

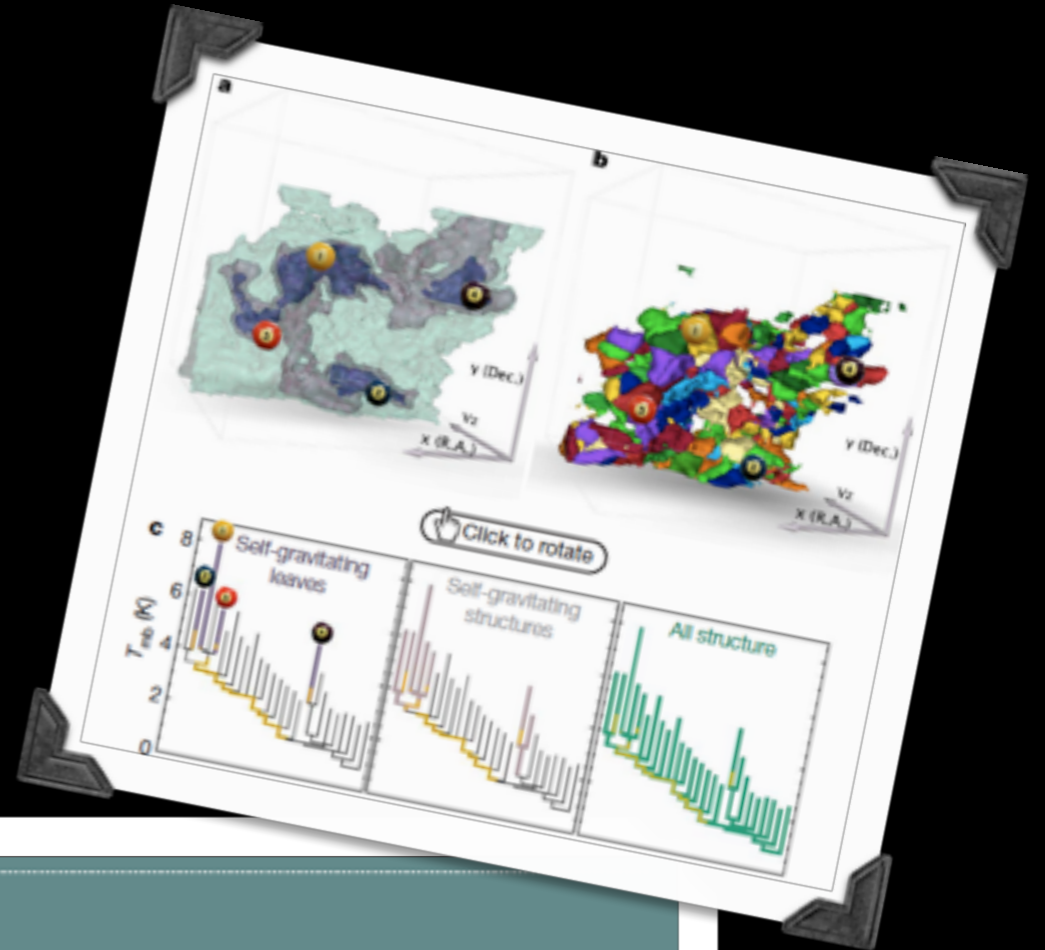


# WorldWide Telescope

Microsoft  
Research

# Seeing Science

## Data Visualization in Modern Research (and teaching!)



### The Art of Numbers

Empirical and Mathematical Reasoning 19. The Art of Numbers: The Visual Display of Information

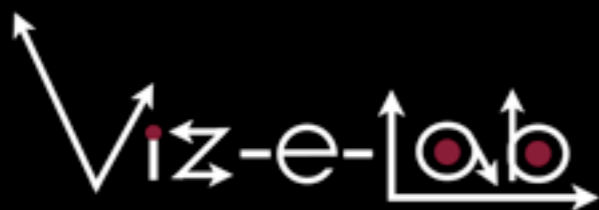
Professor Alyssa A. Goodman (Astronomy)

**Course website**

Duration: 05:30

*What kind of credentials are those??*

**Alyssa A. Goodman**  
Harvard University (HCO+IIC)  
Smithsonian Astrophysical Observatory  
Scholar-in-Residence, WGBH







IMG\_4705



IMG\_4661



1268



IMG\_4130



IMG\_4129



IMG\_4128



fun this was!



IMG\_3343



IMG\_3343



IMG\_3338



3251



IMG\_3238



View



Confirm Name



Edit



Rotate



Flag



Hide



Slideshow



Book



Calendar



Card



MobileMe



Facebook



Flickr



Email



Set Desktop



iWeb



iDVD





19 out of 22?

# Relative Strengths



**Pattern Recognition**  
**Creativity**



**Calculations**



“Interoocularity”

(see work of John Tukey)

“Image and Meaning”

(see work of Felice Frankel,  
and [imageandmeaning.org](http://imageandmeaning.org))



# “Image and Meaning”



# What...

...is easier now than before?

*fast computation, animation, 3D*

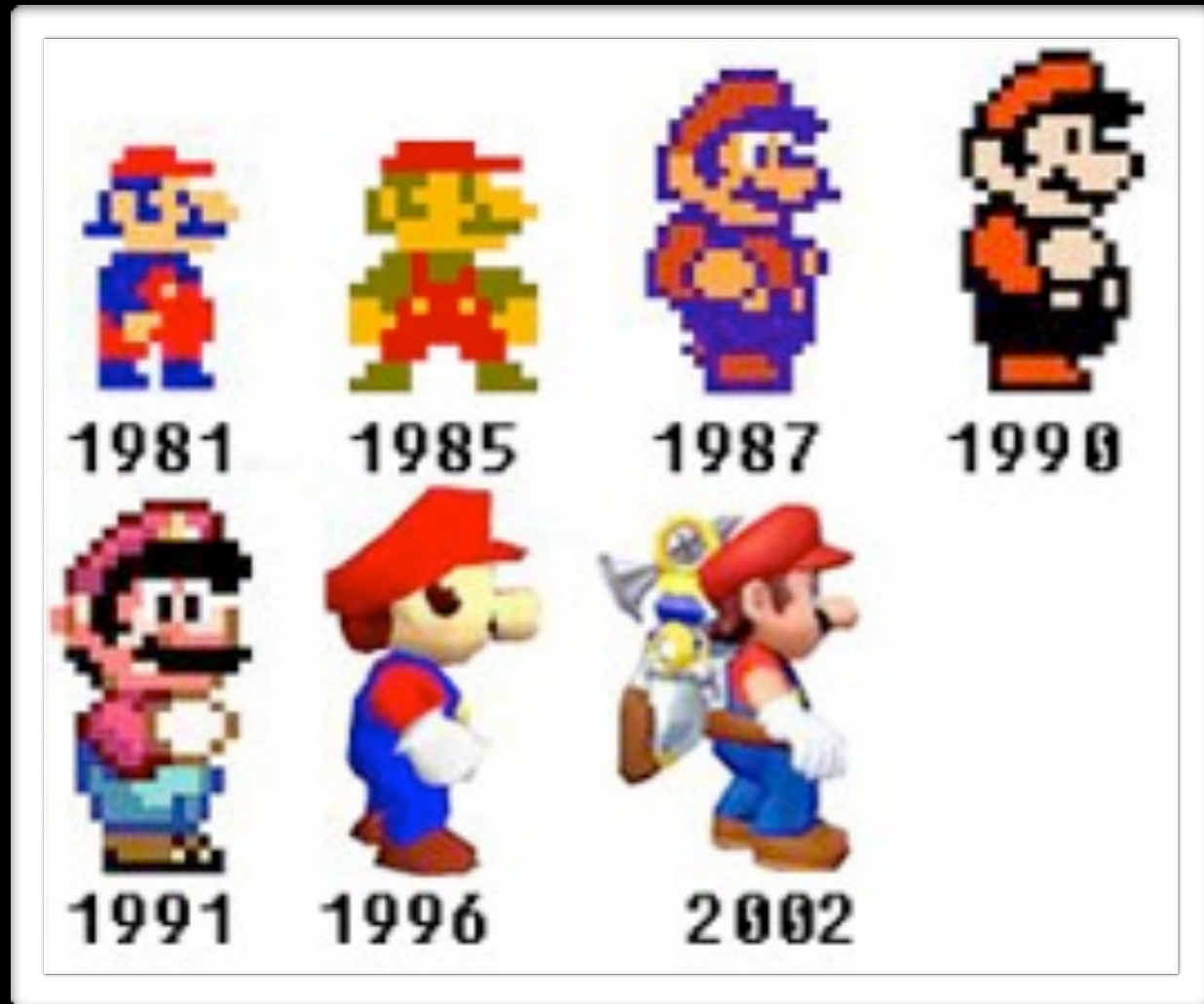
...was easier before than now?

*craftsmanship*

...should be easier in the future?

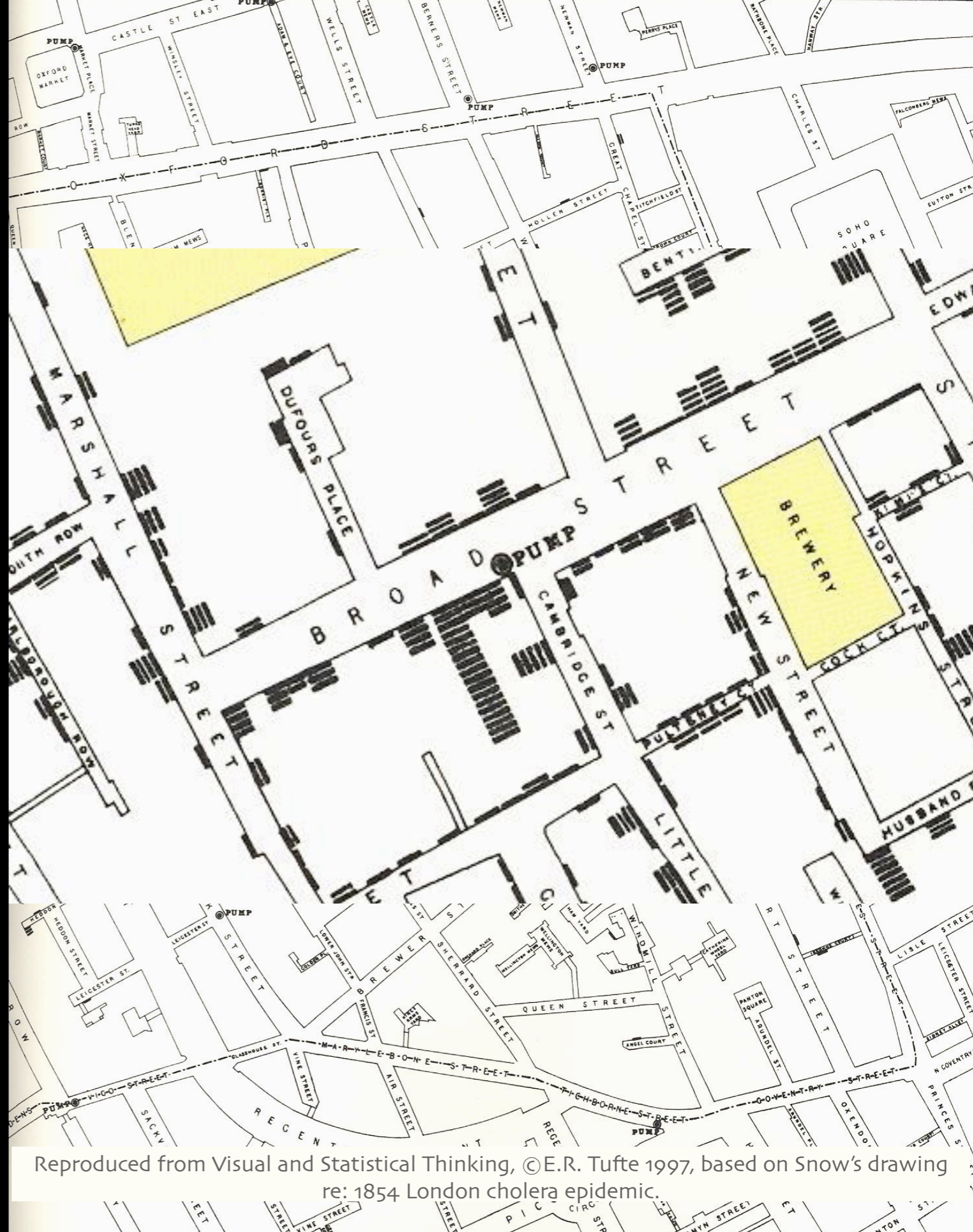
*modular craftsmanship, linked views*

“Easier”



2011

# Craftsmanship (in 1854)



Reproduced from Visual and Statistical Thinking, © E.R. Tufte 1997, based on Snow's drawing re: 1854 London cholera epidemic.

Data • Dimensions • Display

# Craftsmanship (in 1854)

Displaying  
“high-dimensional” data

with

“multi-functioning  
graphical elements”



Reproduced from Visual and Statistical Thinking, © E.R. Tufte 1997, based on Snow's drawing re: 1854 London cholera epidemic.

# What Computers *Can* Let us Craft

## Elements...

- ✓ Maps
- ✓ Tables
- ✗ Graphs
- ✓ Charts
- ✓ Illustrations
- ✓ Combinations

Live Scoreboard | Celtics.com

SCOREBOARD

DEN	116	WAS	72	POR	97	PHI	46	MIL	34	DAL	26-11	LAL	25-11
CHA	119	BOS	79	NJN	70	SAS	52	UTA	34	SAC	14-21	SEA	9-27
FINAL		2:34	4th	0:50	4th	Halftime	5:36	2nd	10:00		10:00		10:00

COURTSIDE LIVE

19-16 STANDINGS

Fouls 1 4 0

Fell :20

1	2	3	4	OT	T
18	17	24	13		72
18	19	26	16		79

02:46

Fouls 1 3 1

Fell :20

30-5 STANDINGS

COURTSIDE LIVE BOX SCORE PLAY-BY-PLAY Highlights Watch the Game Listen to the Game

WAS SELECT: ○ ALL ● ACTIVE 5

PLAYER NAME	PTS	REB	AST	F
<input type="checkbox"/> Daniels, Antonio	7	2	8	0
<input checked="" type="checkbox"/> Stevenson, DeSha	11	3	4	2
<input checked="" type="checkbox"/> Jamison, Antawn	18	10	0	3
<input checked="" type="checkbox"/> Butler, Caron	14	3	1	3
<input checked="" type="checkbox"/> Haywood, Brenda	12	5	0	3
<input type="checkbox"/> Blatche, Andray	3	5	0	3
<input checked="" type="checkbox"/> Mason, Roger	3	1	1	5
<input type="checkbox"/> Songaila, Darius	2	1	1	2
<input type="checkbox"/> Young, Nick	2	0	0	0
<input type="checkbox"/> Pecherou, Oleksiy	0	1	0	0
<input type="checkbox"/> Arenas, Gilbert				
<input type="checkbox"/> McGuire, Dominic				

BOS SELECT: ○ ALL ● ACTIVE 5

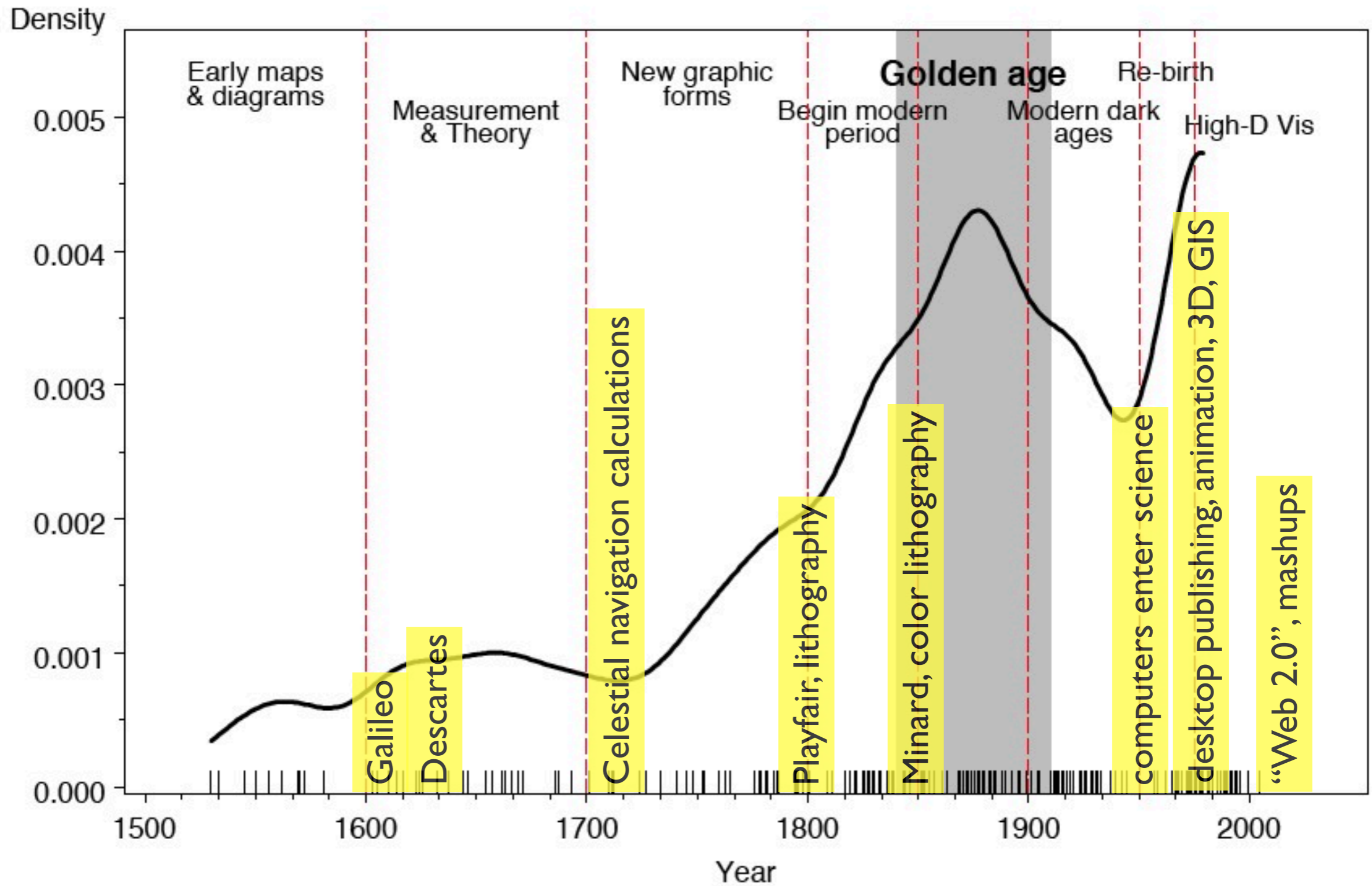
PLAYER NAME	PTS	REB	AST	F
<input type="checkbox"/> Rondo, Rajon	4	2	2	2
<input checked="" type="checkbox"/> Allen, Ray	16	6	3	2
<input checked="" type="checkbox"/> Garnett, Kevin	21	6	6	3
<input checked="" type="checkbox"/> Pierce, Paul	16	4	2	3
<input type="checkbox"/> Perkins, Kendrick	9	3	1	3
<input checked="" type="checkbox"/> House, Eddie	5	6	3	1
<input type="checkbox"/> Allen, Tony	4	4	0	0
<input type="checkbox"/> Davis, Glen	1	0	0	2
<input checked="" type="checkbox"/> Posey, James	3	2	0	2
<input type="checkbox"/> Pollard, Scott				
<input type="checkbox"/> Scalabrine, Brian				
<input type="checkbox"/> Powe, Leon				

