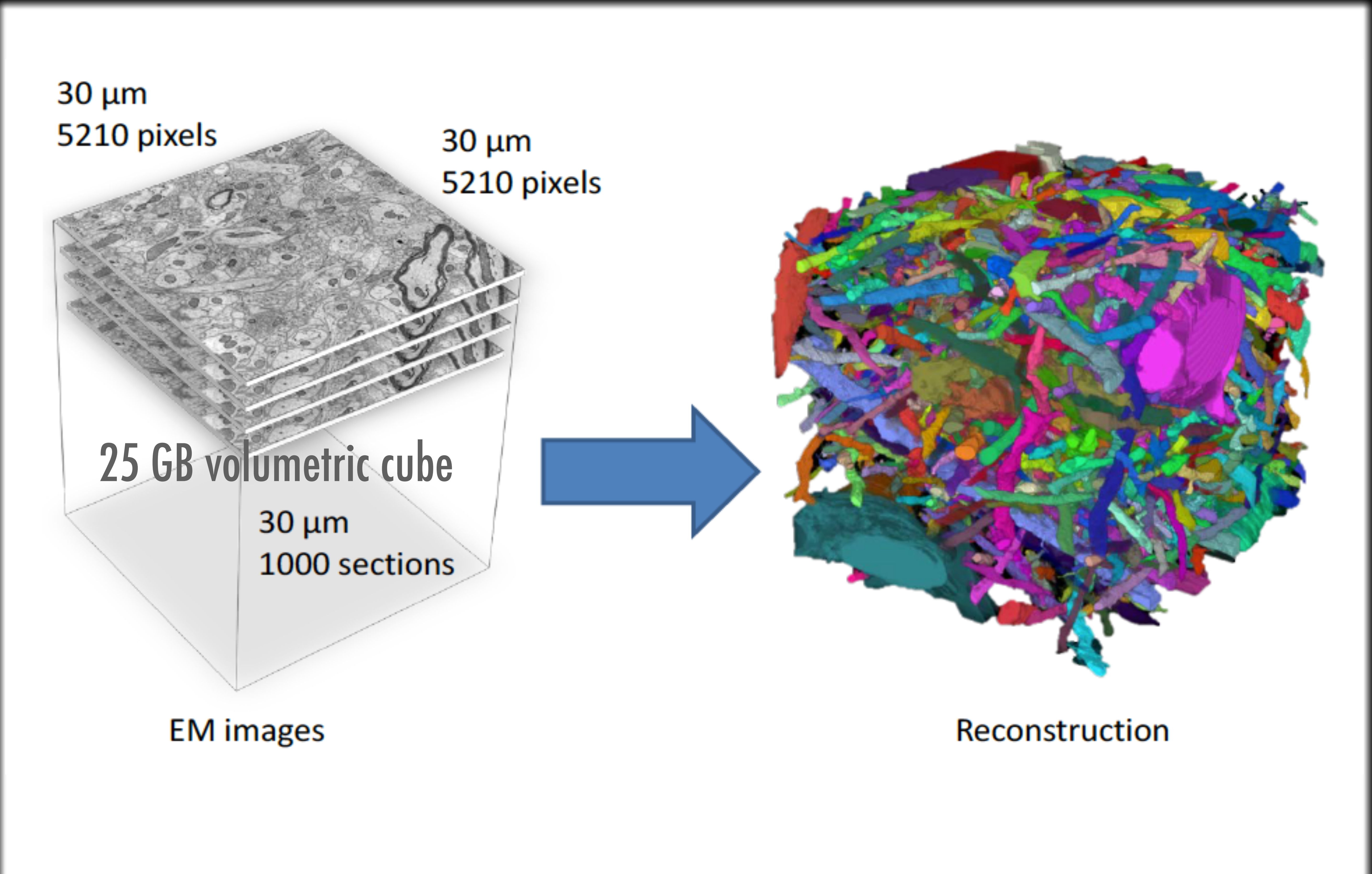
Guided Tours
Search
View
Settings
Install Windows Client
Use Layer Manager to Control User Settings
Name My Location
Lat 37:47:15
Alt 0 m
Lng -123:35:23
View From This Location
2015/02/11 04:40:33
Real Time
Now
Galactic Plane Mode
WorldWide Telescope
ZOONIVERSE
Look At
Sky
Imagery
Digitized Sky Survey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



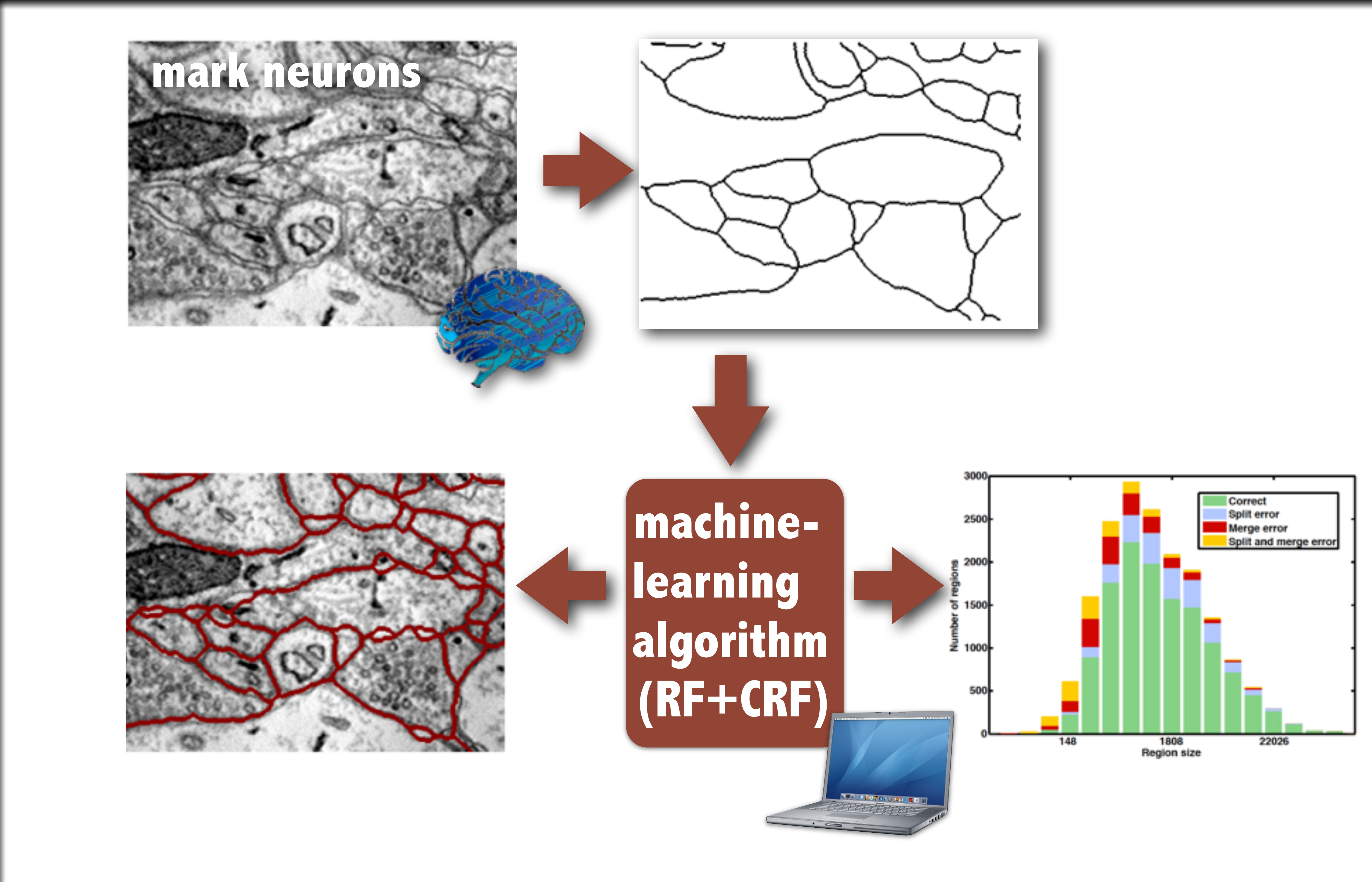
example here from: ***Beaumont****, Goodman, Kendrew, Williams & Simpson 2014; based on* ***Milky Way Project*** *catalog (Simpson et al. 2013), which came from* ***Spitzer/GLIMPSE*** *(Churchwell et al. 2009, Benjamin et al. 2003), cf. Shenoy & Tan 2008 for discussion of HAC;* ***astroml.org*** *for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

BIG DATA AND "HUMAN-AIDED COMPUTING"

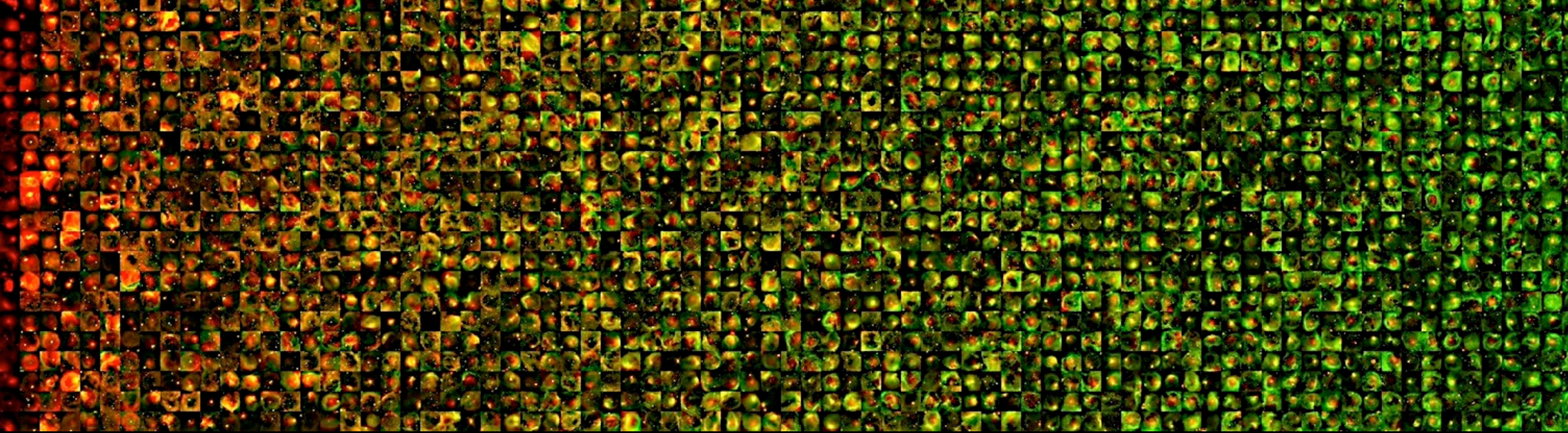


example here from: Kaynig...Lichtman...Pfister et al. 2013, "Large-Scale Automatic Reconstruction of Neuronal Processes from Electron Microscopy Images"; cf. Shenoy & Tan 2008 for discussion of HAC; ***astroml.org*** *for machine learning advice/tools*

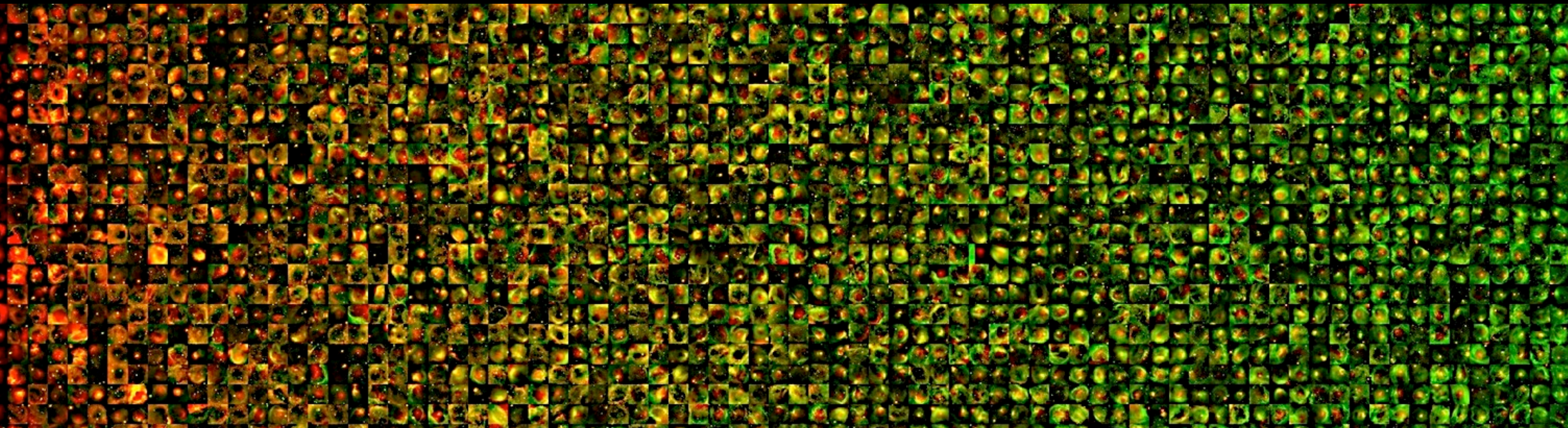
BIG DATA AND "HUMAN-AIDED COMPUTING"



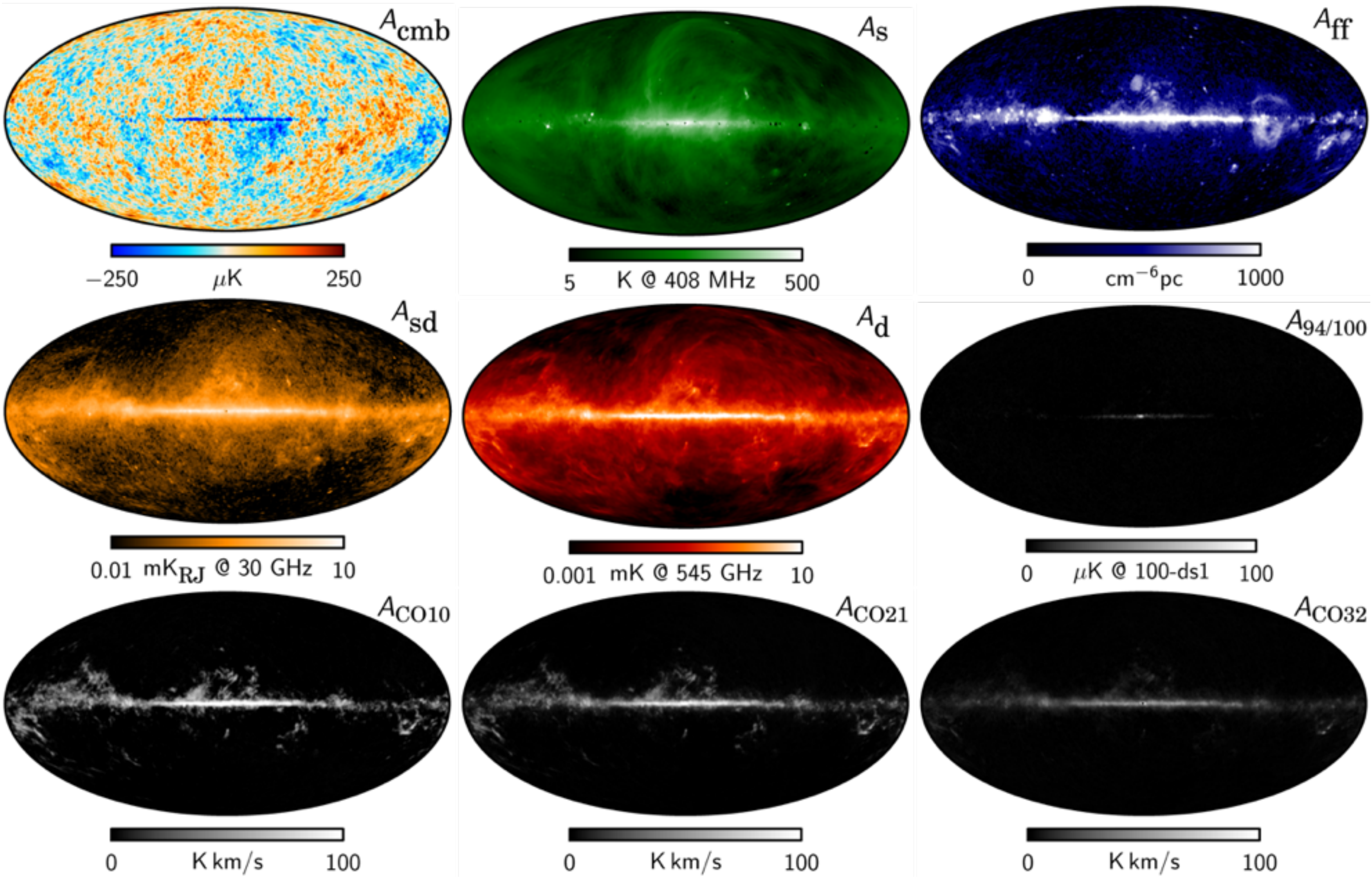
example here from: Kaynig...Lichtman...Pfister et al. 2013, "Large-Scale Automatic Reconstruction of Neuronal Processes from Electron Microscopy Images"; cf. Shenoy & Tan 2008 for discussion of HAC; ***astroml.org*** *for machine learning advice/tools (Note: RF=Random Forest; CRF=Conditional Random Fields.)*



BIG DATA, WIDE DATA



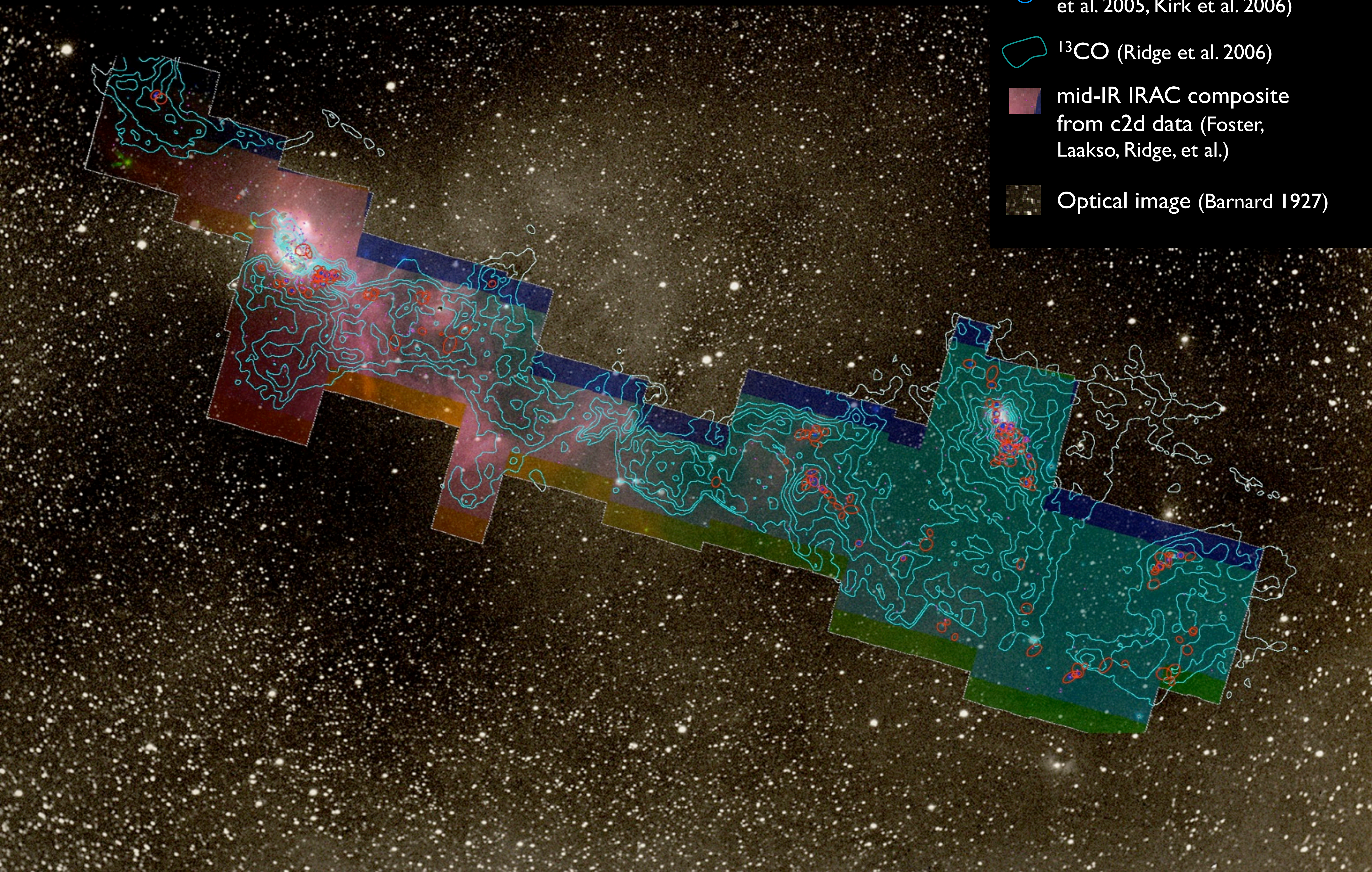
WIDE DATA

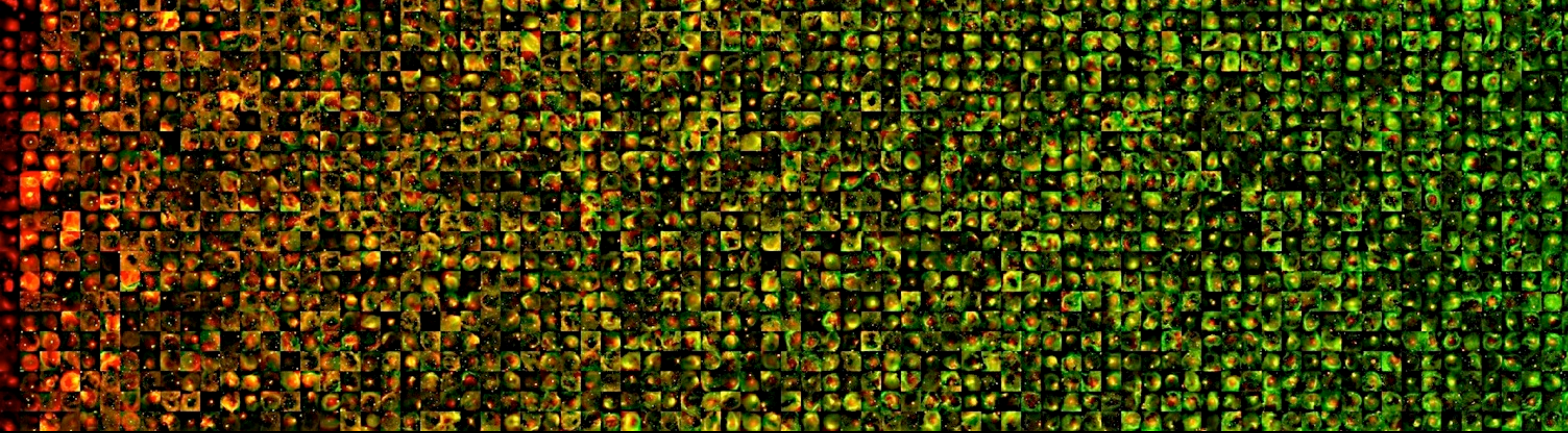


Temperature Foreground amplitudes from Commander, Planck Data [Feb 2015]

