

WorldWide Telescope

Microsoft
Research

The Art of Numbers



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



4268



IMG_4130



IMG_4129



IMG_4128



y fun this was!



IMG_3343



IMG_3343



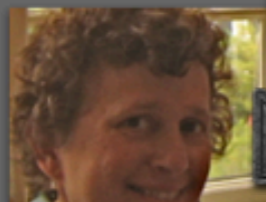
IMG_3338



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



“Interocularity”

(see work of John Tukey)

“Image and Meaning”

(see work of Felice Frankel,
and imageandmeaning.org)

The Art of Numbers

Data • Dimensions • Display

What...

...is easier now than before?

fast computation, animation, 3D

...was easier before than now?

craftsmanship

...should be easier in the future?

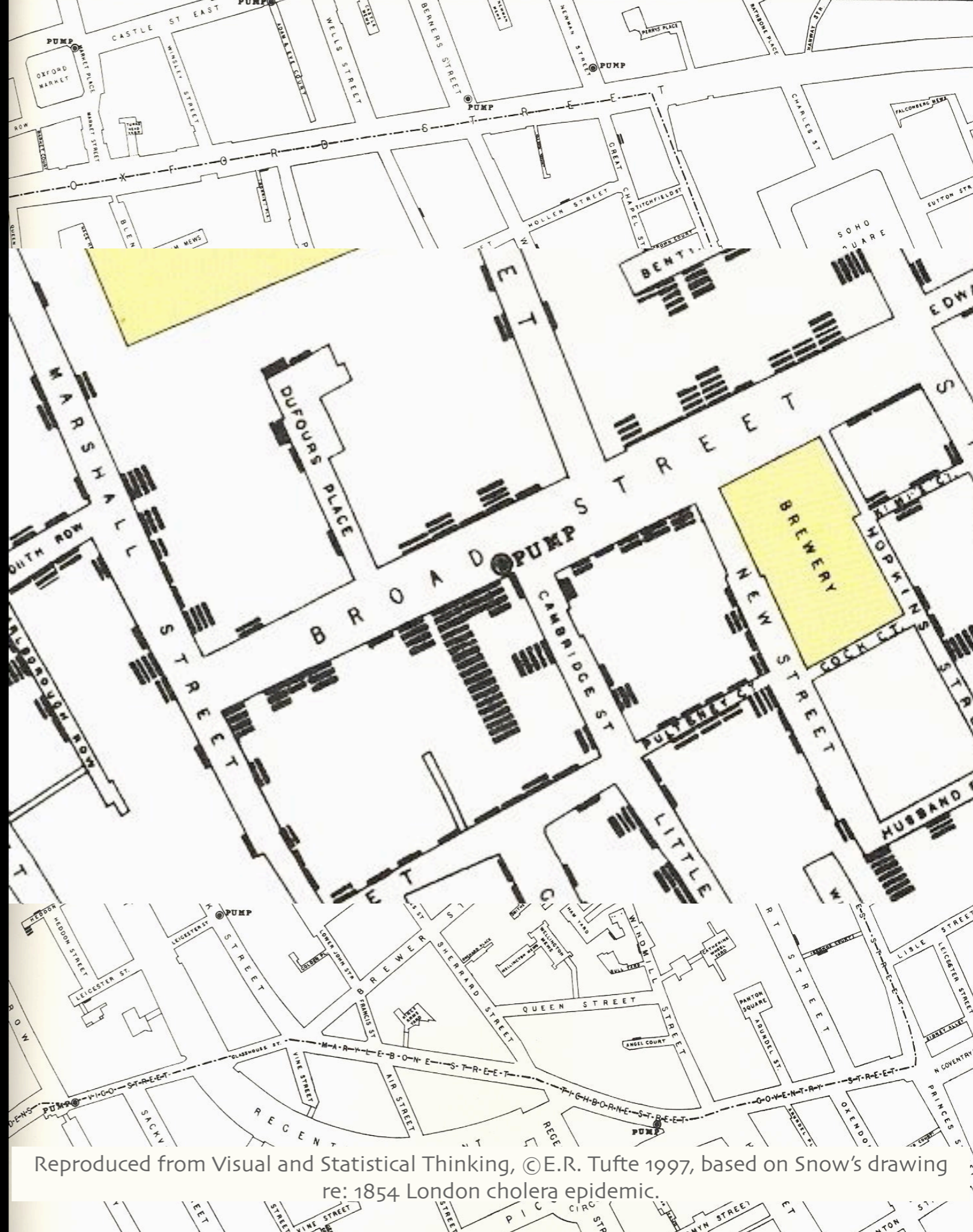
modular craftsmanship, linked views

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

COURTSIDE LIVE

19-16 STANDINGS

Fouls 1, Foul 4, :20

02:46

1 2 3 4 OT T

18	17	24	13		72
18	19	26	16		79

Fouls 1, Foul 3, :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
Daniels, Antonio	7	2	8	0
Steuenson, DeSha	11	3	4	2
Jamison, Antawn	18	10	0	3
Butler, Caron	14	3	1	3
Haywood, Brenda	12	5	0	3
Blatche, Andray	3	5	0	3
Mason, Roger	3	1	1	5
Songaila, Darius	2	1	1	2
Young, Nick	2	0	0	0
Pecherou, Oleksiy	0	1	0	0
Arenas, Gilbert				
McGuire, Dominic				

BOS SELECT: ○ ALL ● ACTIVE 5

PLAYER NAME	PTS	REB	AST	F
Rondo, Rajon	4	2	2	2
Allen, Ray	16	6	3	2
Garnett, Kevin	21	6	6	3
Pierce, Paul	16	4	2	3
Perkins, Kendrick	9	3	1	3
House, Eddie	5	6	3	1
Allen, Tony	4	4	0	0
Davis, Glen	1	0	0	2
Posey, James	3	2	0	2
Pollard, Scott				
Scalabrino, Brian				
Powe, Leon				