TD Banknorth GARDEN

WIZARDS CELTICS

WAS show: ● made shots ✓ X missed shots ✓ BOS show: ● made shots ✓ X missed shots ✓

# Milestones: Time course of developments



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



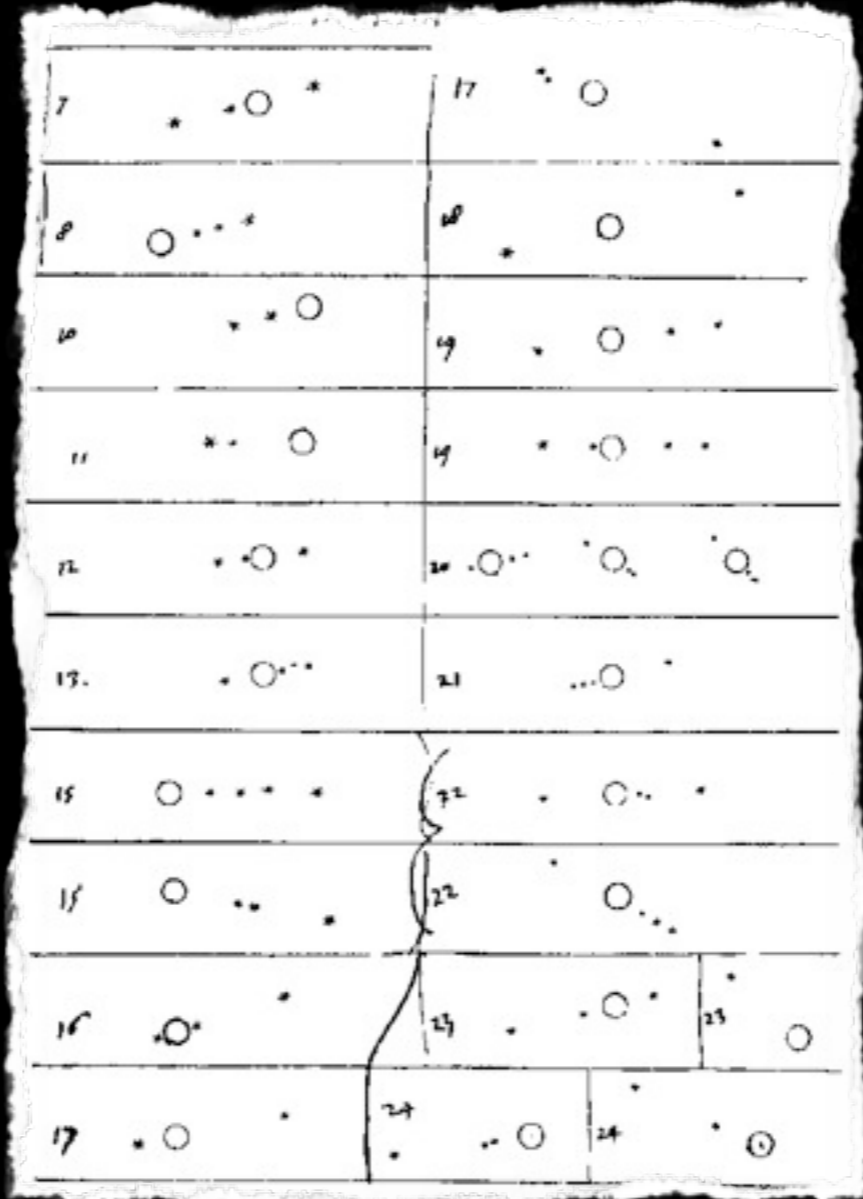
# Galileo Galilei (1564-1642)

*Scop. Principe.*

Galileo Galilei Familiare Seruo della Ser. V. inuigilante  
 do assistuare et lo ogni spirito se bene no solo satisfaco  
 aluano che non della stessa di Mathematico nelle sue  
 Vie di Padova,

Inuere d'auere determinato di presentare al Scop. Principe  
 l'occhio et lo piacere di giuamenti inestimabile se ogni  
 negozio et in circa marittima o torrette stano di tenere que  
 sto nuovo artificio nel maggior segreto et solam a disposizione  
 di V. Ser. L'occhio sanato dalle piu se di te speculazioni di  
 proprietta in l'uantaggi di scoprire Logici et Vole dell' inimic  
 et vale here et pu di tempo prima et ogni sempre noi et distinguend  
 il numero et la qualita de i Vastelli guidare la sua forza  
 palloptici alla caccia et combattimento o alla fuga, o pure sans  
 nella campagna sperta vedere et particolarly Distinguer ogni suo  
 tutto et propriamento.

*Aprile 7. di gennaio*  
*Giorno si vede a si*  
*Aprile 8. di*  
*Aprile 10. si vede in tale situazione*  
*Aprile 13. si vede in maniera a Giorno 4 Stelle*  
*Aprile 14. di anglo*  
*Aprile 15. si vede in la pressi a 4 con in migli la 4 con di*  
 spante dalla 3<sup>a</sup> L'occhio si am  
 Lo spazio delle 3. meridionali ad om  
 maggiore del diametro di 7. et ca  
 in via in linea retta.



*SIDERIUS NUNCIVS*

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

East \* ○ \* \* West

0 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 precise!

East \* \* ○ \* \* West

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

East \*\* ○ \* \* West

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

On the fifth, the sky was cloudy.

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

East \* ○ \* West

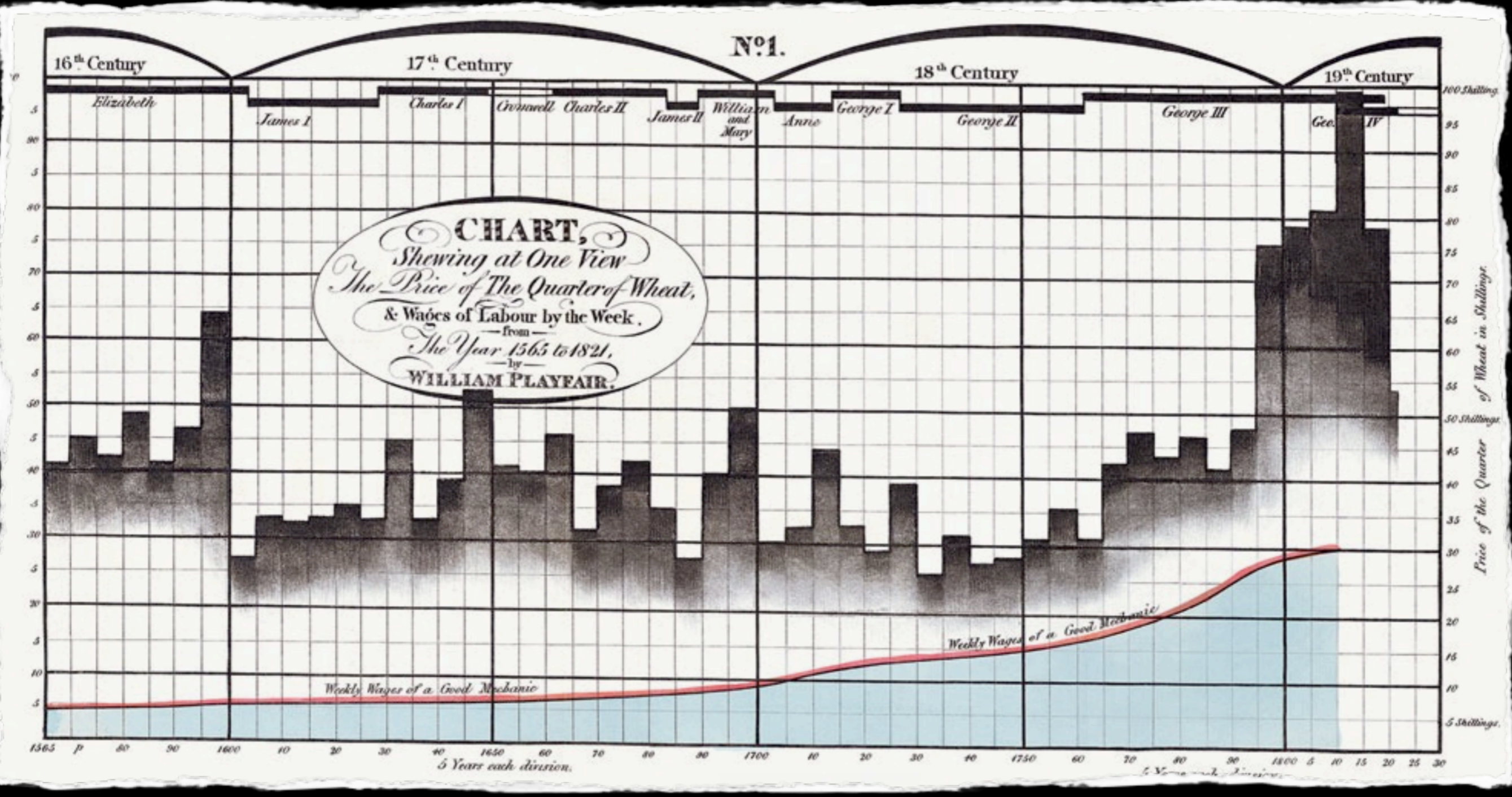
in the adjoining figure. The eastern one was 2 minutes and the  
 western one 3 minutes from Jupiter. They were on the same straight  
 line with Jupiter and equal in magnitude.

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

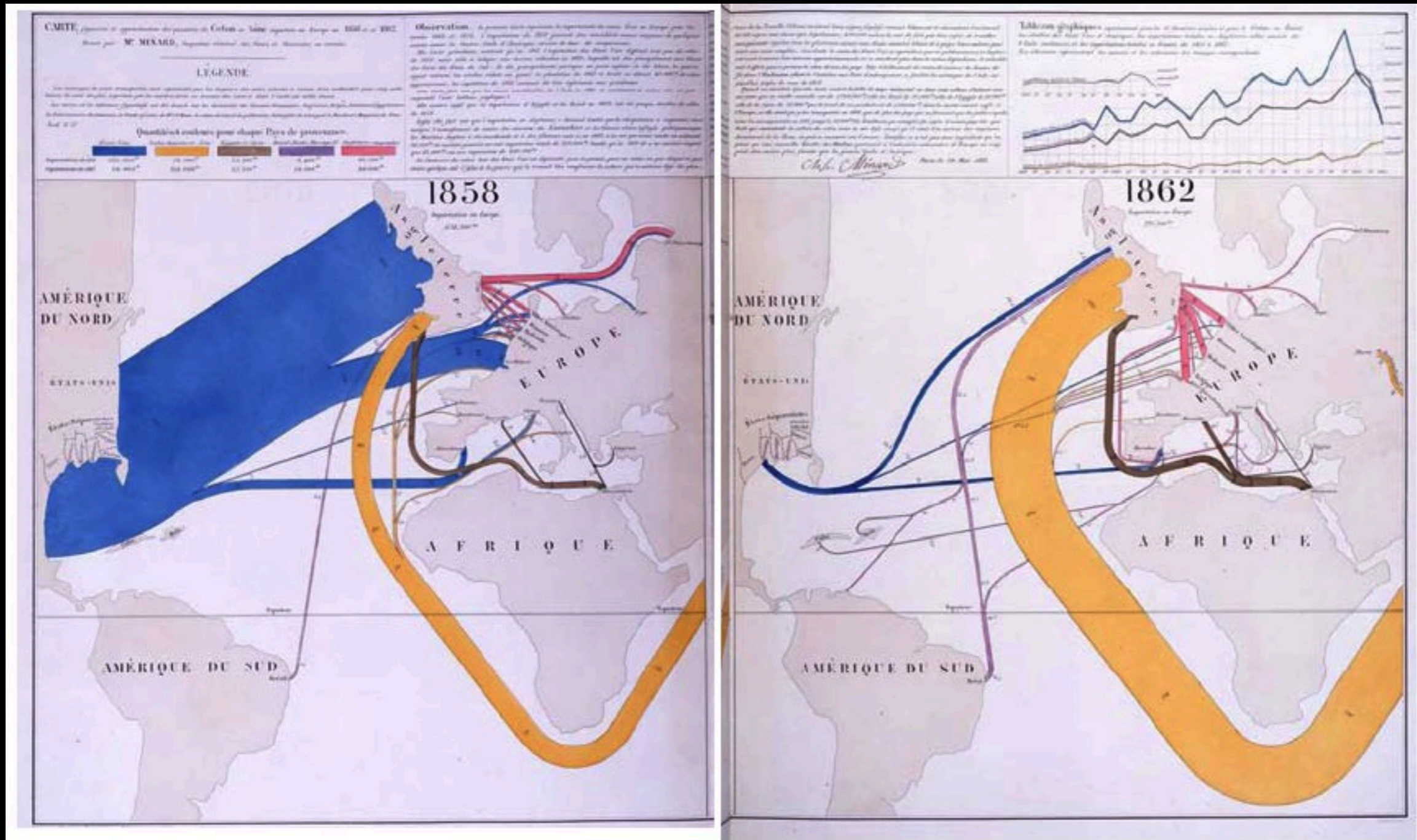
Notes for & re-productions of Siderius Nunciuss



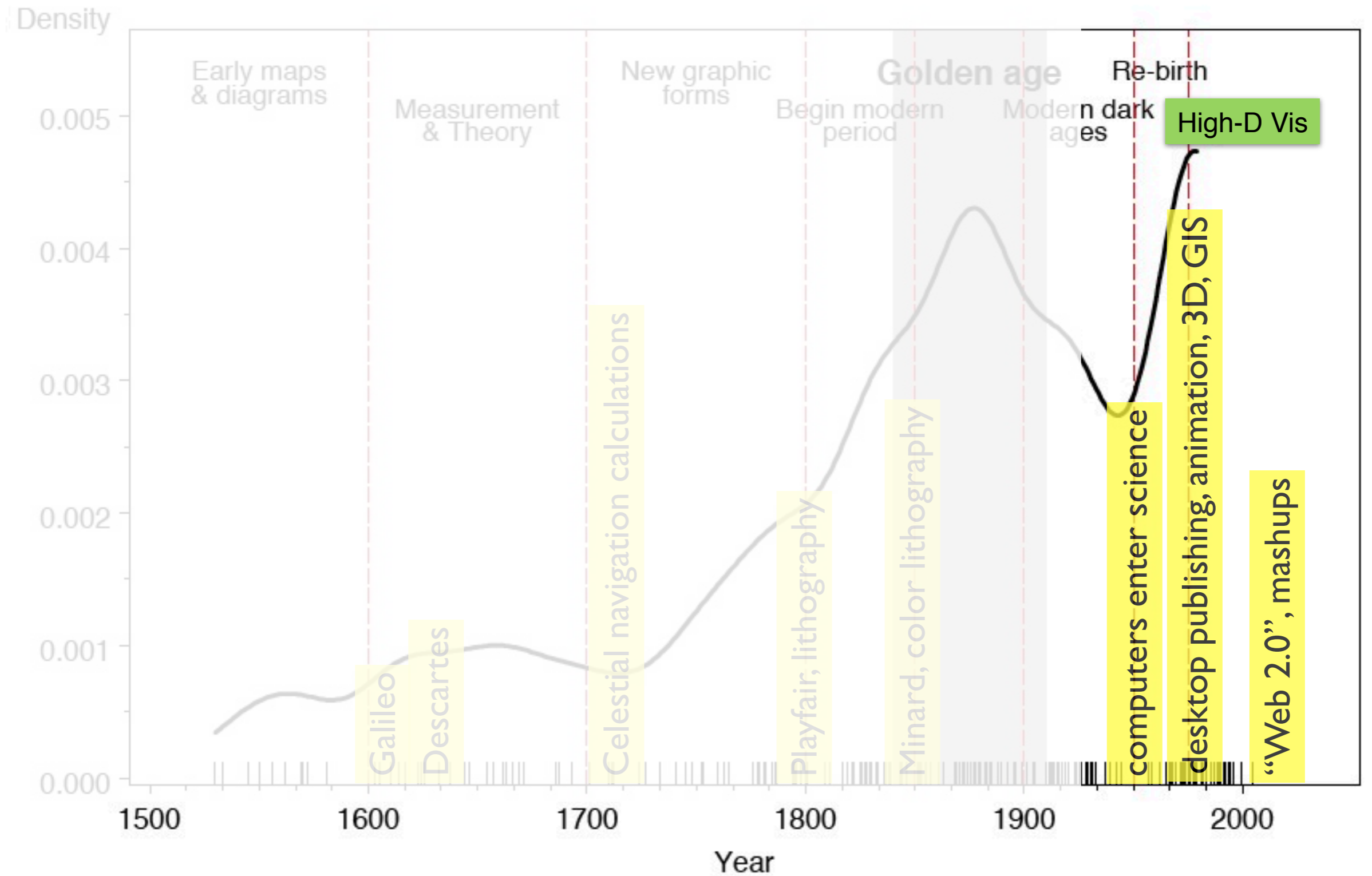
# William Playfair (1759-1823)