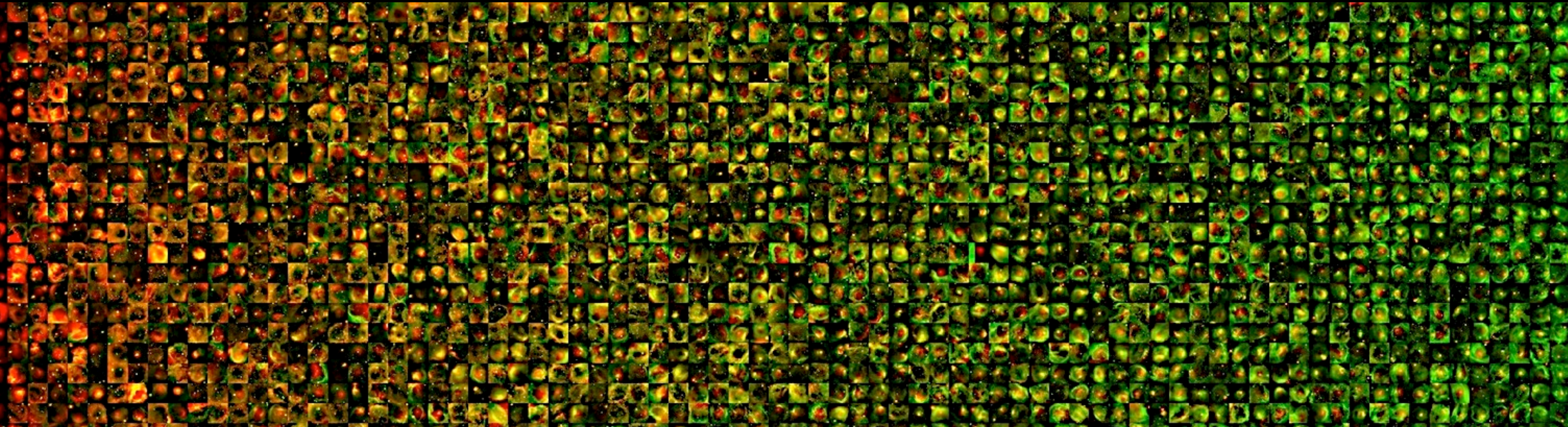
WIDE DATA

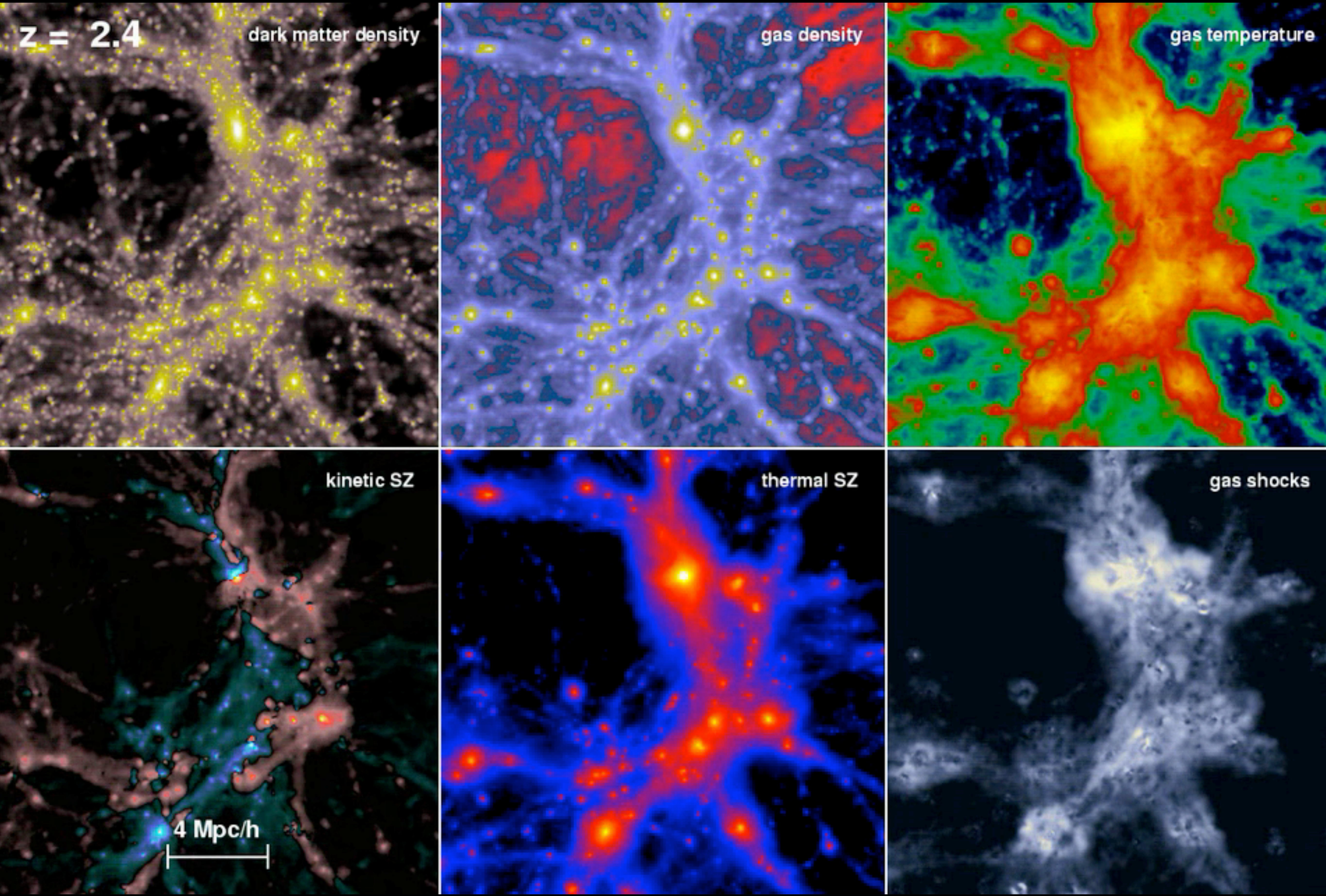
COMPLETE





BIG AND WIDE DATA





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

RESOLUTION

CONTEXT

BIG DATA

WIDE DATA

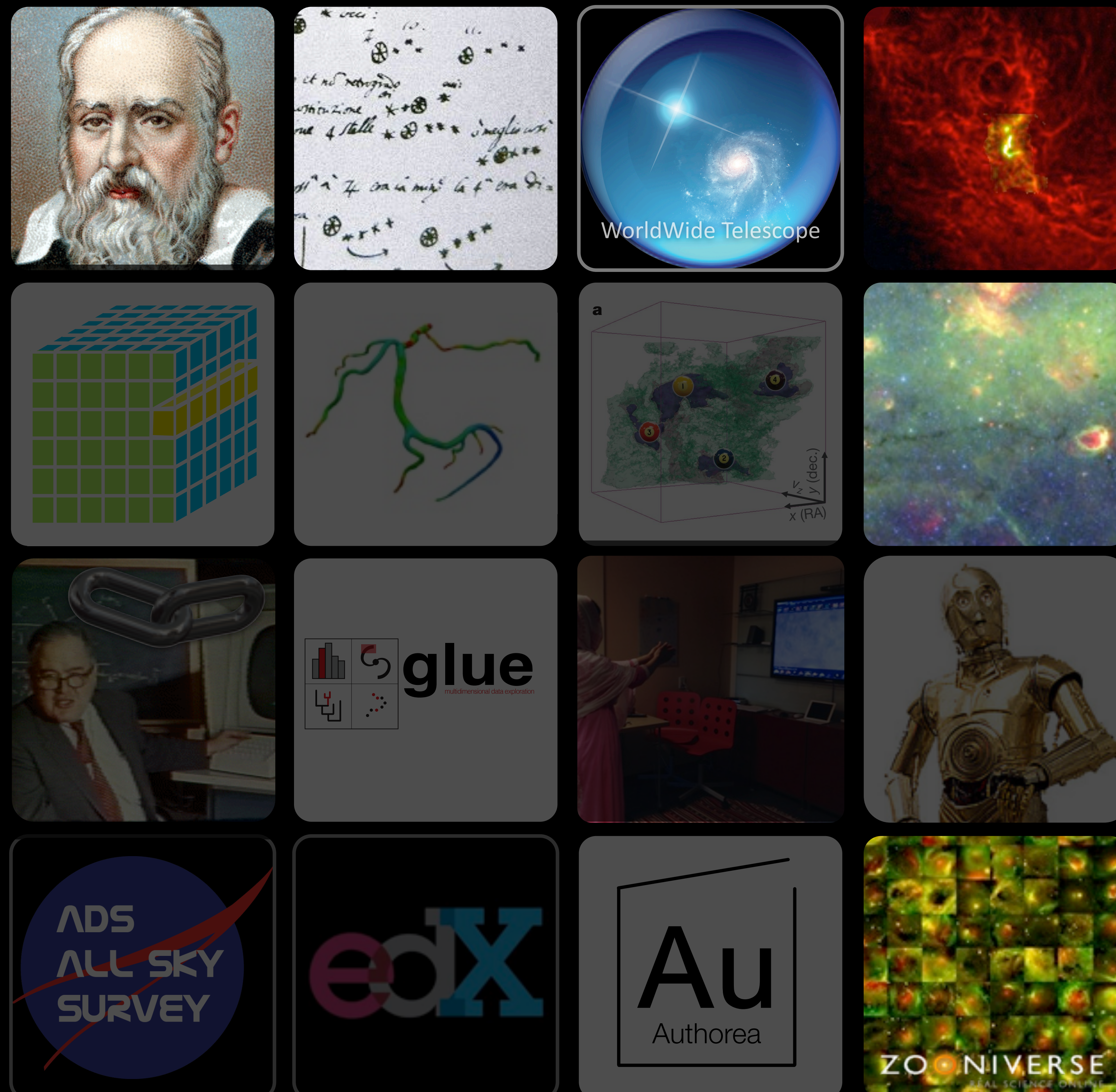
DIMENSIONALITY

LINKED VIEWS

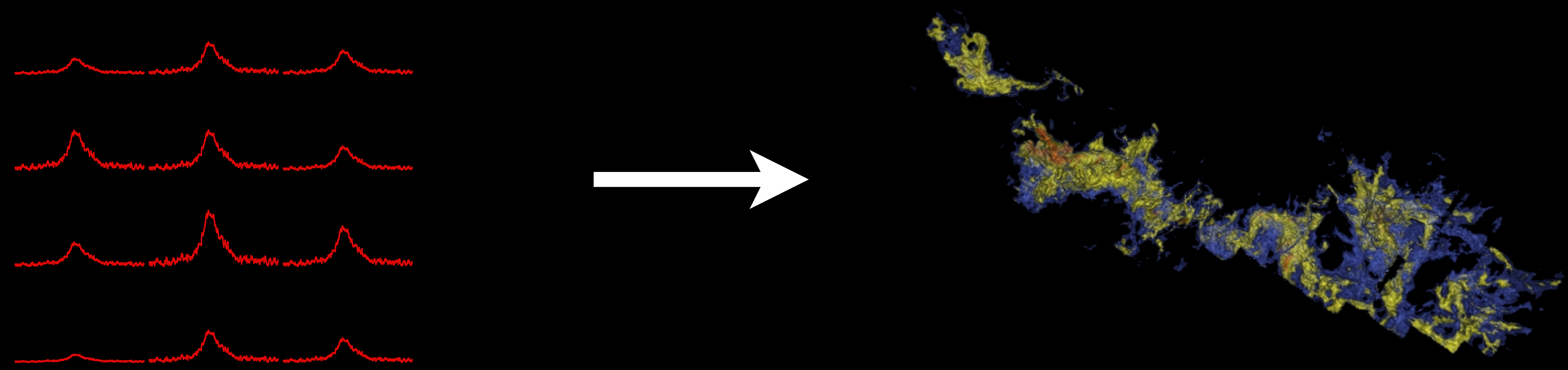
INTERACTION

COMMUNICATION

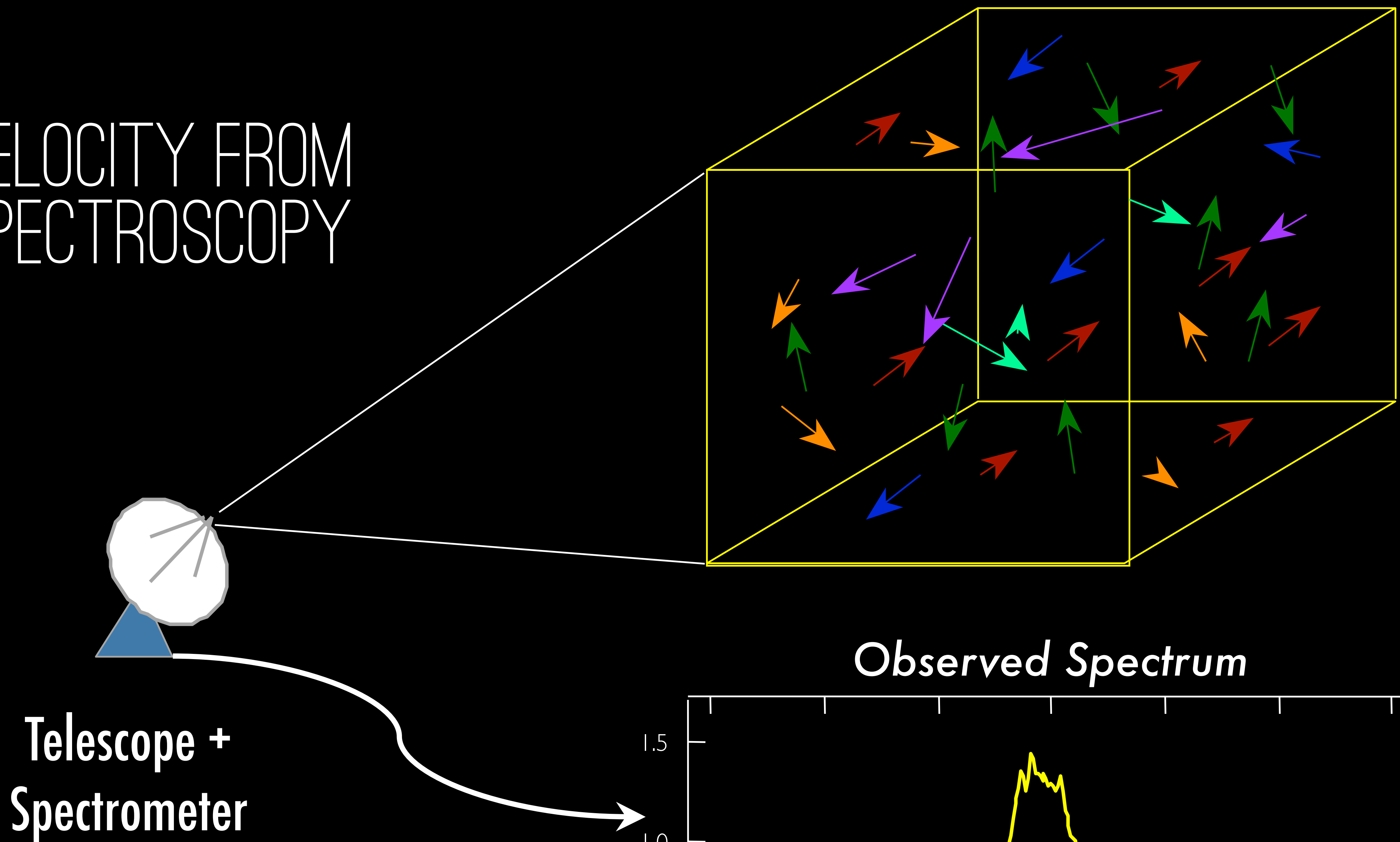
EDUCATION

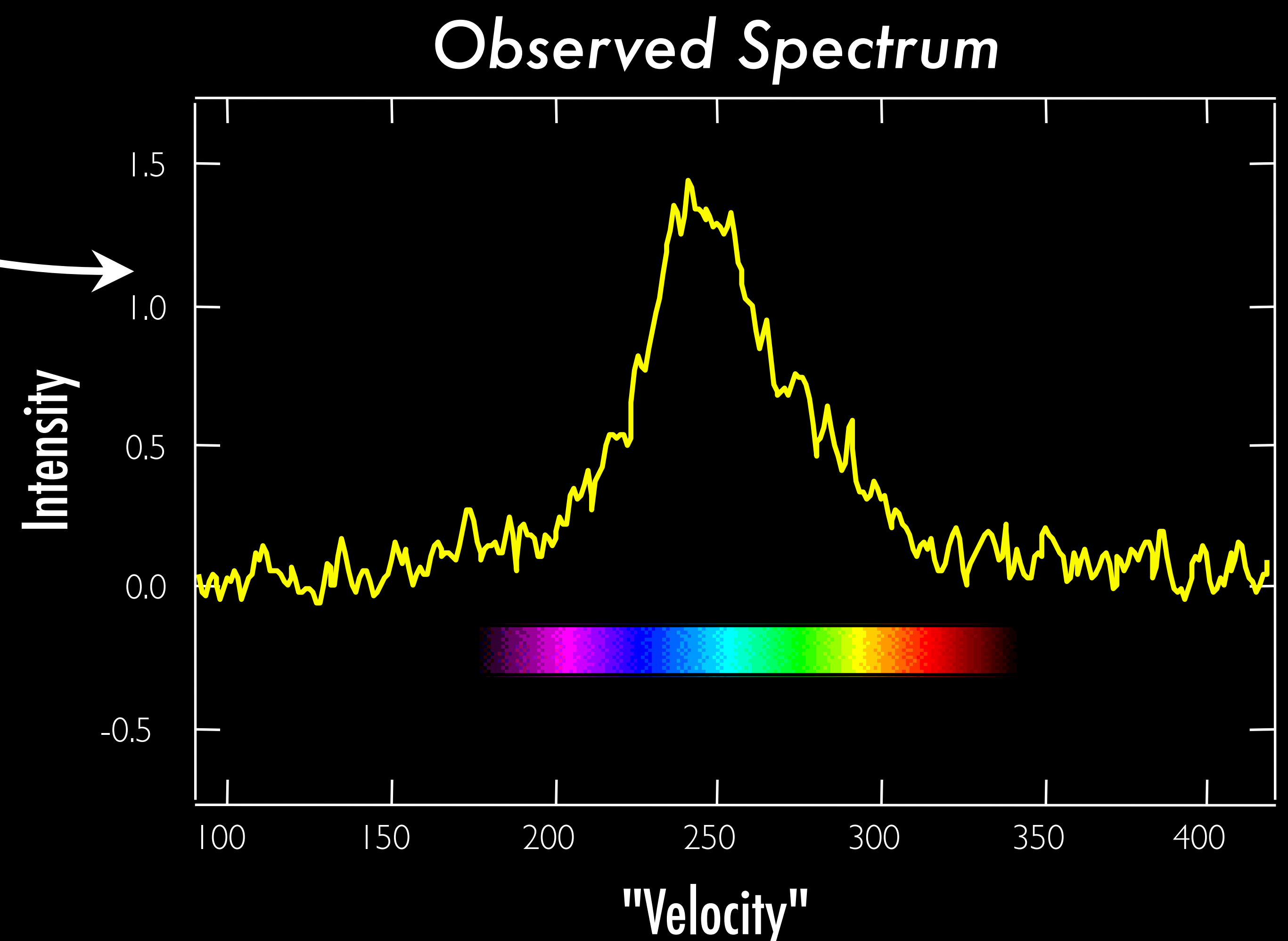


ADDING A THIRD DIMENSION



VELOCITY FROM SPECTROSCOPY

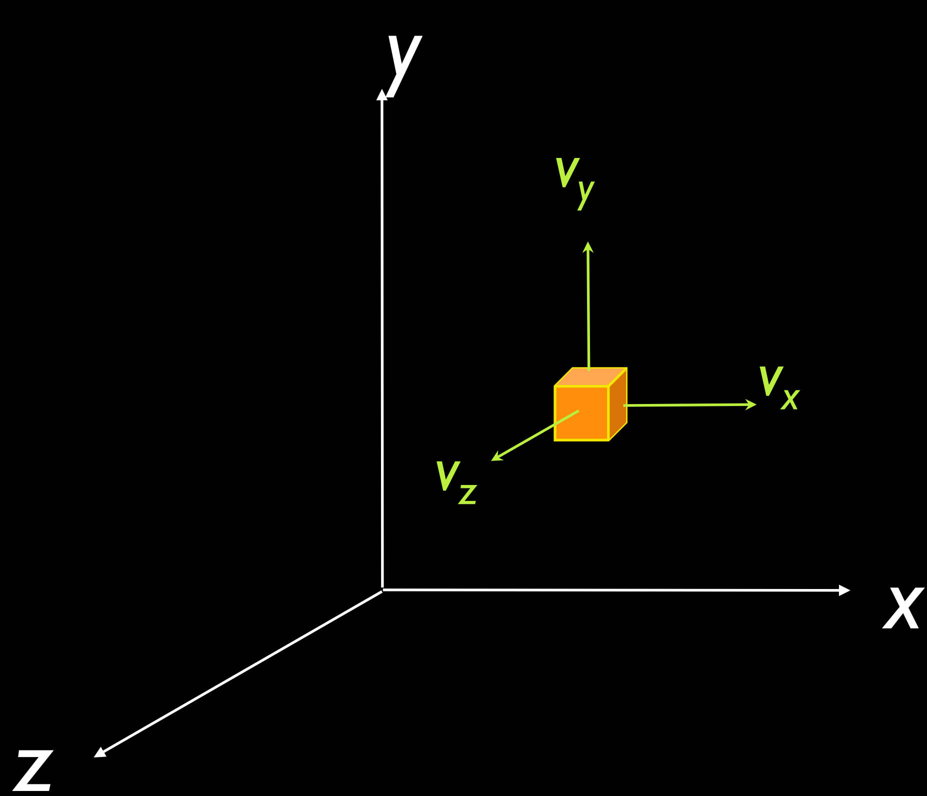




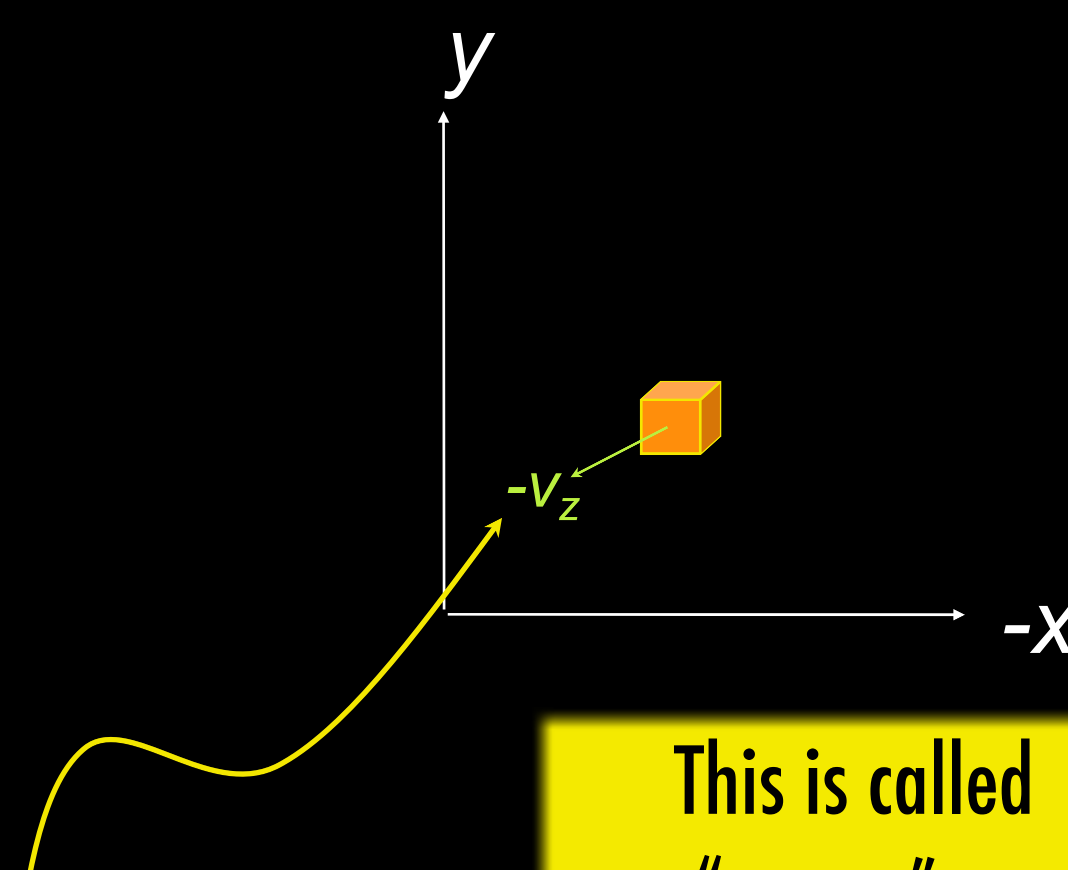
All thanks to Doppler

SPECTRAL-LINE MAPPING GIVES A "THIRD" DIMENSION

We wish we could measure...



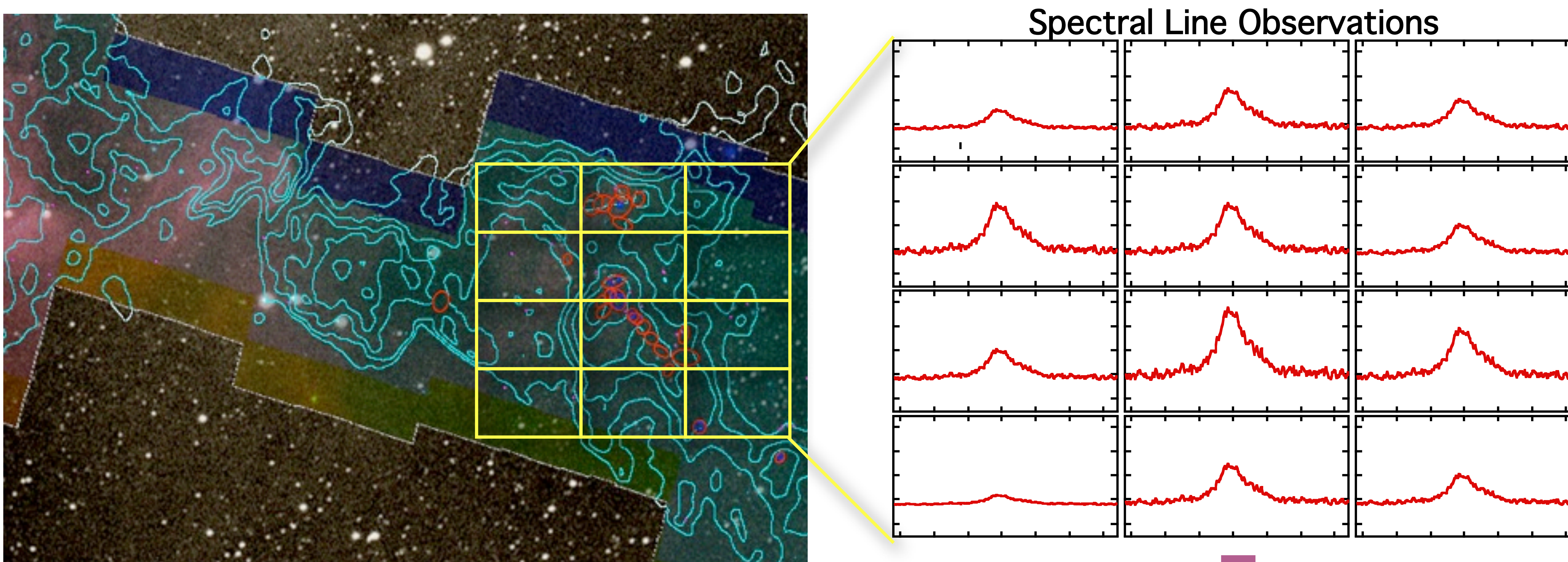
But we can measure...

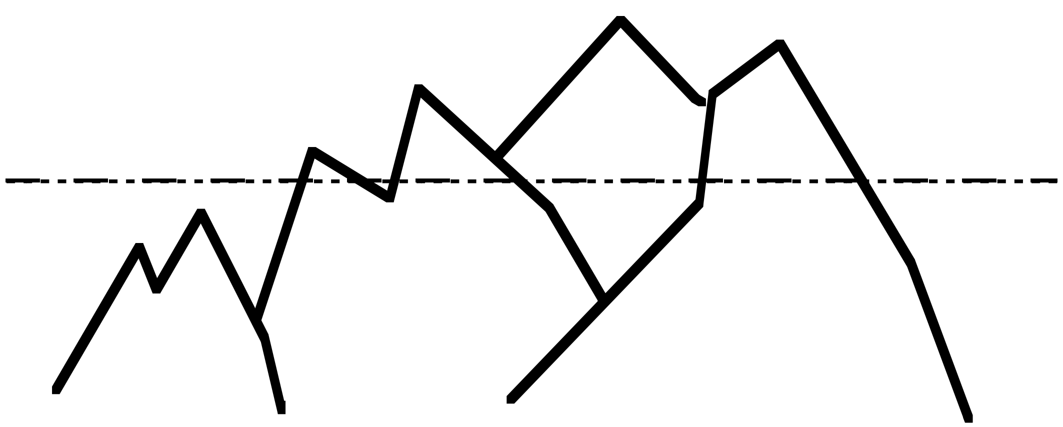


v_z only
from
"spectral-line maps"

This is called
"*p-p-v*" or
"position-position-velocity" space.

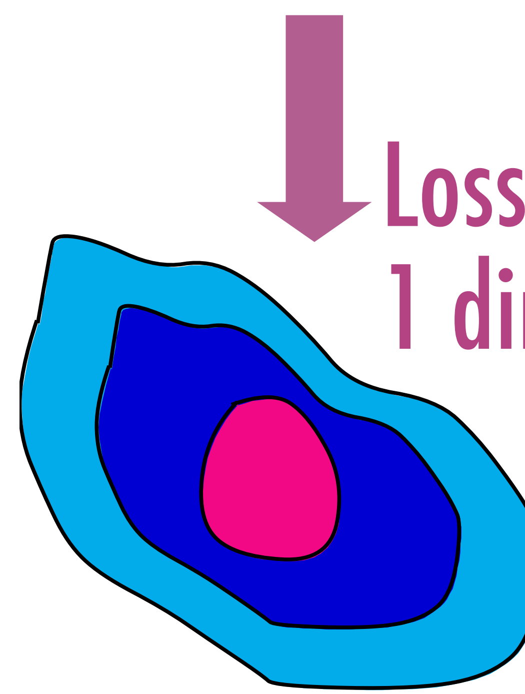
THIRD DIMENSION OFTEN HIDDEN



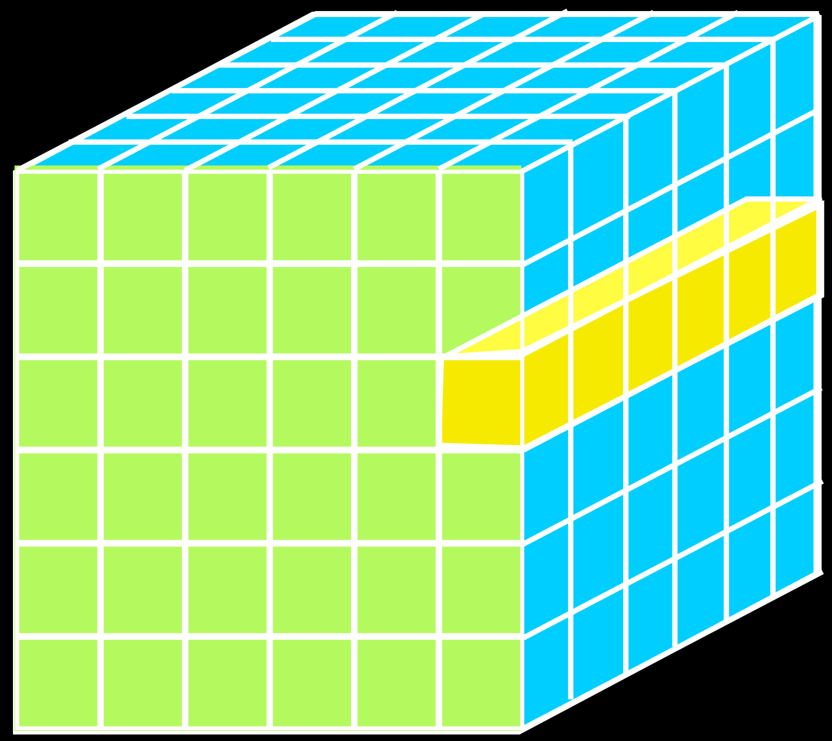


Mountain Range

No loss of information



Loss of 1 dimension



"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"

WIDE DATA, "IN 3D"

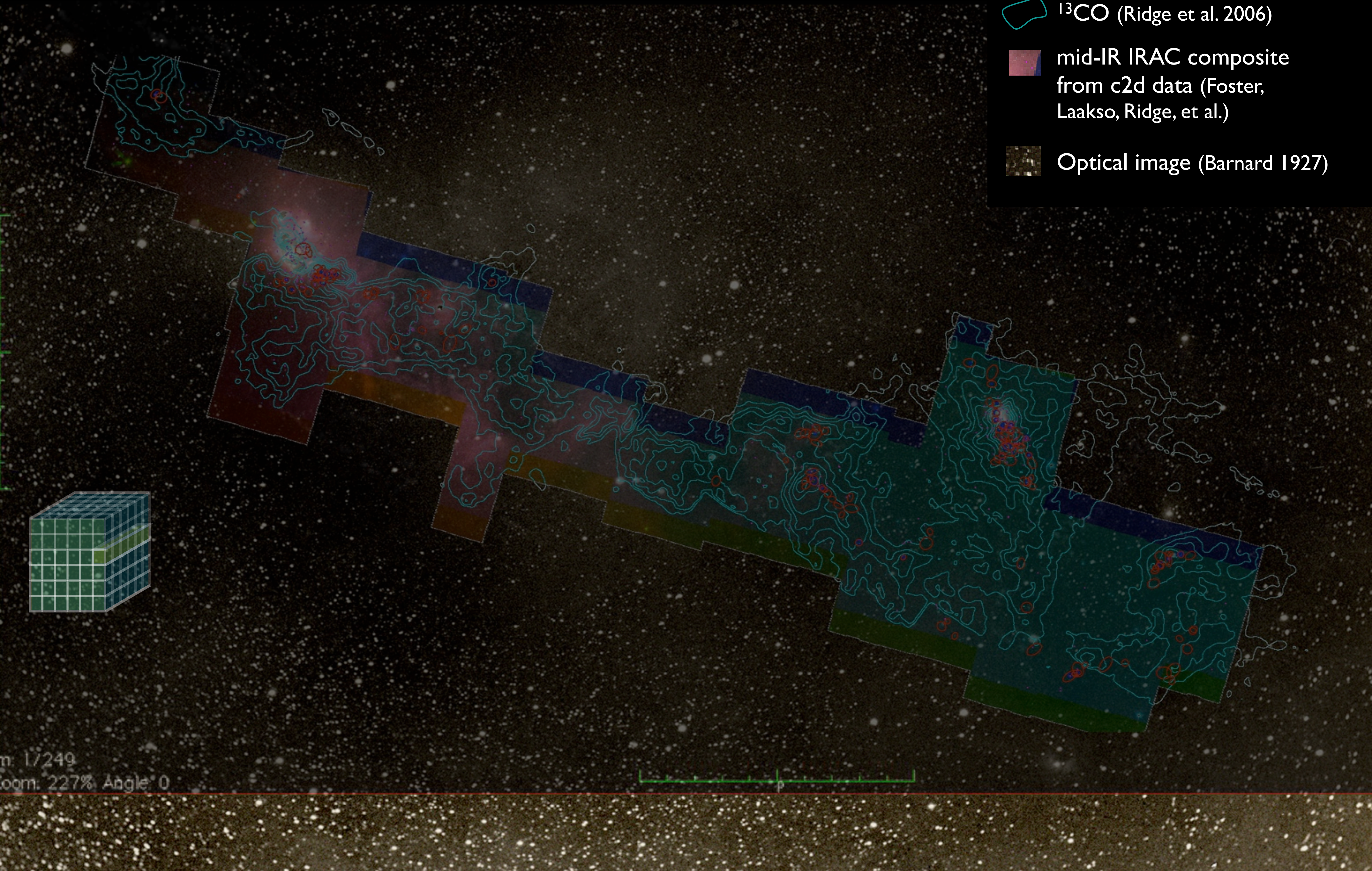
mm peak (Enoch et al. 2006)

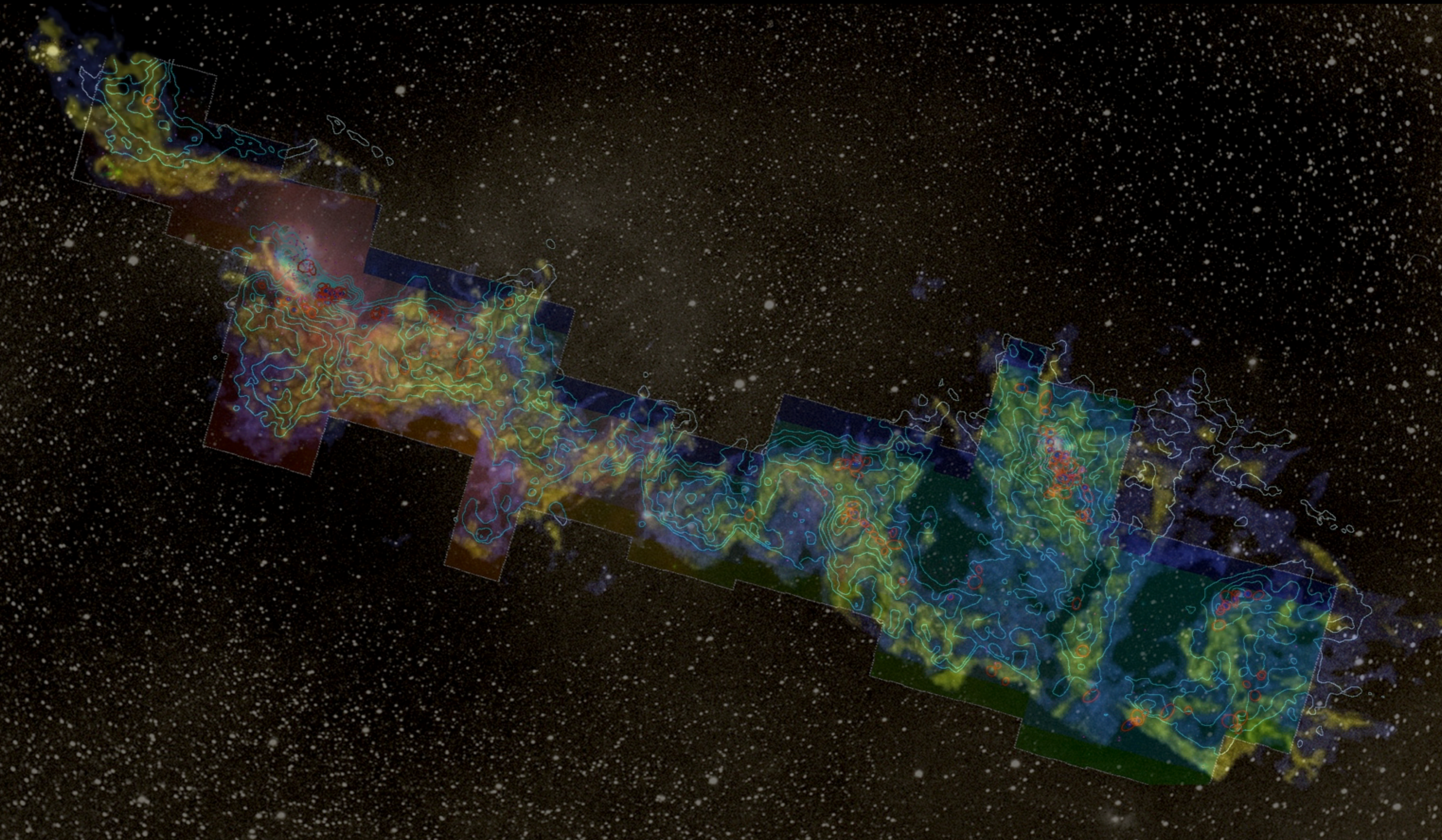
sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)

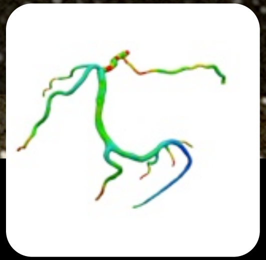
^{13}CO (Ridge et al. 2006)

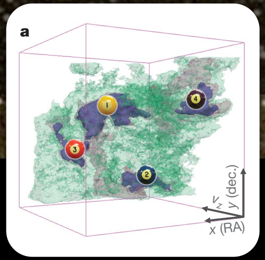
mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al.)

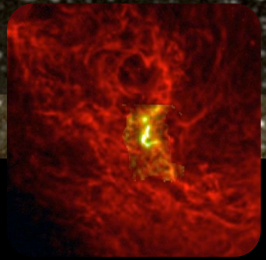
Optical image (Barnard 1927)







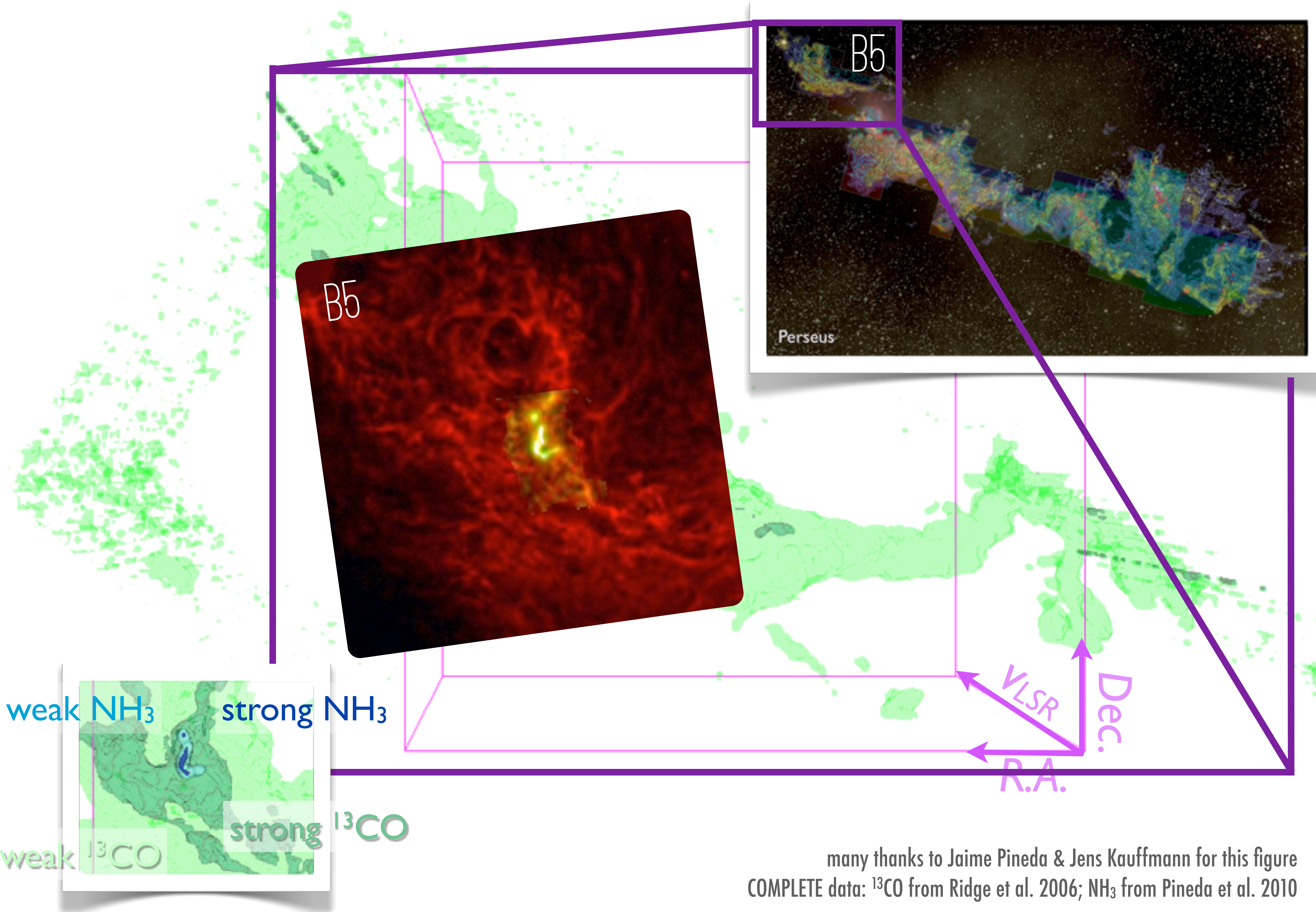




AstronomicalMedicine@IIC

COMPLETE

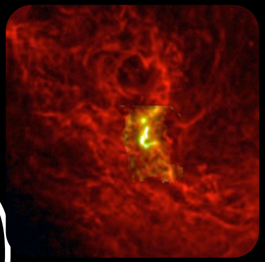
RESOLUTION, CONTEXT, DIMENSIONALITY, WIDE DATA

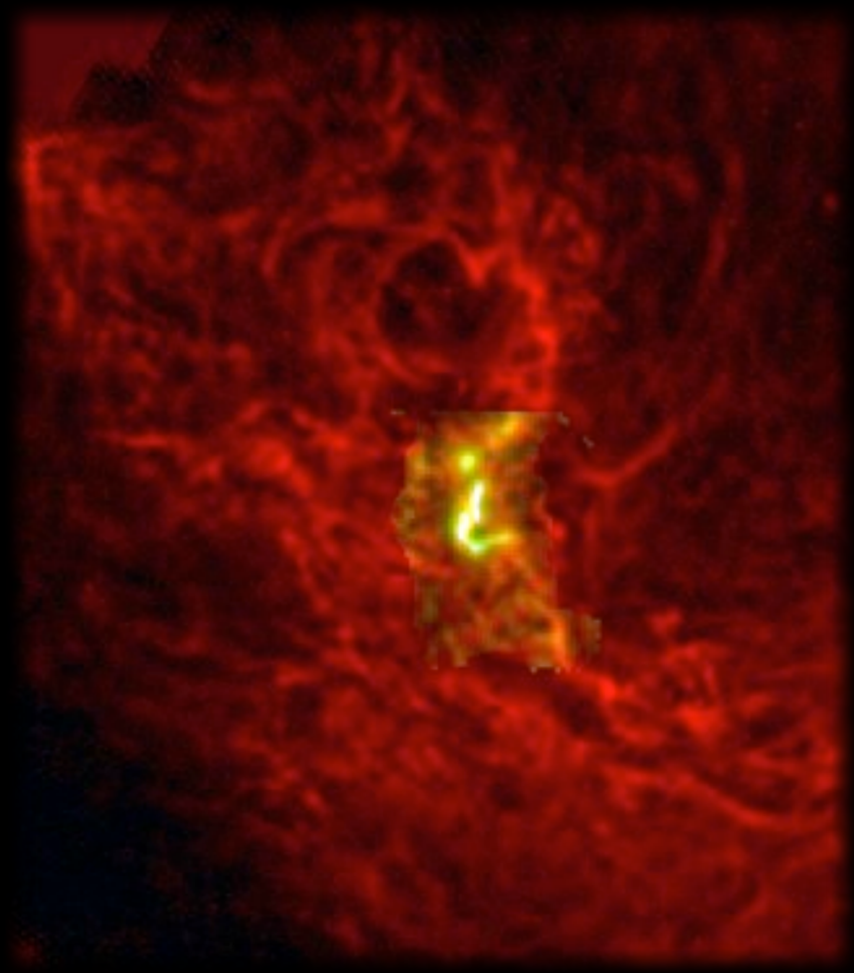


many thanks to Jaime Pineda & Jens Kauffmann for this figure

COMPLETE data: ^{13}CO from Ridge et al. 2006; NH_3 from Pineda et al. 2010

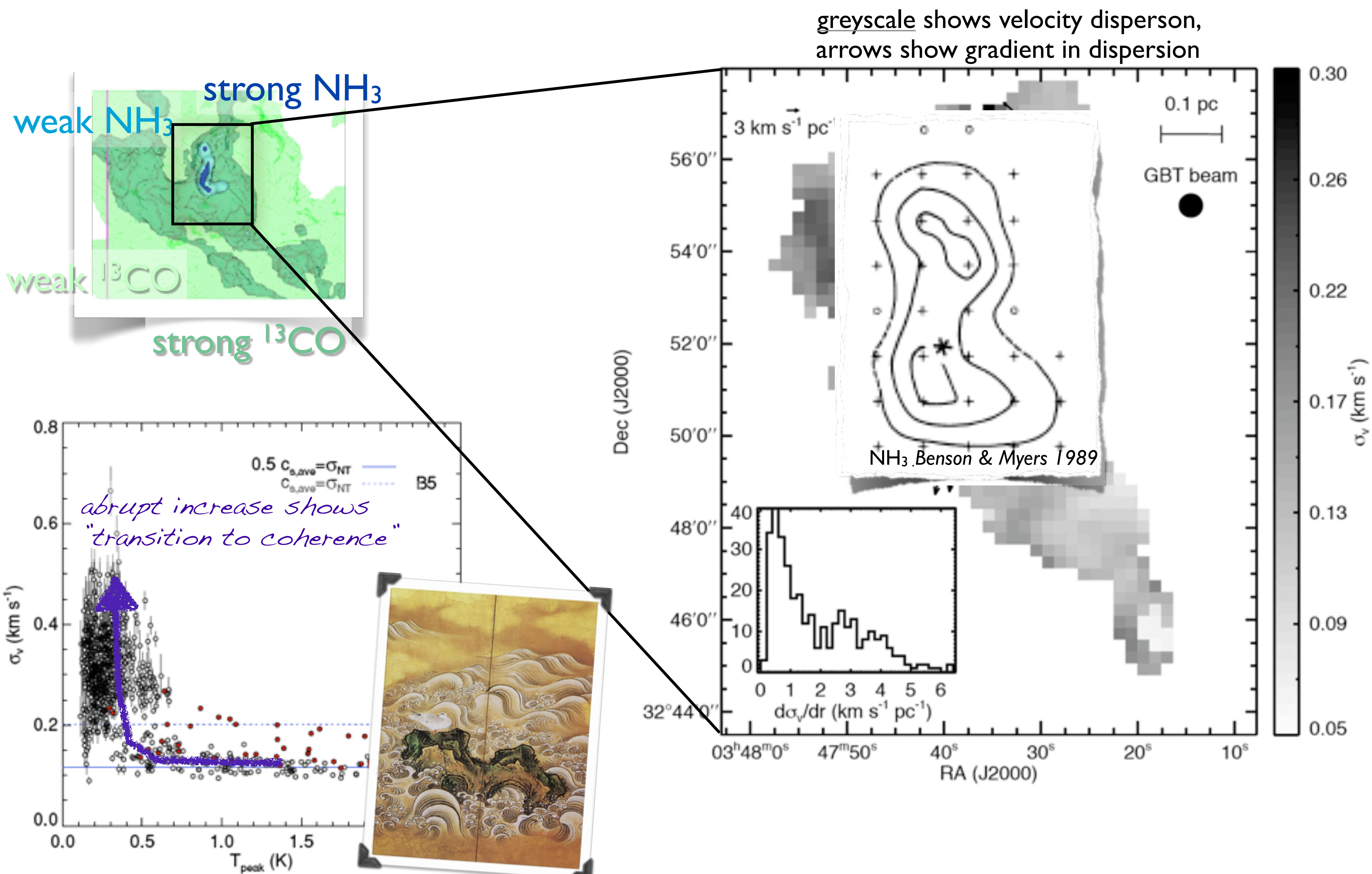
COHERENT CORES
"ISLANDS OF CALM IN TURBULENT SEAS"(?)