TD Banknorth GARDEN

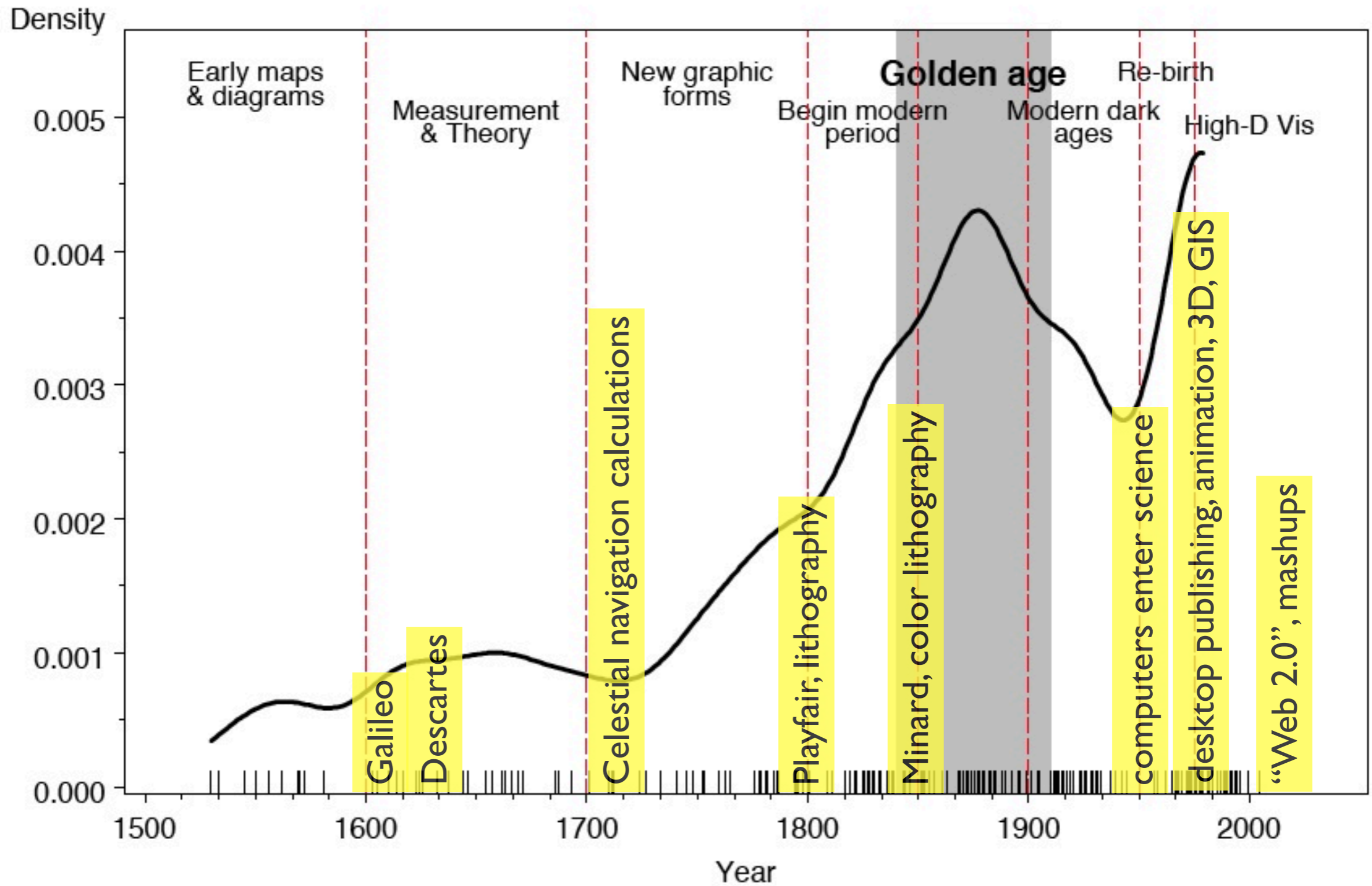
WIZARDS

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)

Sc. Principale.

Galileo Galilei, Familiare Seruo della Ser. V. inuigilante
 do assiduo, et lo ogni spirito se bene no solo satisfar
 aluano che non della lettera di Madonata nelle sue
 Dio di Padova,

Inuere diuere determinate di presentare al Sc. Principe
 l'occhio et la p. di giuamenti inestimabile se ogni
 negozio et in circa marittima o terreste stimo di tenere que
 sto nuovo artificio nel maggior segreto et solap a disposizione
 di V. Ser. L. Galileo conato dalle piu uide speculazioni di
 prospettua in l'uantaggio di scoprire Legni et Vele dell' inimico
 a due hore et piu di tempo prima che gli scuopra noi et distinguend
 il numero et la qualita de i Vascelli giudicare le sue forze
 ballottarsi alla caccia et combattimento o alla fuga, o pure essi
 nella campagna aperta uedere et particolarly distinguere ogni suo
 posto et fortificamento.

Adi 7. di gennaio
 Giove si uede a 7. * uici: 10. 11.
 Adi 8. uici * * * * *
 4. * * * * * ora diuy diretto et no retrogrado
 Adi 12. si uede in tale uisione * * * * *
 N. 13. si uede in uisione a Giove 4 stelle * * * * *
 Adi 14. è angelo * * * * *
 N. 15. * * * * * la pressi a 4. ora in uici la 4. ora di =
 sbante dalla 3. a gruppo terra * * * * *
 Lo spazio delle 3. uide uide no om
 maggiose del diametro di 7. et c.
 in una linea retta.

7	* * ○ *	17	* ○
8	○ * * *	18	* ○
10	* * ○	19	* ○ * *
11	* * ○	19	* ○ * *
12	* ○ *	20	○ * ○ ○
13	* ○ * *	21	... ○ *
15	○ * * *	22	* ○ * *
15	○ * * *	22	* ○ * *
16	○ * *	23	* ○ * *
16	○ * *	23	* ○ * *
17	* ○ *	24	* ○ * *
17	* ○ *	24	* ○ * *

SIDERIUS NUNCIUS

On the third, at the seventh hour, the stars were arranged in this
 quence. The eastern one was 1 minute, 30 seconds from Jupiter
 the 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 precisely