# Charles Joseph Minard, in color (1781-1870)



# Milestones: Time course of developments

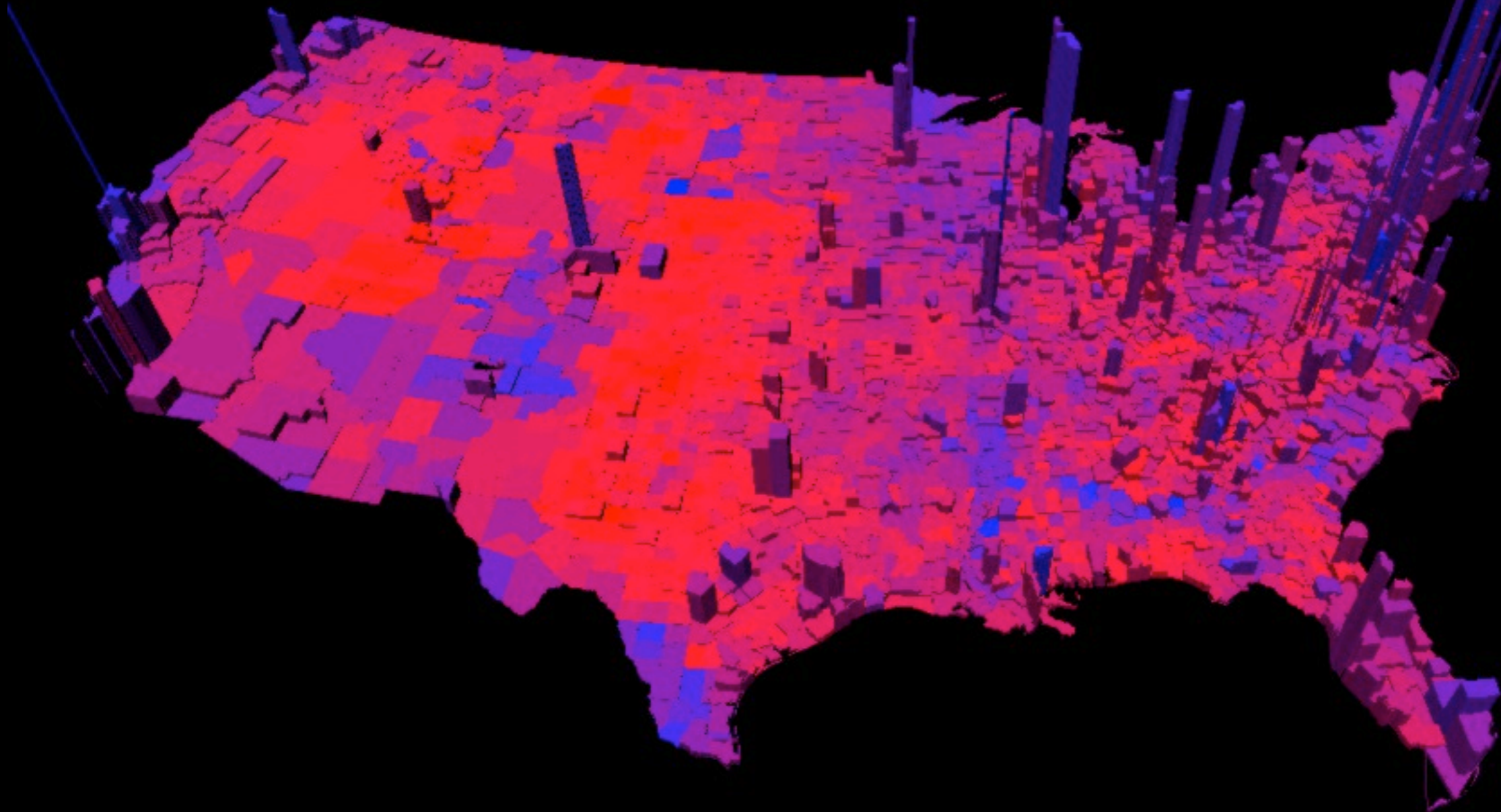


adapted from Friendly, "The Golden Age of Statistical Graphics," *Statistical Science*, in press (2008)

High-D Vis

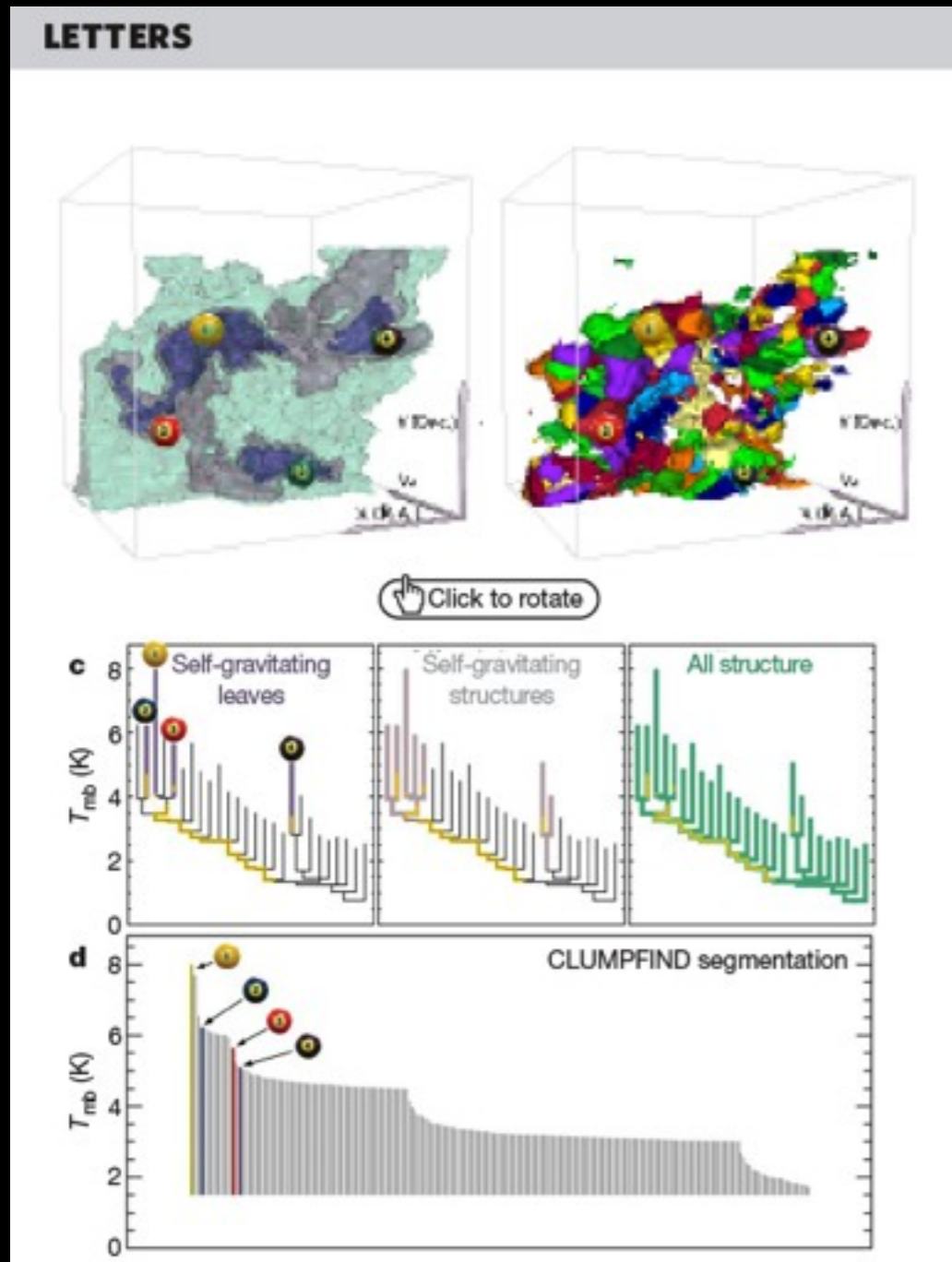
Data • Dimensions • Display

# “High-dimensional” or “Multivariate” Data and High(er) Dimensional Displays

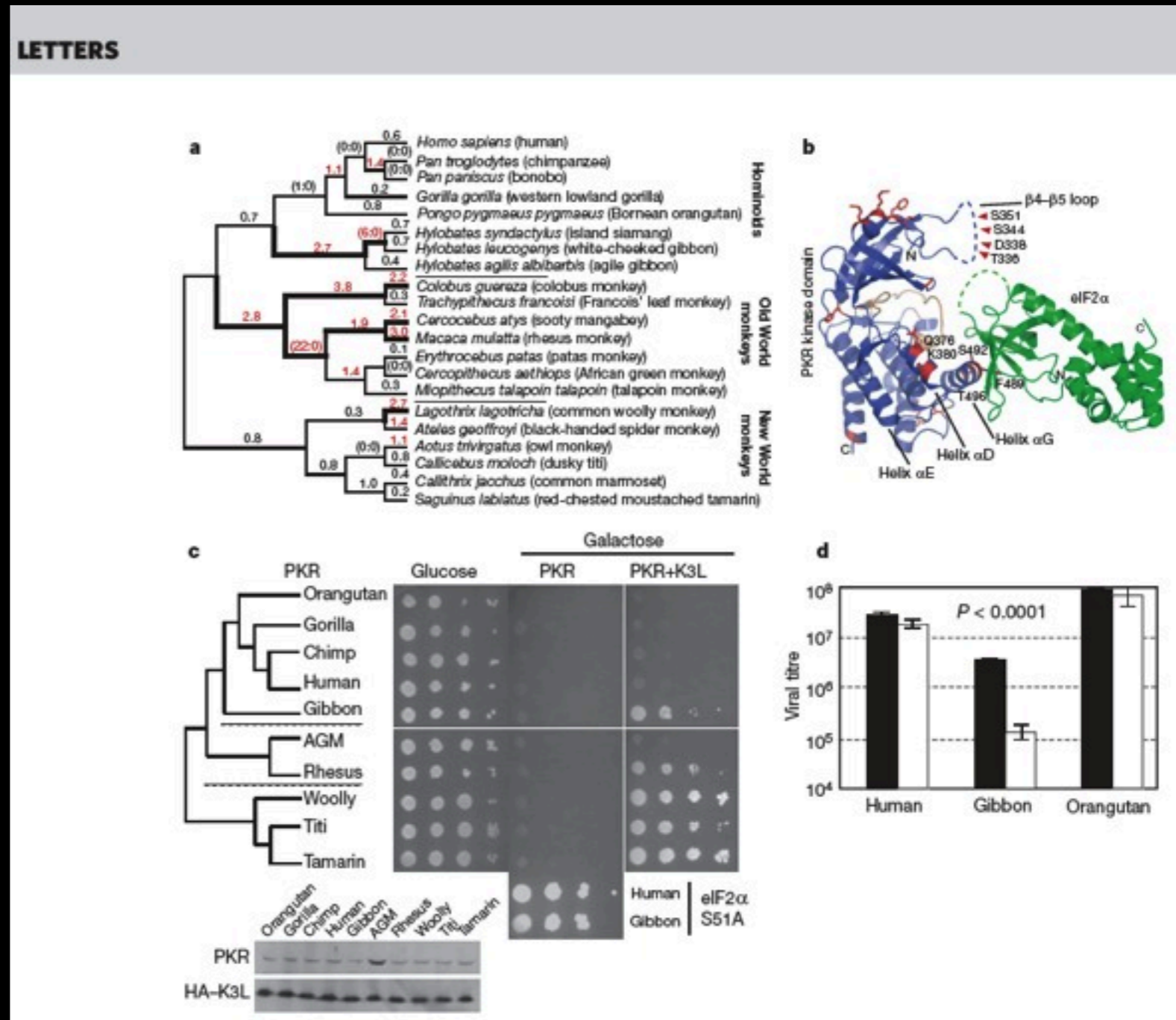


*This map **displays** 2 quantities as a function of 2 spatial dimensions.  
...Is that 4 dimensions?*

# “High-dimensional” or “Multivariate” Data (Astronomy=Biology)

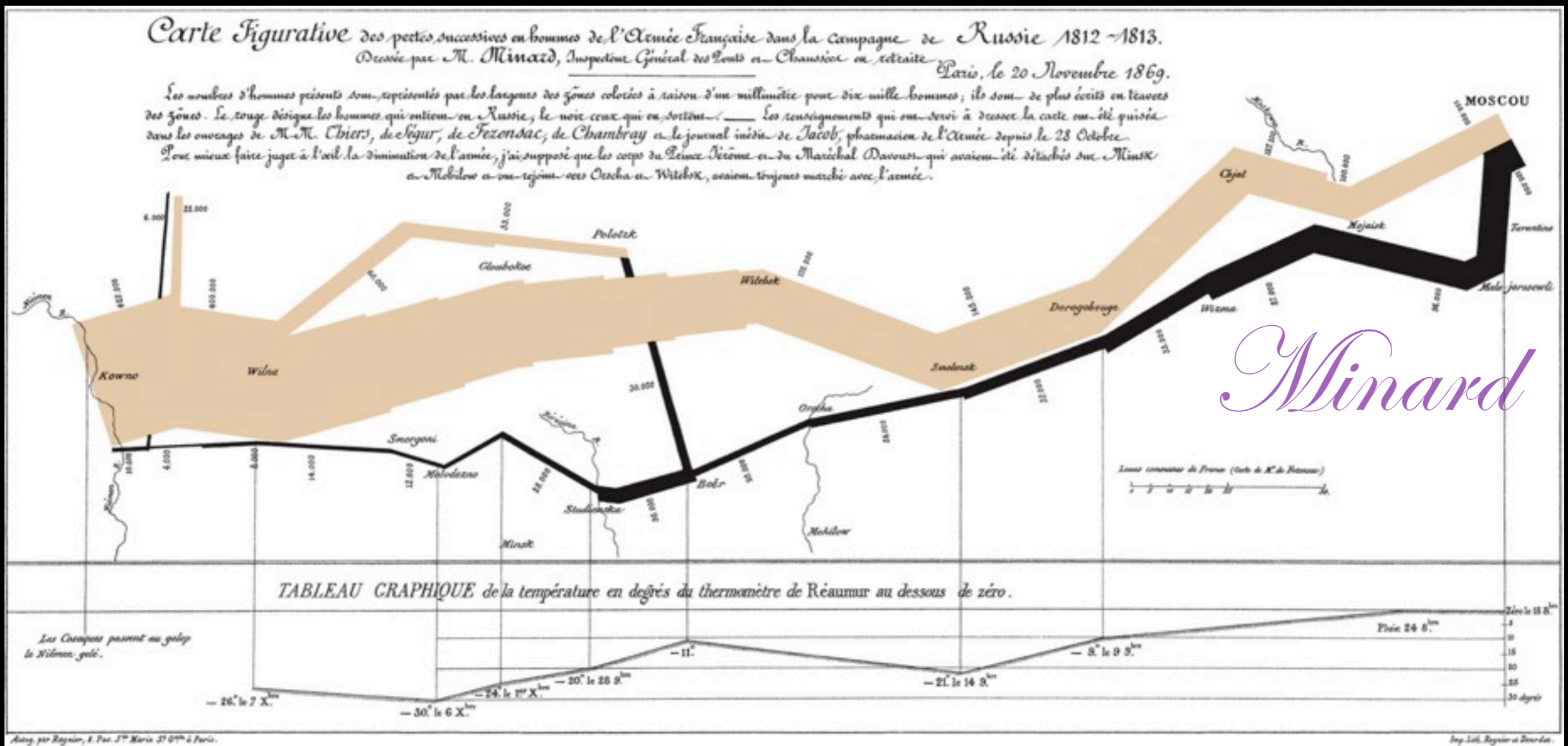
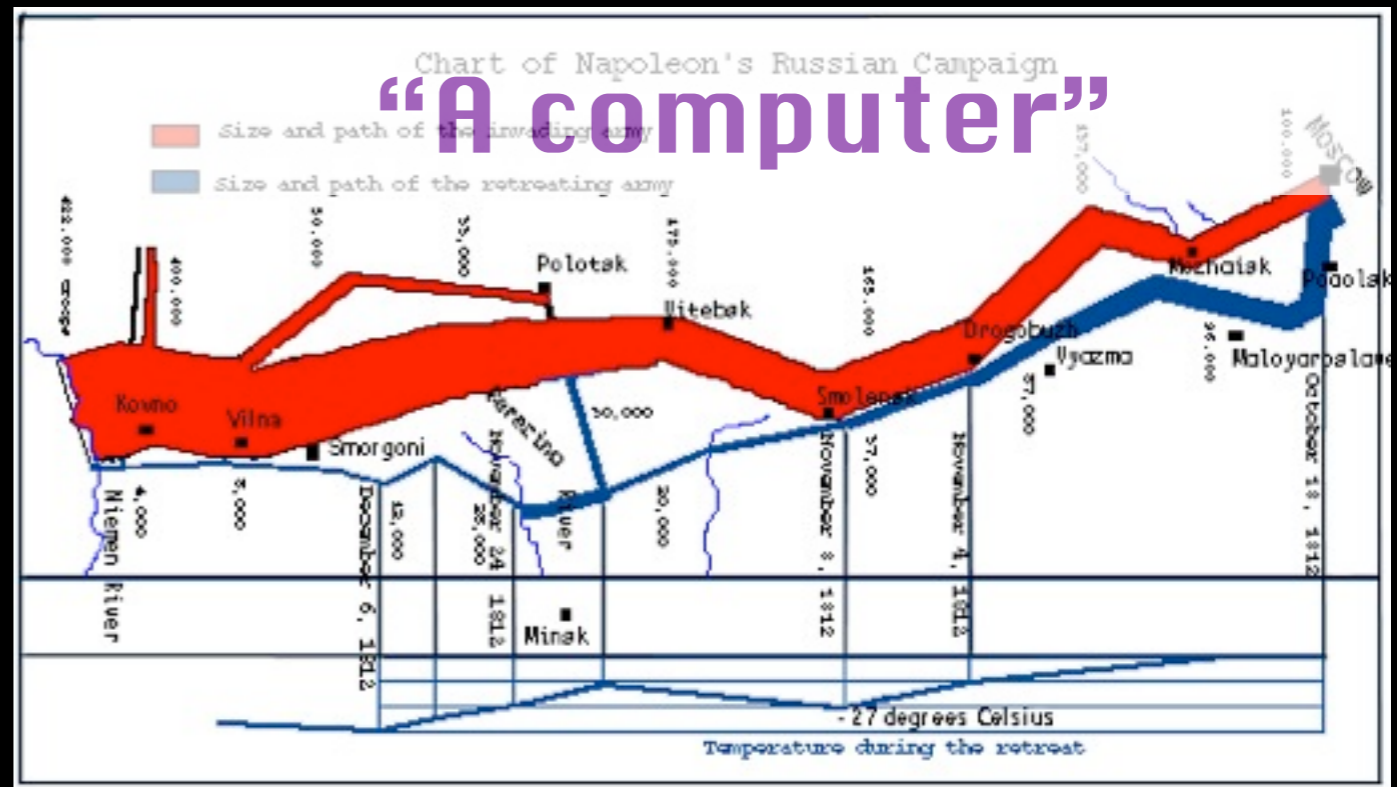