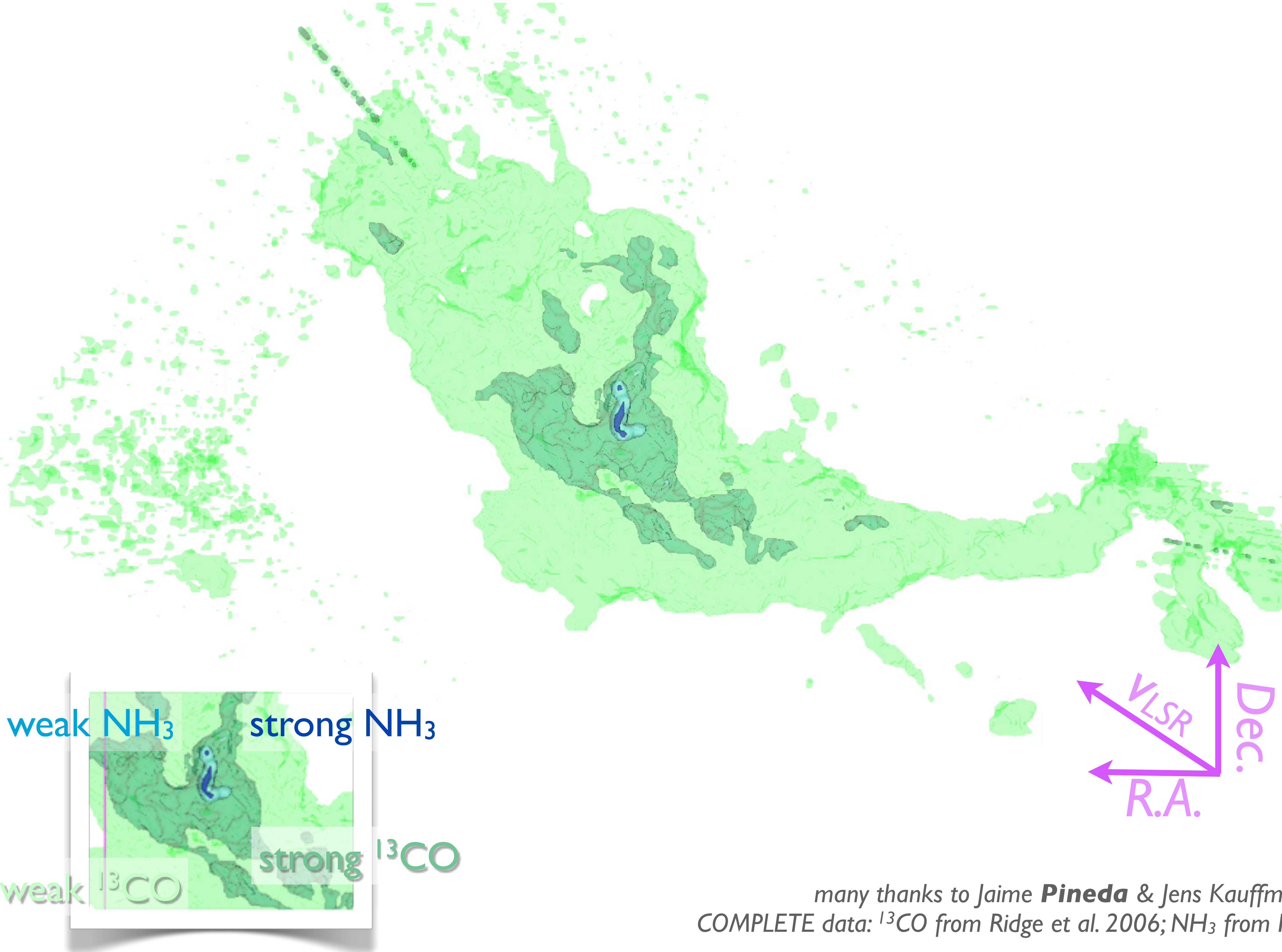
30-year story: Myers & Benson 1983, Goodman et al. 1998, Pineda et al. 2010, 2011, 2014

2010: "HIGH" RESOLUTION→EVIDENCE FOR "COHERENCE" IN DENSE CORES



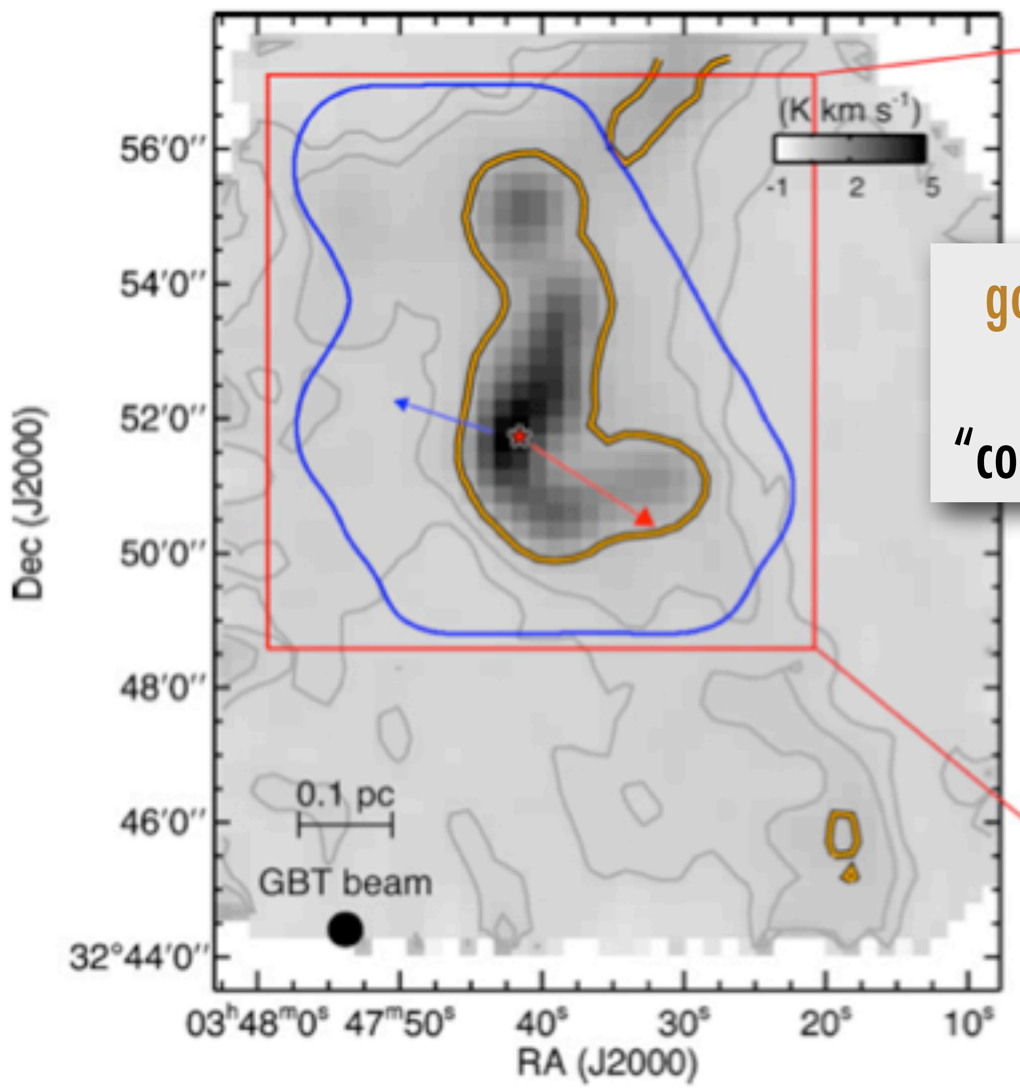
GBT NH_3 observations of the B5 core (Pineda et al. 2010)

DIMENSIONALITY: COHERENT CORE BURIED WITHIN B5



*many thanks to Jaime **Pineda** & Jens Kauffmann for this figure*
COMPLETE data: ^{13}CO from Ridge et al. 2006; NH_3 from Pineda et al. 2010

EVEN HIGHER RESOLUTION… UNEXPECTED SUB-STRUCTURE?!

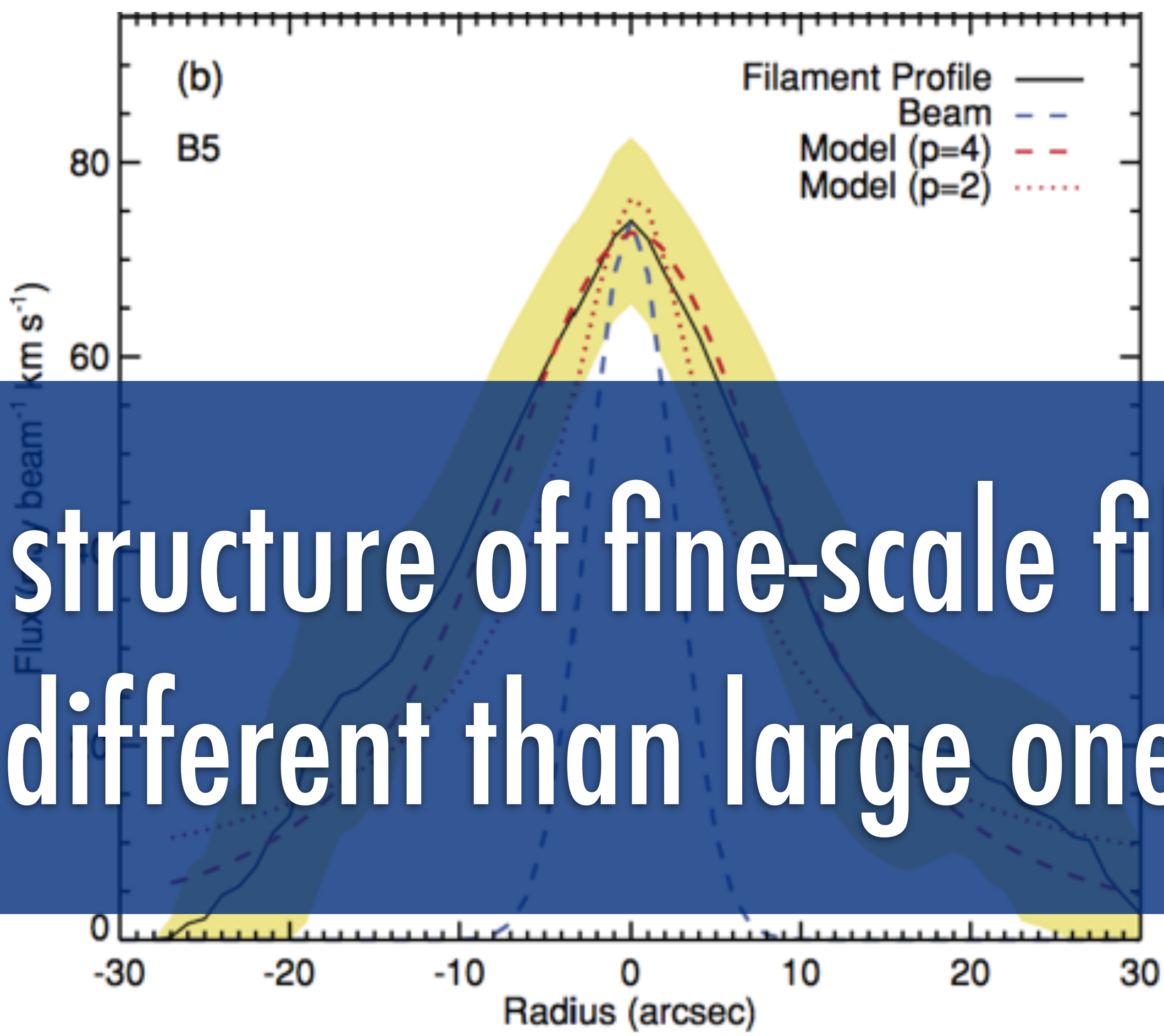


gold contour shows "coherent" core

Figure 1. Left panel: integrated intensity map of B5 in NH_3 (1,1) obtained with GBT. Gray contours show the 0.15 and 0.3 K km s^{-1} level in NH_3 (1,1) integrated intensity. The orange contours show the region in the GBT data where the non-thermal velocity dispersion is subsonic. The young star, B5–IRS1, is shown by the star in both panels. The outflow direction is shown by the arrows. The blue contour shows the area observed with the EVLA and the red box shows the area shown in the right panel. Right panel: integrated intensity map of B5 in NH_3 (1,1) obtained combining the EVLA and GBT data. Black contour shows the 50 mJy beam^{-1} km s^{-1} level in NH_3 (1,1) integrated intensity. The yellow box shows the region used in Figure 4. The northern starless condensation is shown by the dashed circle.

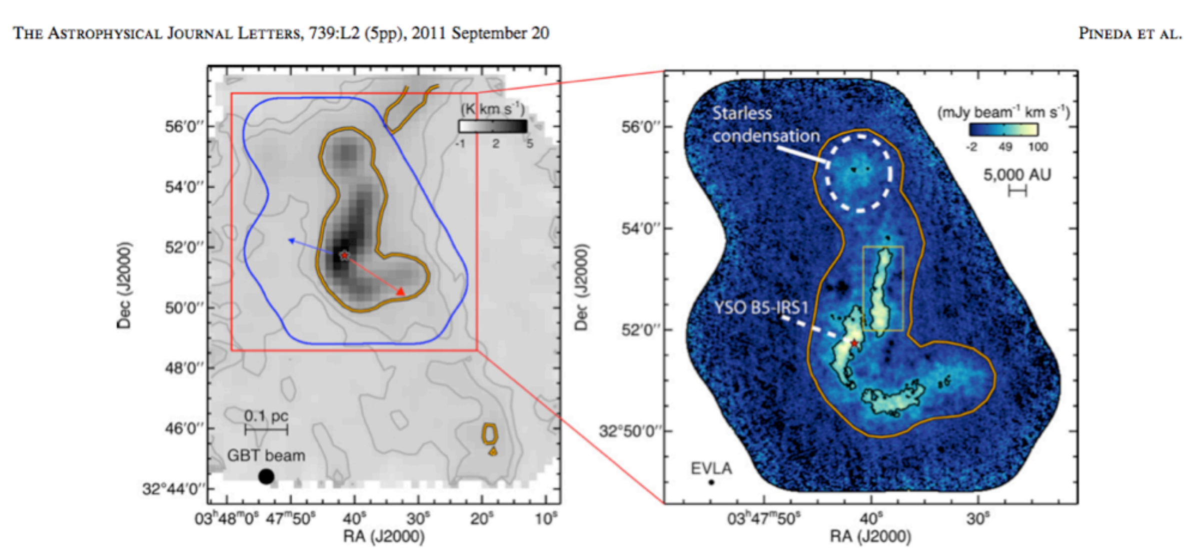
Pineda et al. 2011

BUT MAYBE IT'S DIFFERENT?



Density structure of fine-scale filaments is different than large ones.

isothermal, hydrostatic filaments, not turbulent ones?



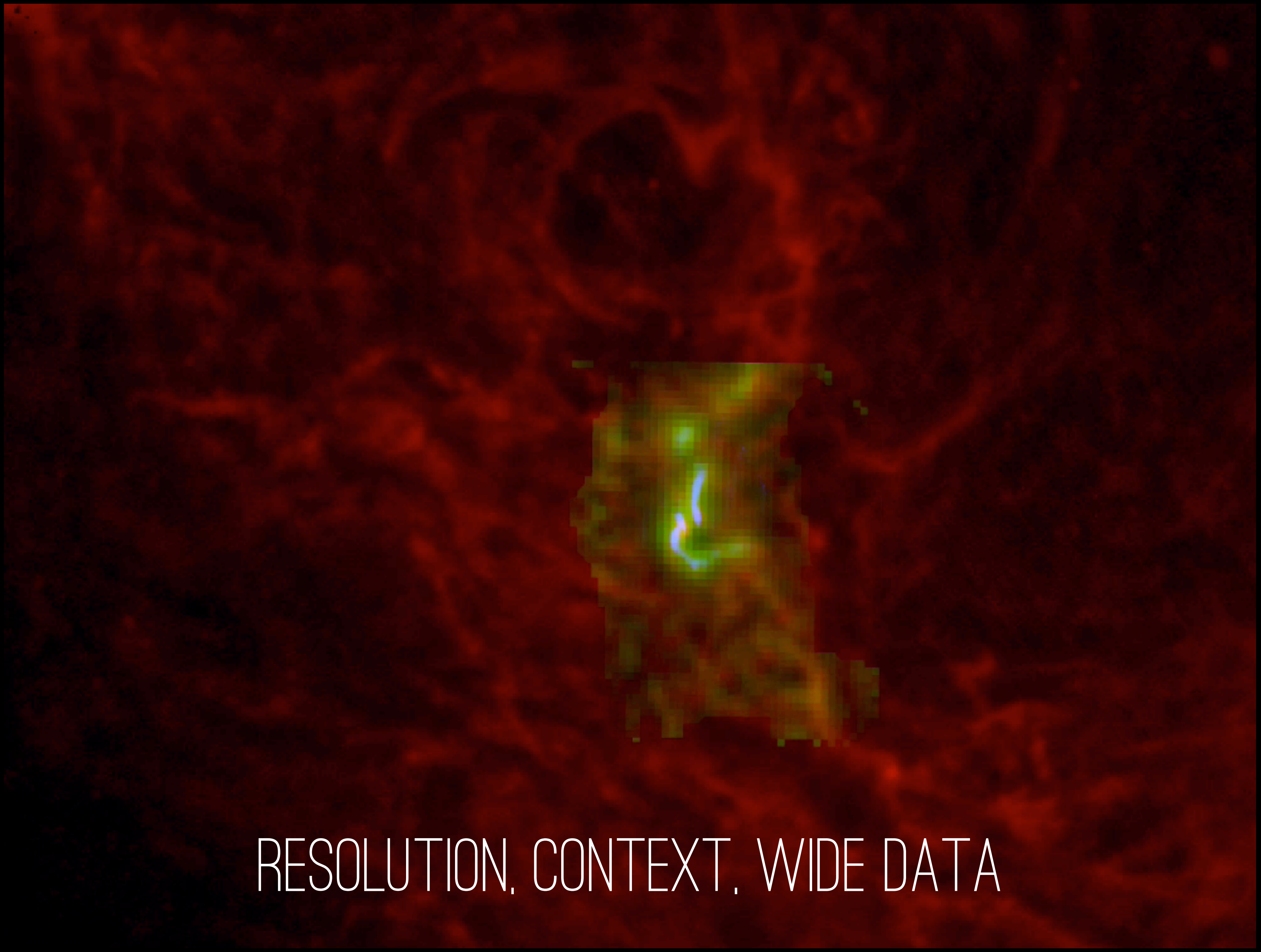
Pineda et al. 2011

SHHH…THIS WILL APPEAR IN NATURE, TOMORROW

Pineda, Offner, Parker, Arce, Goodman, Caselli, Fuller, Bourke & Corder 12 February 2015, Nature (do not reproduce without permission)

What if filaments continue across “core” boundaries?!

blue =VLA ammonia (high-density gas); green=GBT ammonia (lower-res high-density gas); red=Herschel 250 micron continuum (dust)



Goodman, Chen, Offner & Pineda 2014 in prep.

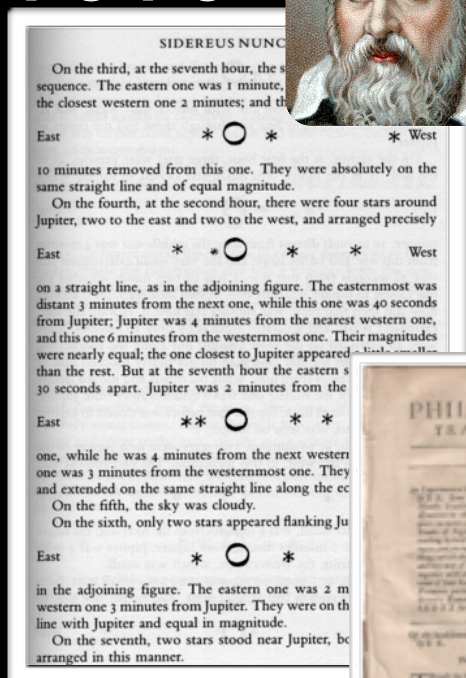
Herschel data from Gould Belt Survey

1998

2008

COMMUNICATION

1610


SIDEREUS NUNC

On the third, at the seventh hour, the s
sequence. The eastern one was 1 minute,
the closest western one 2 minutes; and th

East * ○ * * West

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

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

East * •○ * * West

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

East ** ○ * *

one, while he was 4 minutes from the next wester
one was 3 minutes from the westernmost one. They
and extended on the same straight line along the ec

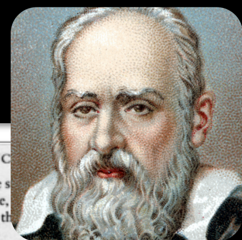
On the fifth, the sky was cloudy.

On the sixth, only two stars appeared flanking Ju

East * ○ *

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

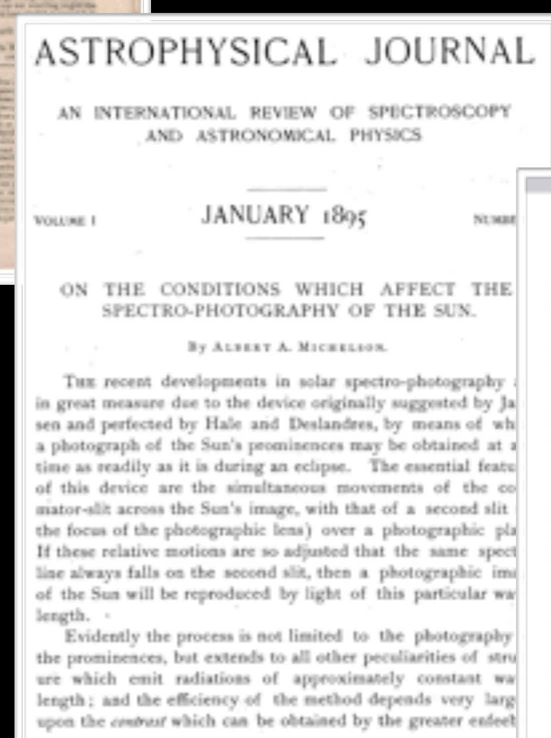
On the seventh, two stars stood near Jupiter, bo
arranged in this manner.



1665


PHILOSOPHICAL TRANSACTIONS

1895


ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

VOLUME I JANUARY 1895 NUMBE

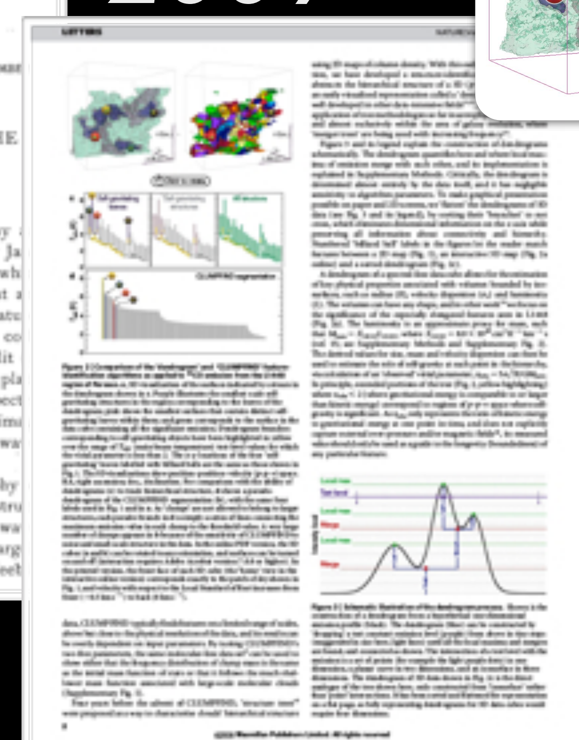
ON THE CONDITIONS WHICH AFFECT THE SPECTRO-PHOTOGRAPHY OF THE SUN.

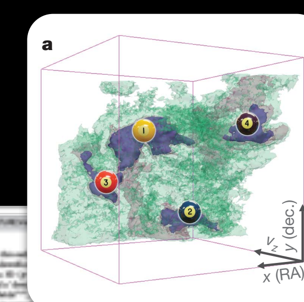
By ALBERT A. MICHELSON.

THE recent developments in solar spectro-photography
in great measure due to the device originally suggested by Ja
sen and perfected by Hale and Deslandres, by means of wh
a photograph of the Sun's prominences may be obtained at
time as readily as it is during an eclipse. The essential featu
of this device are the simultaneous movements of the co
mator-slit across the Sun's image, with that of a second slit
the focus of the photographic lens) over a photographic pla
If these relative motions are so adjusted that the same spect
line always falls on the second slit, then a photographic im
of the Sun will be reproduced by light of this particular wa
length.

Evidently the process is not limited to the photography
the prominences, but extends to all other peculiarities of stru
ure which emit radiations of approximately constant wa
length; and the efficiency of the method depends very larg
upon the *contrast* which can be obtained by the greater enfeeb

2009





2009

3D PDF

INTERACTIVITY IN A "PAPER"

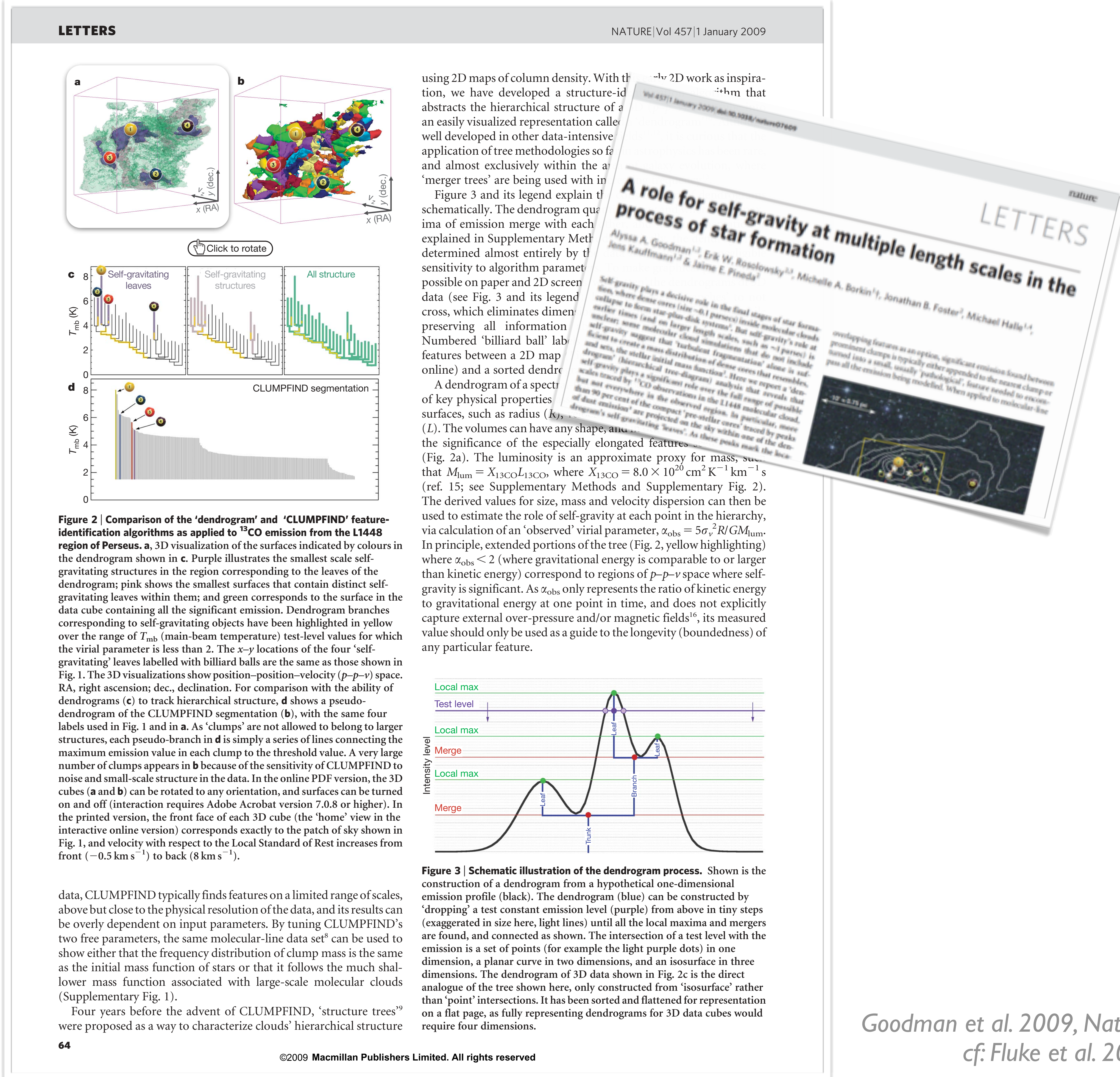


Figure 2 | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. a, 3D visualization of the surfaces indicated by colours in the dendrogram shown in **c**. Purple illustrates the smallest scale self-gravitating 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 ly 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 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.