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

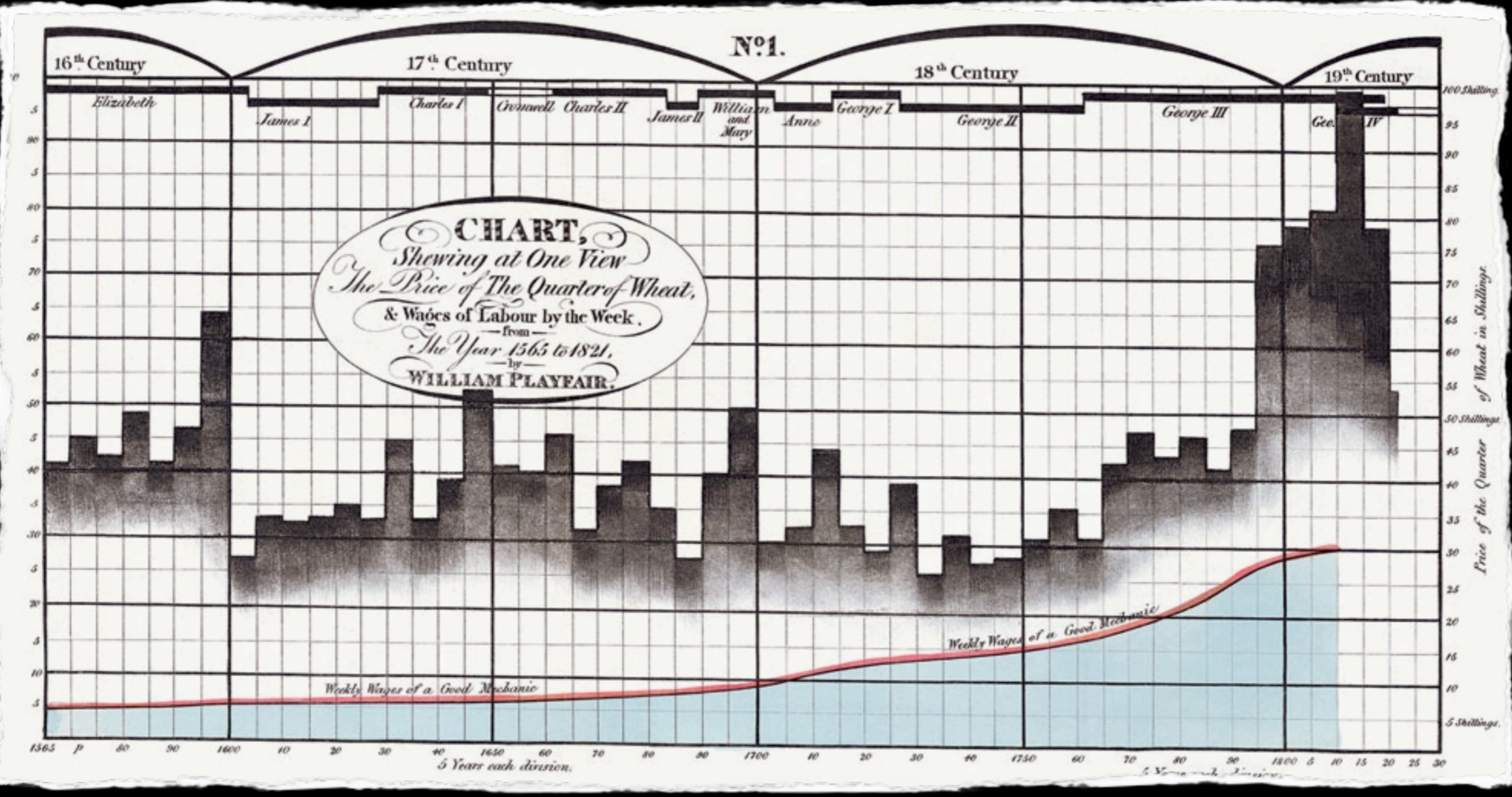
East * ○ * West