Goodman et al. *Nature*, 2009

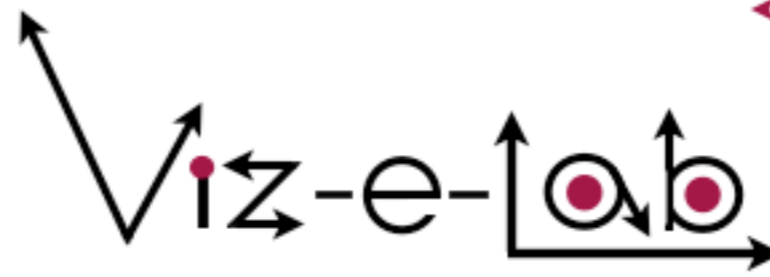


Elde et al. *Nature*, 2008

How much are we held back today by **digital tools**?







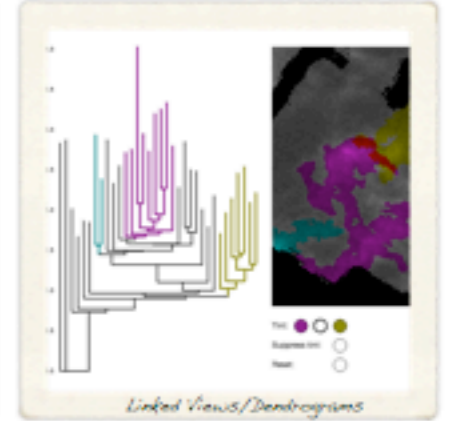
Projects  
2011



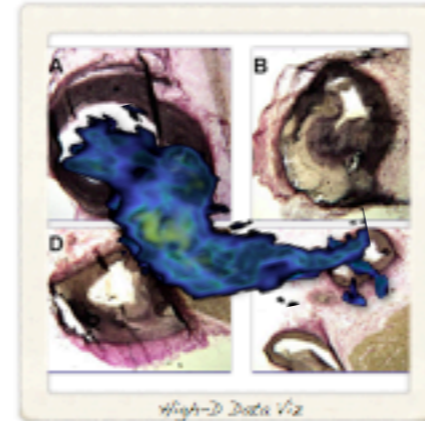
*"Taste-Testing"*



*Worldwide Telescope/Ambassadors*



*Linked Views/Dendrograms*



*High-D Data Viz*



*Seamless Astronomy*



*Wolbach User Experience Lab*



*ADS Labs*



*CfA Astronomy Dataverse*



*VAO/Online Astronomy User Group*

How can we advance the **digital** tools for scientists?

collaborators/contacts at CfA

Seamless Astronomy: Alyssa Goodman Online Astronomy Group, CfA Data Archives: Gus Muench ADS Group: Alberto Accomazzi  
WorldWide Telescope Ambassadors: Pat Udomprasert High-Dimensional Data Visualization & Interactions: Michelle Borkin  
Wolbach Library Lab at CfA : Christopher Erdmann VAO at CfA: Pepi Fabbiano Social Networks in Science: Alberto Pepe  
Questions about using the Viz-e-Lab? Contact Sarah Block, 5-7331, [sblock@cfa.harvard.edu](mailto:sblock@cfa.harvard.edu)



# Astronomical Medicine

[am.iic.harvard.edu](http://am.iic.harvard.edu)

Alyssa Goodman (IIC/CfA/FAS)

Michael Halle (IIC/SPL/HMS)

Ron Kikinis (SPL/HMS)

Douglas Alan (IIC)

Michelle Borkin (IIC)

Jens Kauffmann (CfA/IIC)

Erik Rosolowsky (CfA)

Nick Holliman (U. Durham)

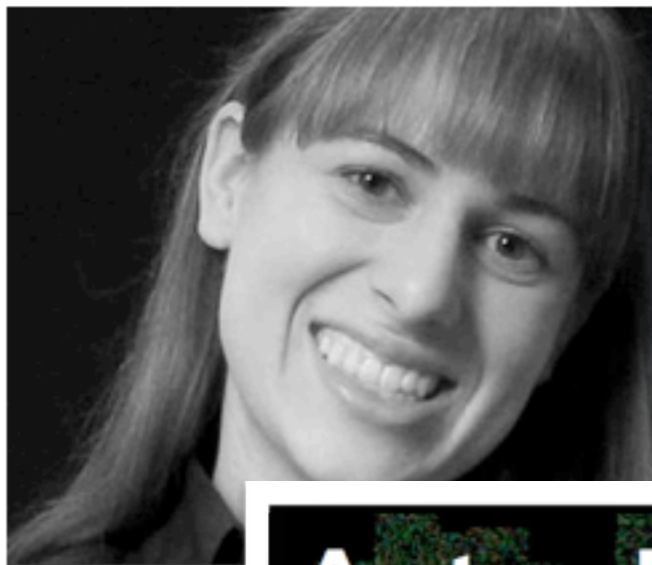


# The AstroMed Story



Themes	TED Conferences	TED
Speakers	TEDx Events	TED
Talks	TED Prize	
Translations	TED Fellows	

## TED Fellows The TED Fellows Directory > Michelle Borkin 2009



Michelle Borkin is now a SEAS PhD Student, advised by Profs. Alyssa Goodman (Astronomy) and Hanspeter Pfister (SEAS), and IIC +AstroMed became the bases for the Viz-e-Lab



## 2011 Visual Business Intelligence

A blog by Stephen Few

Home About Consulting Workshops Courses Examples Library **Blog** Discuss

### VisWeek 2011 – Award-Worthy Visualization Research

On Tuesday in this blog I expressed my frustration with VisWeek’s information visualization research awards process. I don’t want to leave you with the impression, however, that the state of information visualization research is bleak. Each year at VisWeek I find a few gems produced by thoughtful, well-trained information visualization researchers. They identified potentially worthy pursuits and did well-designed research that produced useful results. While puzzling over the criteria that the judges must have used when selecting this year’s best paper, I spent a few minutes considering the criteria that I would use were I a judge, and came up with the following list with points totaling to 100:

Effectiveness (It does what it’s supposed to do and does it well.) – 30 points

Usefulness (What it does addresses real needs in the world.) – 30 points

10 points

ses.) – 10 points

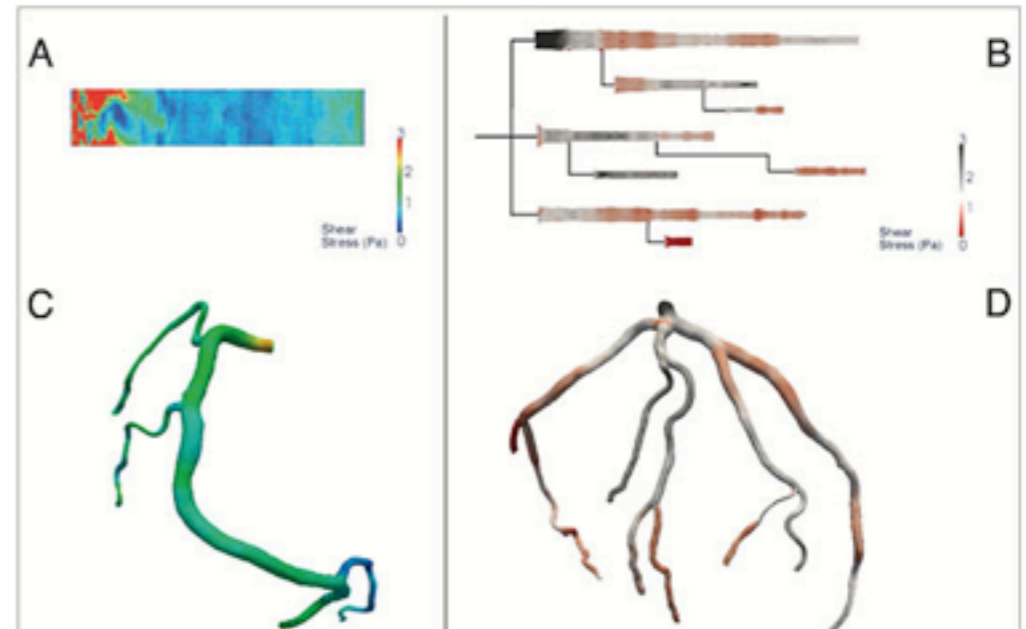
ew way.) – 10 points

e.) – 10 points

to some degree, but this gives you an idea of the importance of each.

e by its elegance and exceptional usefulness Harvard University’s School of Engineering and

Applied Sciences titled “Evaluations of Artery Visualizations for Heart Disease Diagnosis.”



TEDGlobal 2009

## AstroMed09

The Inaugural Sydney International Workshop on Synergies in Astronomy and Medicine

14–16 December, 2009  
The University of Sydney

### Bio






Michelle Borkin interdisciplinary and image analysis. She wrote her work on the application of astronomical data as part of the "AstroMed" project at Harvard's Initiative for Data-Driven Works with the development of tools to improve their effectiveness in multiple

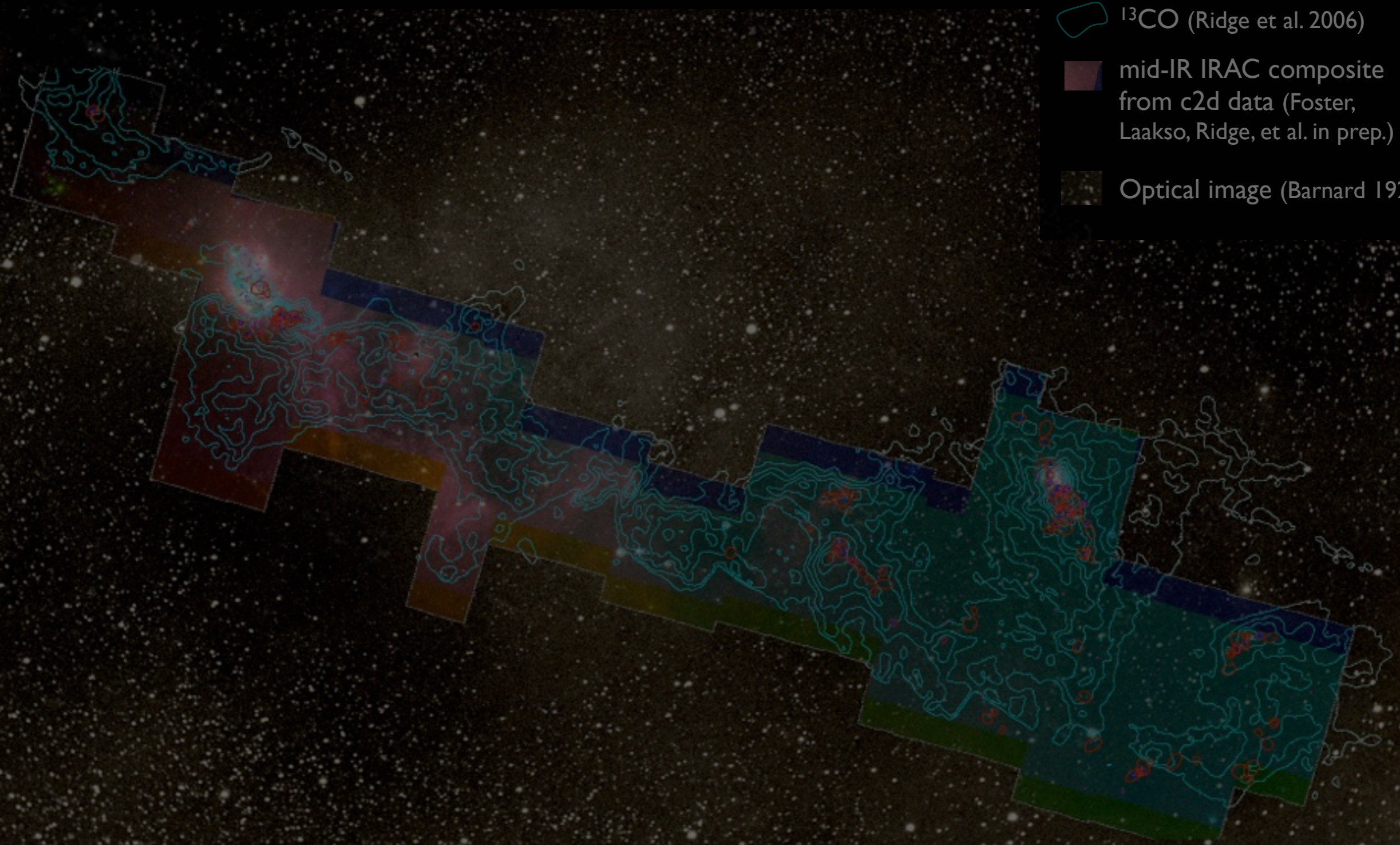
serting a stent

to prevent a heart attack:

# COMPLETE Perseus

Image size: 1305 x 733  
VL: 63 WW: 127

-  mm peak (Enoch et al. 2006)
-  sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)
-   $^{13}\text{CO}$  (Ridge et al. 2006)
-  mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al. in prep.)
-  Optical image (Barnard 1927)

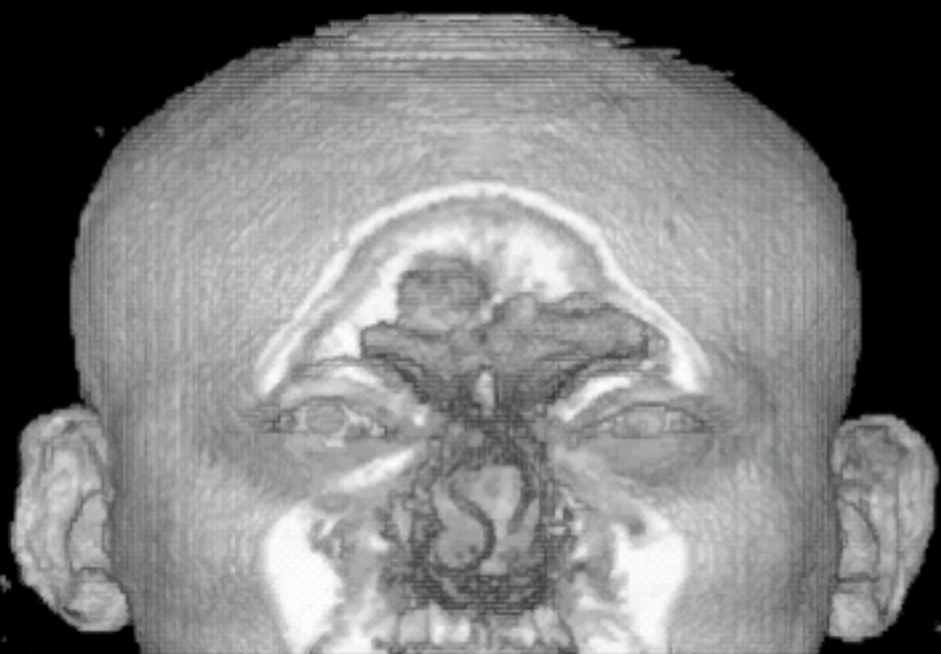


m: 1/249  
Zoom: 227% Angle: 0



# “Astronomical Medicine”

“KEITH”



“z” is depth into head

“PERSEUS”