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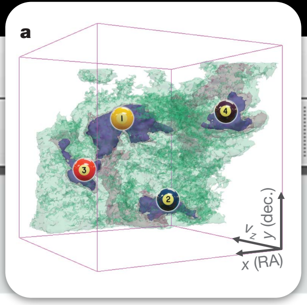
Vol 457|1 January 2009|doi:10.1038/nature07609
nature
LETTERS

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

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

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

Create
1 / 4
131%
Share



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

LETTERS

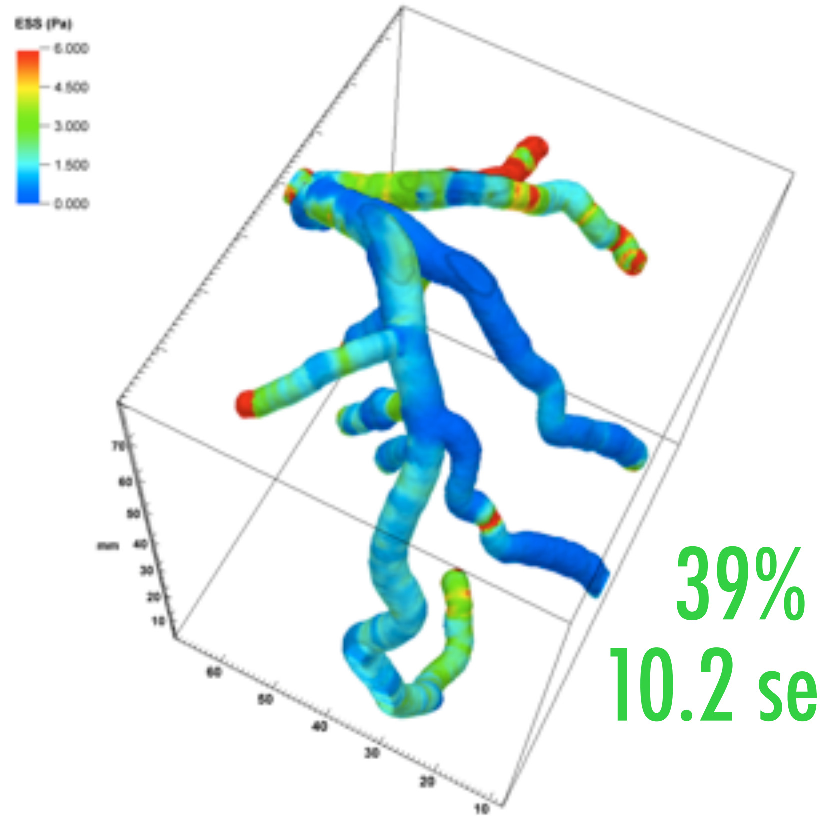
A role for self-gravity at multiple length scales in the process of star formation

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)



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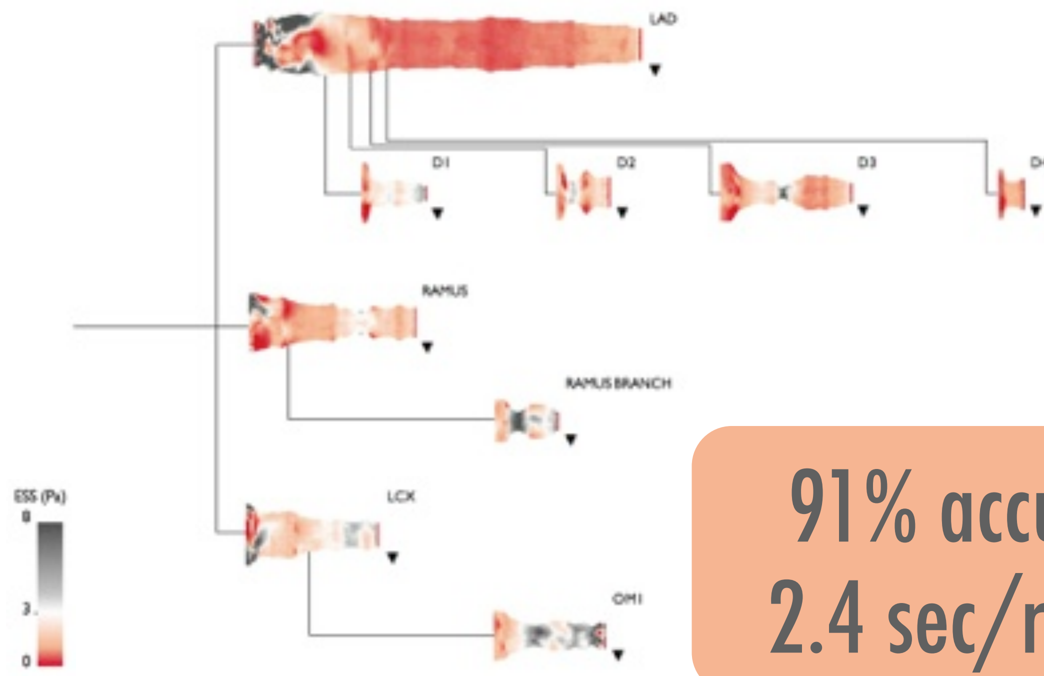
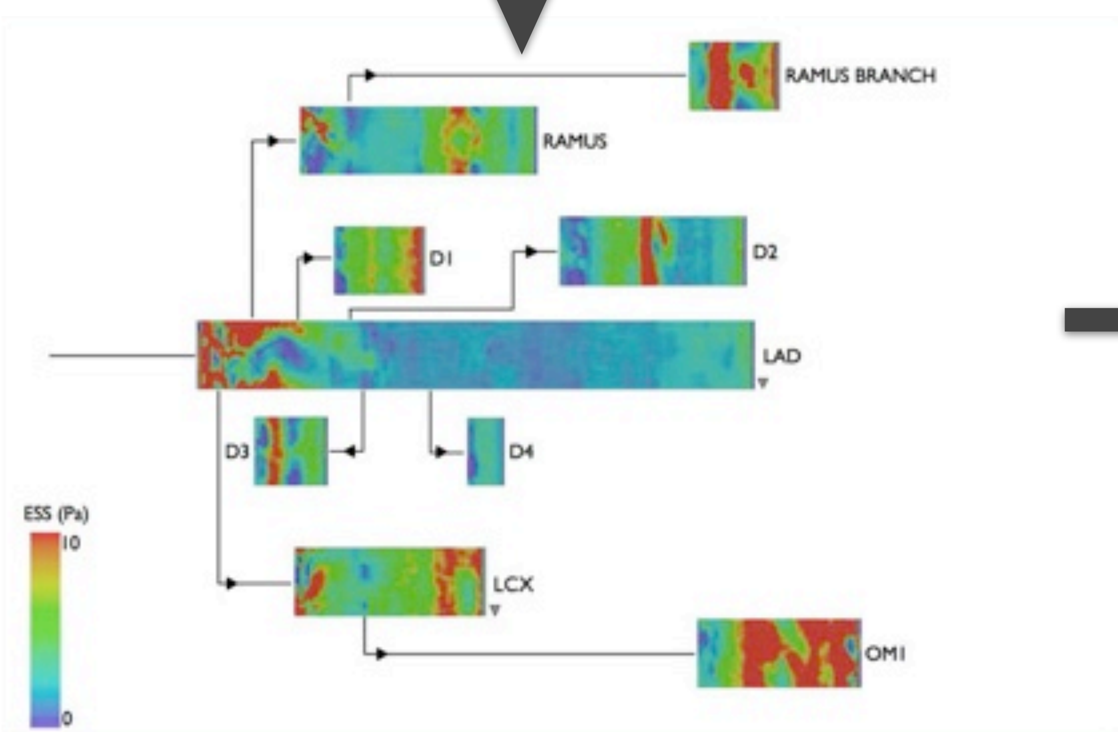
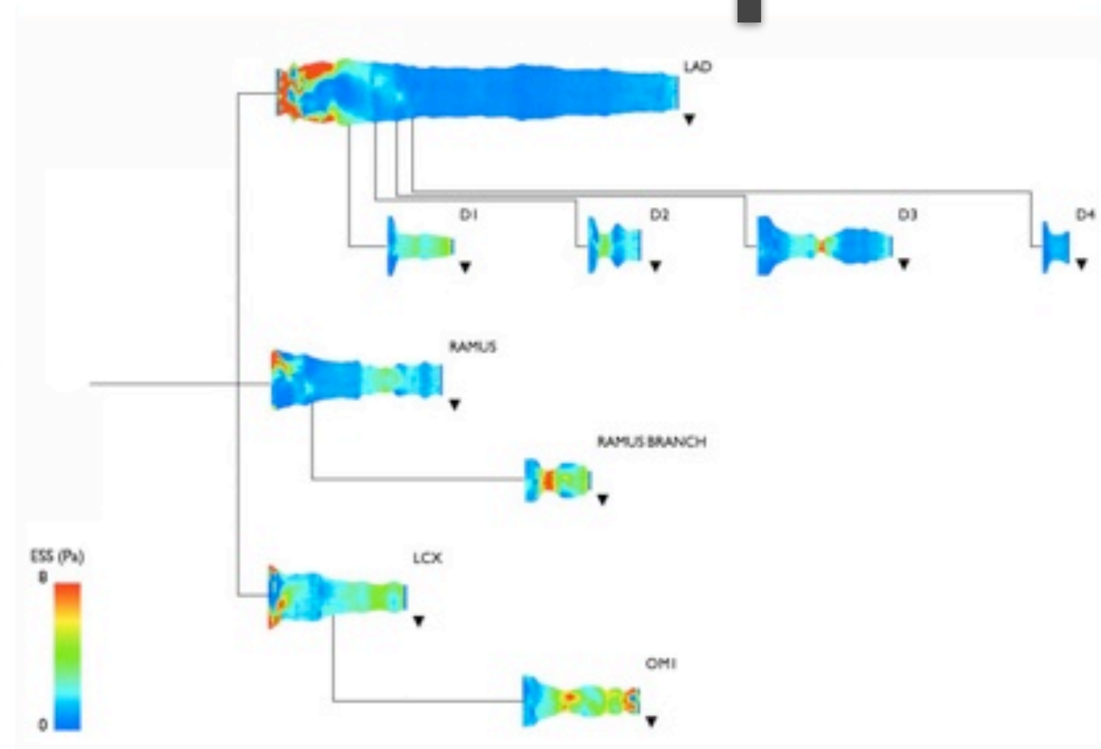
10.2 sec/region



91% accurate
2.4 sec/region





Borkin et al. 2011
cf. colorbrewer2.org

RESOLUTION

CONTEXT

BIG DATA

WIDE DATA

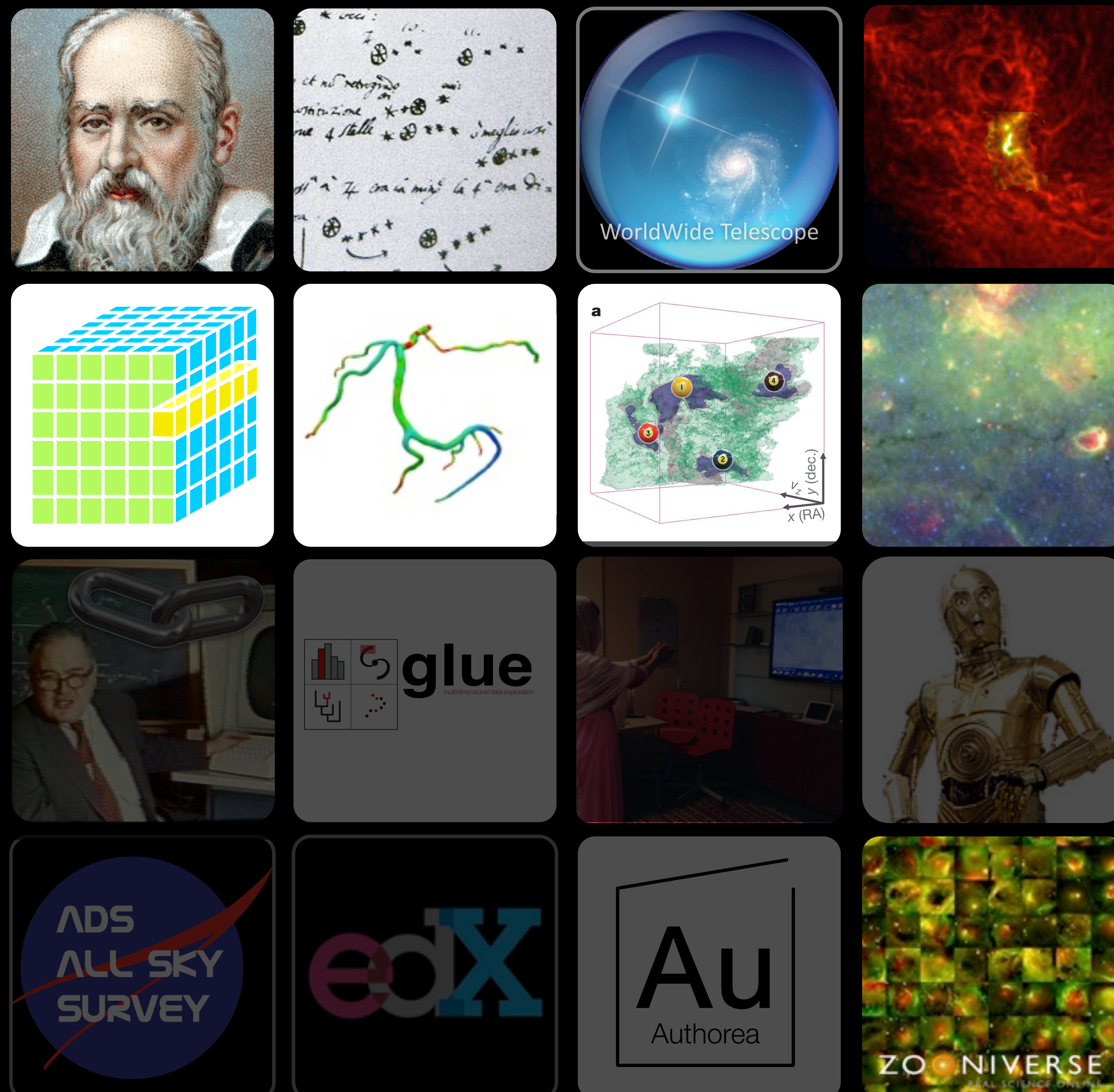
DIMENSIONALITY

LINKED VIEWS

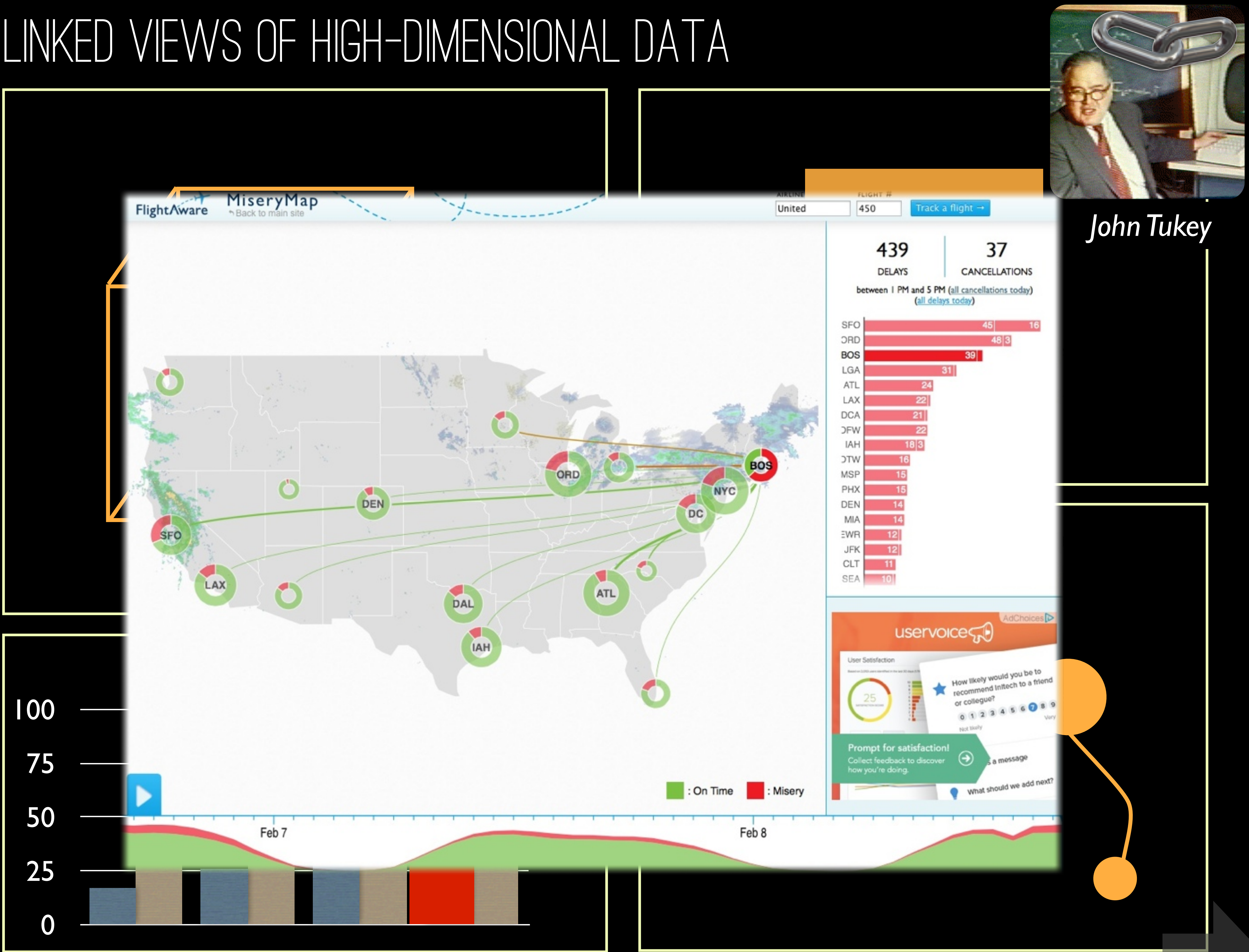
INTERACTION

COMMUNICATION

EDUCATION



LINKED VIEWS OF HIGH-DIMENSIONAL DATA



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

TUKEY'S "FOUR ESSENTIALS" (C.1972)

Picturing

Rotation

Isolation

Masking

Selection

and these "need to work together" in a "dynamic display"

Brushing

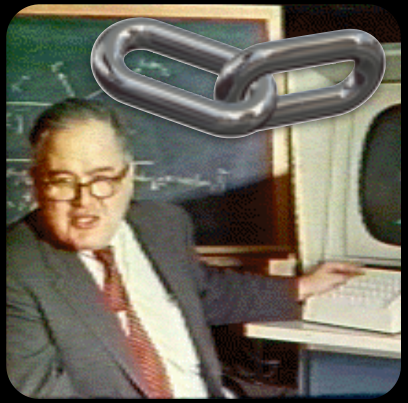
Linking

Results...

1. for immediate insight
2. as visual source of ideas for statistical algorithms

Warning

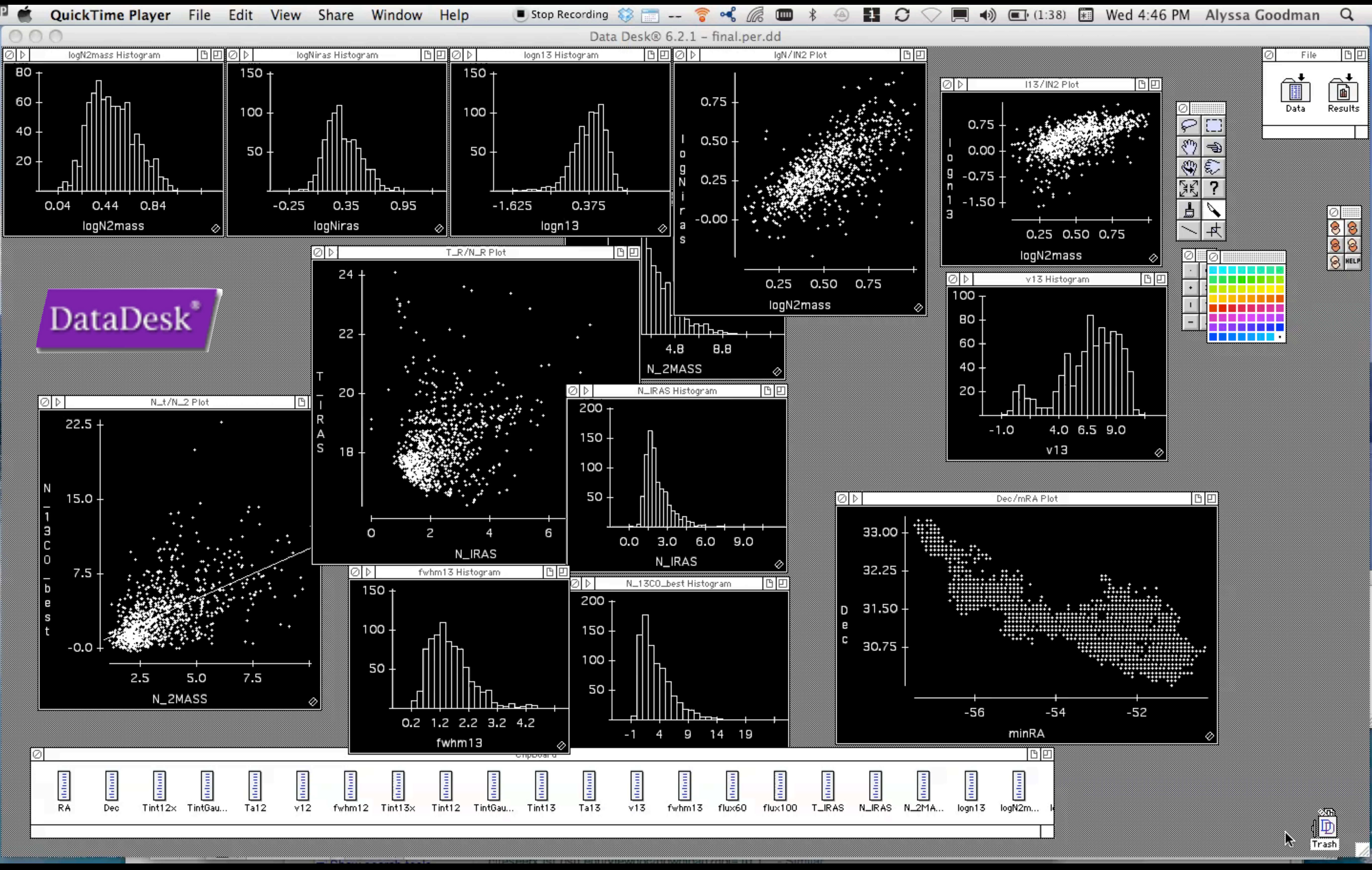
"details of control can make or break such a system"



John Tukey

Watch the PRIM-9 video at: http://stat-graphics.org/movies/prim9.html

DATADESK (EST. 1986)



DATADESK + "STANDARD" 2D POLYGONS

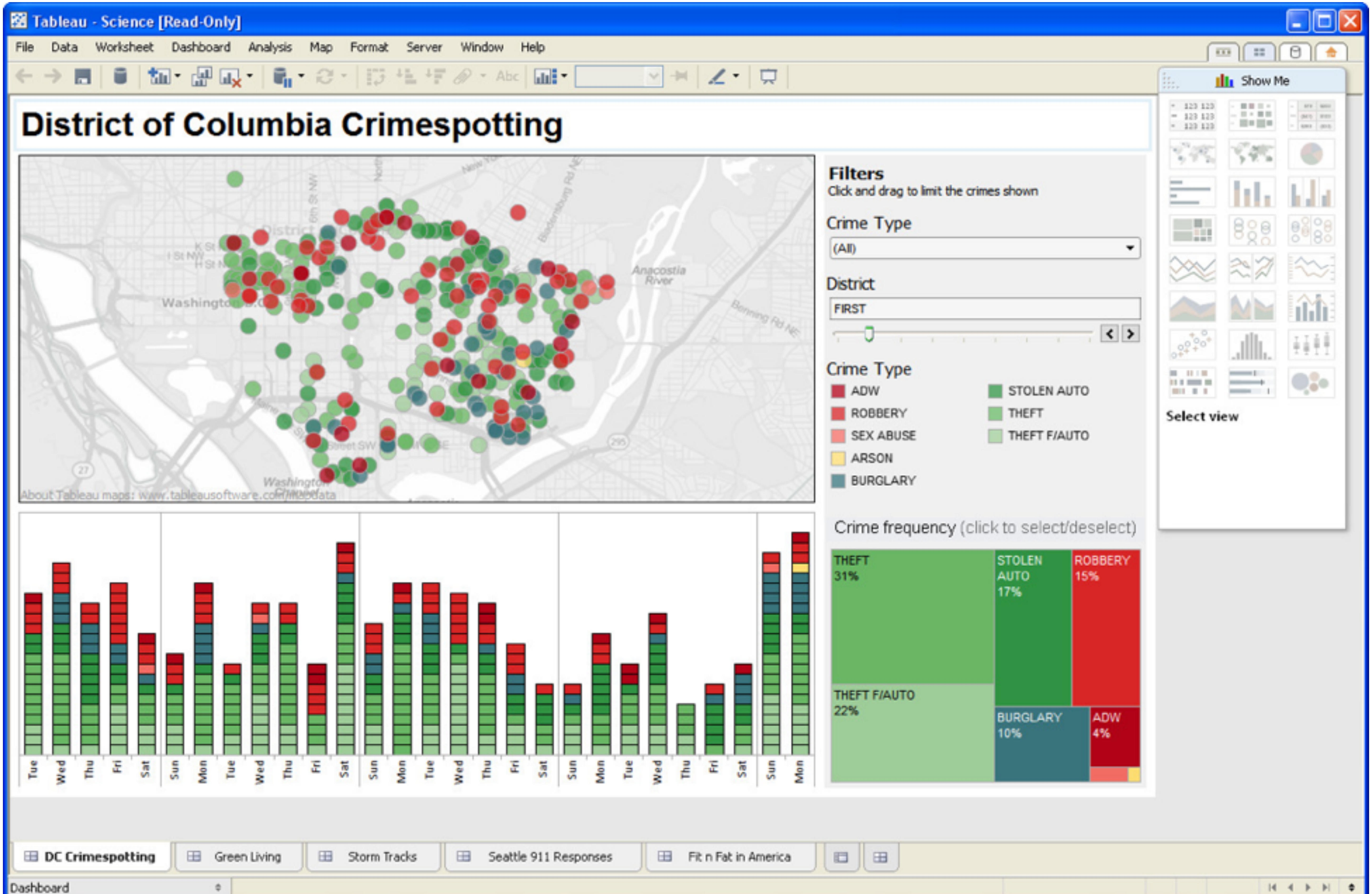
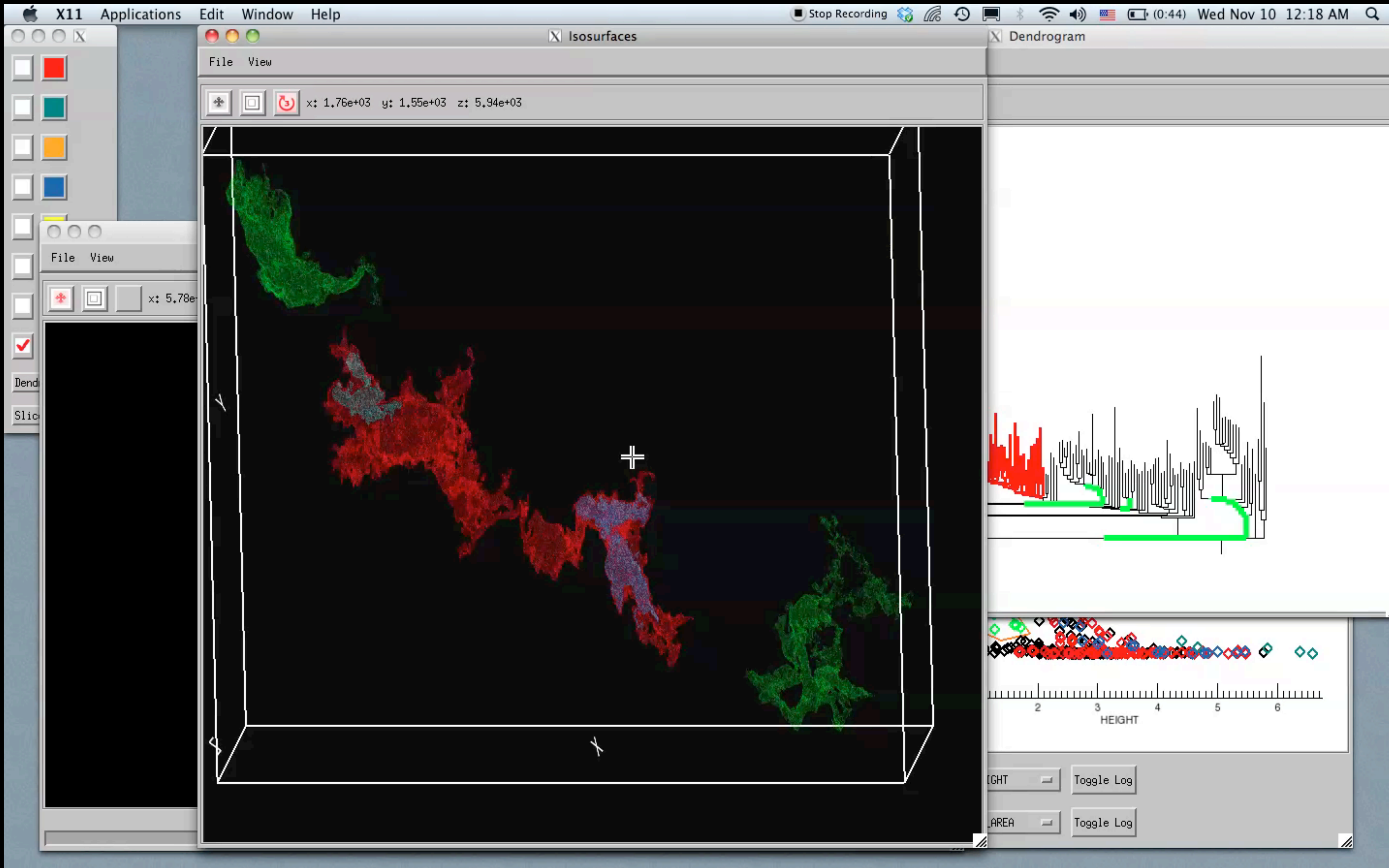


image credit: htableau-32-bit.software.informer.com/screenshot/432751/

LINKED VIEWS OF HIGH-DIMENSIONAL DATA



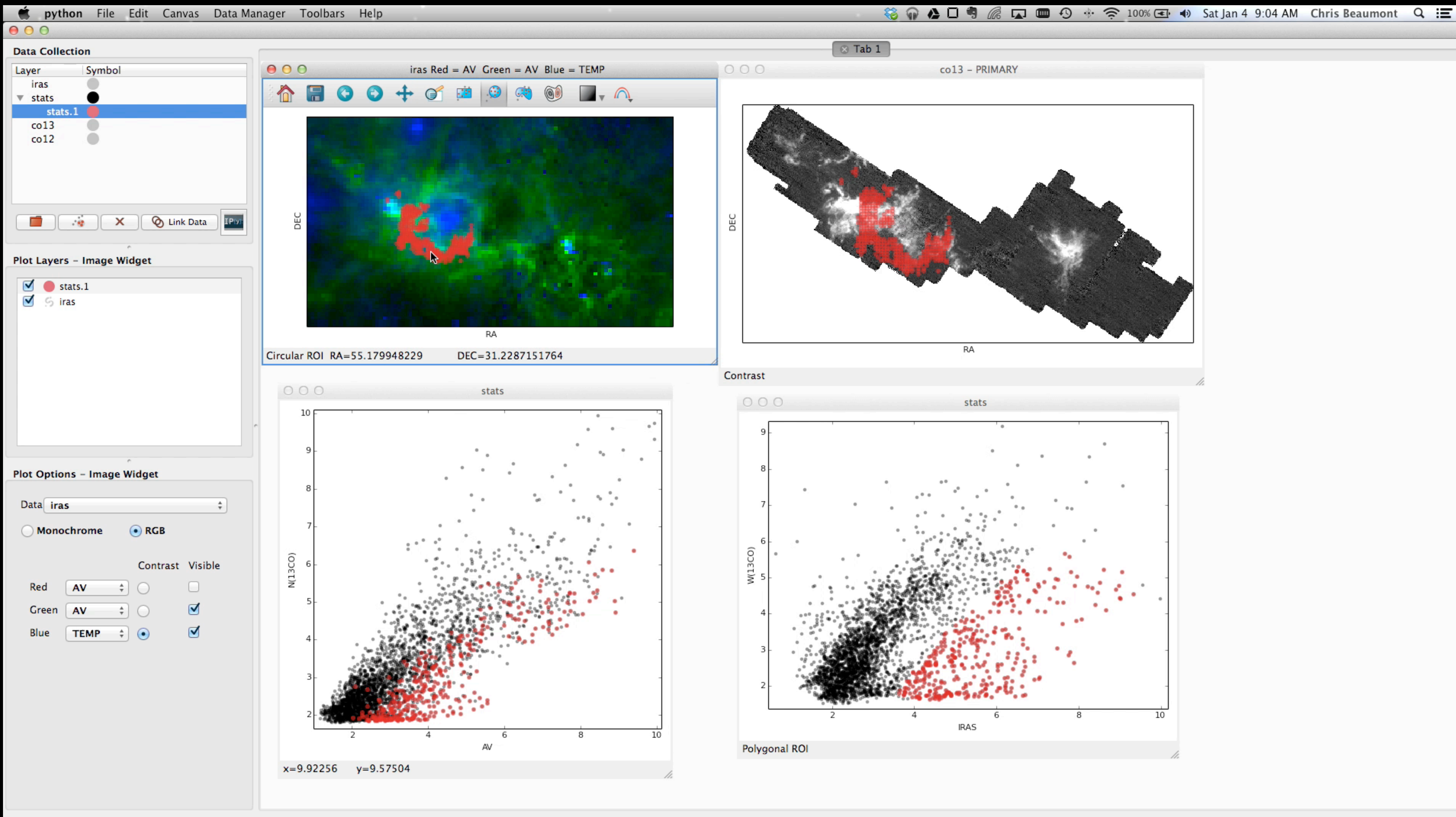
Video & implementation: Christopher Beaumont, Harvard→Counsyl;
inspired by AstroMed work of Douglas Alan, Michelle Borkin, AG, Michael Halle, Erik Rosolowsky

GREAT. BUT THAT WAS ALL FROM ONE DATA FILE.

AND IT WAS IN SOFTWARE THAT COSTS $1000.

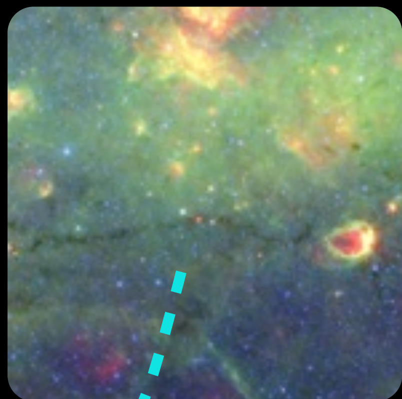
LINKED VIEWS OF HIGH-DIMENSIONAL DATA (IN PYTHON)

GLUE

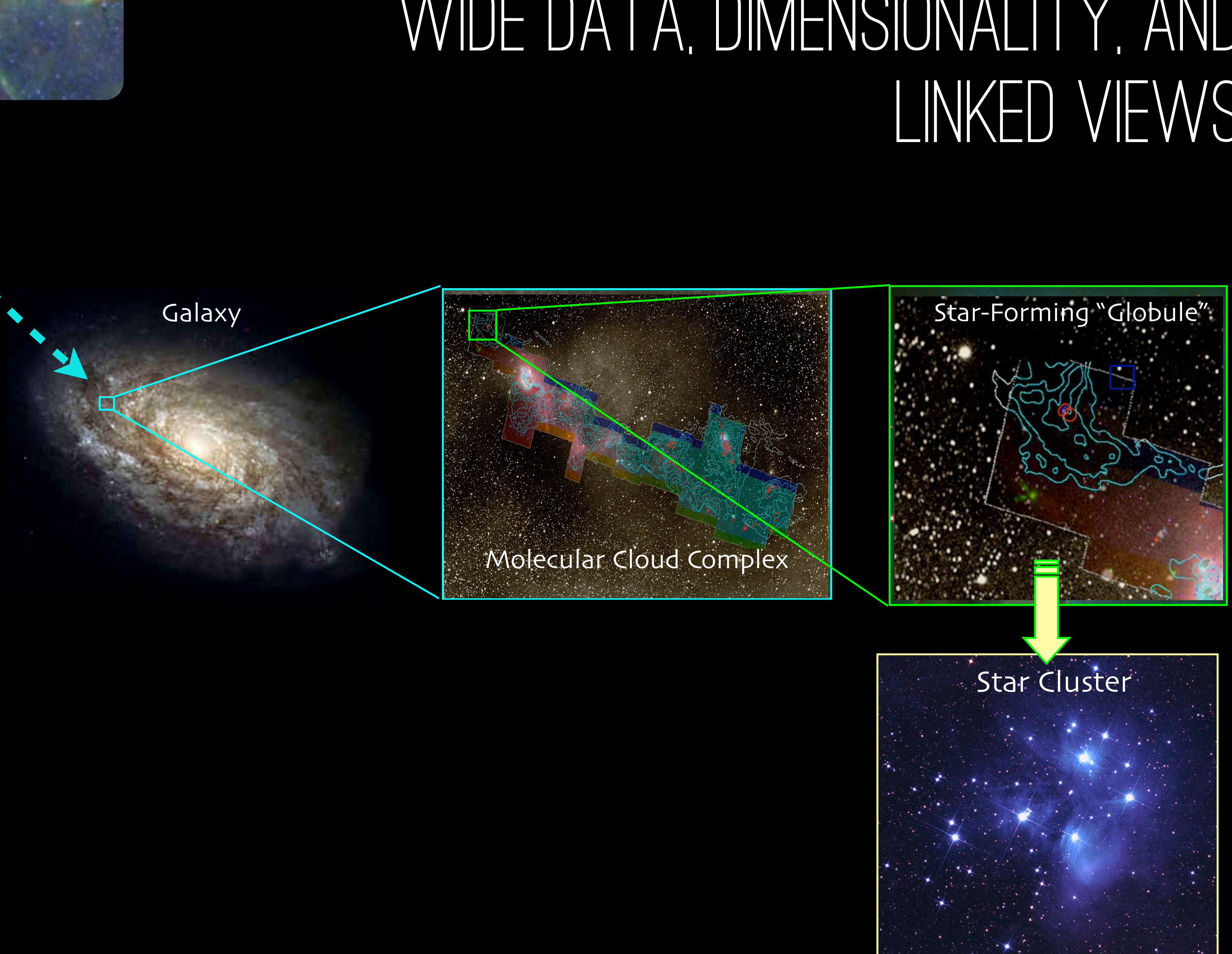


Christopher Beaumont, w/A. Goodman, T. Robitaille & M. Borkin

"Nessie"

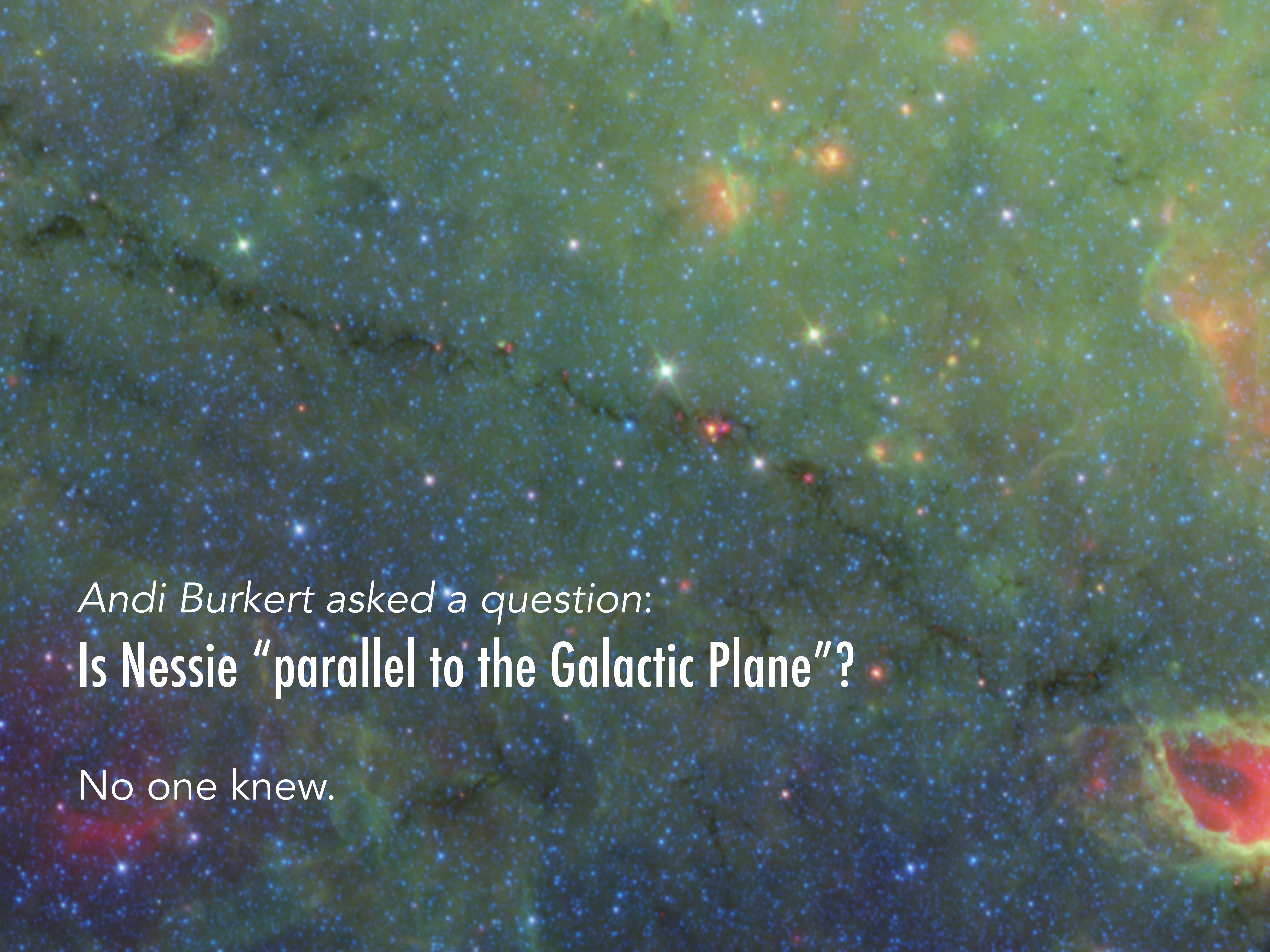


NESSIE'S STORY OF RESOLUTION, CONTEXT, BIG DATA, WIDE DATA, DIMENSIONALITY, AND LINKED VIEWS



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.