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.

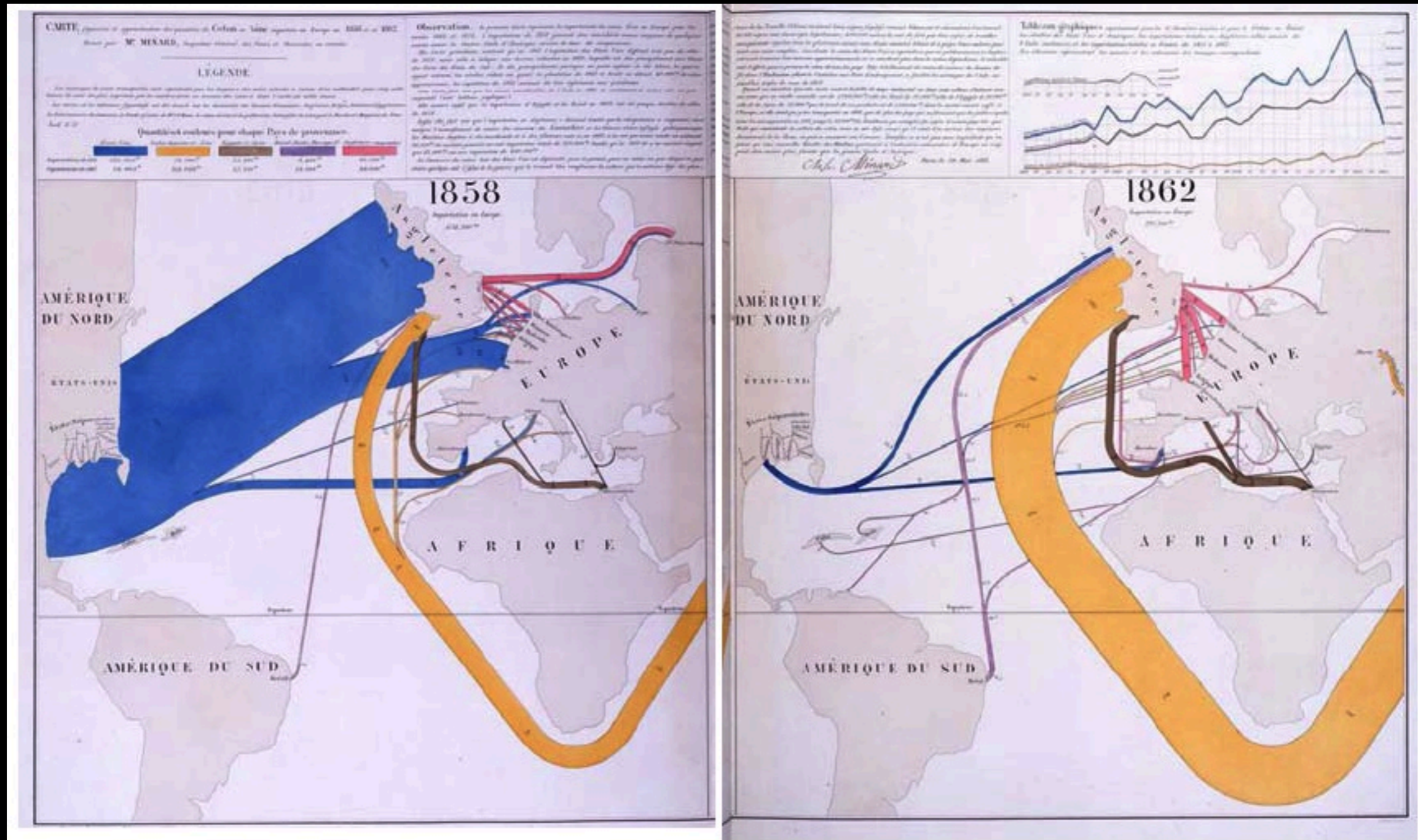
On the seventh, two stars stood near Jupiter both to the east