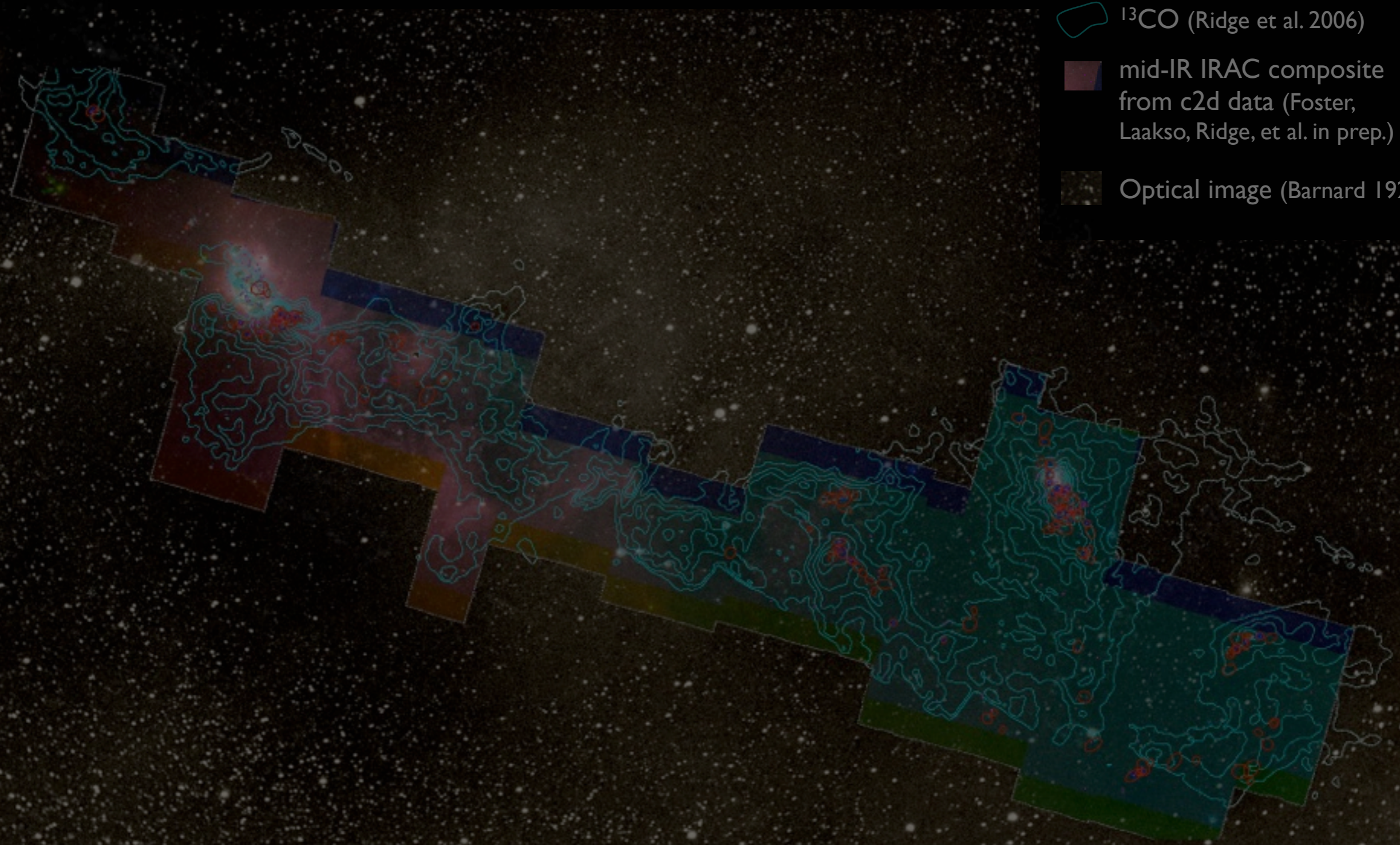
“z” is line-of-sight velocity

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

# COMPLETE Perseus

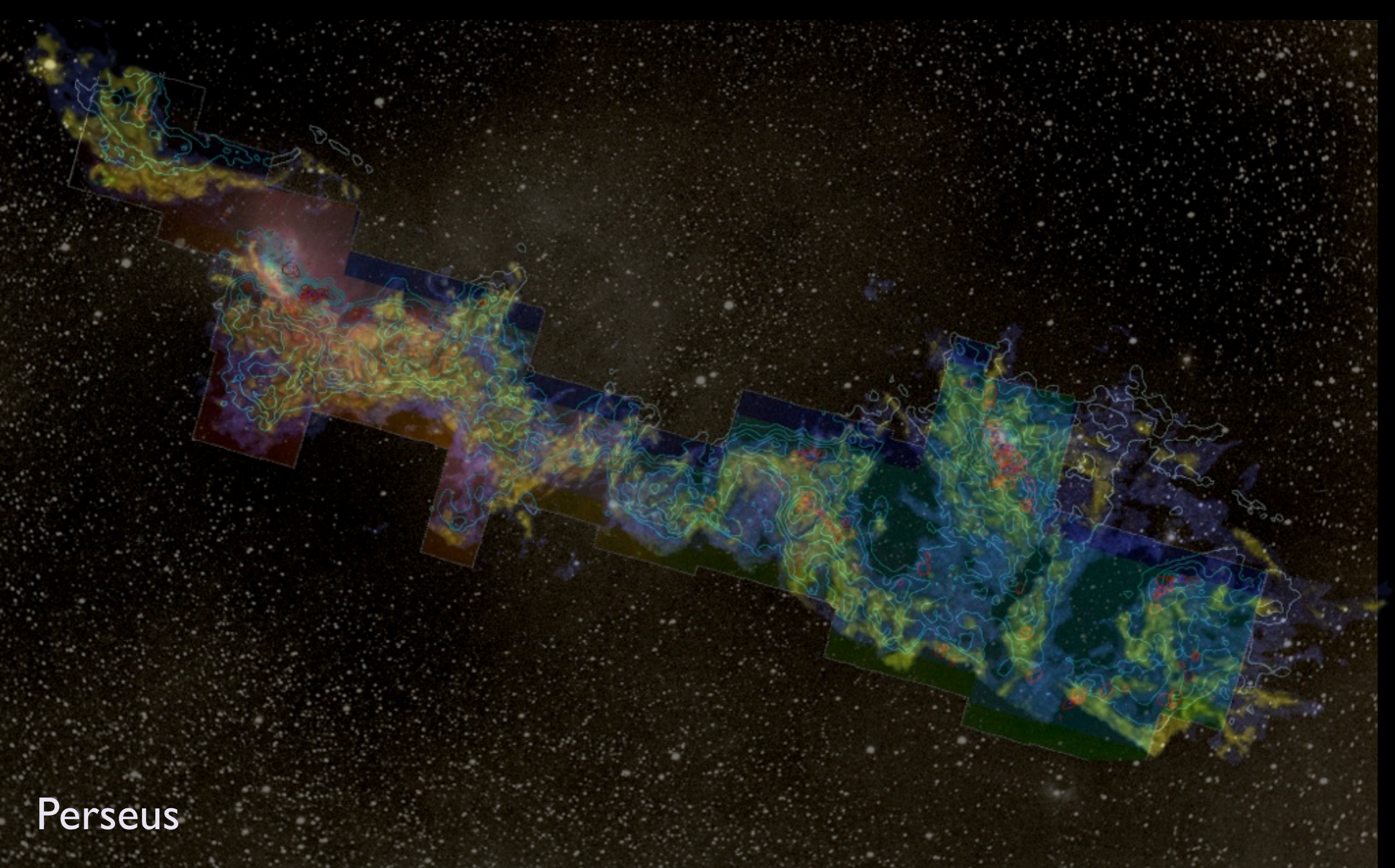
Image size: 1305 x 733  
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-  Optical image (Barnard 1927)



m: 1/249  
Zoom: 227% Angle: 0

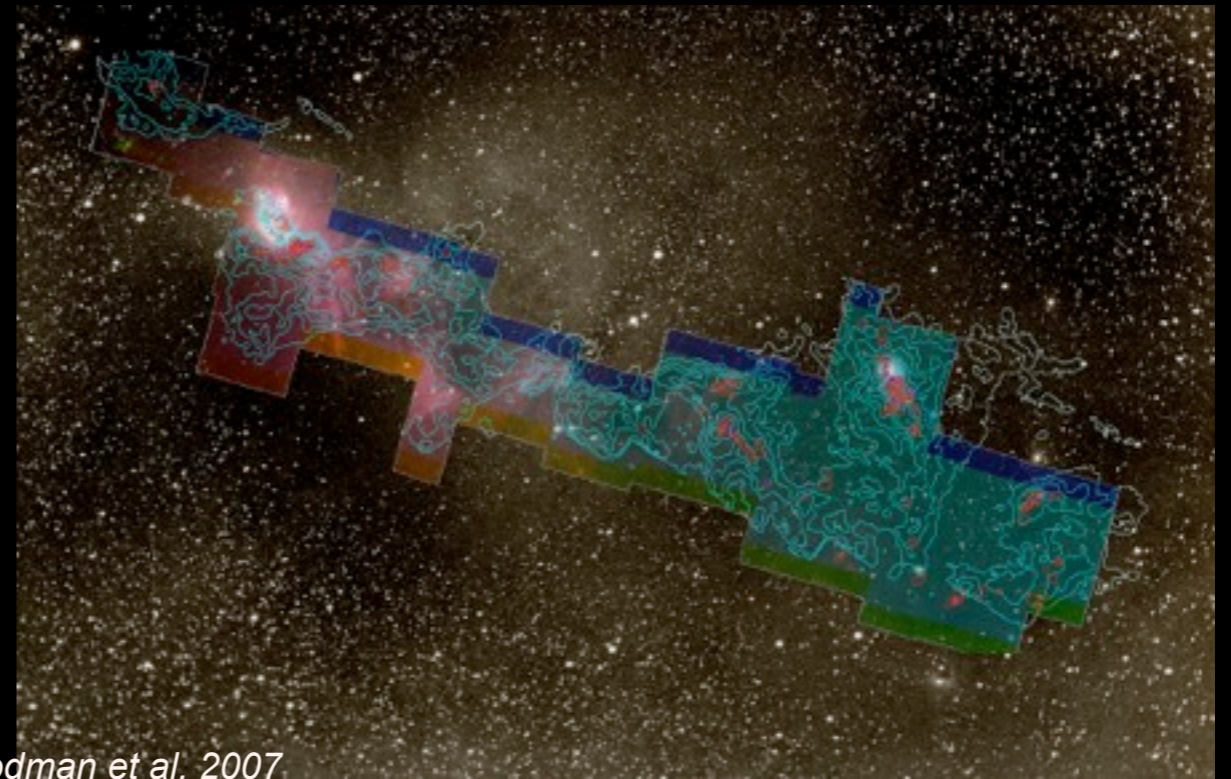




Perseus

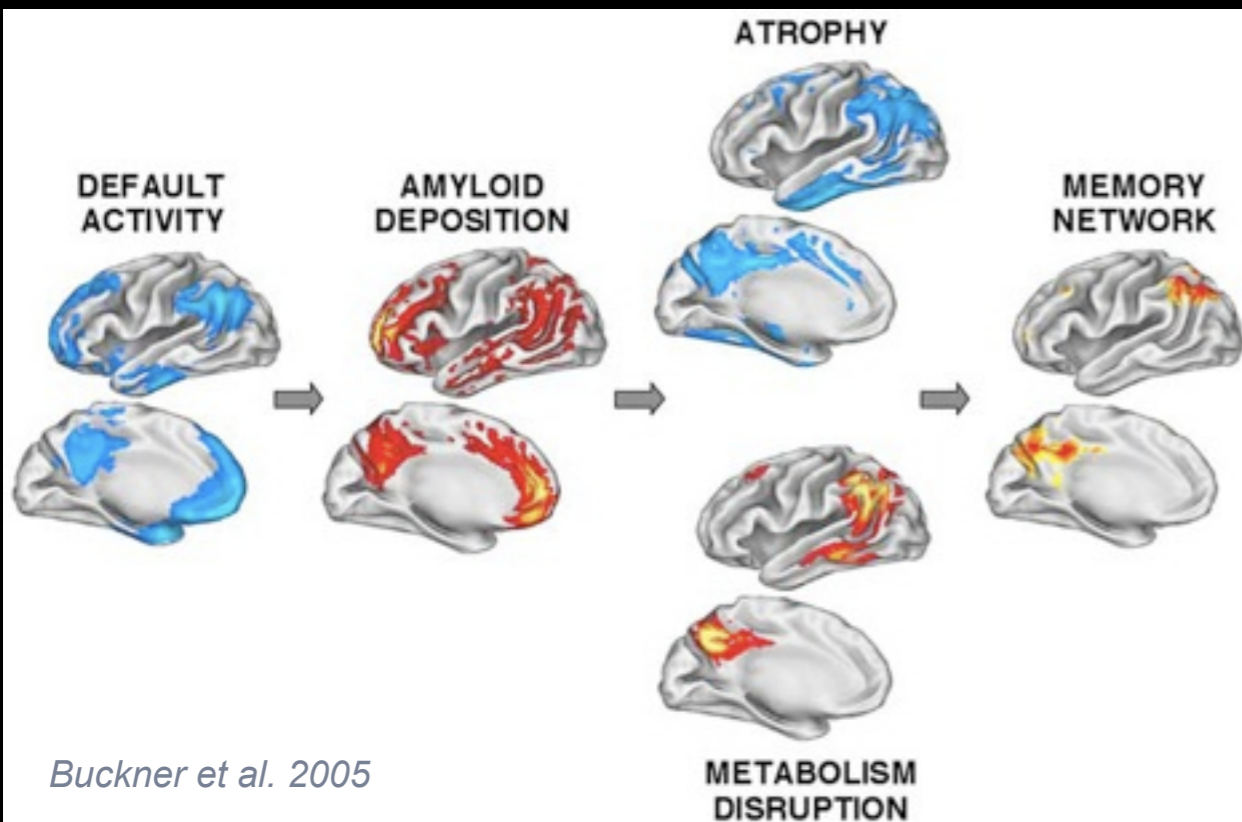
3D Viz made with VolView

Astronomers are not alone...  
*high-D data sets are everywhere in science*



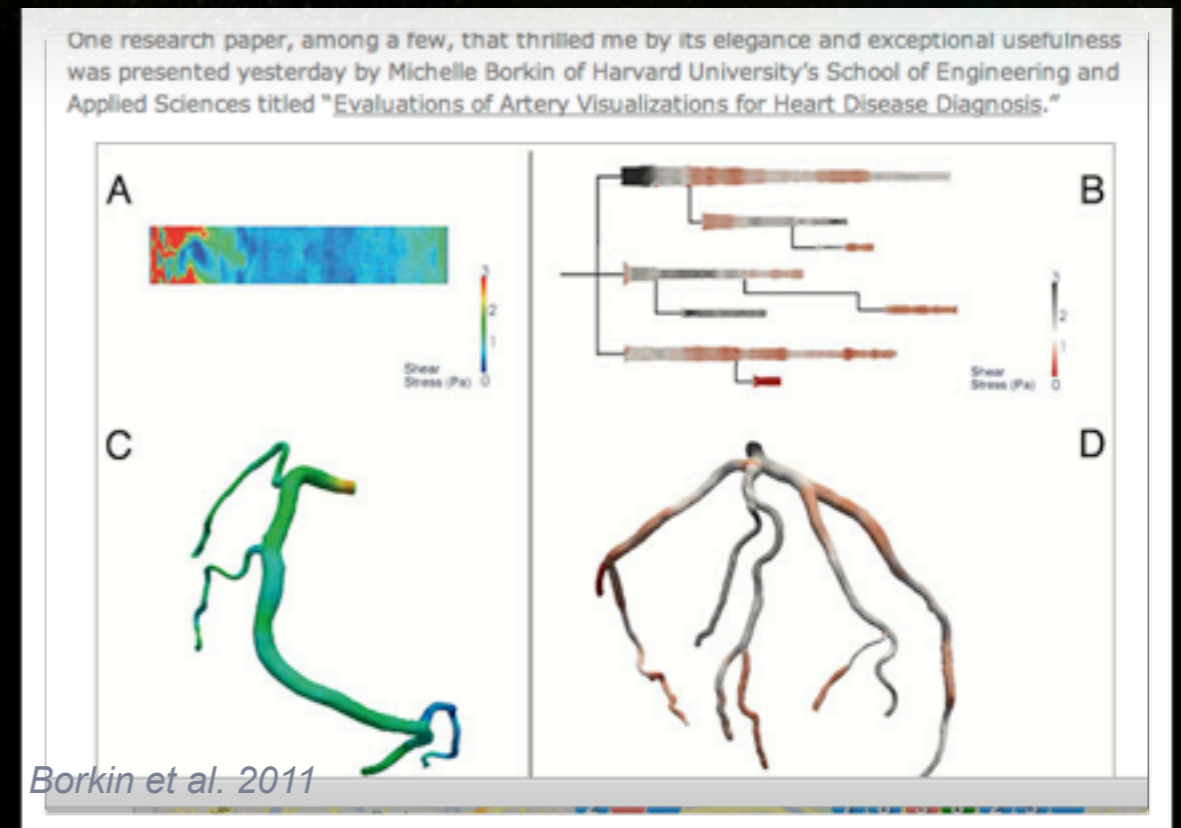
Goodman et al. 2007

## Astrophysics



Buckner et al. 2005

## Brain Science



Borkin et al. 2011

## Blood Flow



# What...

...is easier now than before?

*fast computation, animation, 3D*

...was easier before than now?

*craftsmanship*

...should be easier in the future?