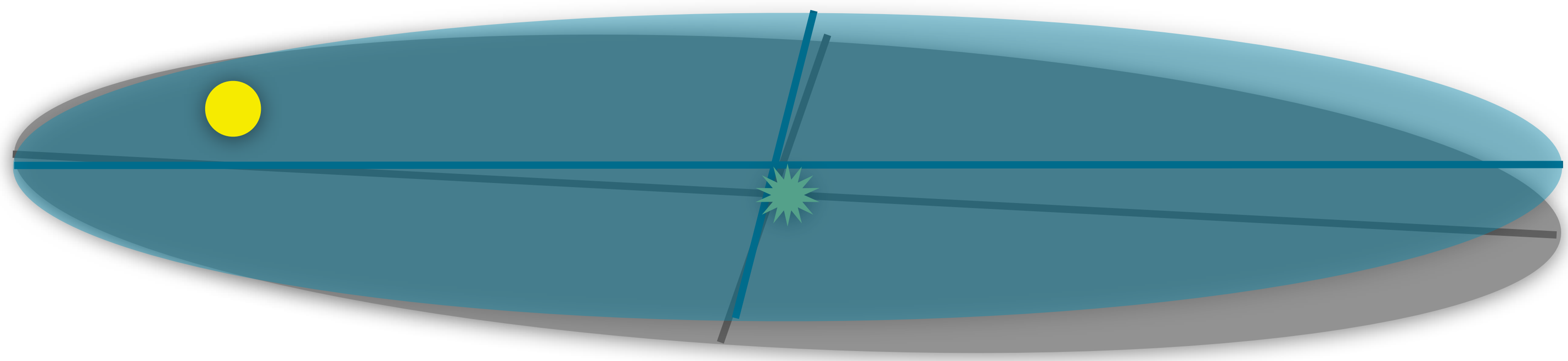
THE MILKY WAY

"Galactic Plane"

The Milky Way
(Artist's Conception)

"Is Nessie Parallel to the Galactic Plane?"

Where are we, really?



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

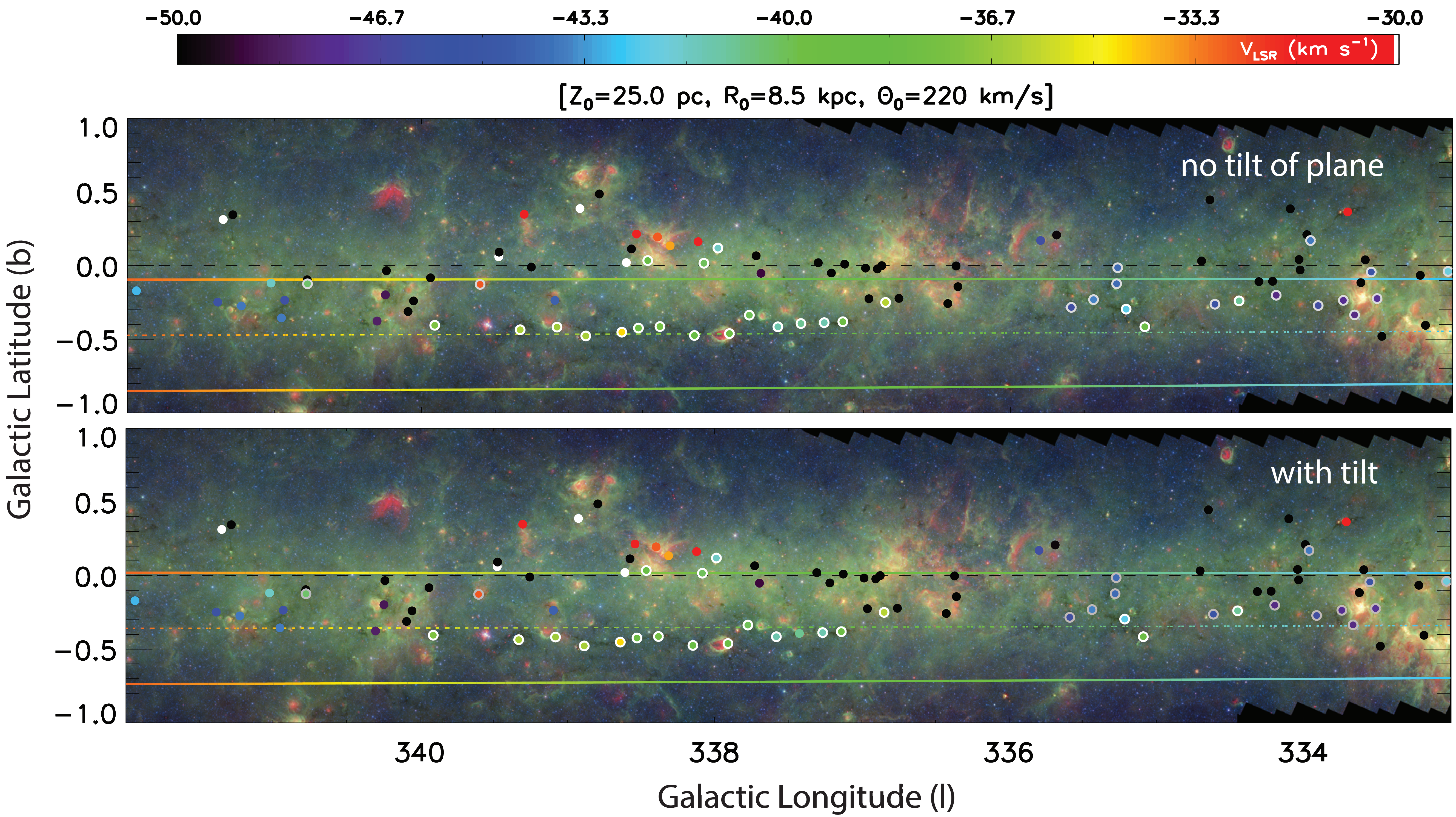
\+

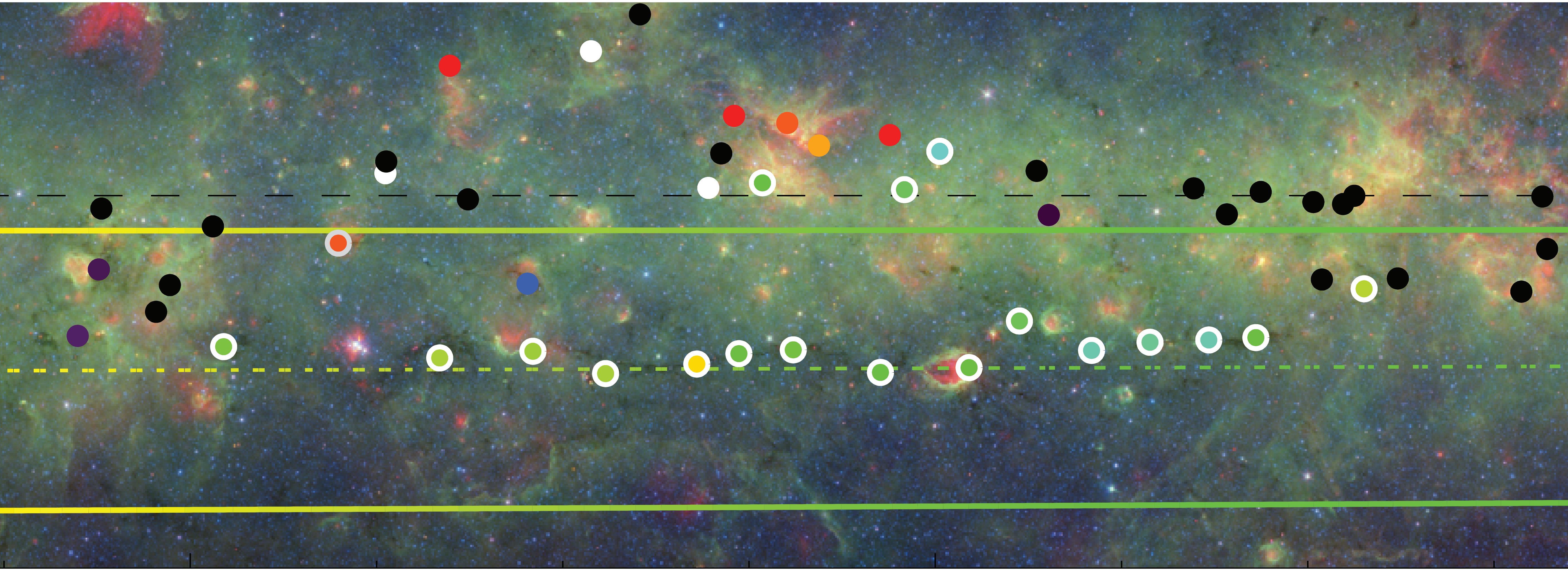
Galactic Center is ~20 light years offset from the IAU Milky Way Center

=

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!

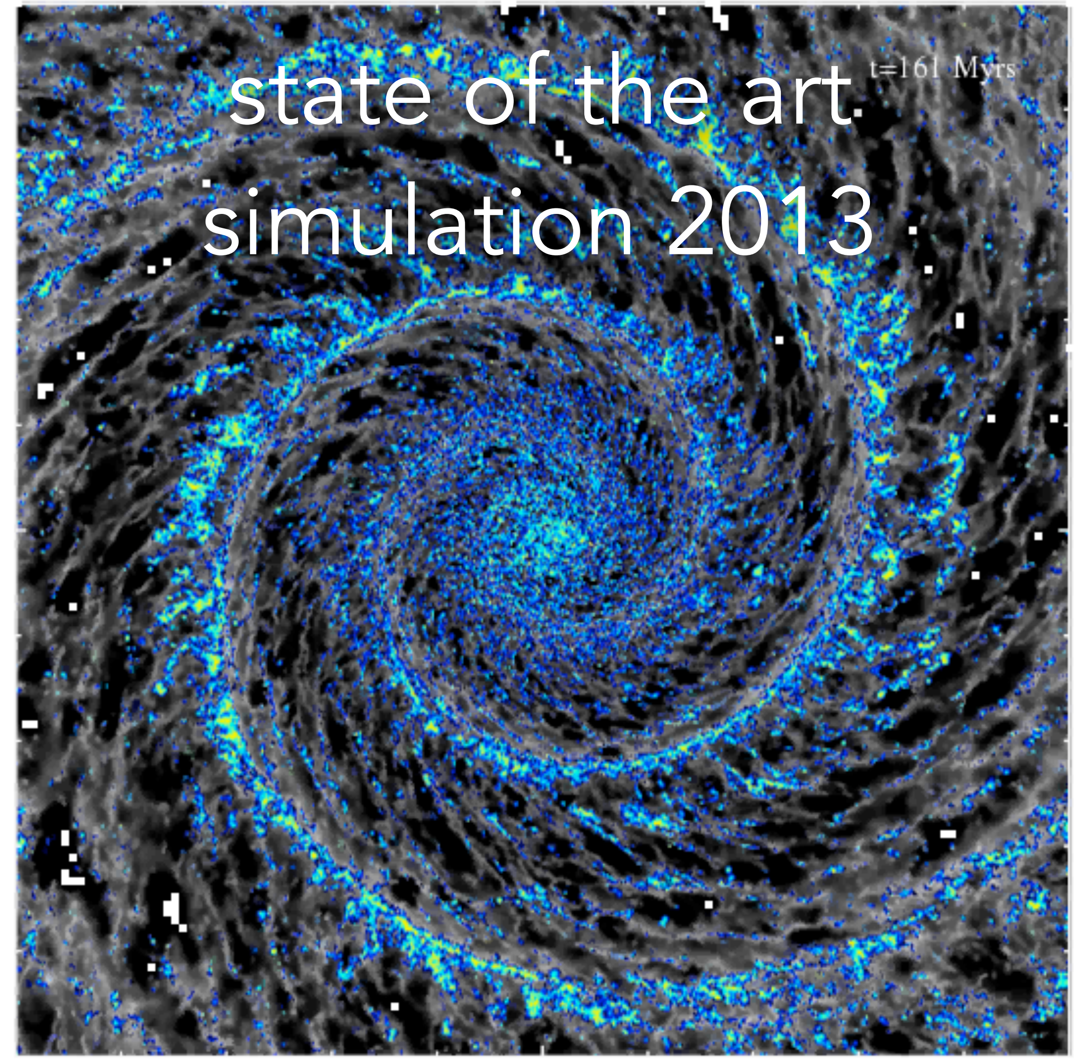


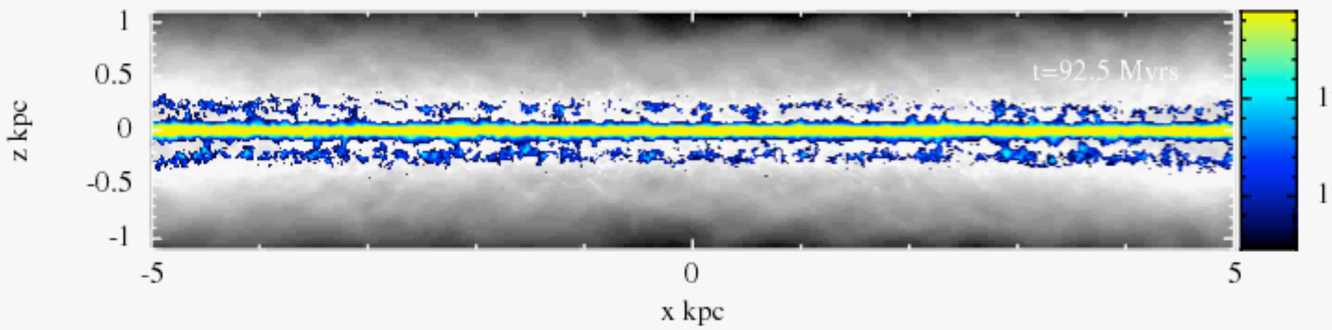


...eerily precisely...

How do we know the velocities?

A full 3D skeleton?



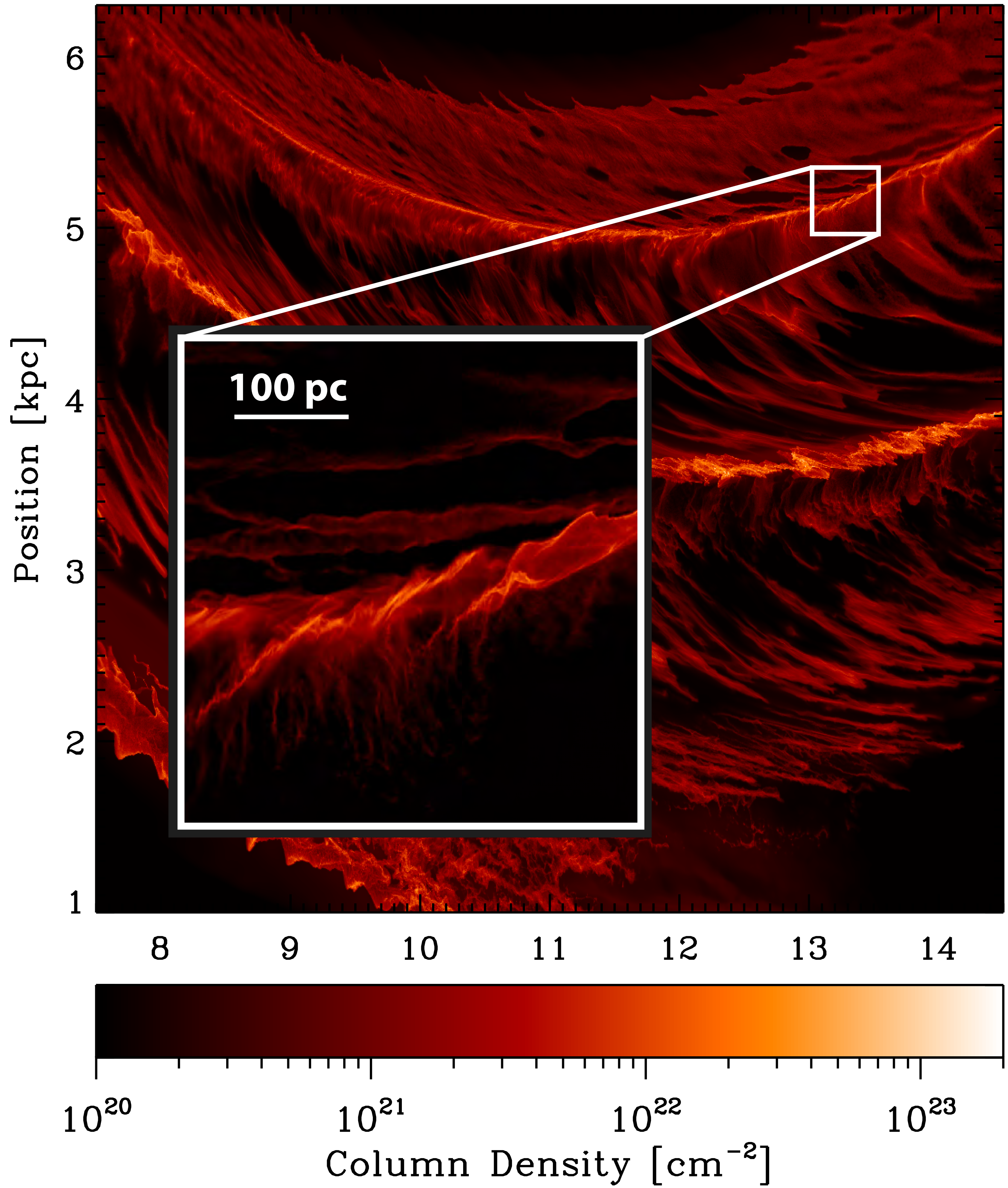


(flipped) image of IC342 from Jarrett et al. 2012; WISE Enhanced Resolution Galaxy Atlas

simulations courtesy Clare Dobbs

New!

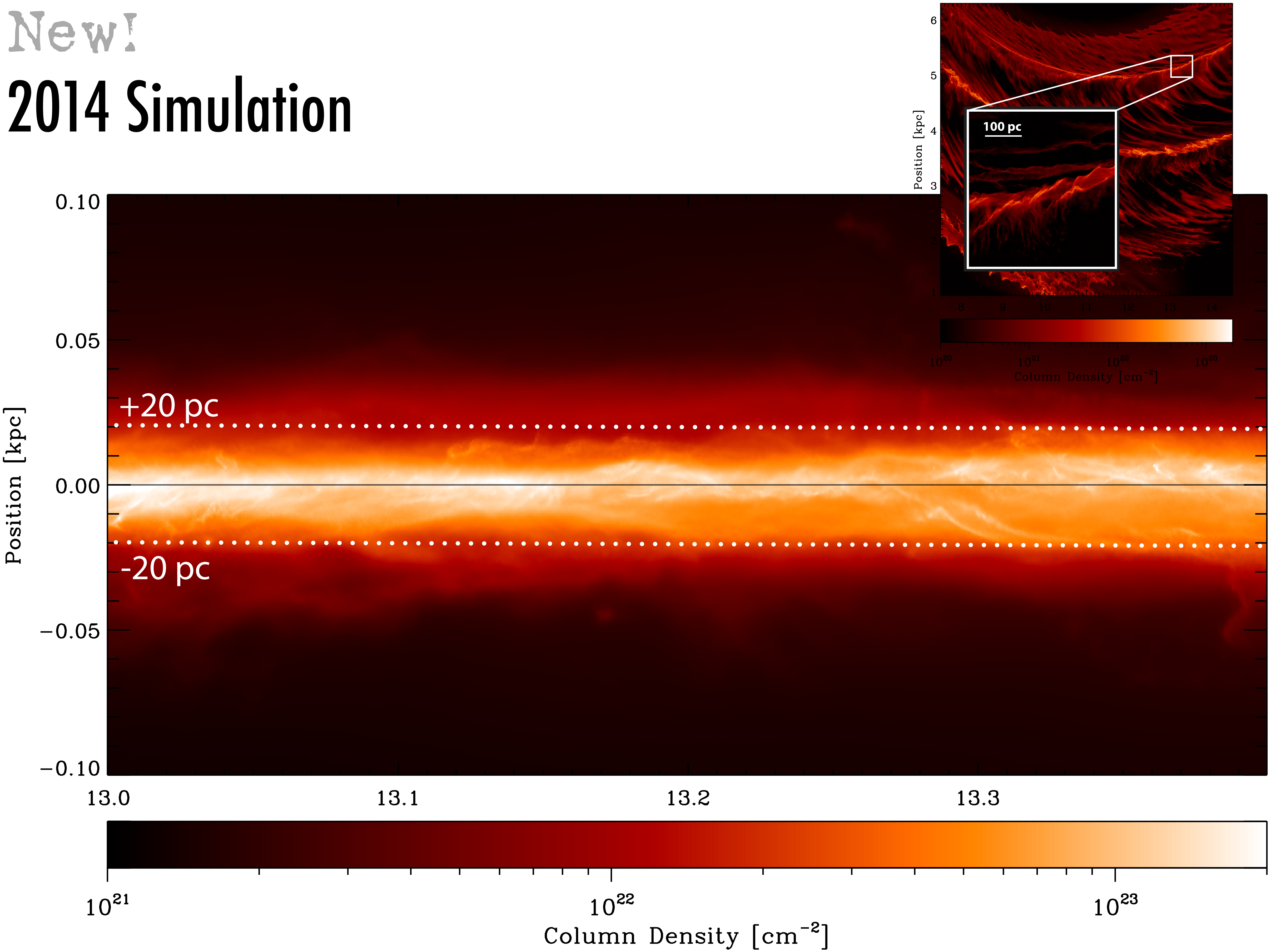
2014 Simulation



Smith et al. 2014, using AREPO

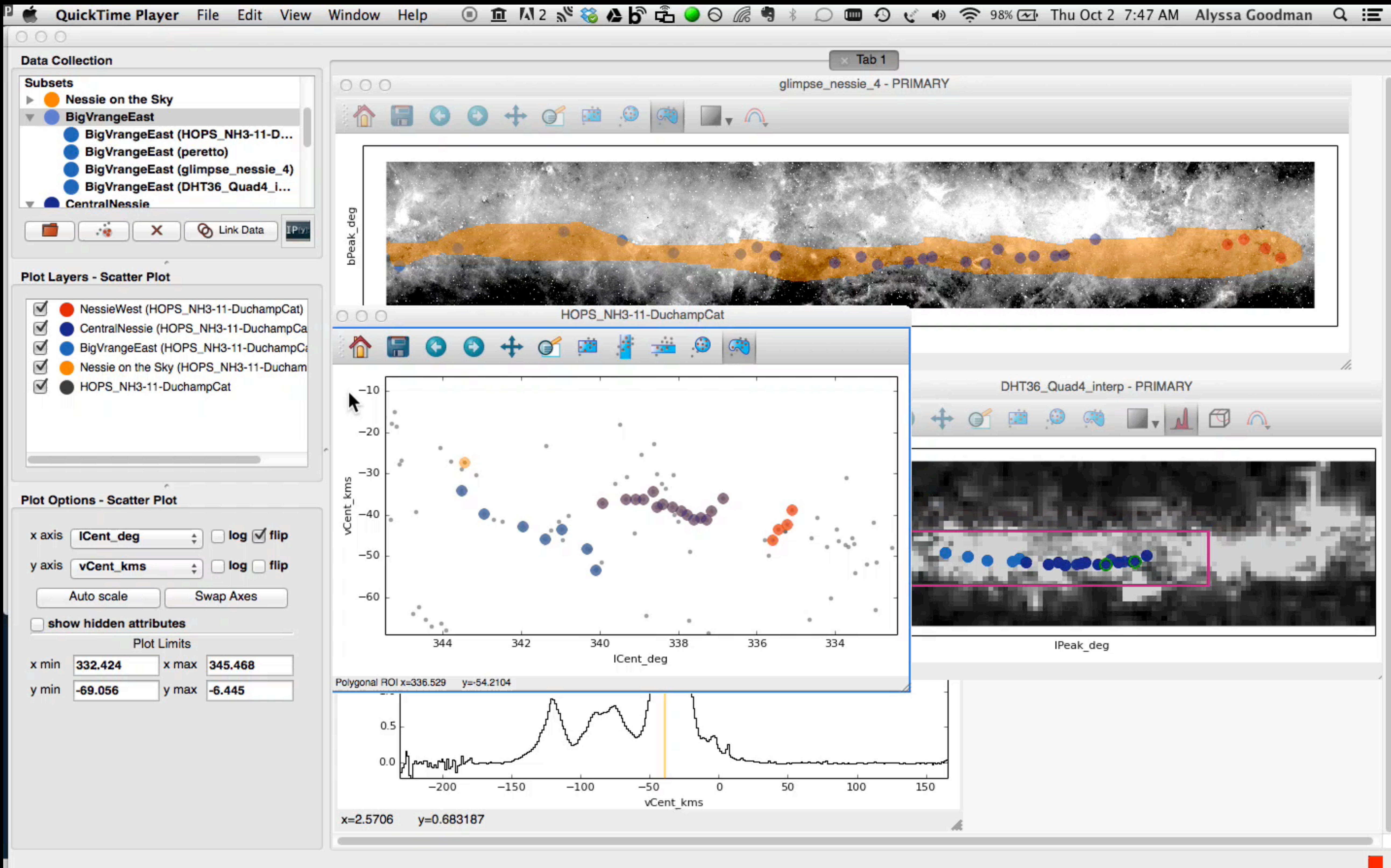
New!

2014 Simulation



Smith et al. 2014, using AREPO

NESSIE IN GLUE



RESOLUTION

CONTEXT

BIG DATA

WIDE DATA

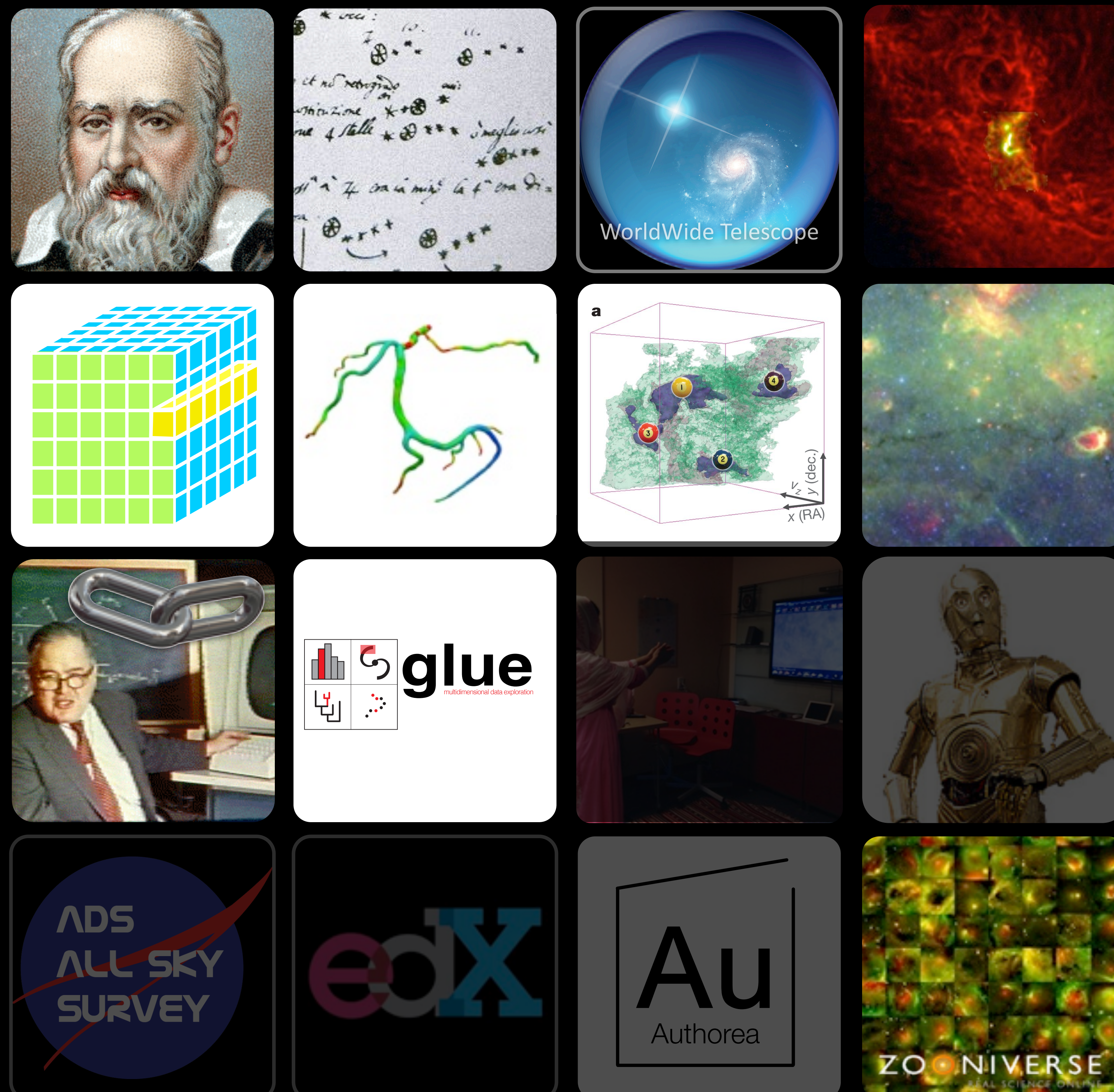
DIMENSIONALITY

LINKED VIEWS

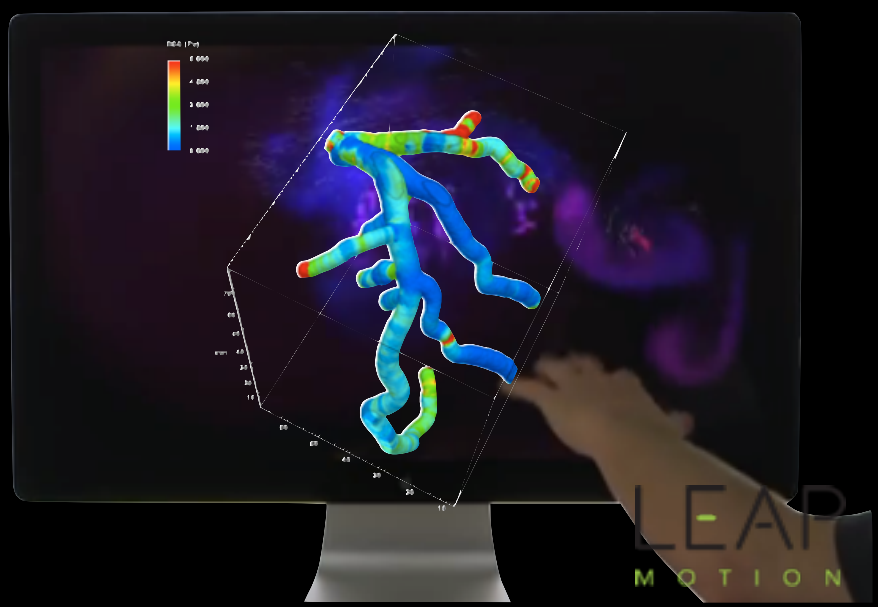
INTERACTION

COMMUNICATION

EDUCATION



INTERACTION BEYOND FLATLAND IS AN UNSOLVED PROBLEM



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

Microsoft
HoloLens

RESOLUTION

CONTEXT

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WIDE DATA

DIMENSIONALITY

LINKED VIEWS

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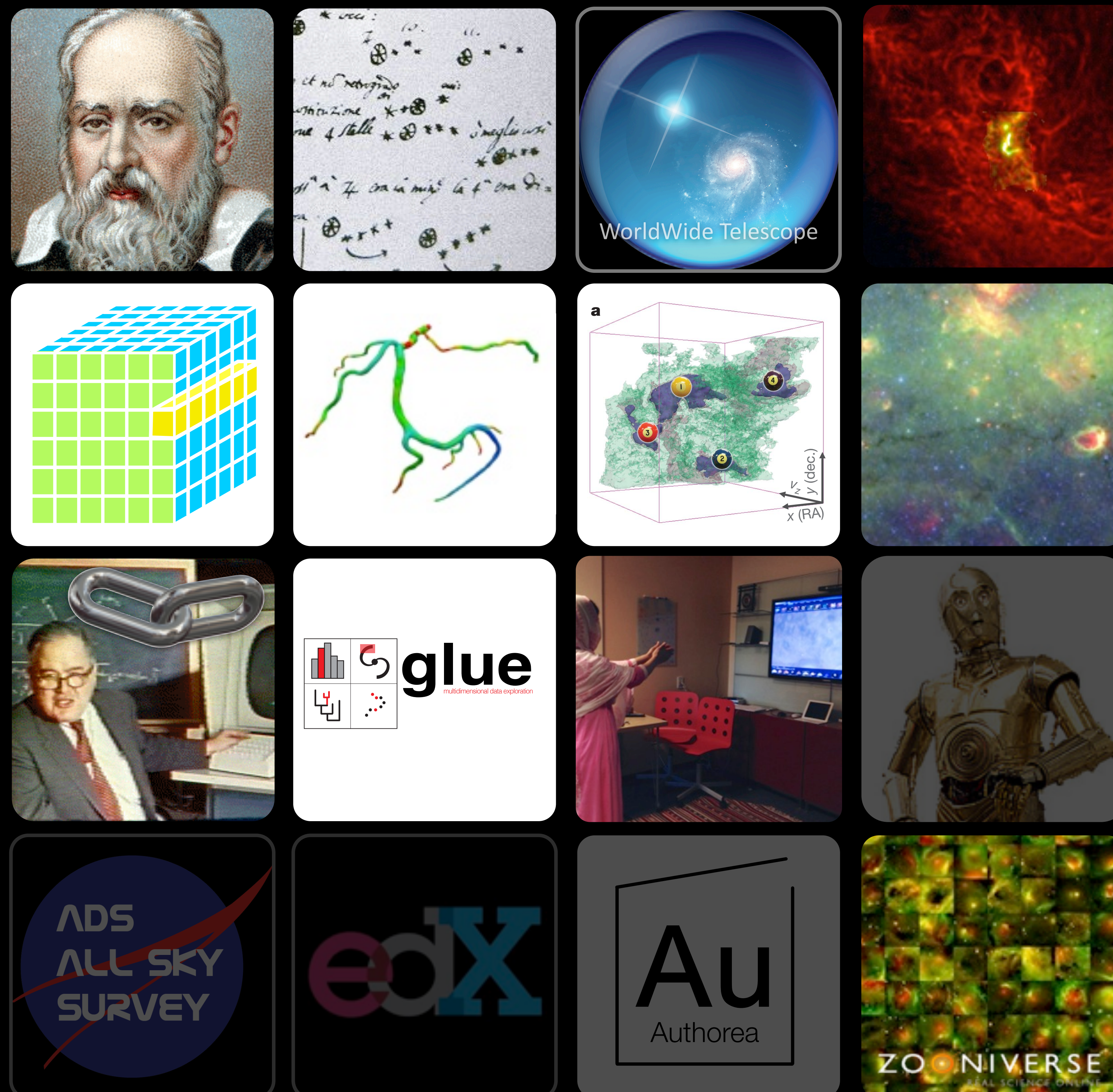
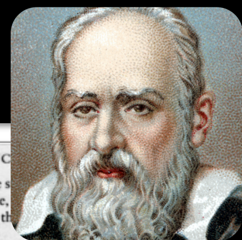
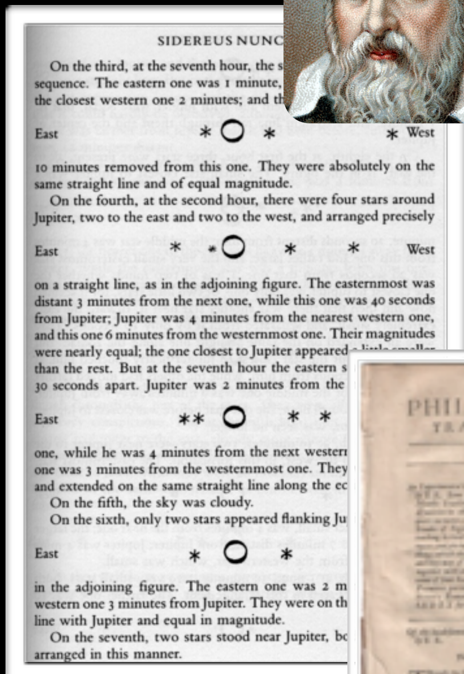
EDUCATION