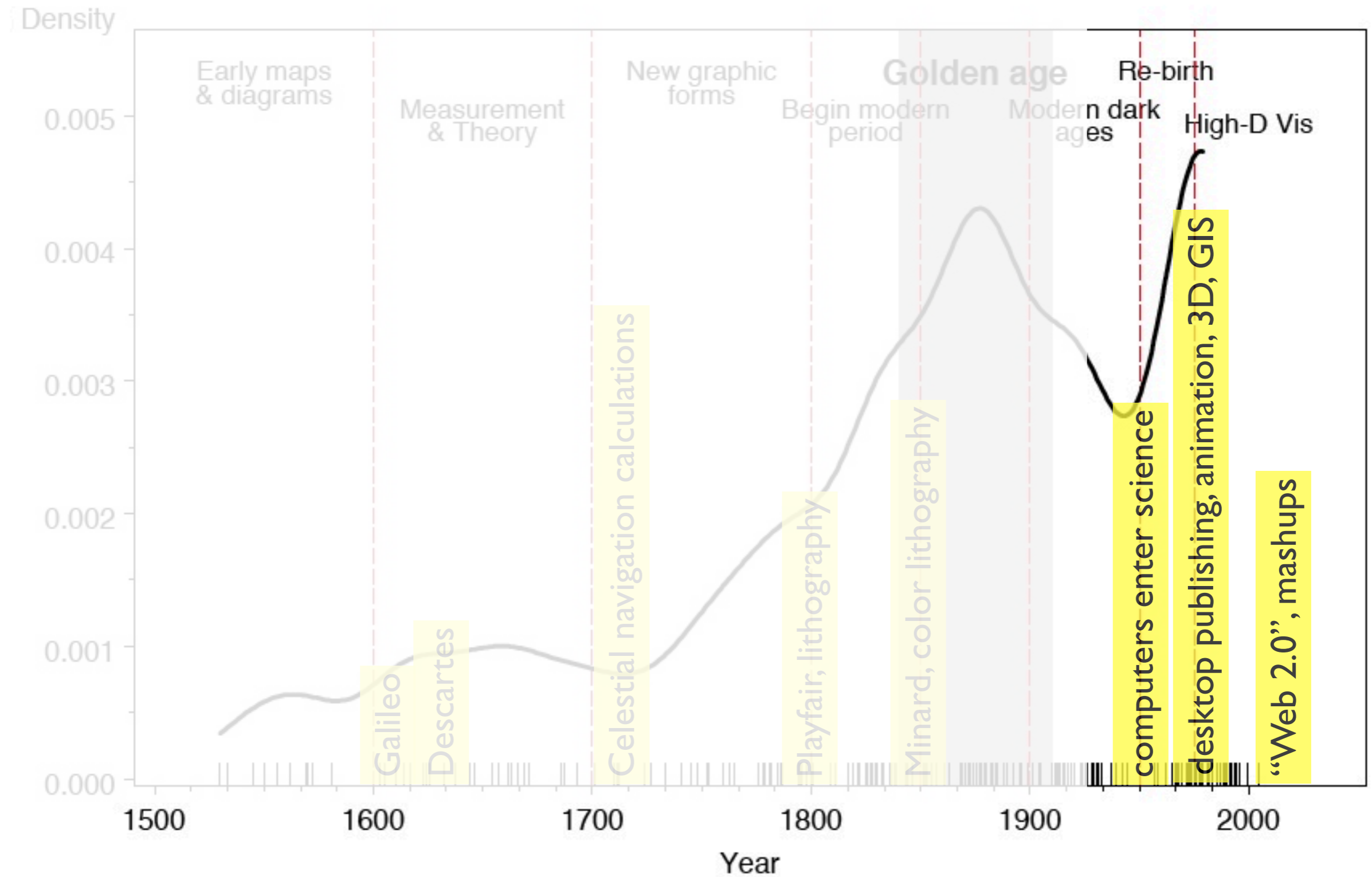
William Playfair (1759-1823)