*modular craftsmanship, linked views*

# The “Easier” Future, for Everyone

## *Modular Craftsmanship & Linked Views*

The Future we can see from “now”...

more **display modes** available (**3D PDF**, **touch** interfaces, stereo+)

**re-usable tools/mashups** (Many Eyes, Google Maps+, crowdsourcing)

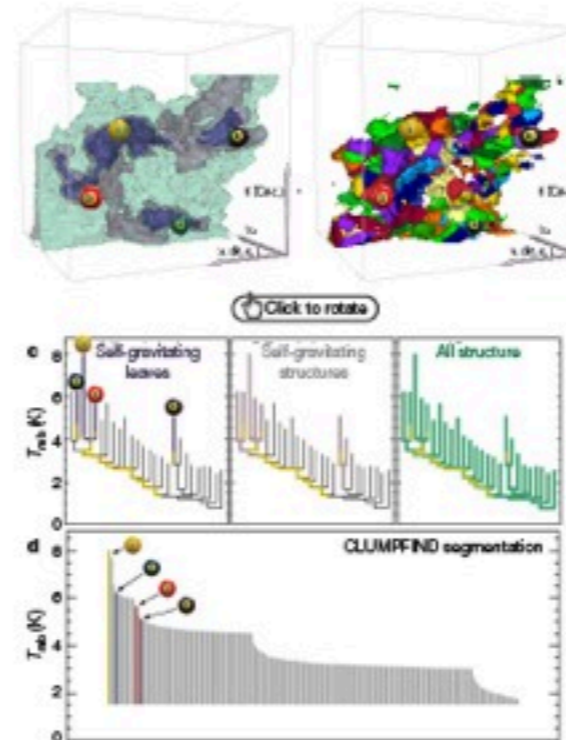
live, **interactive linked views** (DataDesk, Tableau, GapMinder, **WWT**...)

## Unsolved Questions...

(feasibility of) **templates/language** (e.g. Grammar of Graphics)

improved graphical representation of **uncertainty**

## 3D PDF



**Figure 2** | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to  $^{13}\text{CO}$  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  $T_{\text{mb}}$  (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 dump to the threshold value. A very large number of dumps 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 ( $-0.5 \text{ km s}^{-1}$ ) to back ( $8 \text{ km s}^{-1}$ ).

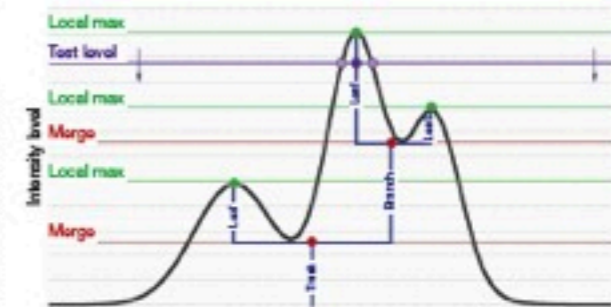
data, CLUMPFIND typically finds features on a limited range of scales, above but close to the physical resolution of the data, and its results can be overly dependent on input parameters. By tuning CLUMPFIND's two free parameters, the same molecular-line data set<sup>8</sup> can be used to show either 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'<sup>9</sup> were proposed as a way to characterize clouds' hierarchical structure

using 2D maps of column density. With this early 2D work as inspiration, we have developed a structure-identification algorithm that abstracts the hierarchical structure of a 3D ( $p$ - $p$ - $v$ ) data cube into an easily visualized representation called a 'dendrogram'<sup>10</sup>. Although well developed in other data-intensive fields<sup>11,12</sup>, it is curious that the application of tree methodologies so far in astrophysics has been rare, and almost exclusively within the area of galaxy evolution, where 'merger trees' are being used with increasing frequency<sup>13</sup>.

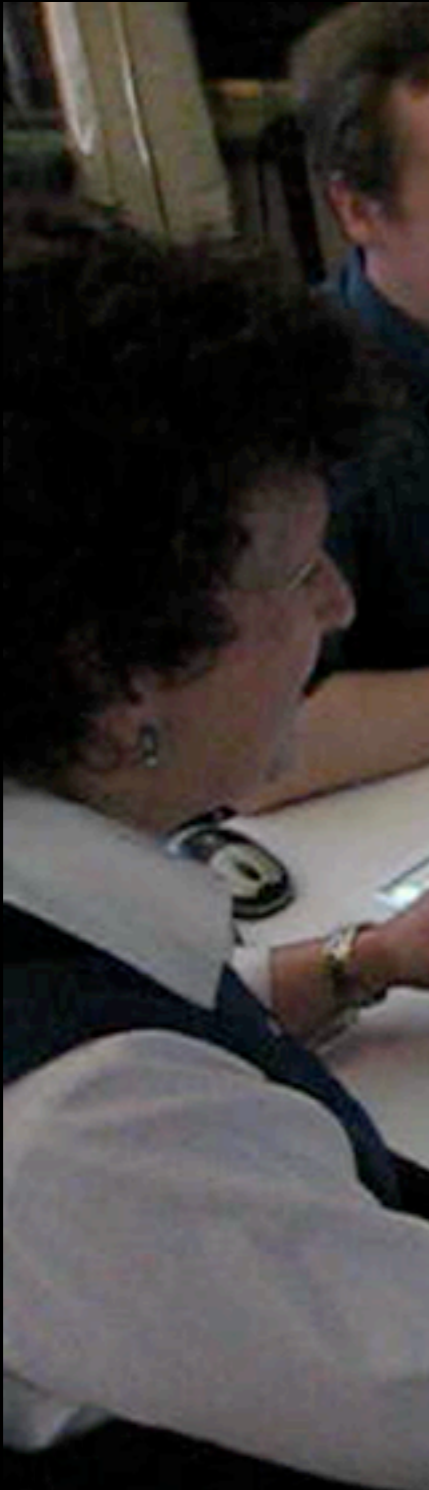
Figure 3 and its legend explain the construction of dendrograms schematically. The dendrogram quantifies how and where local maxima of emission merge with each other, and its implementation is explained in Supplementary Methods. Critically, the dendrogram is determined almost entirely by the data itself, and it has negligible sensitivity to algorithm parameters. To make graphical presentation possible on paper and 2D screens, we 'flatten' the dendrograms of 3D data (see Fig. 3 and its legend), by sorting their 'branches' to not cross, which eliminates dimensional information on the x axis while preserving all information about connectivity and hierarchy. Numbered 'billiard ball' labels in the figures let the reader match features between a 2D map (Fig. 1), an interactive 3D map (Fig. 2a online) and a sorted dendrogram (Fig. 2c).

A dendrogram of a spectral-line data cube allows for the estimation of key physical properties associated with volumes bounded by isosurfaces, such as radius ( $R$ ), velocity dispersion ( $\sigma_v$ ) and luminosity ( $L$ ). The volumes can have any shape, and in other work<sup>14</sup> we focus on the significance of the especially elongated features seen in L1448 (Fig. 2a). The luminosity is an approximate proxy for mass, such that  $M_{\text{dust}} = X_{13\text{CO}} I_{13\text{CO}}$ , where  $X_{13\text{CO}} = 8.0 \times 10^{20} \text{ cm}^{-2} \text{ K}^{-1} \text{ km}^{-1} \text{ s}$  (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,  $\alpha_{\text{obs}} = 5\sigma_v^2 R / GM_{\text{dust}}$ . In principle, extended portions of the tree (Fig. 2, yellow highlighting) where  $\alpha_{\text{obs}} < 2$  (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  $\alpha_{\text{obs}}$  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<sup>16</sup>, 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.

# “Off the Desktop”



Slideshow: Tabletop Computers *Continued*  
 By Meredith Ringel Morris  
 First Published December 2008

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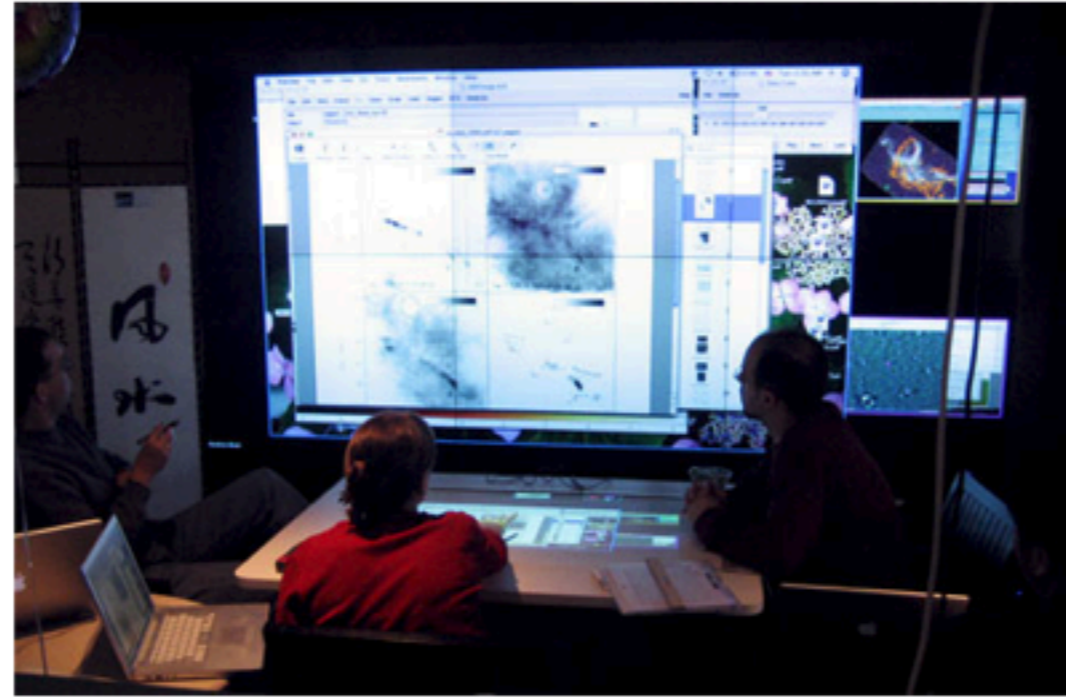
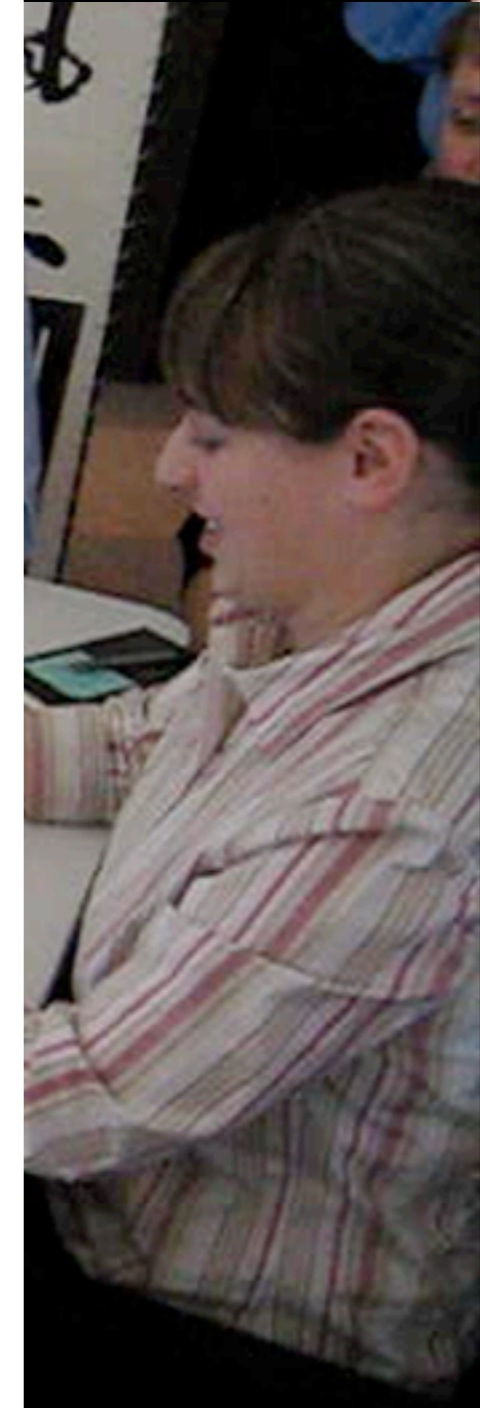
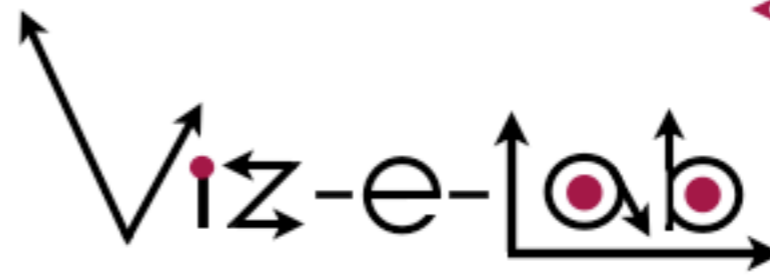


PHOTO: HAO JIANG, DANIEL WIGDOR, CLIFTON FORLINES, AND CHIA SHEN

**UBITABLE:** Users can interact with surface computers through auxiliary devices, such as laptops, phones, and PDAs. The display on the auxiliary device can convey private or sensitive content to a single user, while group-appropriate content can appear on the tabletop display. Chia Shen and her colleagues at Mitsubishi Electric Research Laboratories, in Cambridge, Mass., have explored auxiliary interactions with surface computers in their UbiTable project, in which two people with laptops collaborate over a tabletop display. Recently, Shen expanded the UbiTable into an interactive room called the WeSpace. People can share data on their laptops with other people in the room, using both a table and a large display wall. Here, three Harvard University astrophysicists discuss radio and IR spectrum images using the WeSpace.





Projects  
2011



How can we advance the **digital** tools for scientists?

collaborators/contacts at CfA

Seamless Astronomy: Alyssa Goodman Online Astronomy Group, CfA Data Archives: Gus Muench ADS Group: Alberto Accomazzi  
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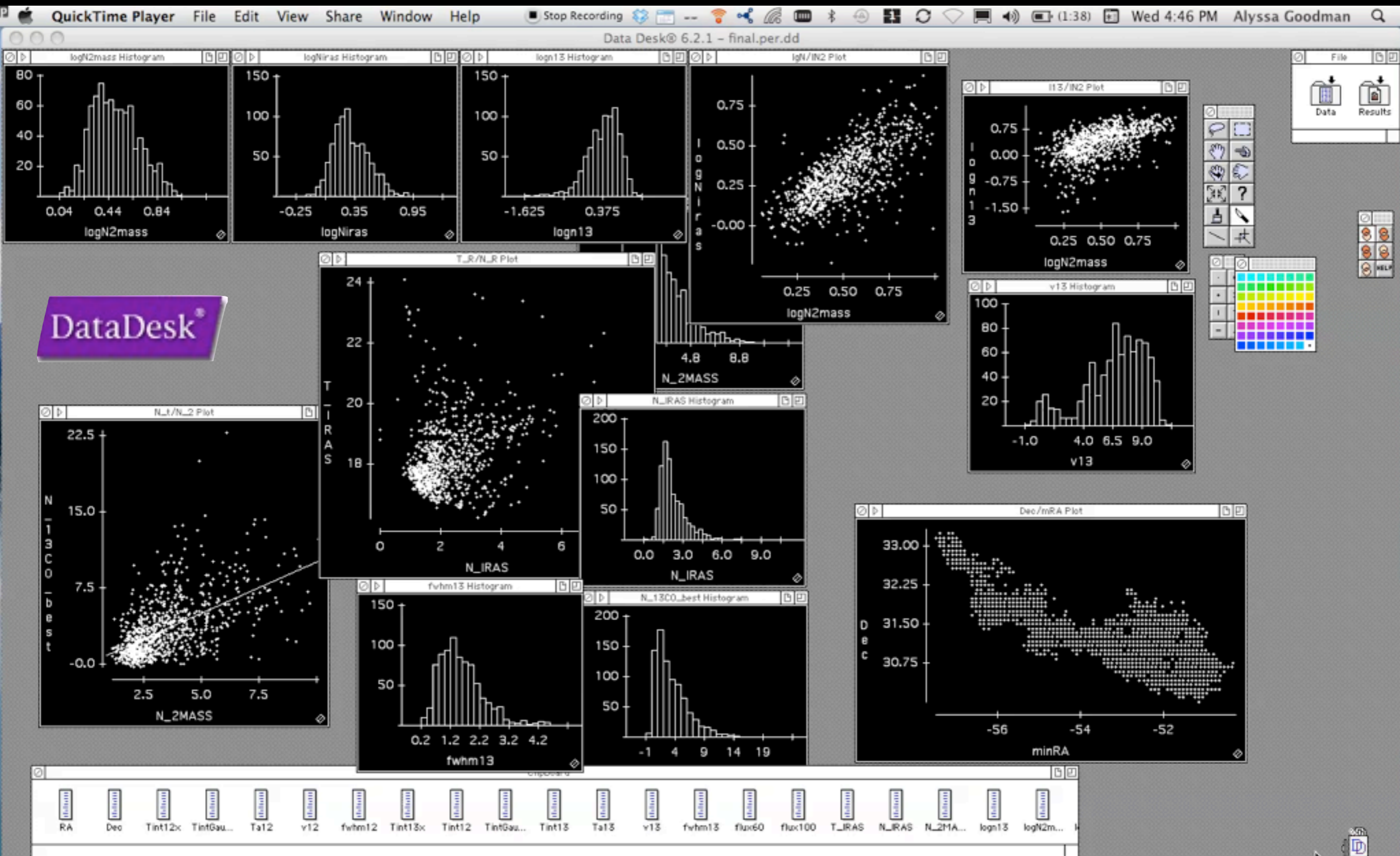
# “Seamless Astronomy” and “Linked Views”