COMMUNICATION

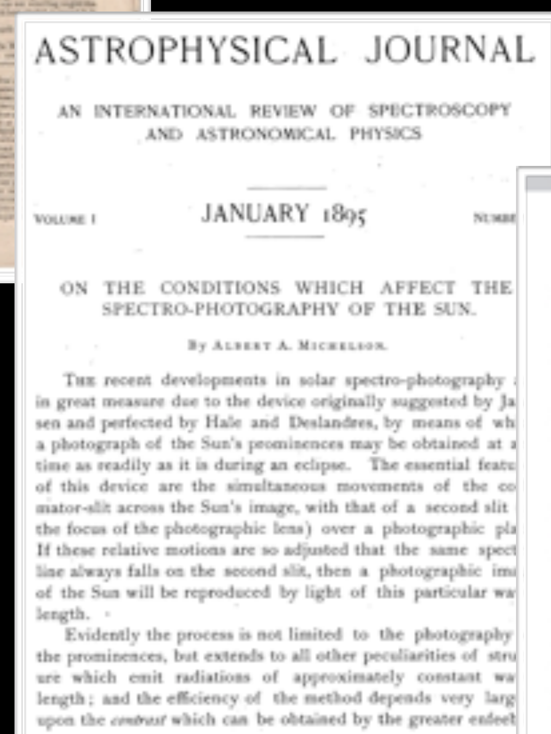
1610



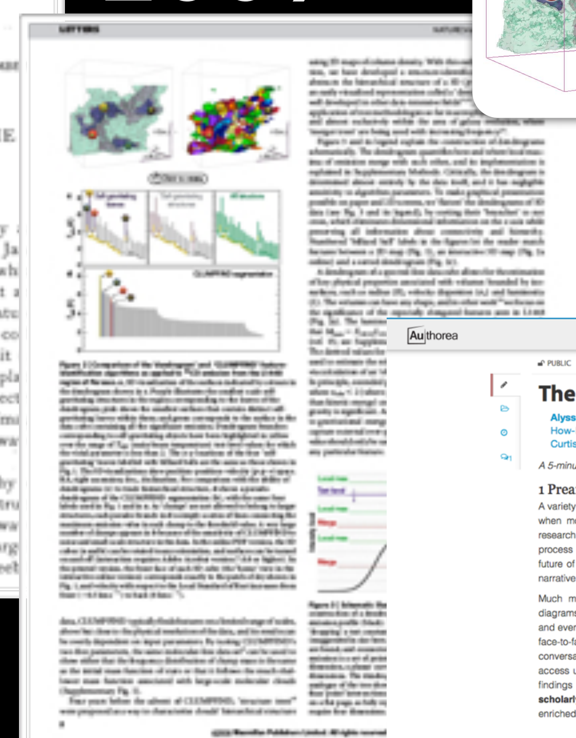


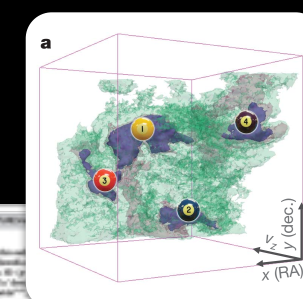
1665

1895



2009





2015

WorldWide Telescope

glue

D3PO

Au
Authorea

Au
Authorea

FEATURED ARTICLES ABOUT PLANS BLOG FEEDBACK HELP ALYSSA GOODMAN

PUBLIC ROUGH DRAFT Index Settings Fork Quickedit Word Count 42 Comments Export Unfollow

The "Paper" of the Future

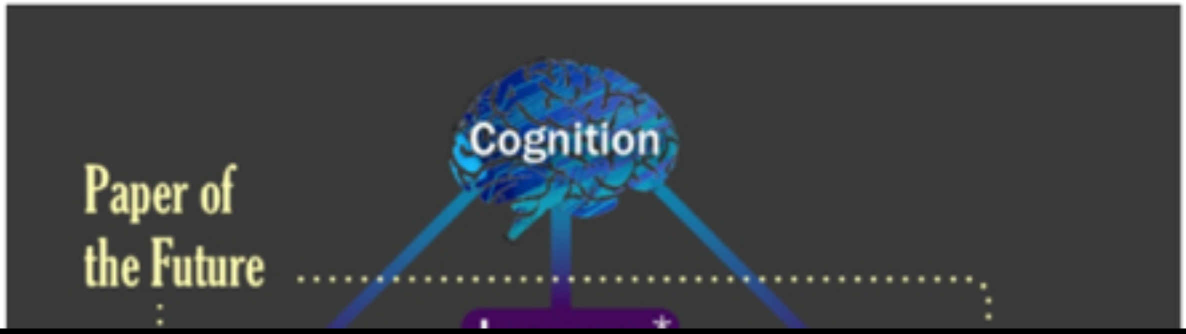
Alyssa Goodman, Josh Peek, Alberto Accomazzi, Chris Beaumont, Christine L. Borgman, How-Huan Hope Chen, Merce Crosas, Christopher Erdmann, August Muench, Alberto Pepe, Curtis Wong + Add author Re-arrange authors

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

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.



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 DATA

ADS
ALL SKY
SURVEY

View in Aladin • View in WorldWide Telescope • Demo Videos

[Demo]

RESOLUTION

CONTEXT

BIG DATA

WIDE DATA

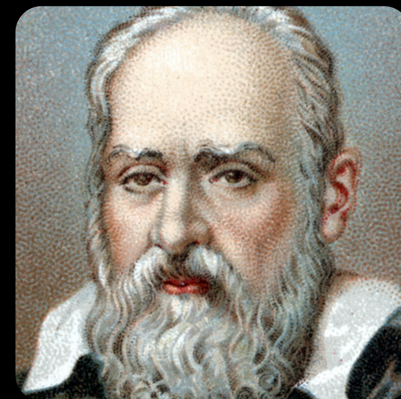
DIMENSIONALITY

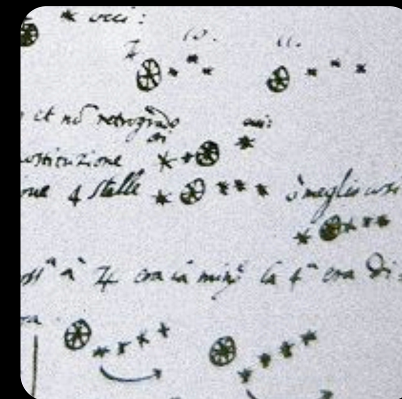
LINKED VIEWS

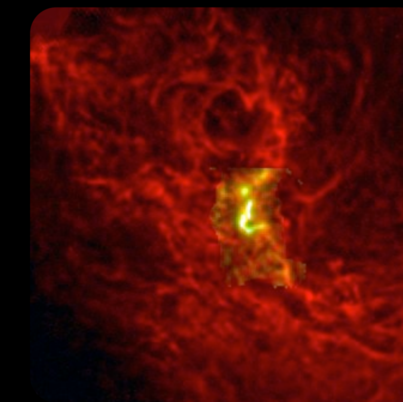
INTERACTION

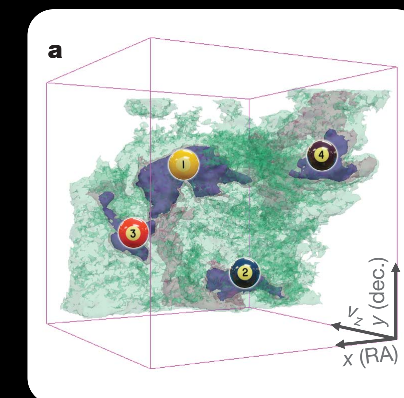
COMMUNICATION

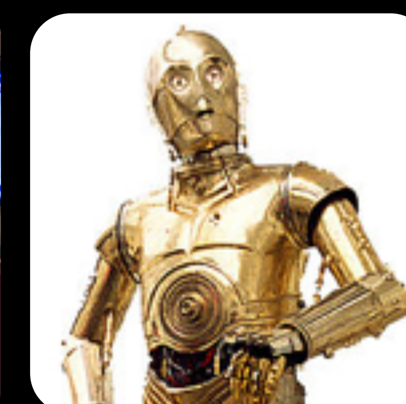
EDUCATION

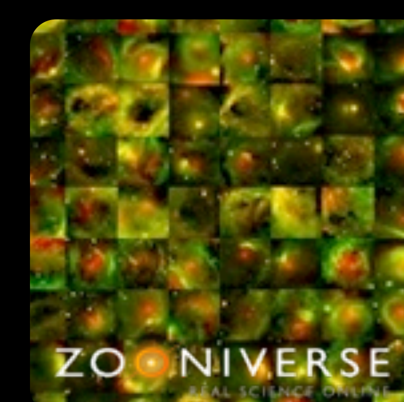










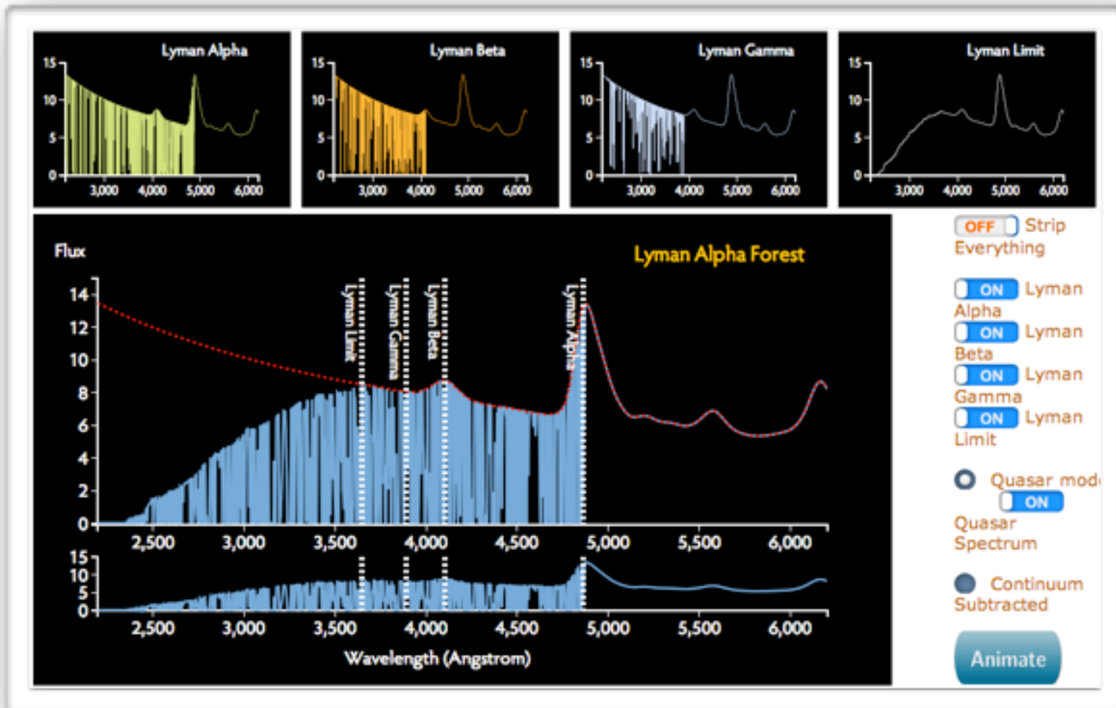


EDUCATION, 2015+

Stephen

Yuan-Sen Ting

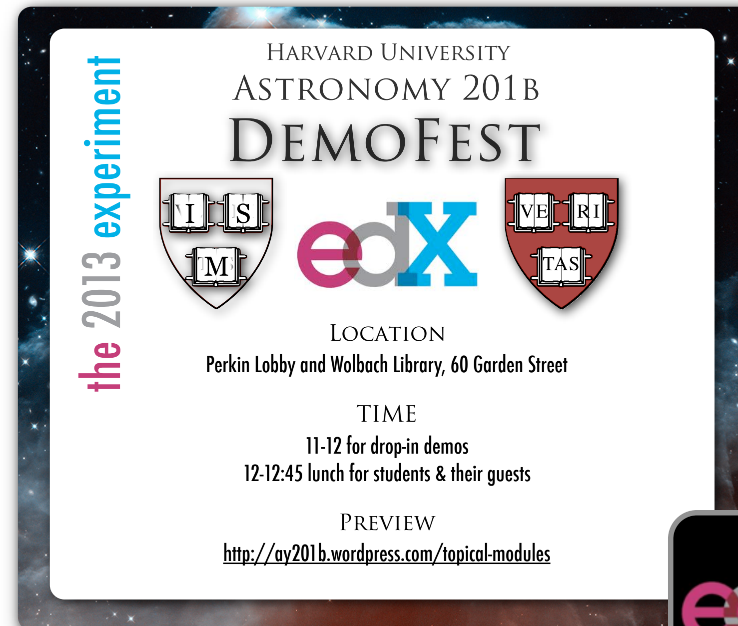
Interstellar Absorption and the Lyman Alpha Forest



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

JavaScript http://portillo.ca/nebula/

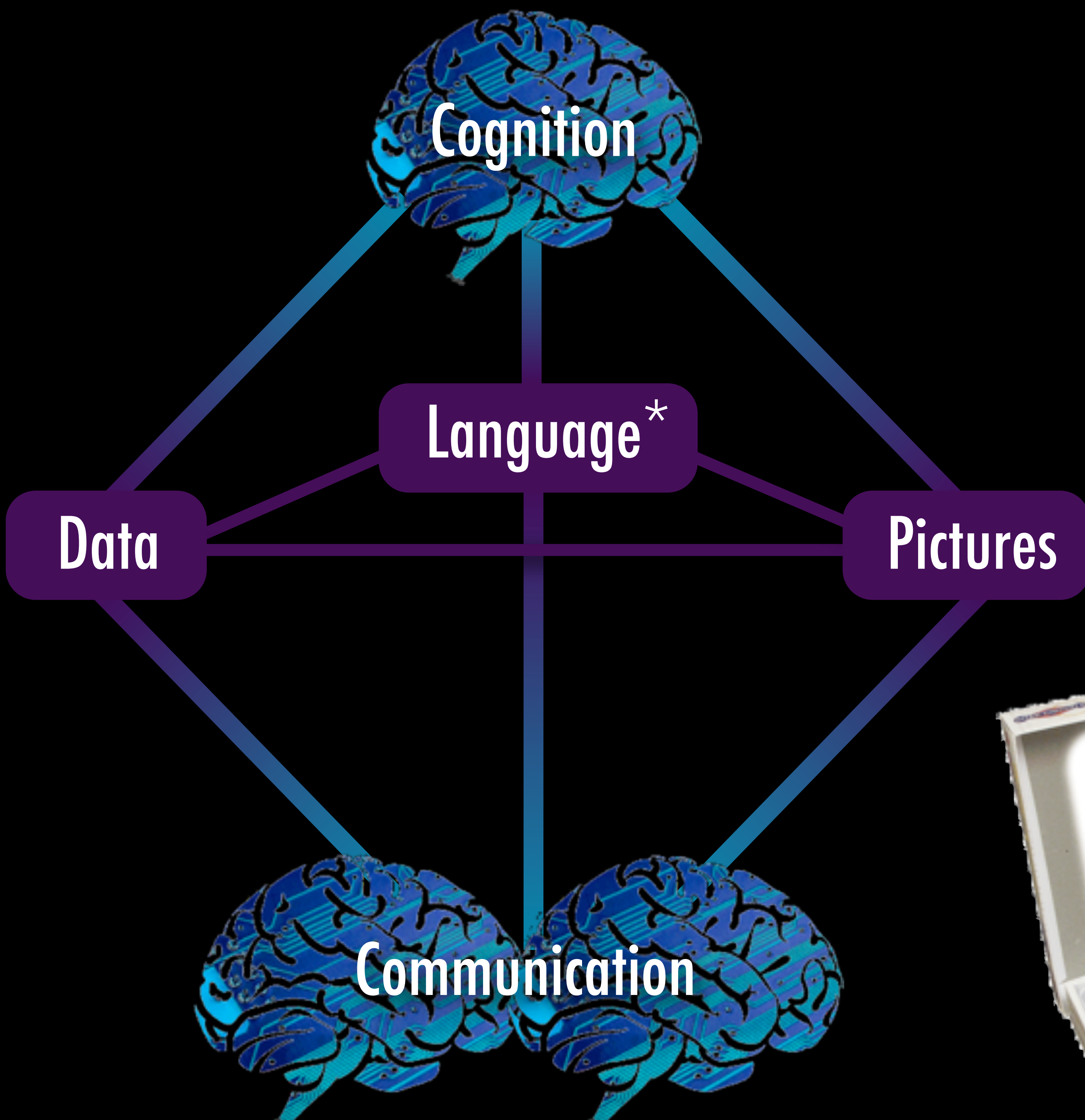
online learning



WWT Ambassadors

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

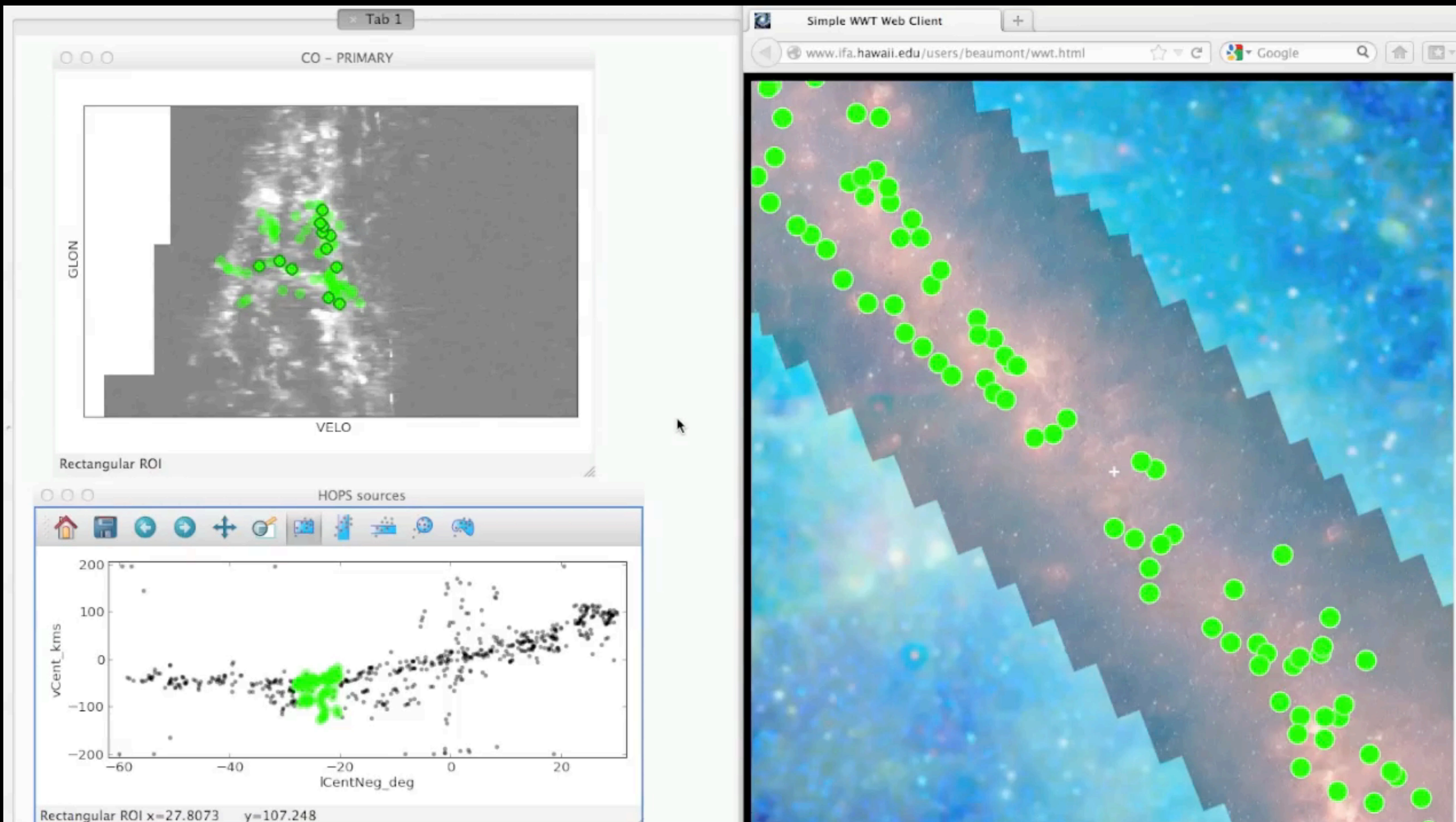
THE FUTURE IS ABOUT **INTEGRATION**



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

glue

WorldWide Telescope



Video courtesy of Chris Beaumont, Lead Glue Architect

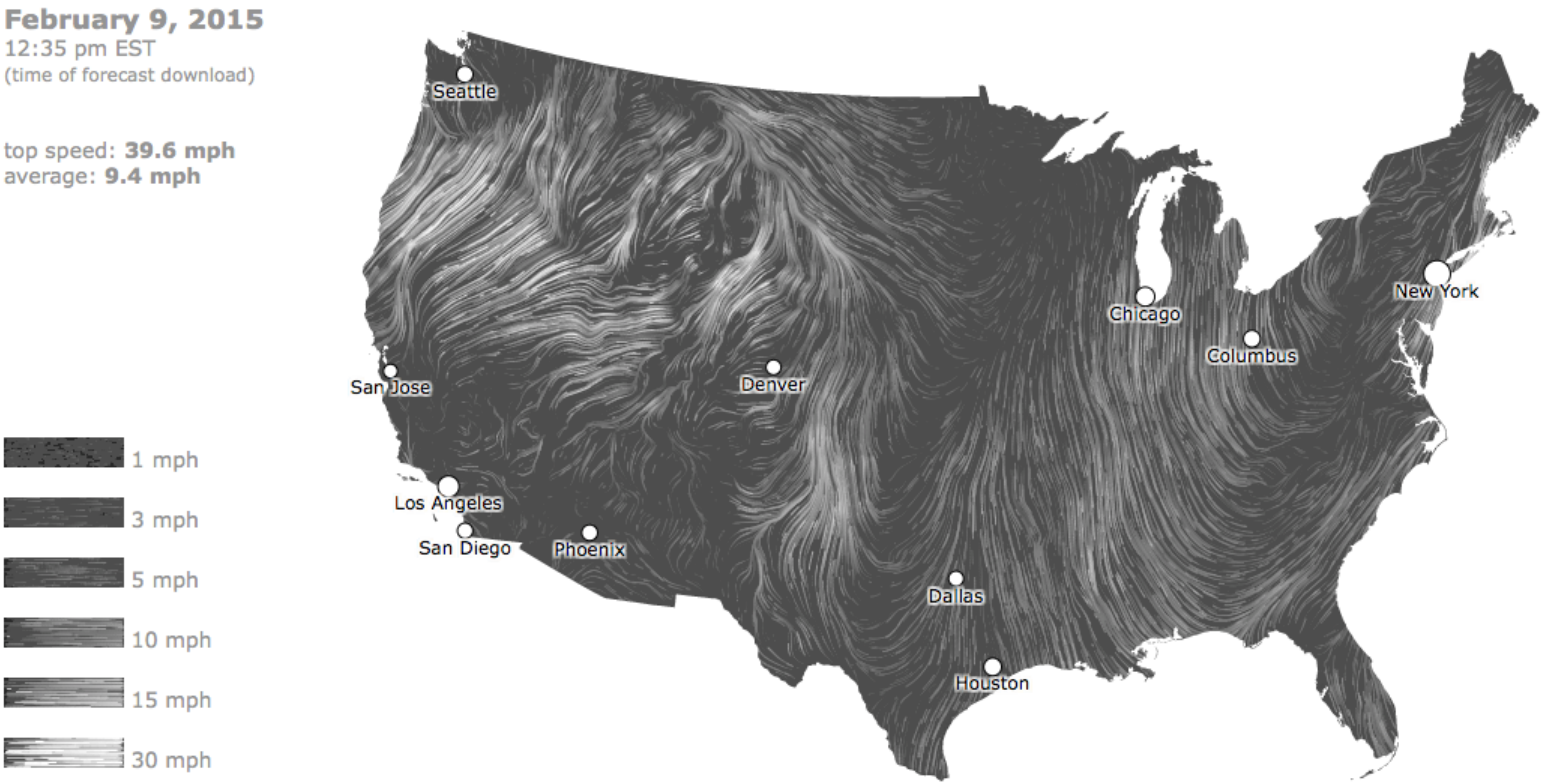
+ALWAYS NEW IDEAS UNDER THE SUN

hint.fm/wind (Fernanda Viegas & Martin Wattenberg)

Credits: Vincent Van Gogh, ESA, Illustration – J.Schmidt, T.Reyes)

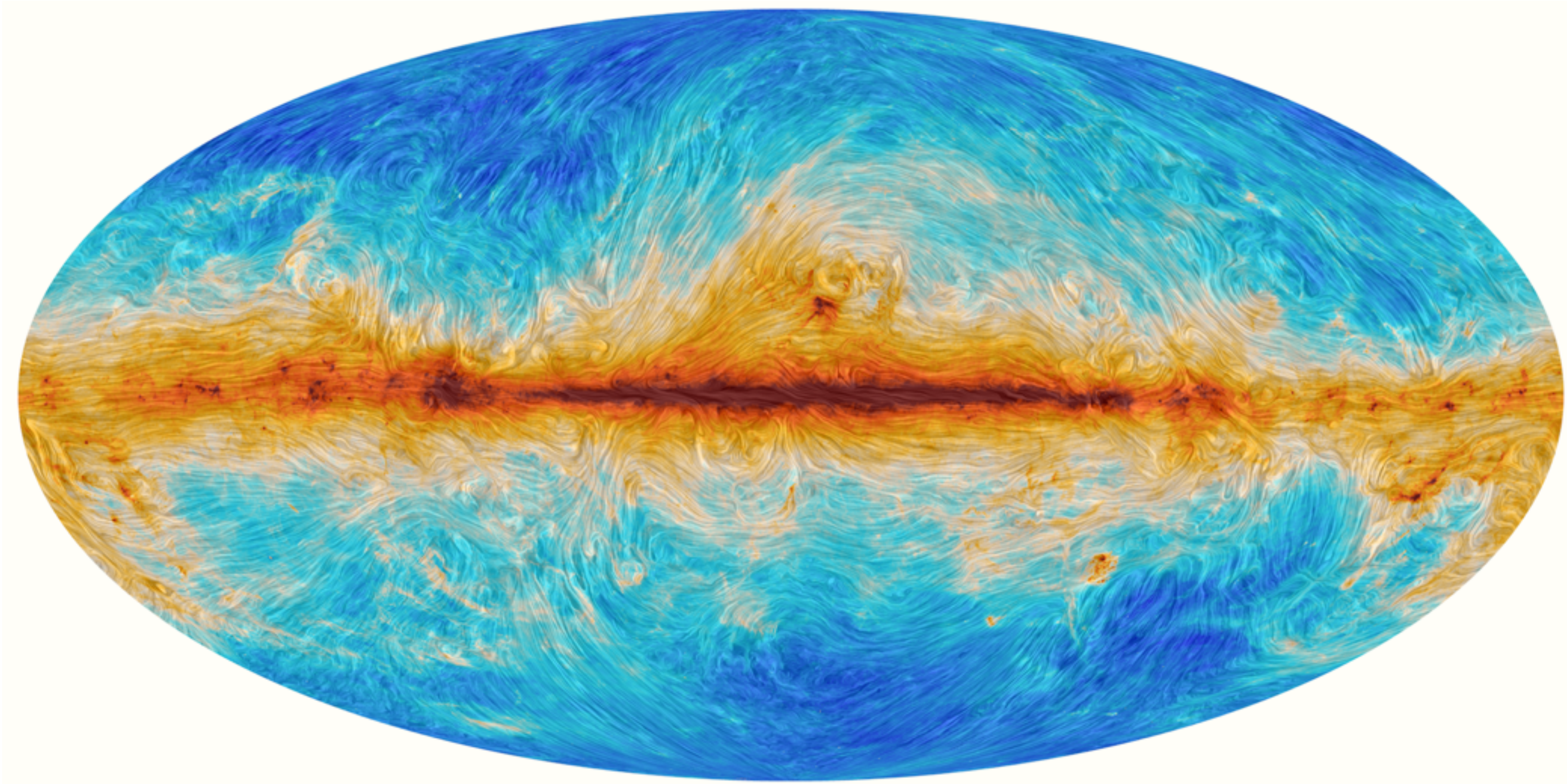
wind map

hint.fm/wind (Fernanda Viegas & Martin Wattenberg)



Darker regions correspond to stronger polarised emission, and the striations indicate the direction of the magnetic field projected on the plane of the sky. (ESA, May 2014.)

http://sci.esa.int/planck/54000-the-magnetic-field-of-our-milky-way-galaxy-as-seen-by-esas-planck-satellite/



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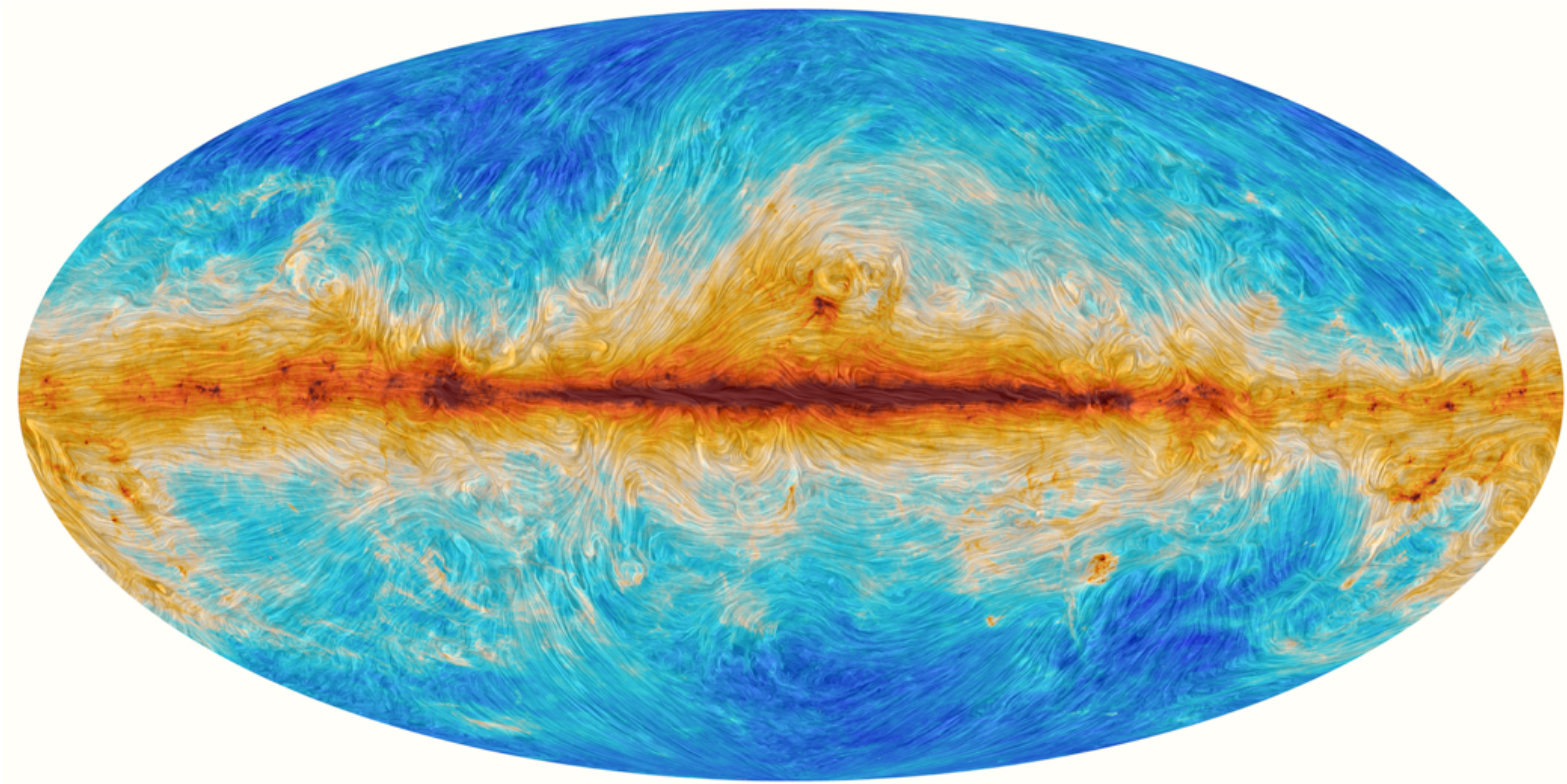

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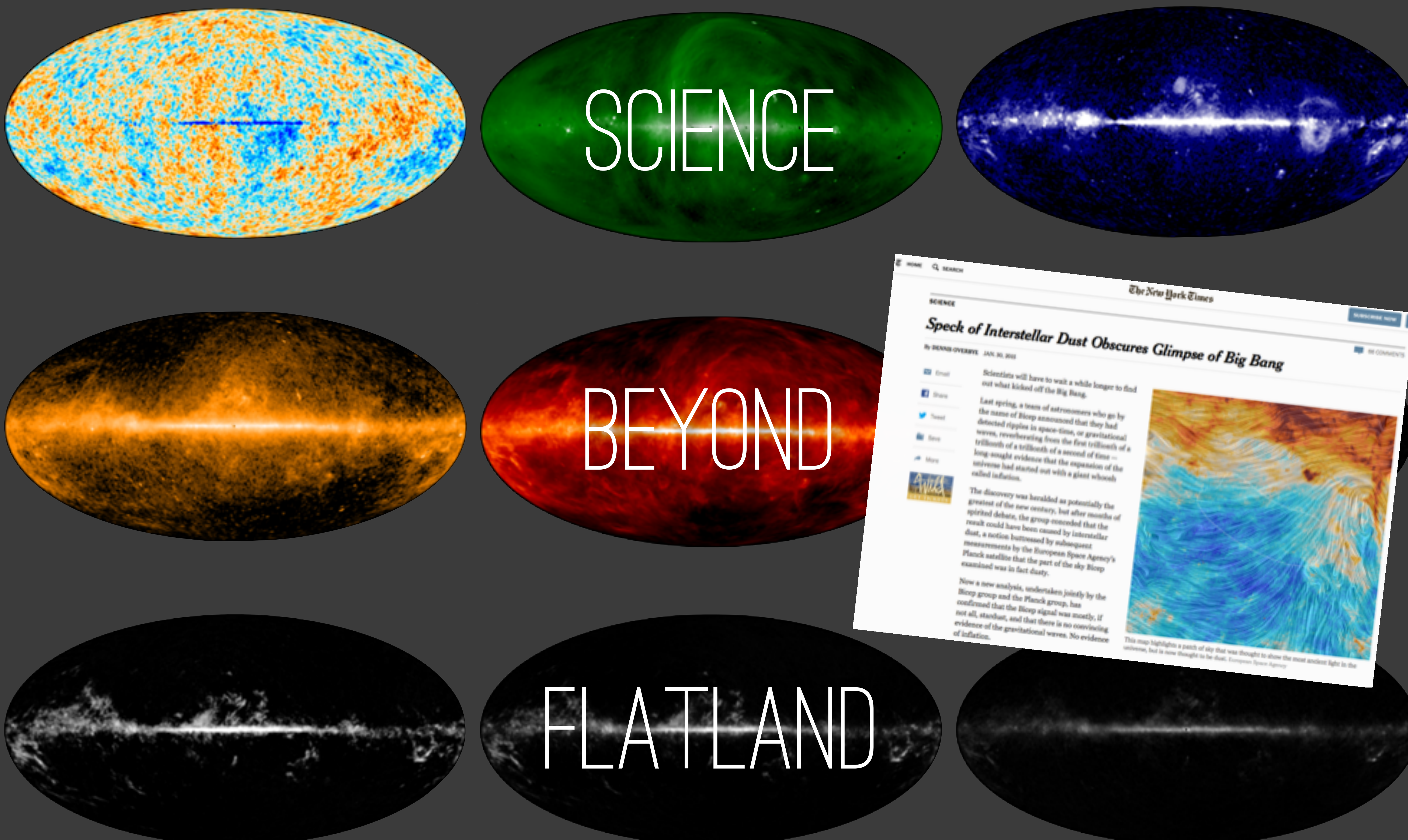

HOME SEARCH

The New York Times

SCIENCE

Speck of Interstellar Dust Obscures Glimpse of Big Bang

By DENNIS OVERBYE JAN. 30, 2015

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Scientists will have to wait a while longer to find out what kicked off the Big Bang.