Charles Joseph Minard, in color (1781-1870)



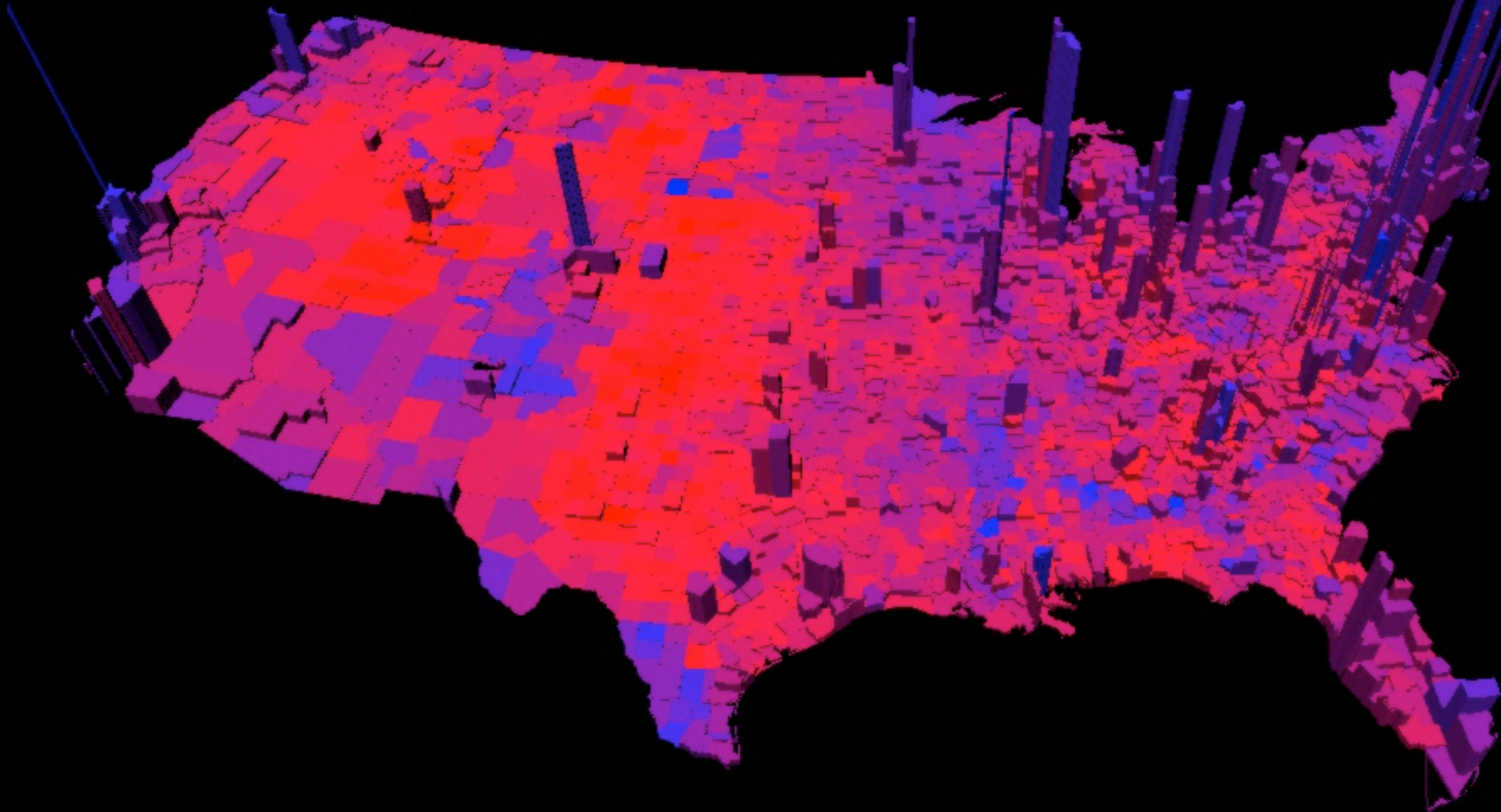
Milestones: Time course of developments



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

Data • Dimensions • Display

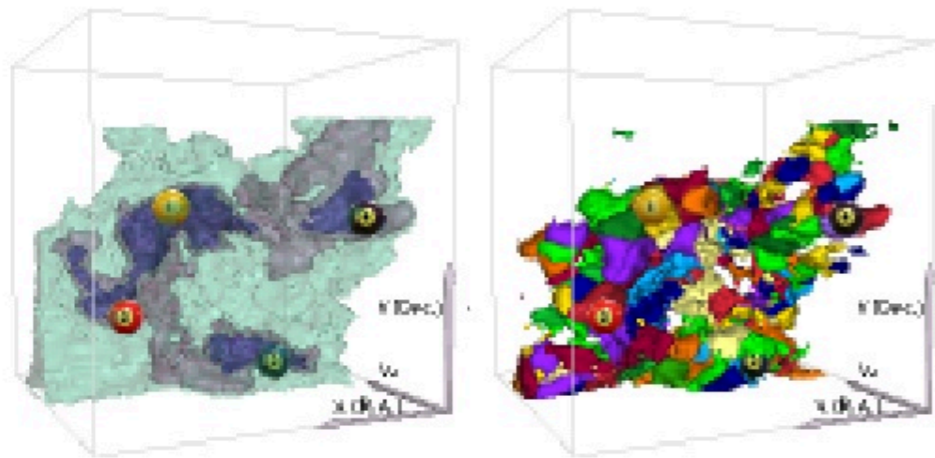