*Contextual,  
High-Dimensional  
View*

*Link*

*Flat,  
Text-Based  
View*

# DataDesk (est. 1986)



# John 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 (...relation to SVM)

## Warning

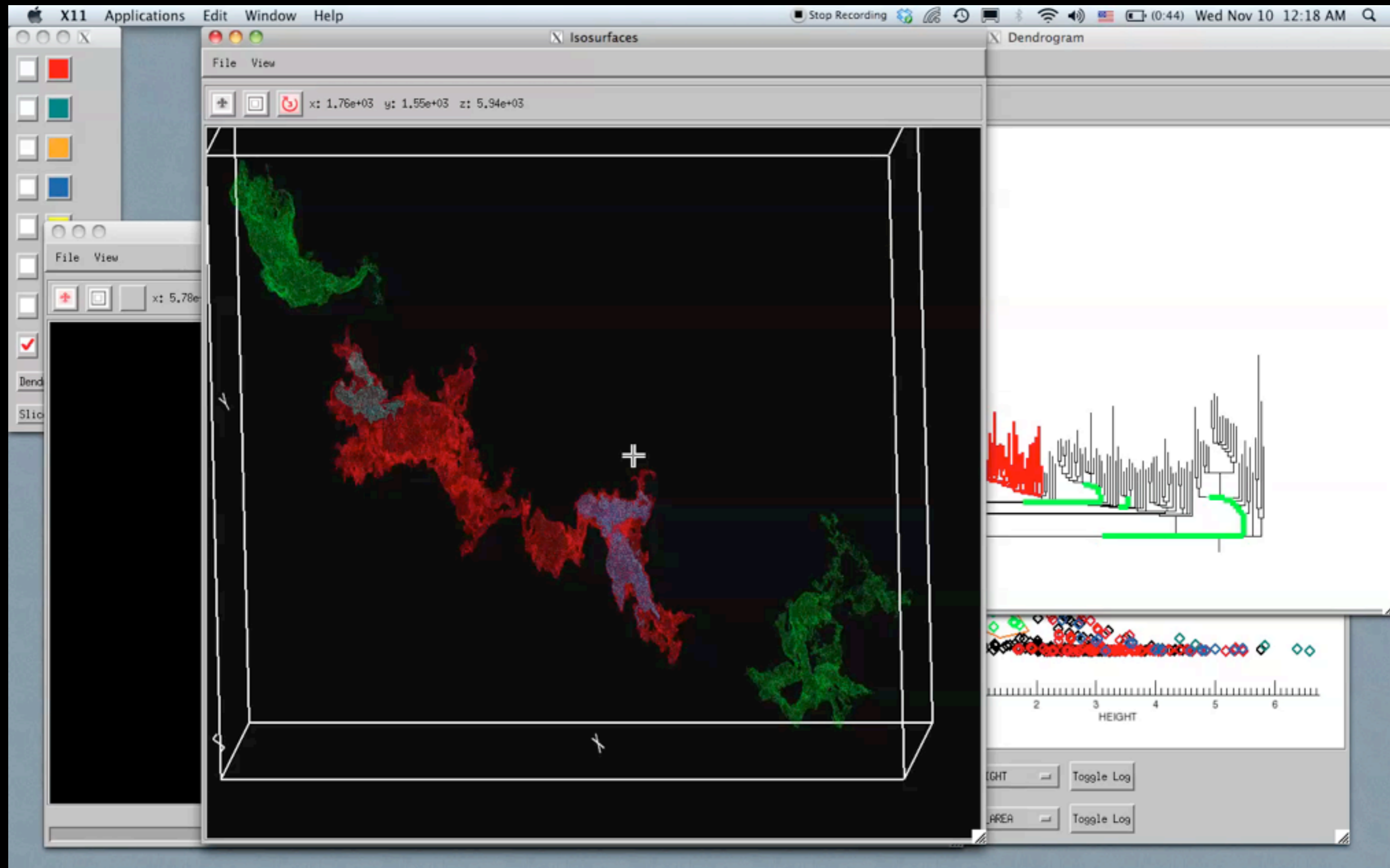
*"details of control can make or break such a system"*

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





# Exemplar: Linked Dendrogram Views in IDL



*Video & implementation: Christopher Beaumont, CfA/UHawaii;  
inspired by AstroMed work of Douglas Alan, Michelle Borkin, AG, Michael Halle, Erik Rosolowsky*

# Viz-e-Lab

Projects  
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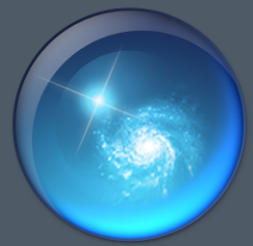


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# Microsoft® Research WorldWide Telescope

Experience WWT at [worldwidetelescope.org](http://worldwidetelescope.org)

The screenshot displays the main interface of WorldWide Telescope. At the top, there is a navigation bar with tabs for 'Explore', 'Guided Tours', 'Search', 'View', and 'Settings'. Below this, a 'Collections' pane shows 'All-Sky Surveys' with several thumbnails: 'Digitized Sky Survey', 'VLSS: VLA Low-frequency Sky Survey', 'WMAP ILC 5-Year', 'SFD Dust Map (Infrared)', 'IRIS: Improved Resolution', '2MASS: Two Micron All Sky Survey', and 'Hydrogen Alpha Full Sky Survey'. The main view shows a large, detailed image of a galaxy with a central crosshair. A 'Finder Scope' window is open, displaying a smaller image of a galaxy and its details: 'Classification: Spiral Galaxy in Andromeda', 'NGC224', 'RA: 00h42m42s', 'Dec: 41 : 16 : 00', 'Distance: 2.5 million light years', 'Alt: 70 : 06 : 26', 'Rise: 00:35', 'Az: 275 : 42 : 17', and 'Transit: Set:'. Below the main view, there is a 'Look At' dropdown menu set to 'Sky', and a 'Context bar' showing 'Andromeda' and '01:58:26'. A 'Context globe' shows the current field of view on a celestial sphere. At the bottom, there is a 'Research' window with 'Image Credits' and a 'Show Object' button. A 'Context bar' at the bottom right shows 'NGC221' and 'M31'. A 'Context globe' at the bottom right shows the current field of view on a celestial sphere.

Seamlessly explore imagery from the best ground and space-based telescopes in the world

Expert led tours of the Universe

Control time to study how the night sky changes

View and compare images from across the electromagnetic spectrum

Much more than "just" the sky at night! 3D features can take you to other planets, stars & galaxies.

Finder Scope links to Wikipedia, publications, and data, so you can learn more

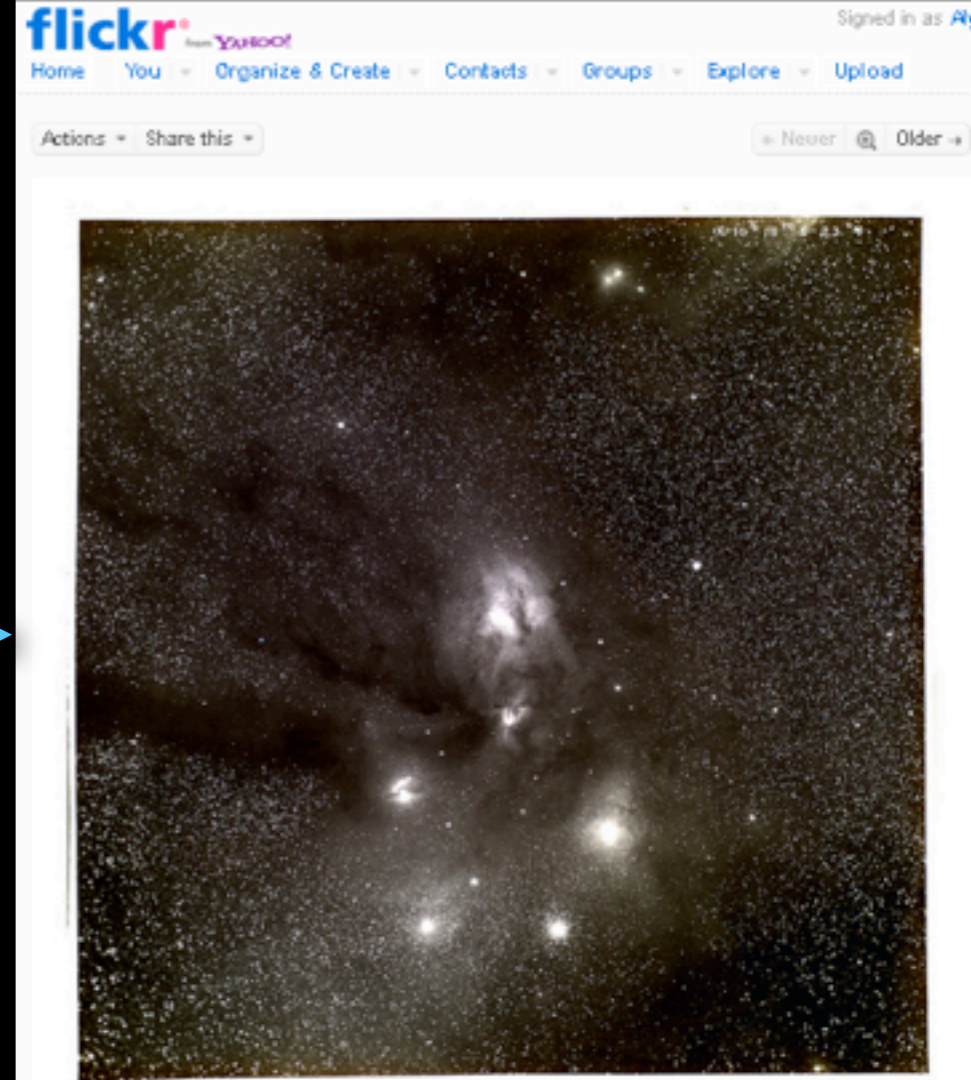
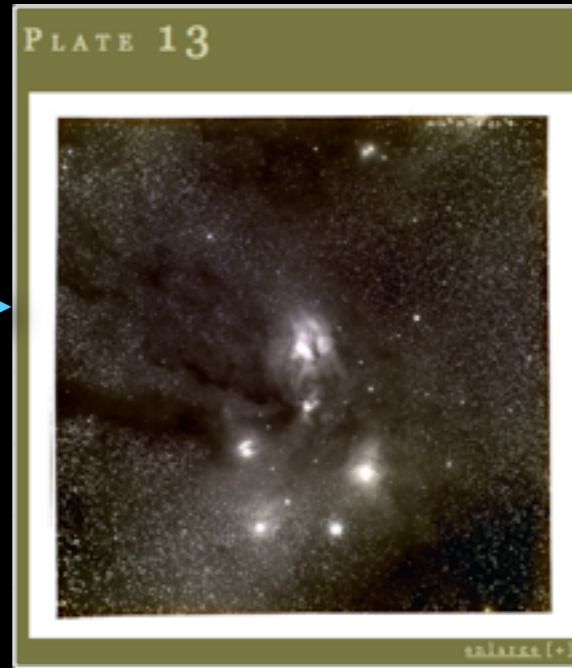
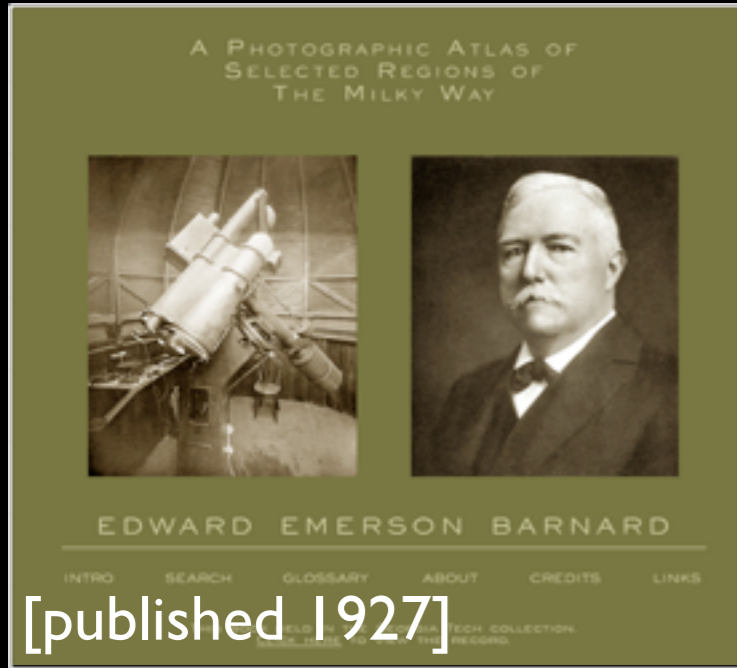
Context bar shows items of interest in current field of view

Context globe shows where you're looking.



# “Seamless Astronomy”...


astrometry.net + flickr + WWT



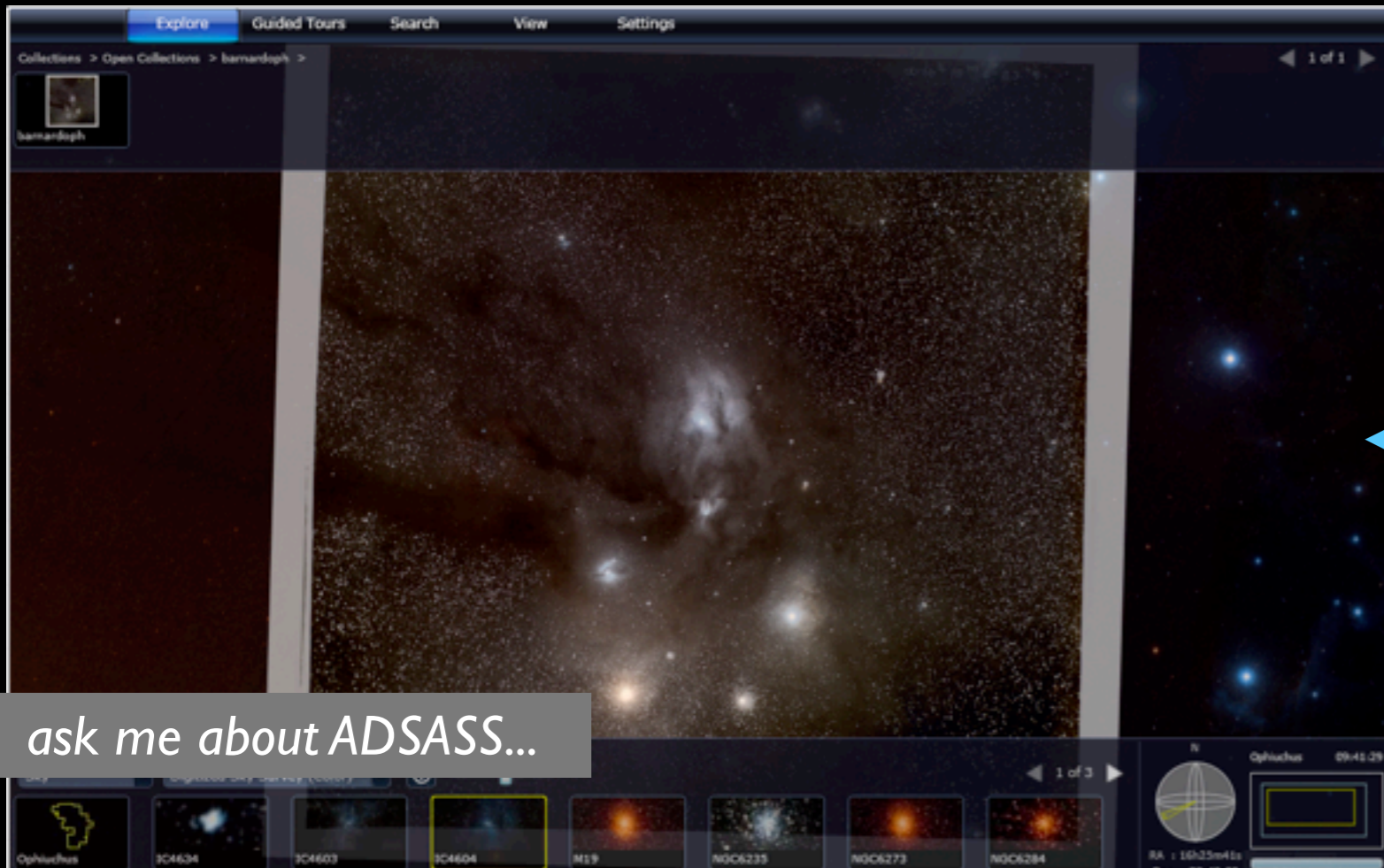
barnardoph

E.E. Barnard's image of Ophiuchus  
[www.library.gatech.edu/bpdi/bpdi.php](http://www.library.gatech.edu/bpdi/bpdi.php)

Comments and faves **astrometry.net**

 **astrometry.net** (6 days ago | reply | delete)  
Hello, this is the blind astrometry solver. Your results are:  
(RA, Dec) center:(246.421365149, -23.6749819397) degrees  
(RA, Dec) center (H-M-S, D-M-S):(16:25:41.128, -23:40:29.935)  
Orientation:178.34 deg E of N  
Pixel scale:52.94 arcsec/pixel  
Parity:Reverse ("Left-handed")  
Field size :9.41 x 9.41 degrees  
Your field contains:  
The star Antares ( $\alpha$ Sco)  
The star Graffias ( $\beta$ 1Sco)  
The star  $\lambda$  Niyat ( $\sigma$ Sco)  
The star  $\tau$ Sco  
The star  $\omega$ 1Soo  
The star  $\nu$ Sco  
The star  $\omega$ 2Soo  
The star  $\omega$ Oph  
The star  $\lambda$ 3Sco  
The star  $\rho$ Sco  
IC 4692  
IC 4601  
NGC 6121 / M 4  
IC 4603  
IC 4604 / rho Oph nebula  
IC 4605

[View in World Wide Telescope](#)





# WWT Ambassadors: WorldWide Telescope For Interactive Learning

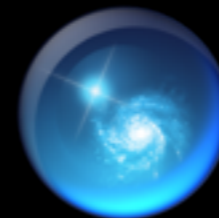
**Alyssa Goodman**  
*Harvard University Professor of Astronomy,  
Microsoft Academic Partner*

**Pat Udomprasert**  
*WWT Program Coordinator*

**Curtis Wong**  
*Microsoft Research, WWT Creator*

**Stephen Strom**  
*NOAO, WWT Tucson Site Advisor*

**Sarah Block**  
*Web site development*



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### About the WWT Telescope Ambassadors Program



WorldWide Telescope (WWT) is a rich visualization environment that functions as a virtual telescope, allowing anyone to make use of professional astronomical data to explore and understand the universe. As of early 2010, the new WWT Ambassadors Program is recruiting astronomically-literate volunteers, including retired scientists engineers—all of whom will be trained to be experts in using WWT as a teaching tool. Ambassadors will give volunteer presentations at public libraries, community centers, museums, and schools, demonstrating WWT's power to help laypeople visualize and understand our universe.