Last spring, a team of astronomers who go by the name of Bicep announced that they had detected ripples in space-time, or gravitational waves, reverberating from the first trillionth of a trillionth of a trillionth of a second of time — long-sought evidence that the expansion of the universe had started out with a giant whoosh called inflation.

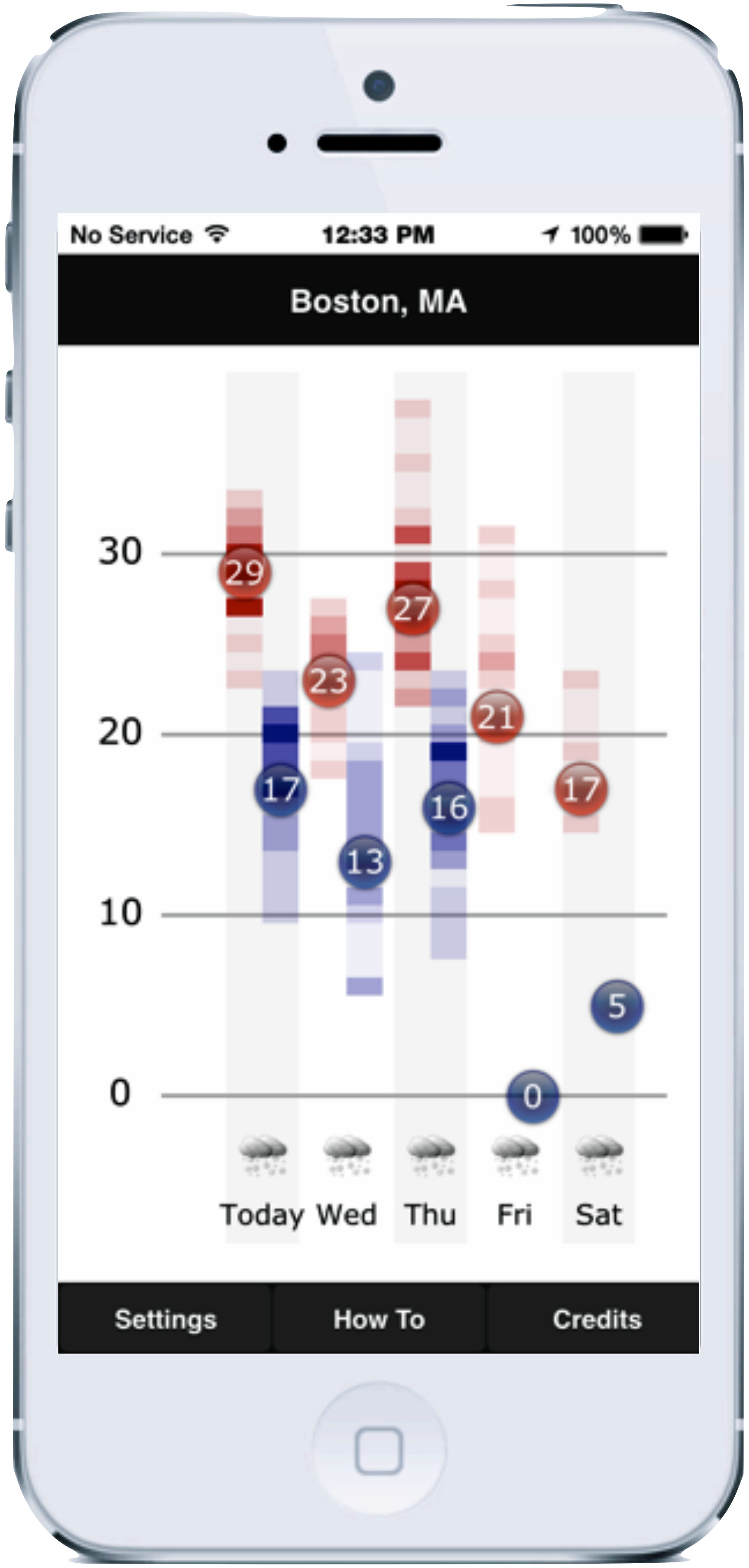
The discovery was heralded as potentially the greatest of the new century, but after months of spirited debate, the group conceded that the result could have been caused by interstellar dust, a notion buttressed by subsequent measurements by the European Space Agency's Planck satellite that the part of the sky Bicep examined was in fact dusty.

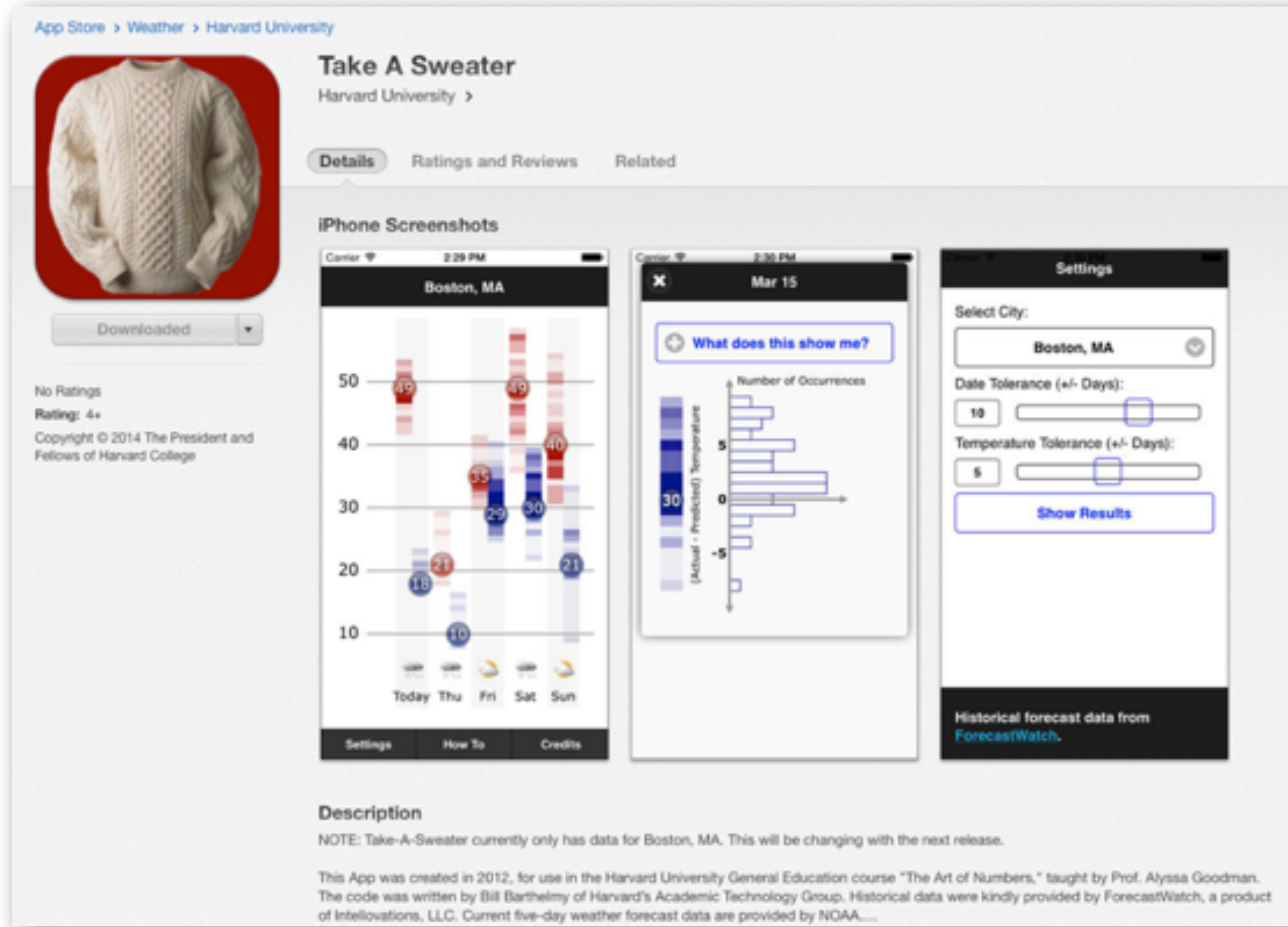
Now a new analysis, undertaken jointly by the Bicep group and the Planck group, has confirmed that the Bicep signal was mostly, if not all, stardust, and that there is no convincing evidence of the gravitational waves. No evidence of inflation.

This map highlights a patch of sky that was thought to show the most ancient light in the universe, but is now thought to be dust. European Space Agency

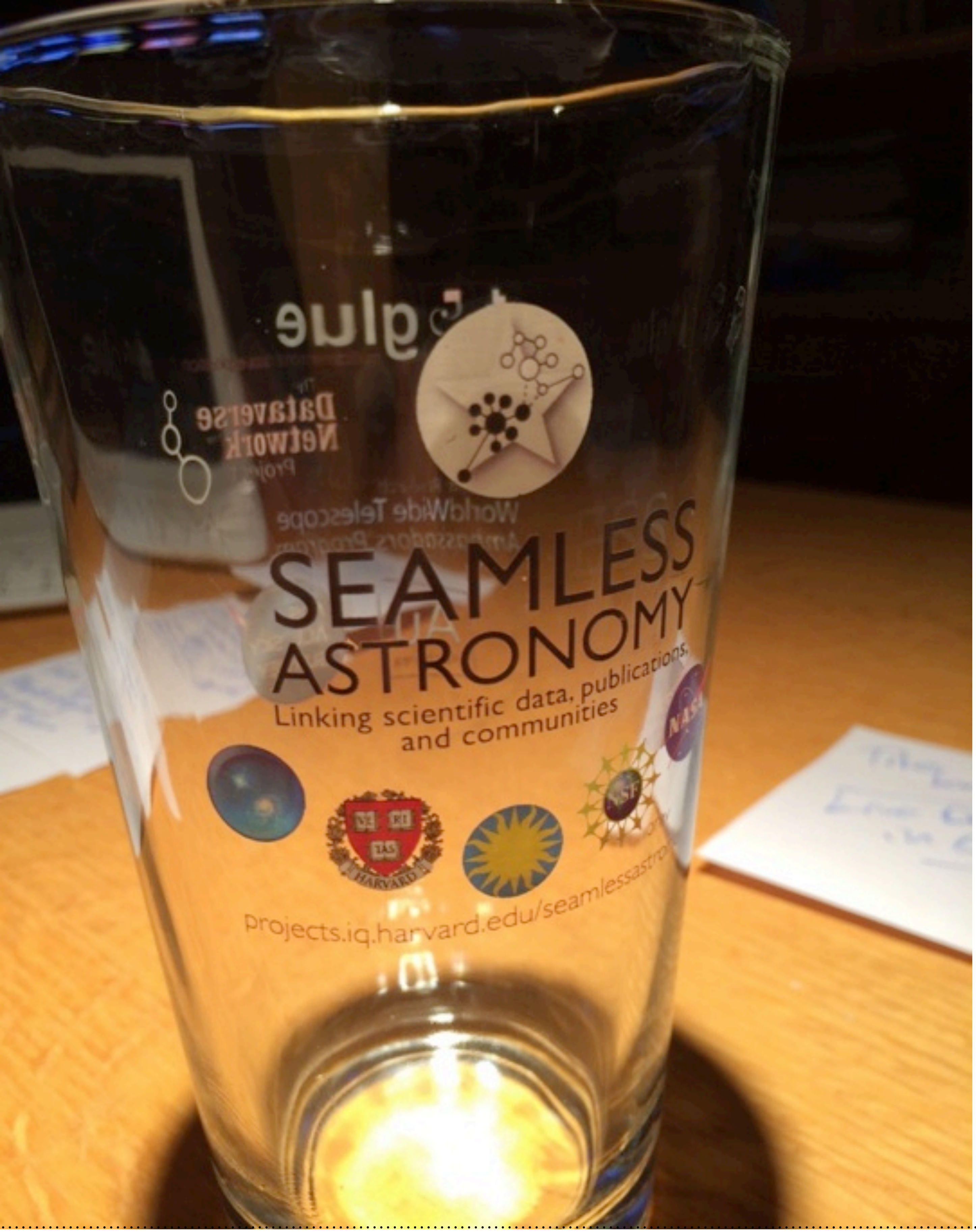
Alyssa A. Goodman • Harvard-Smithsonian Center for Astrophysics • @aagie

Thanks for the Warmth!





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



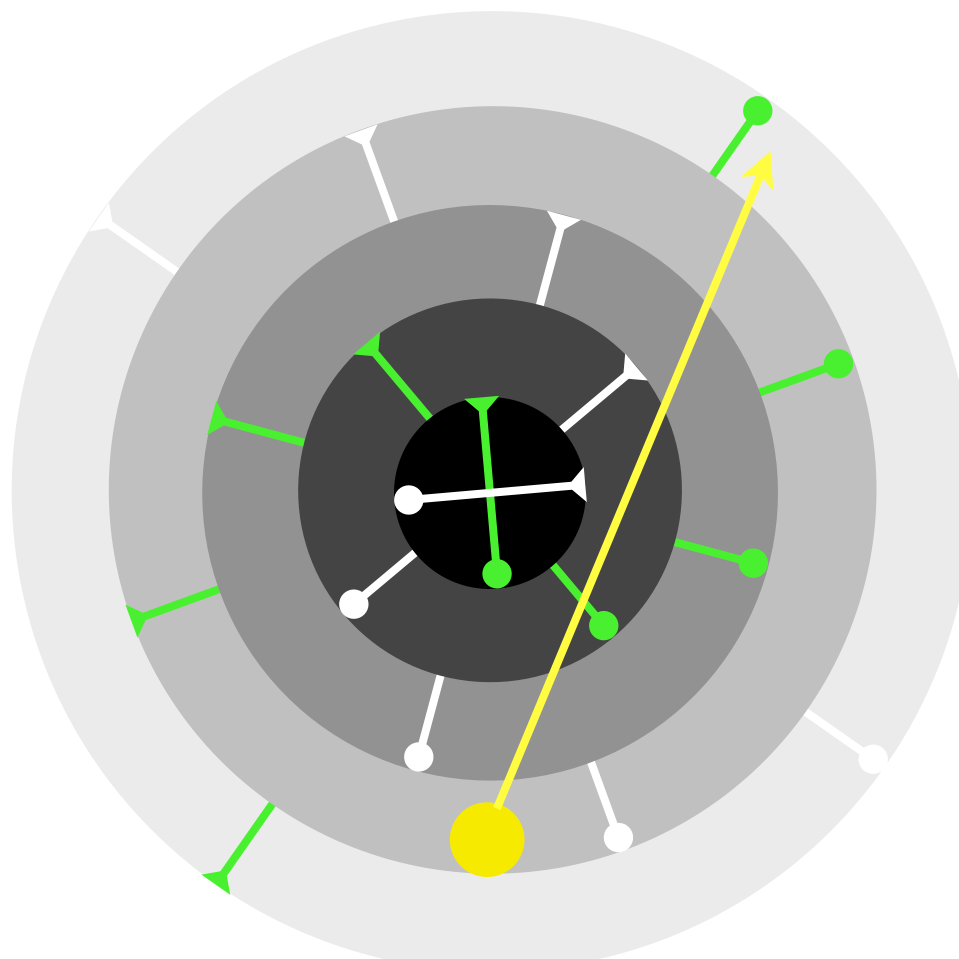
MORE?

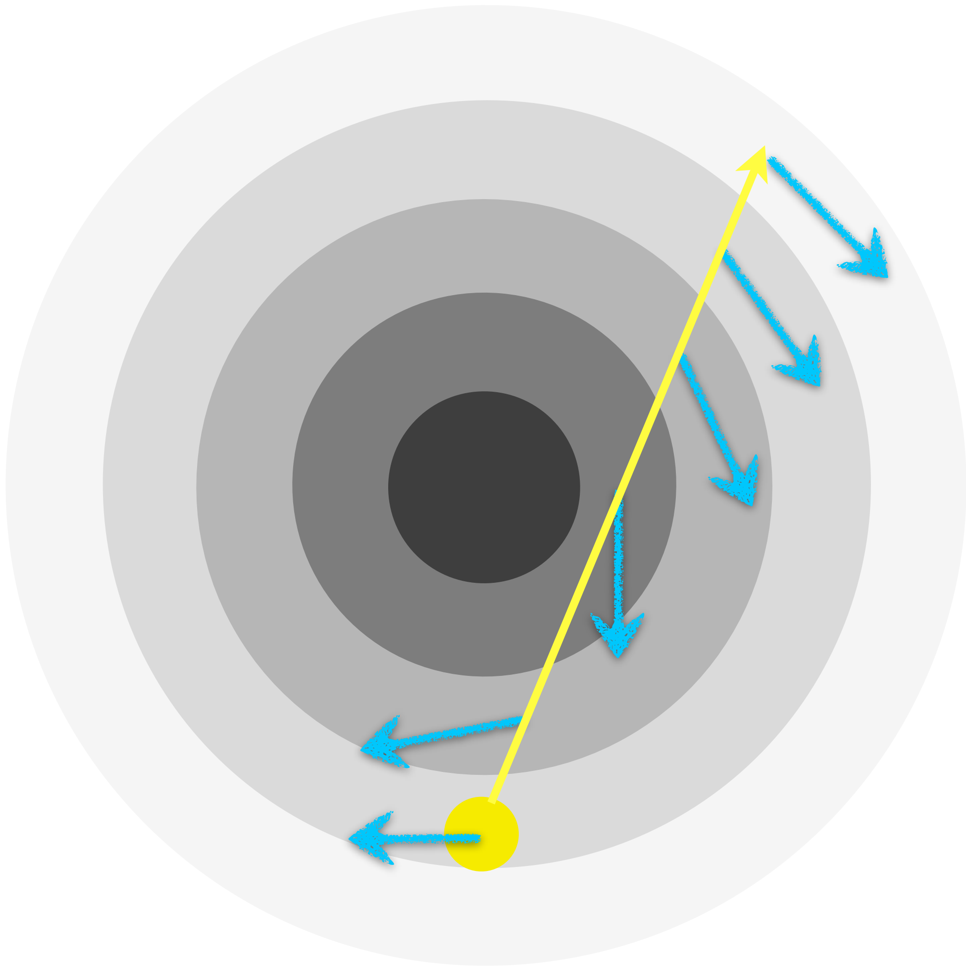
projects.iq.harvard.edu/seamlessastronomy/presentations

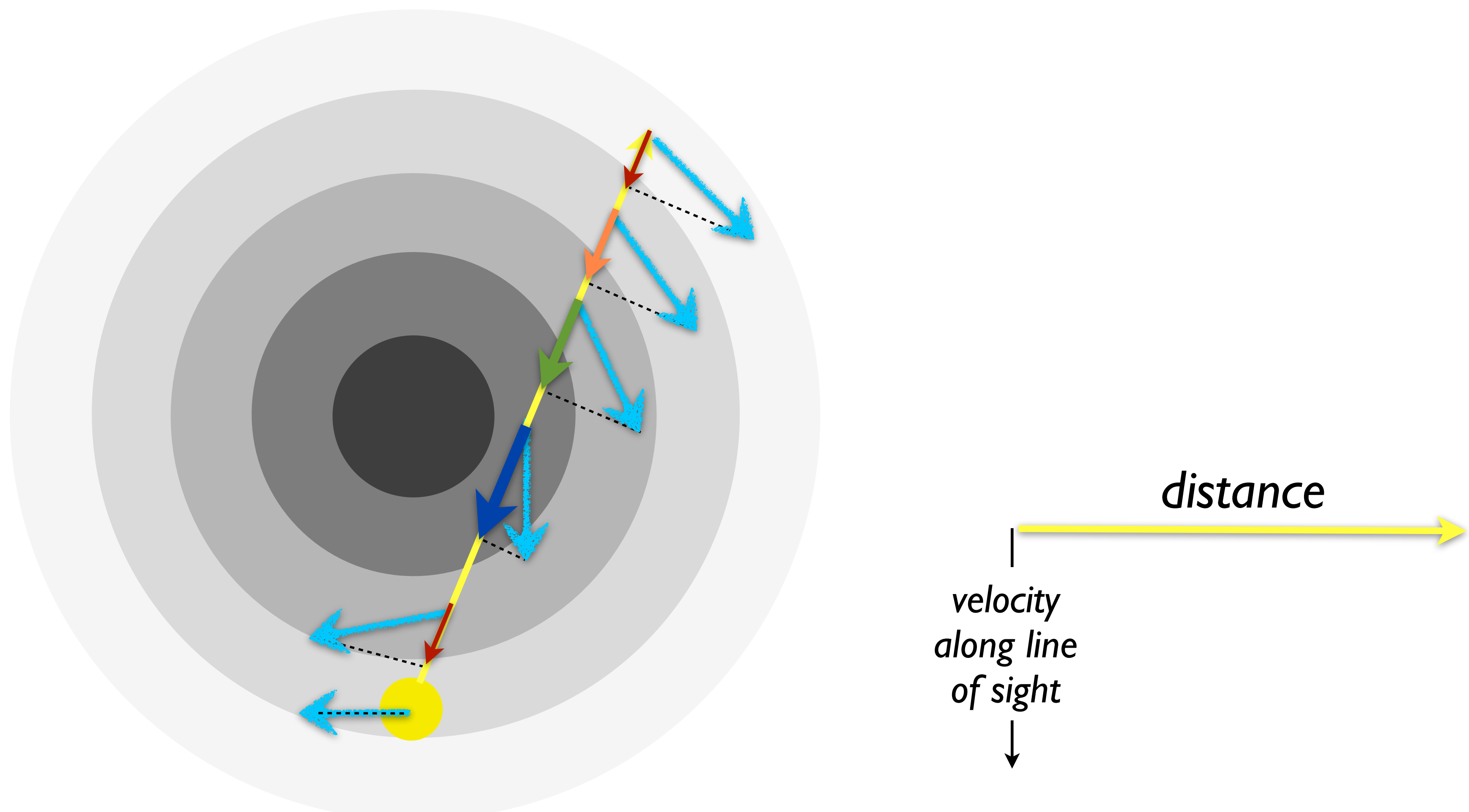
Nessie to B5, the movie.

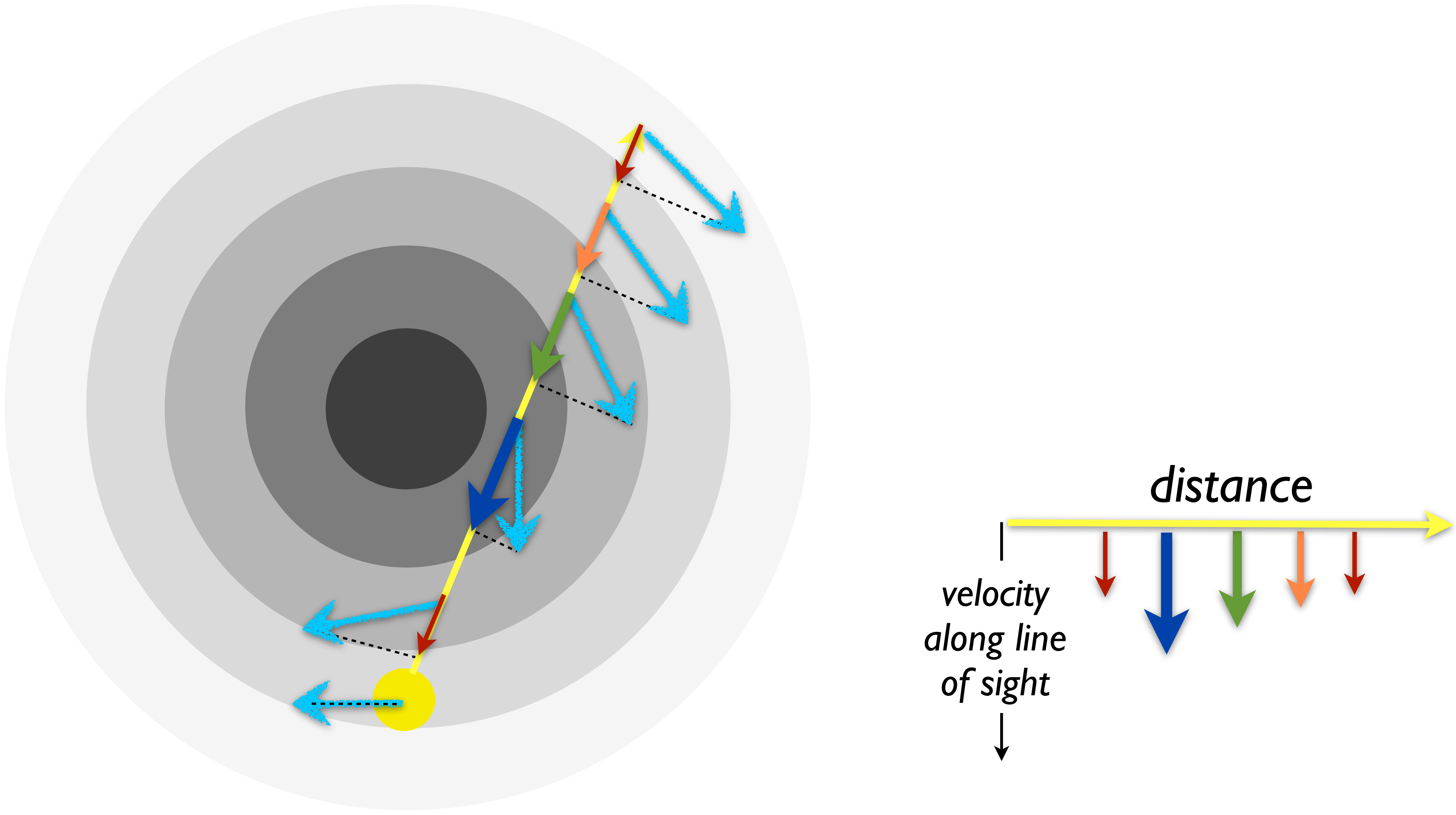
EXTRA SLIDES

A Rotating (Spiral) Galaxy Observed from its Outskirts...