“High-dimensional” or “Multivariate” Data and High(er) Dimensional Displays



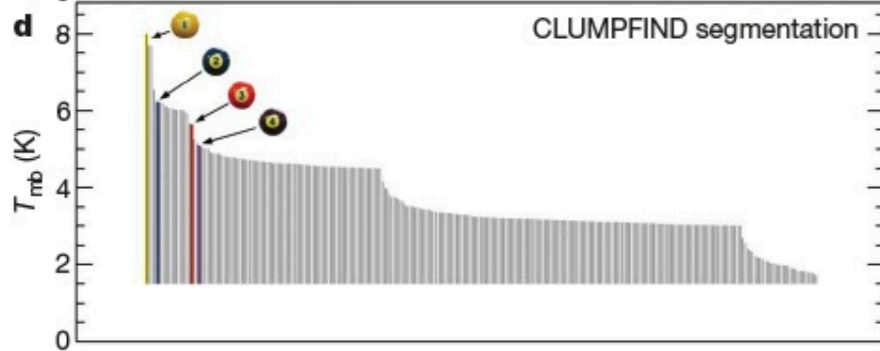
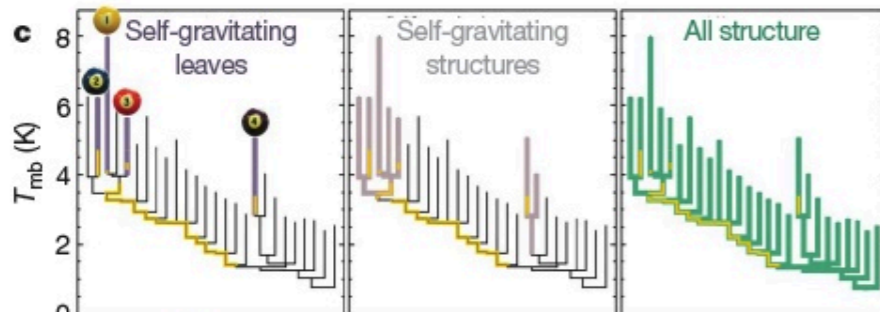
*This map **displays** 2 quantities as a function of 2 spatial dimensions.
...Is that 4 dimensions?*