[Read more](#)

### John Huchra's Universe

Submitted by [patudom](#) on Jan. 11

**John Huchra**, former president of the **American Astronomical Society**, passed away on October 8, 2010.

John's colleagues at the Harvard-Smithsonian Center for Astrophysics, in collaboration with the creators of WorldWide Telescope at Microsoft Research, have created a new, interactive, WWT Tour to honor John and his career. The Tour primarily focuses on John's quest to map the Universe in three dimensions. It is 12.5 minutes long.

The Tour is best experienced inside the WorldWide Telescope program itself. (**Note: You must have the version of WWT released on 1/13/2011 to view all of this Tour's content. You can download it from [here](#).**) As viewed within the WWT program, the Tour content is interactive, allowing users to pause and explore the parts of the Universe featured in the tour, explore web hyperlinks, and more. For those who do not have the desktop client, the Tour has been posted as a video as well.

Video (Interactive WWT features will be disabled)

### John Huchra's Universe



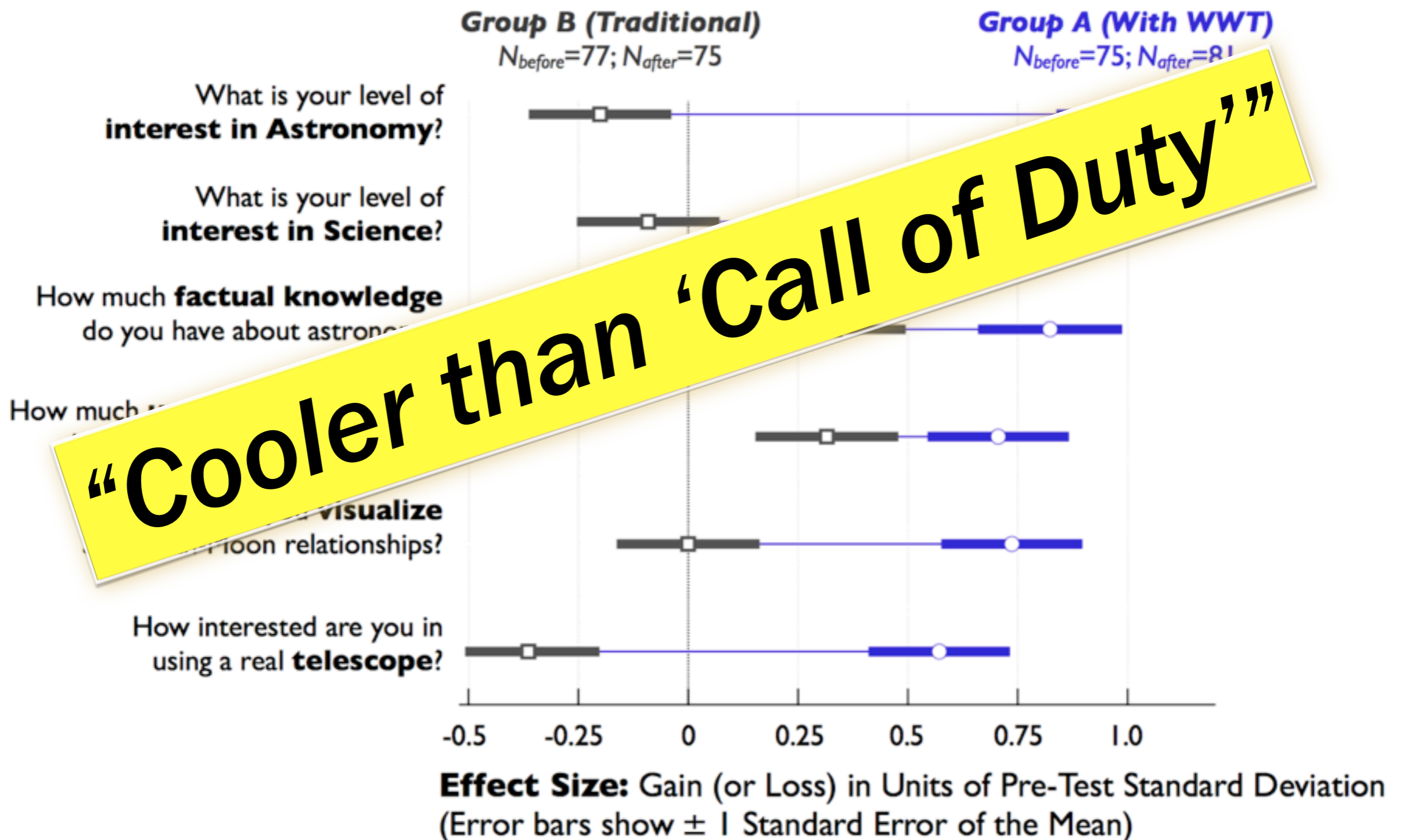
Friends of John Huchra have released a new WWT Tour to honor John and his work. The Tour primarily focuses on John's quest to map the Universe in three dimensions. You can view the Tour [here](#).

### Upcoming

- [Cyberlearning Tools for STEM Education Conference](#)  
Mar. 8 - Mar. 9
- [Cambridge Science Festival](#)  
Apr. 30 - May. 10

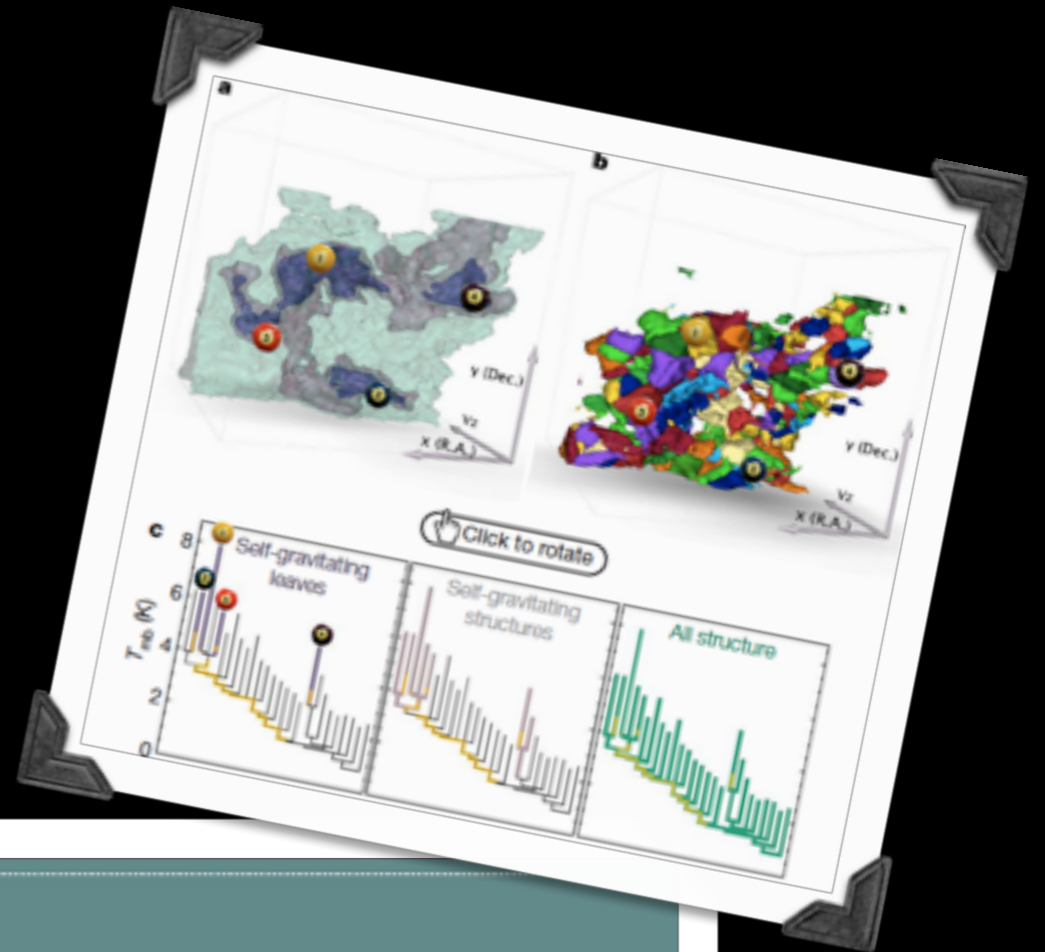
# Gains in Student Interest and Understanding

(“Traditional Way” vs “WWT Way”)



# Seeing Science

*Data Visualization in  
Modern Research  
(and teaching!)*



## The Art of Numbers

Empirical and Mathematical Reasoning 19. The Art of Numbers: The Visual Display of Information

Professor Alyssa A. Goodman (Astronomy)

**Course website**

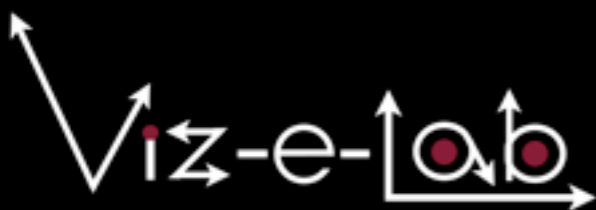
Duration: 05:30

Alyssa A. Goodman

Harvard University (HCO+IIC)

Smithsonian Astrophysical Observatory

Scholar-in-Residence, WGBH





# Viz-e-Lab

Projects  
2011



The next challenges...

collaborators/contacts at CfA

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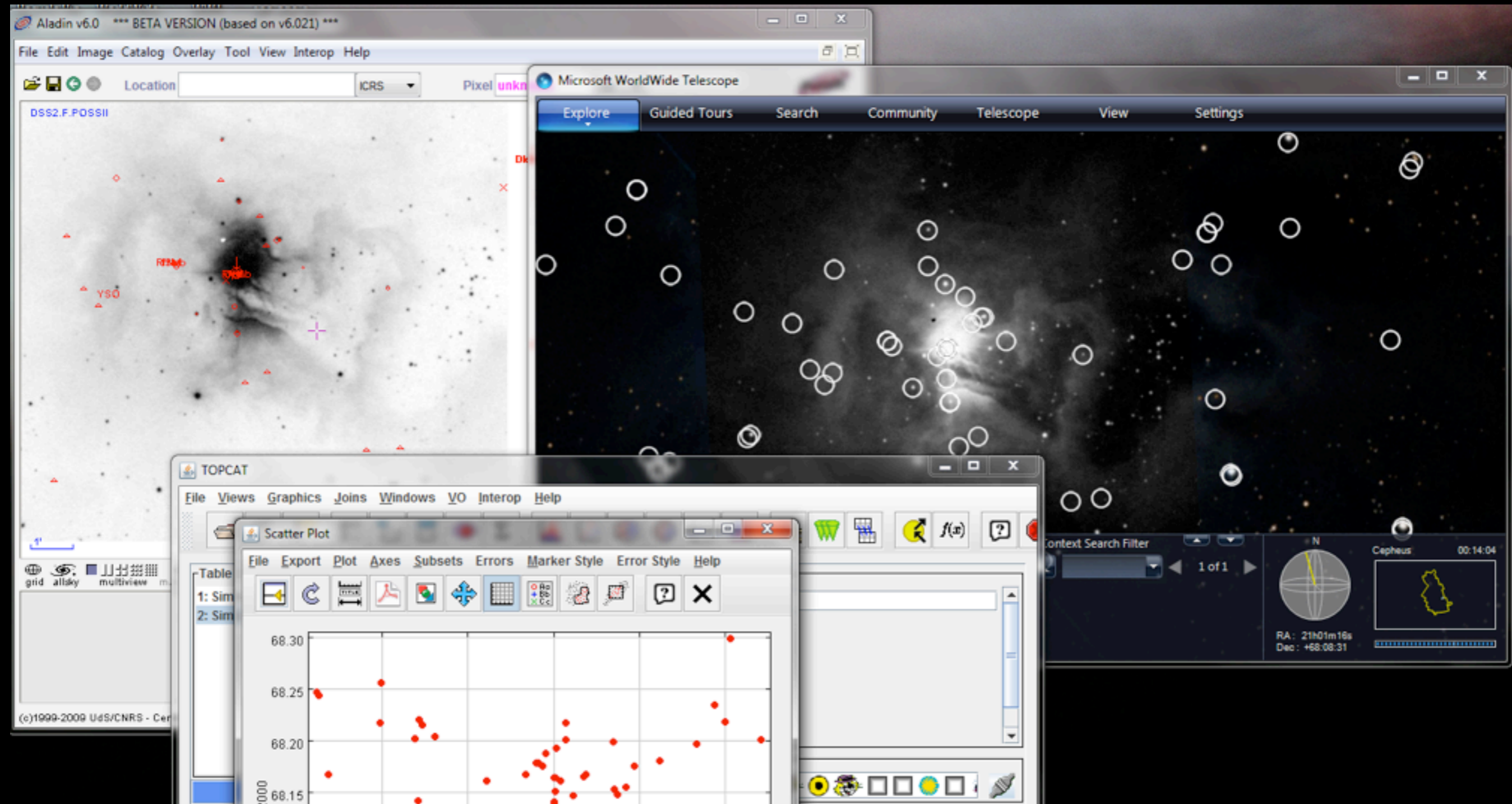
# Challenge #1: 3D Selection

Why?  
How?  
How?



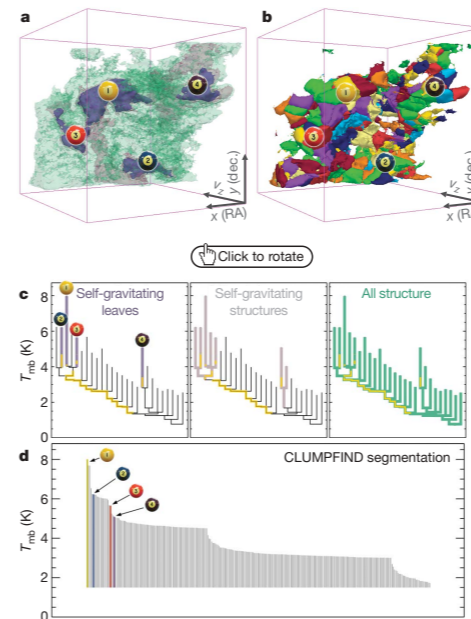
on?

# Challenge #2: Too many windows...



# Challenge #3:

## What does “Publication-Quality” Graphics Mean in an Interactive 3D World?



**Figure 2 | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to  $^{13}\text{CO}$  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  $T_{\text{mb}}$  (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 ( $-0.5 \text{ km s}^{-1}$ ) to back ( $8 \text{ km s}^{-1}$ ).

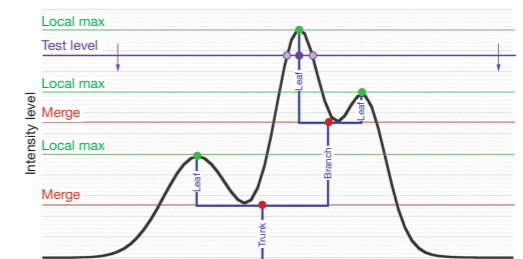
data, CLUMPFIND typically finds features on a limited range of scales, above but close to the physical resolution of the data, and its results can be overly dependent on input parameters. By tuning CLUMPFIND's two free parameters, the same molecular-line data set<sup>8</sup> can be used to show either 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'<sup>9</sup> were proposed as a way to characterize clouds' hierarchical structure

using 2D maps of column density. With this early 2D work as inspiration, we have developed a structure-identification algorithm that abstracts the hierarchical structure of a 3D ( $p$ - $p$ - $v$ ) data cube into an easily visualized representation called a 'dendrogram'<sup>10</sup>. Although well developed in other data-intensive fields<sup>11,12</sup>, it is curious that the application of tree methodologies so far in astrophysics has been rare, and almost exclusively within the area of galaxy evolution, where 'merger trees' are being used with increasing frequency<sup>13</sup>.

Figure 3 and its legend explain the construction of dendrograms schematically. The dendrogram quantifies how and where local maxima of emission merge with each other, and its implementation is explained in Supplementary Methods. Critically, the dendrogram is determined almost entirely by the data itself, and it has negligible sensitivity to algorithm parameters. To make graphical presentation possible on paper and 2D screens, we 'flatten' the dendrograms of 3D data (see Fig. 3 and its legend), by sorting their 'branches' to not cross, which eliminates dimensional information on the  $x$  axis while preserving all information about connectivity and hierarchy. Numbered 'billiard ball' labels in the figures let the reader match features between a 2D map (Fig. 1), an interactive 3D map (Fig. 2a online) and a sorted dendrogram (Fig. 2c).

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Goodman, Rosolowsky, Borkin, Foster, Halle, Kauffmann & Pineda, **Nature**, 2009