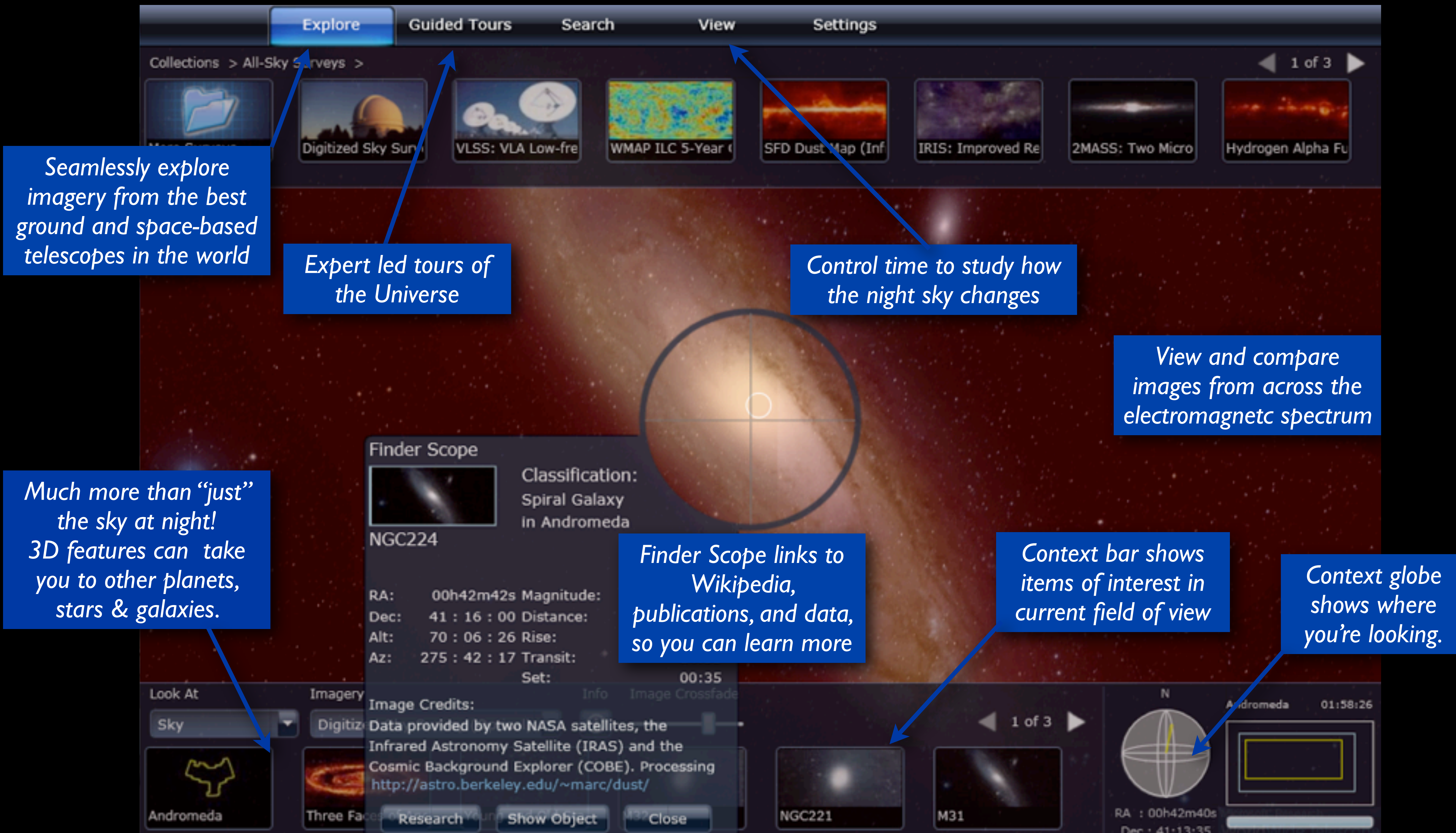

distance
velocity
along line
of sight



back

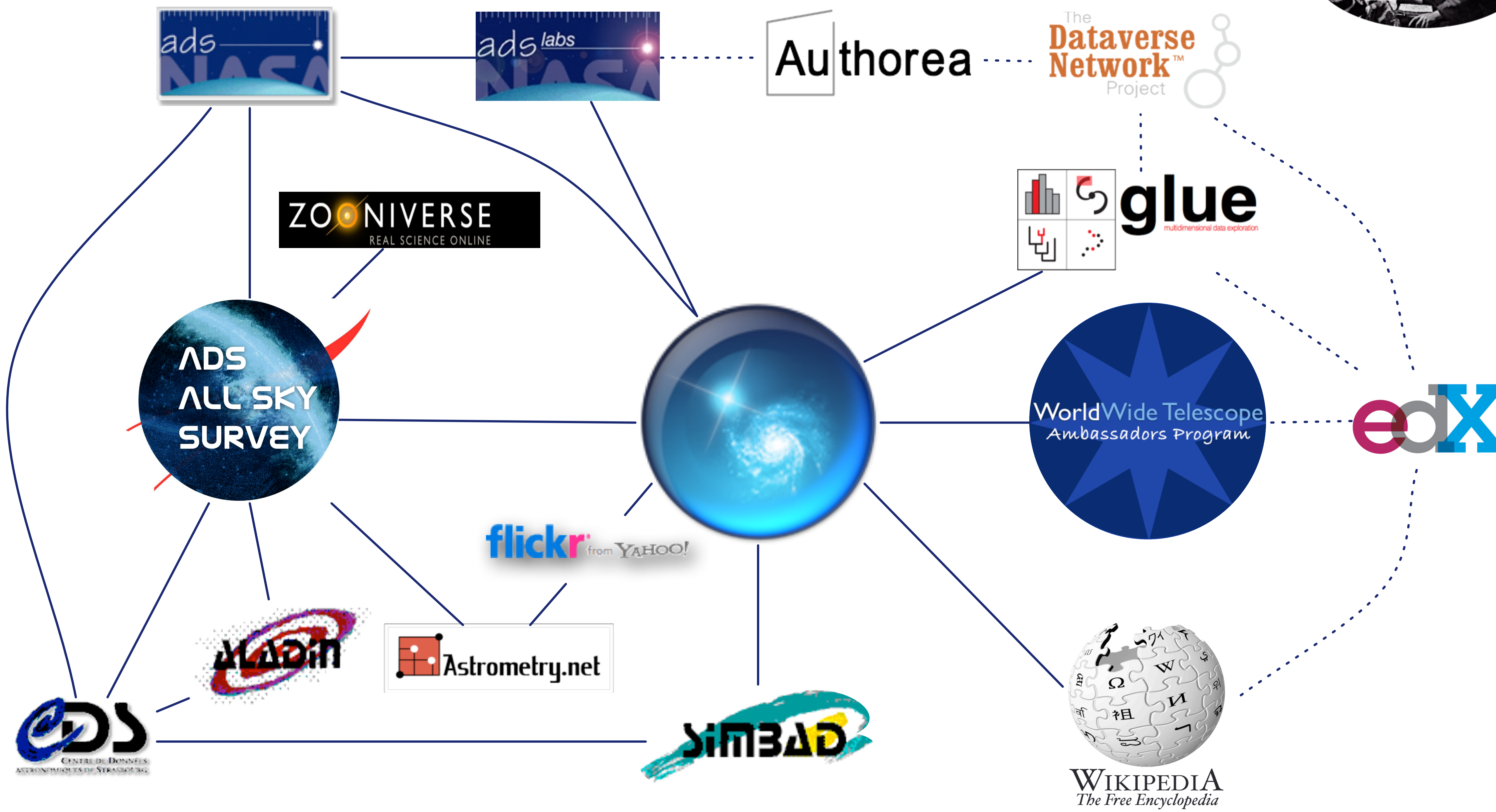
Microsoft® Research
WorldWide Telescope

worldwidetelescope.org



SEAMLESS ASTRONOMY

Linking scientific data, publications, and communities



https://www.cfa.harvard.edu/~agoodman/seamless/

Supported by Microsoft Research, NSF, NASA, Harvard, Smithsonian

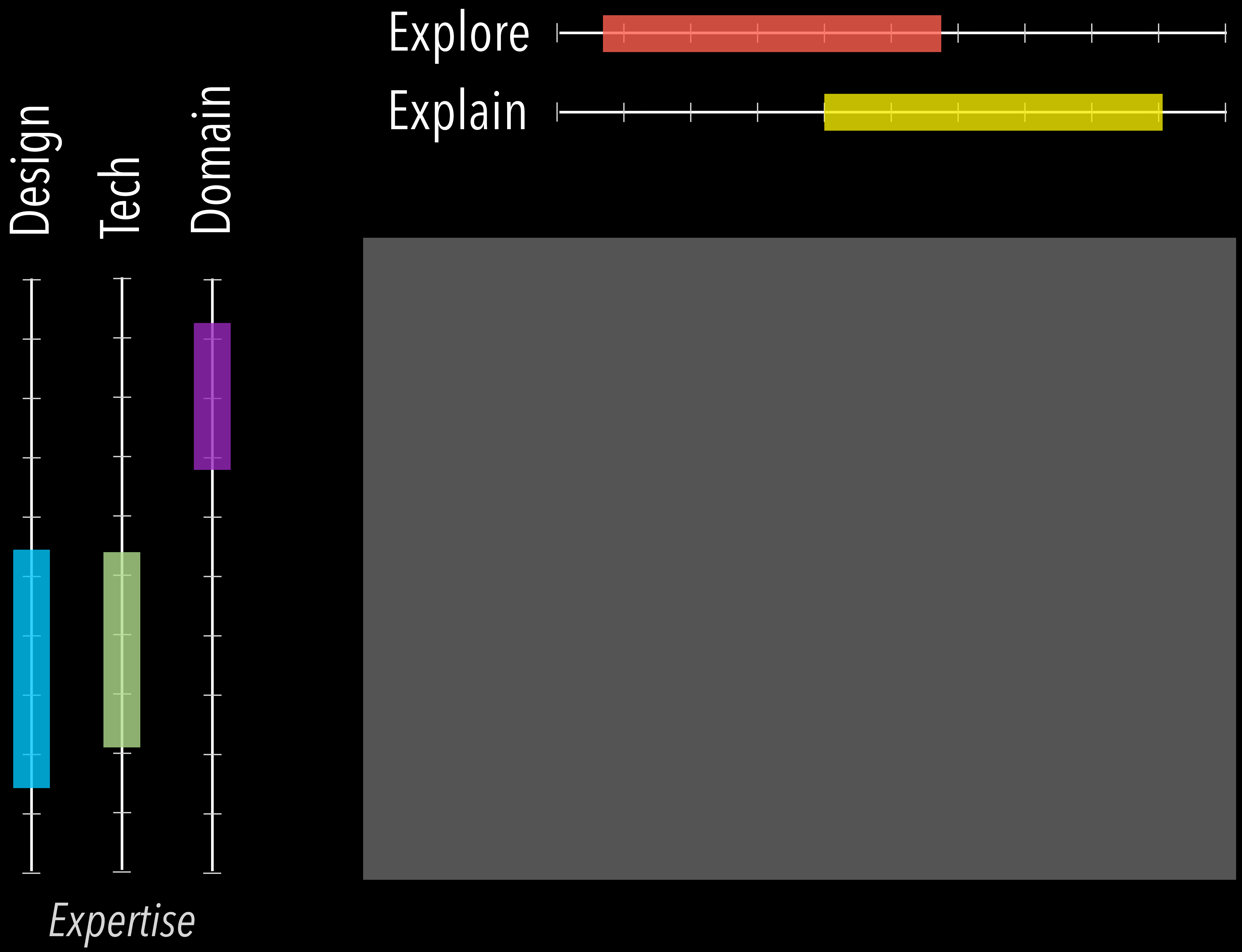
Made possible by MANY collaborators, listed at projects.iq.harvard.edu/seamlessastronomy

Stellar Jet in the Carina Nebula

Hubble Space Telescope • WFC3/UVIS/IR

NASA, ESA, and the Hubble SM4 ERO Team

STScI-PRC09-25b



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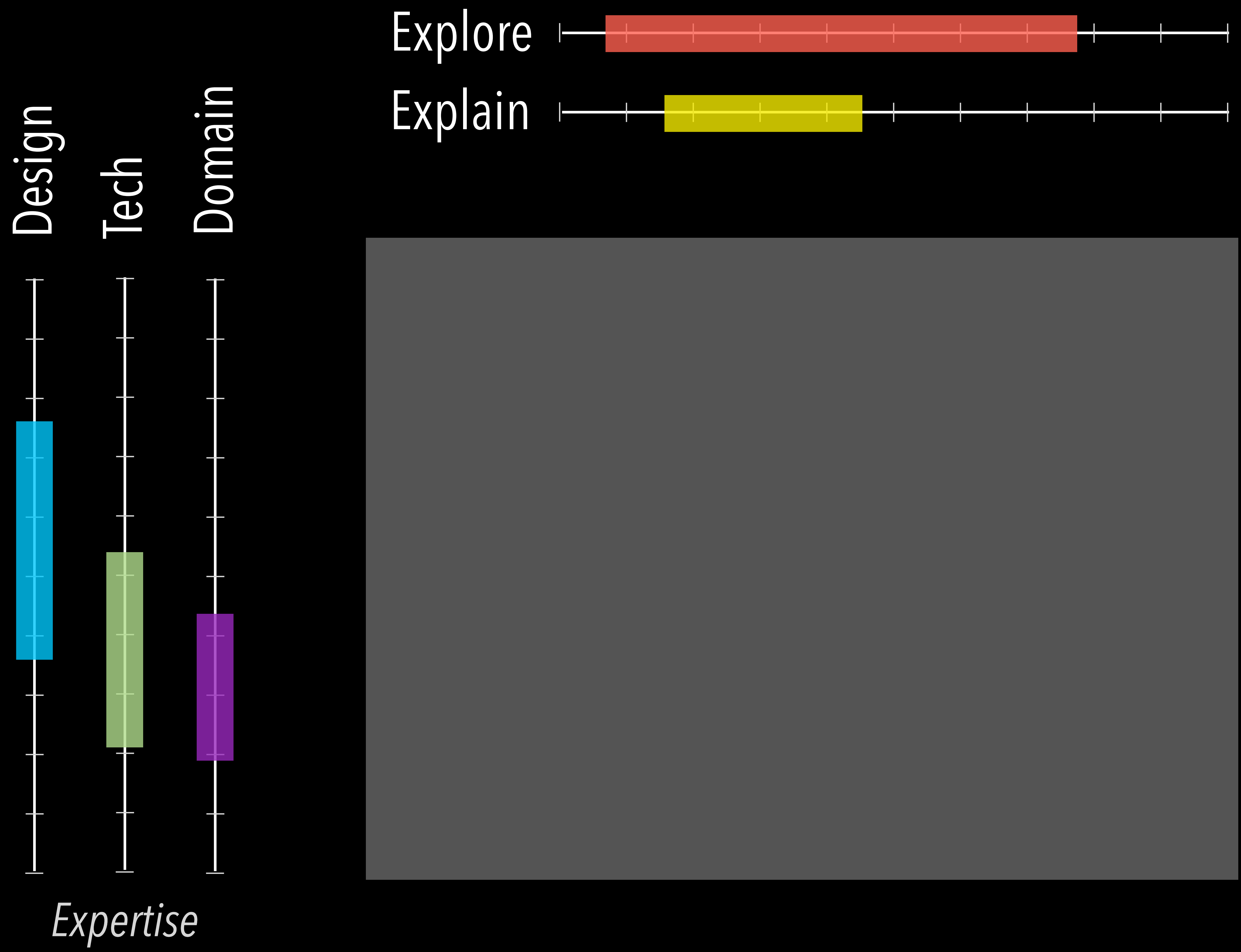
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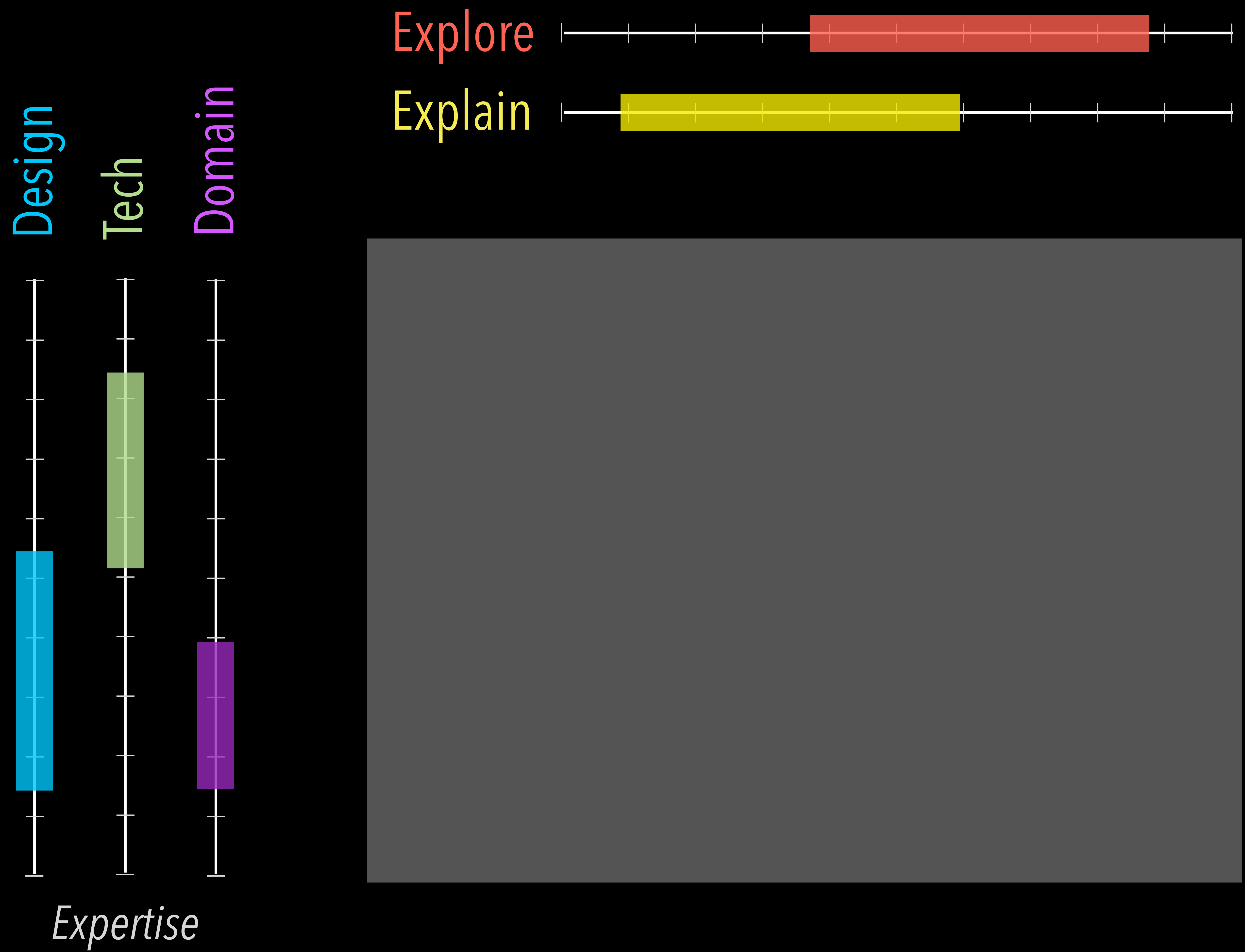
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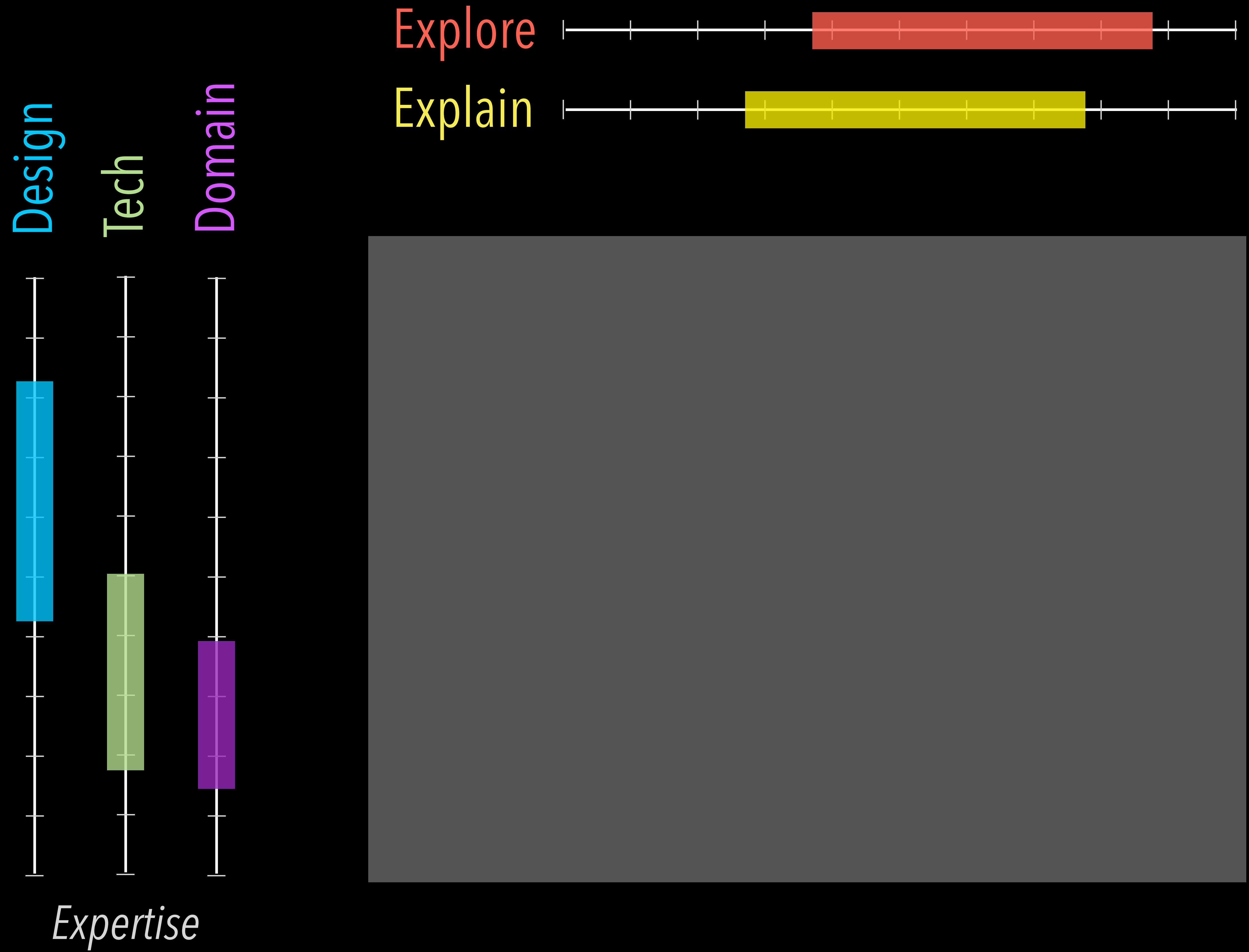
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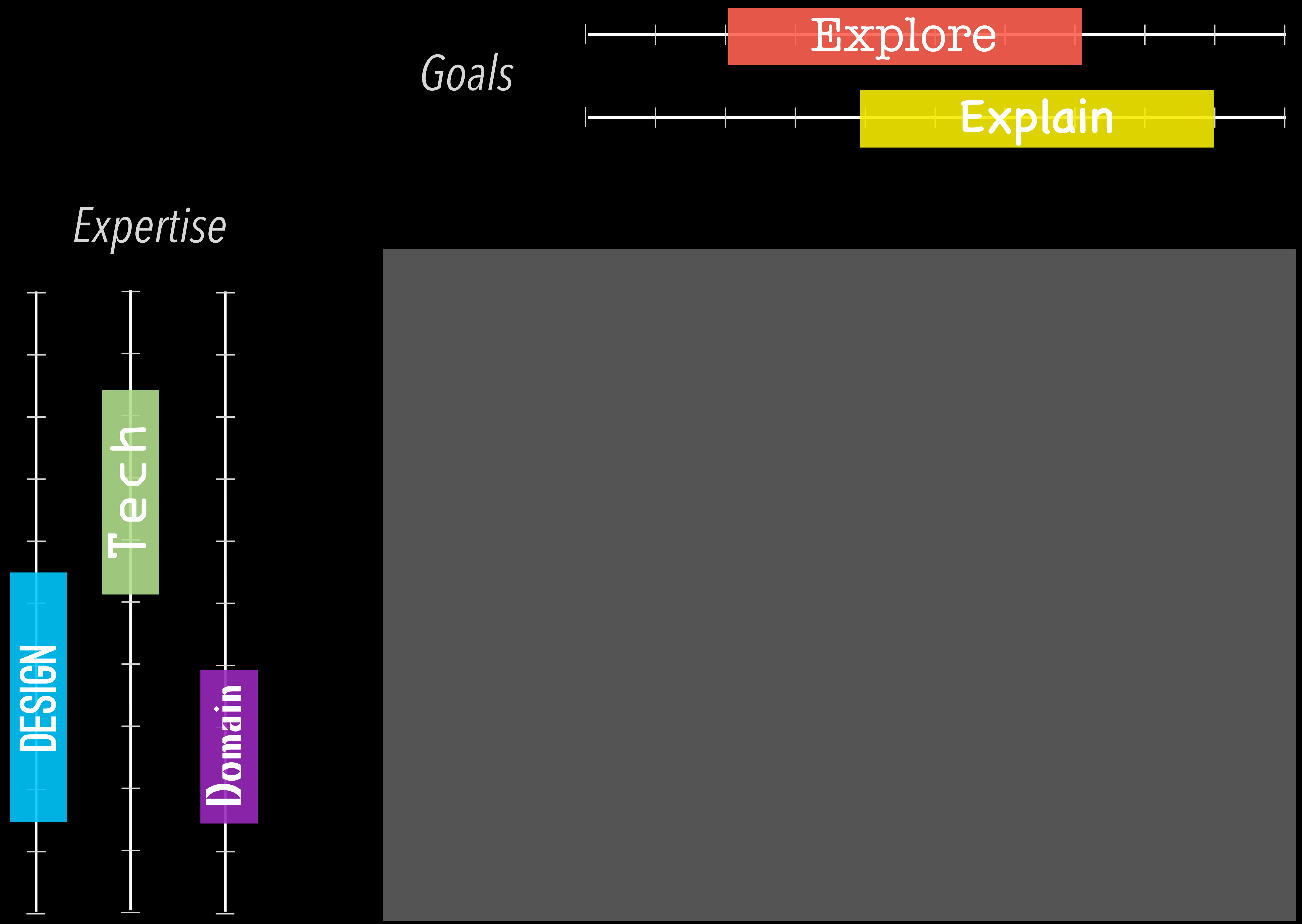
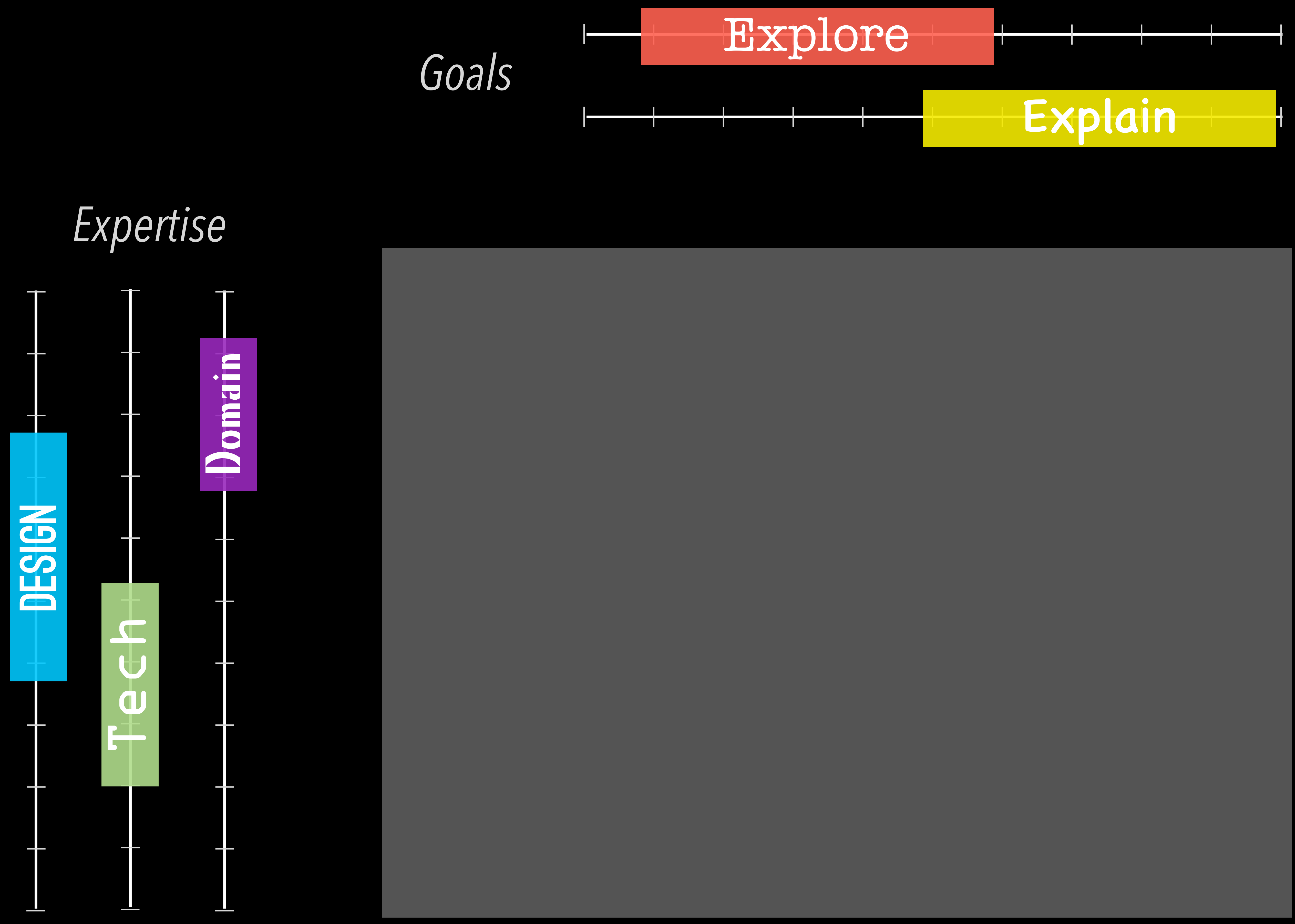

Goals
Explore
Explain
Expertise
DESIGN
Tech
Domain



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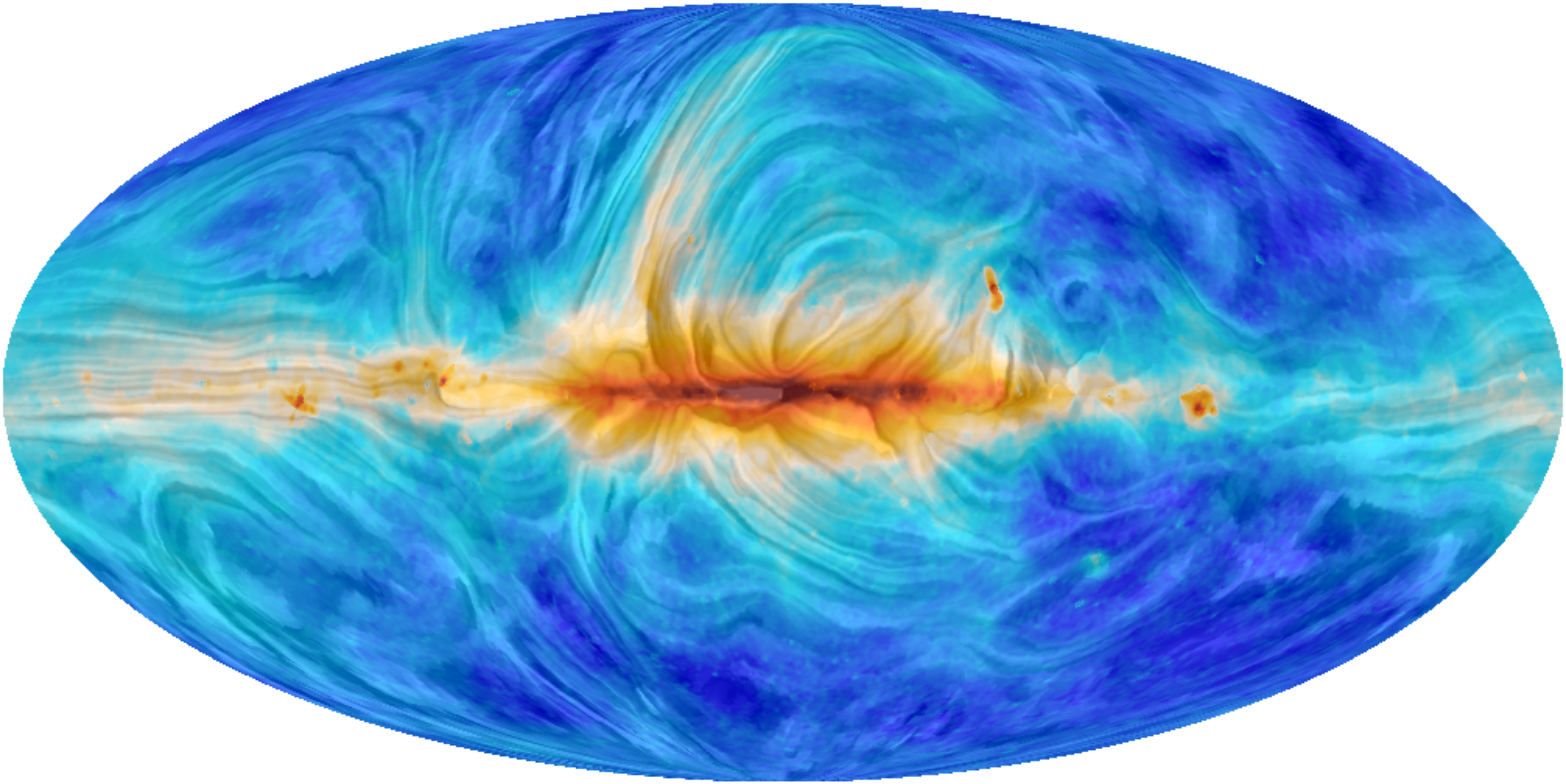
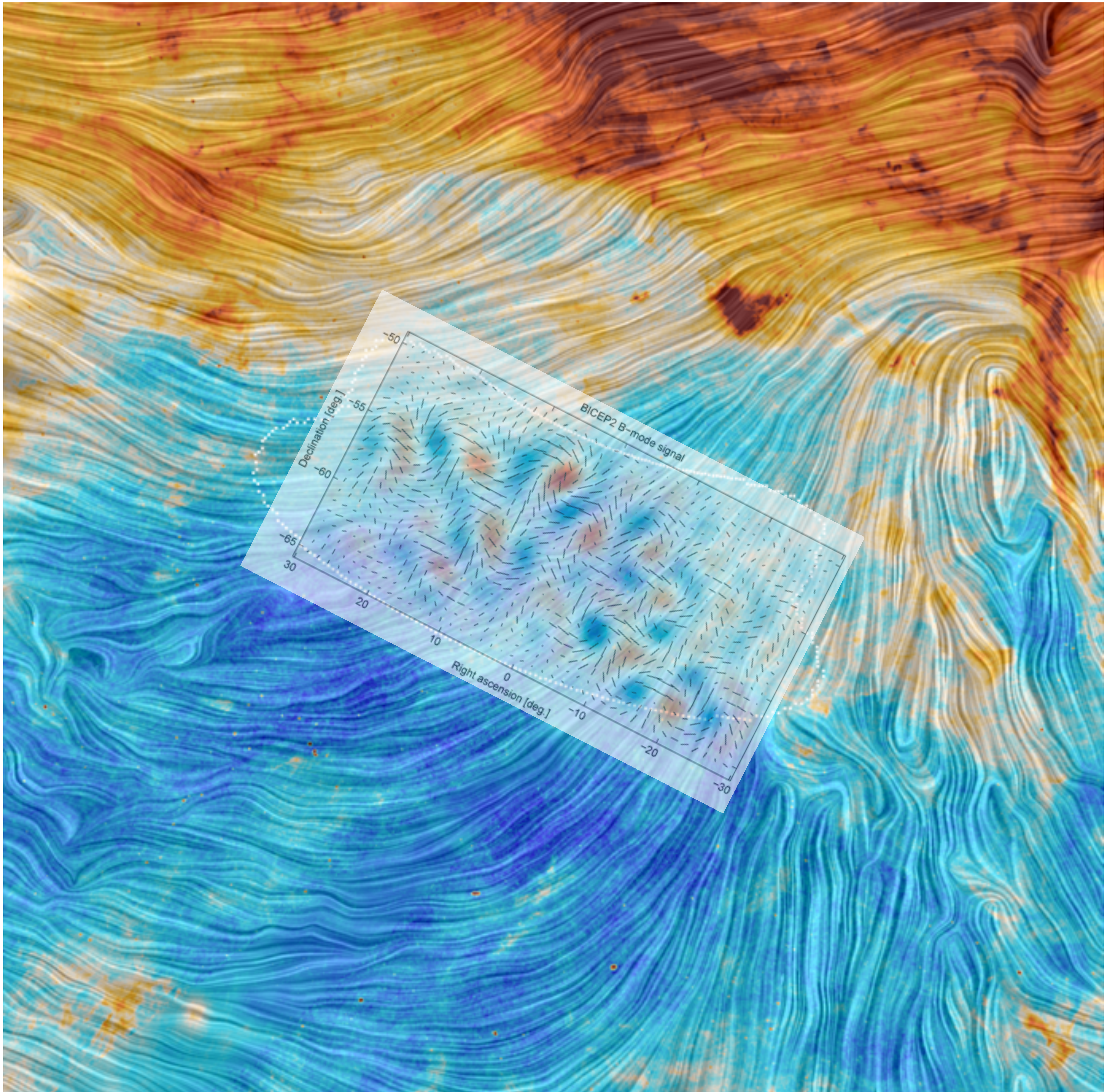
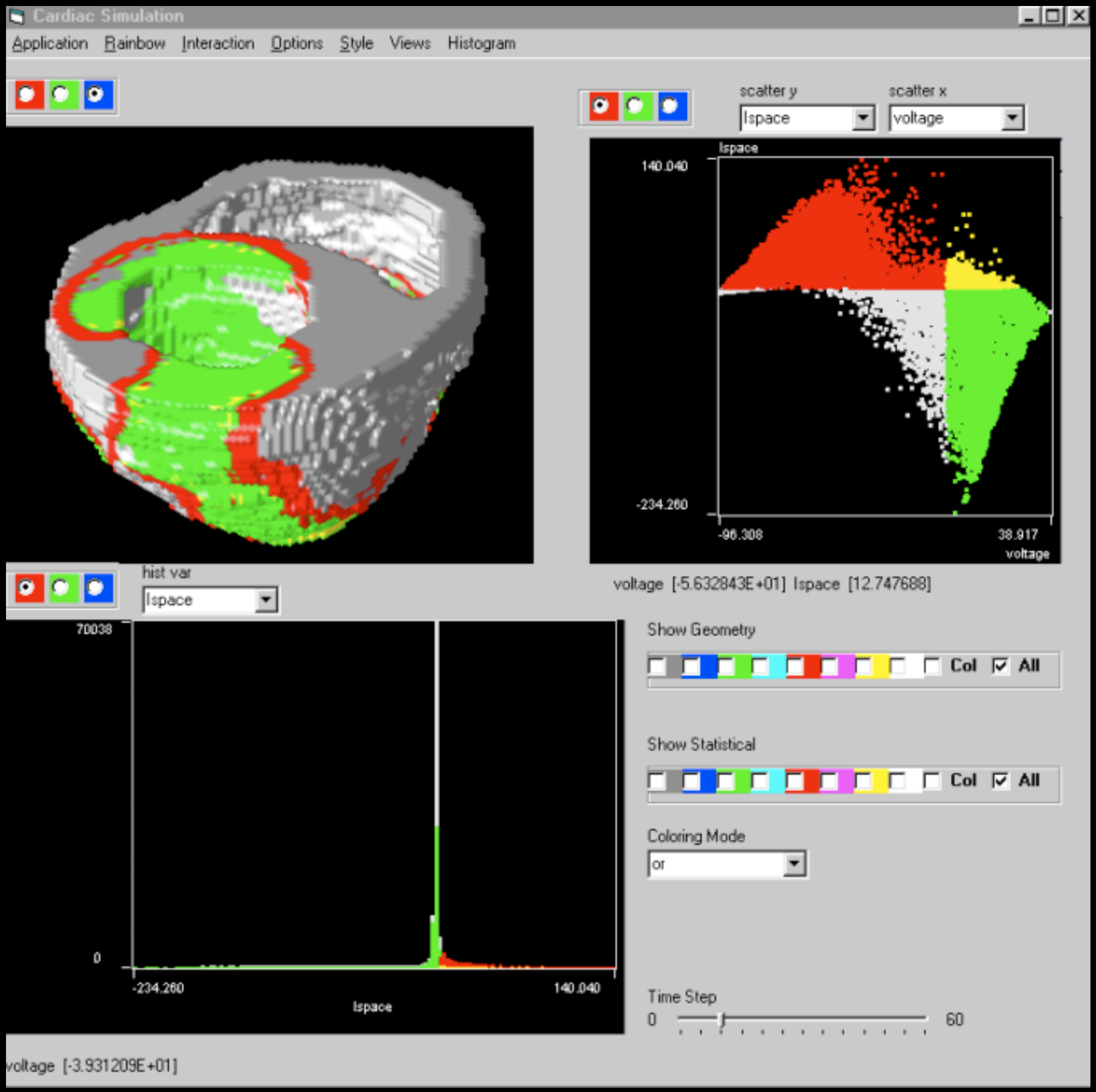


synchrotron polarization


BICEP2 B-mode signal
Declination [deg.]
-50
-55
-60
-65
Right ascension [deg.]
30
20
10
0
-10
-20
-30



screenshot of WEAVE from Gresh et al. 2000,
reproduced as shown in Goodman 2012