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

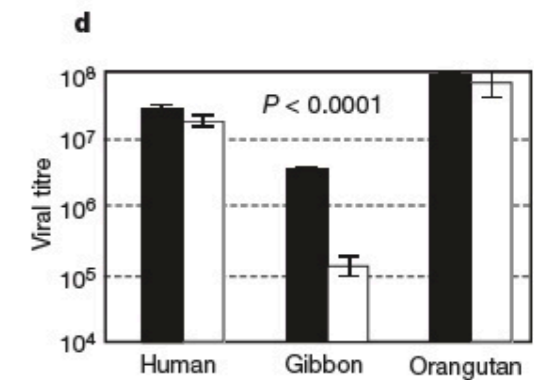
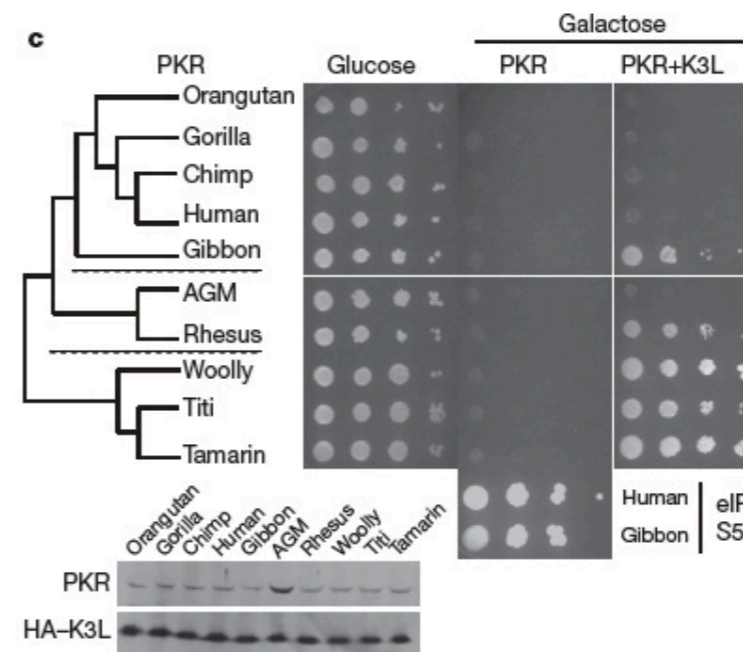
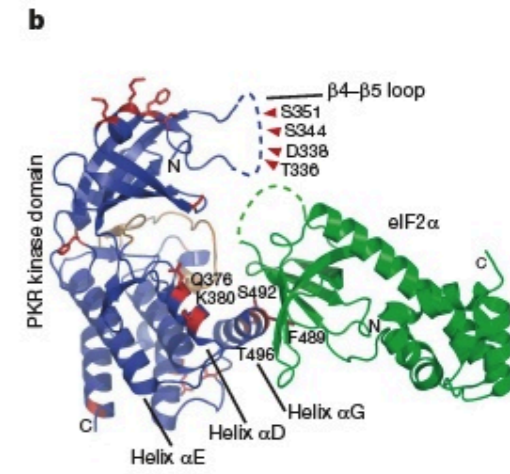
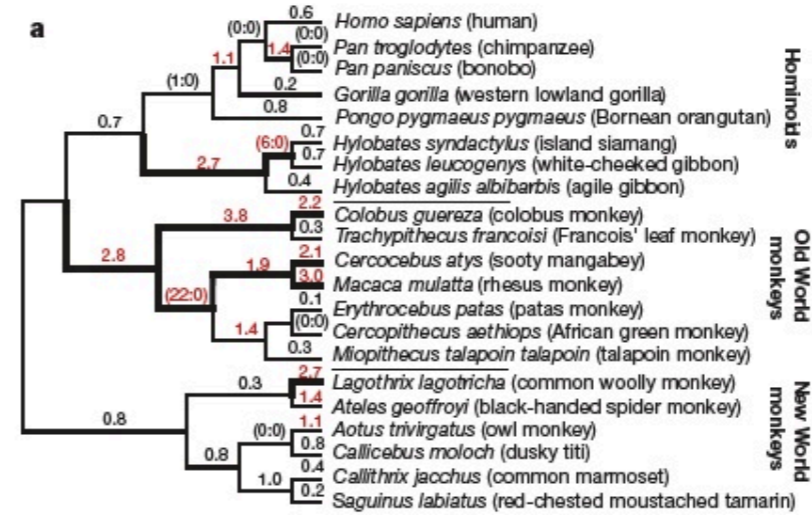
LETTERS



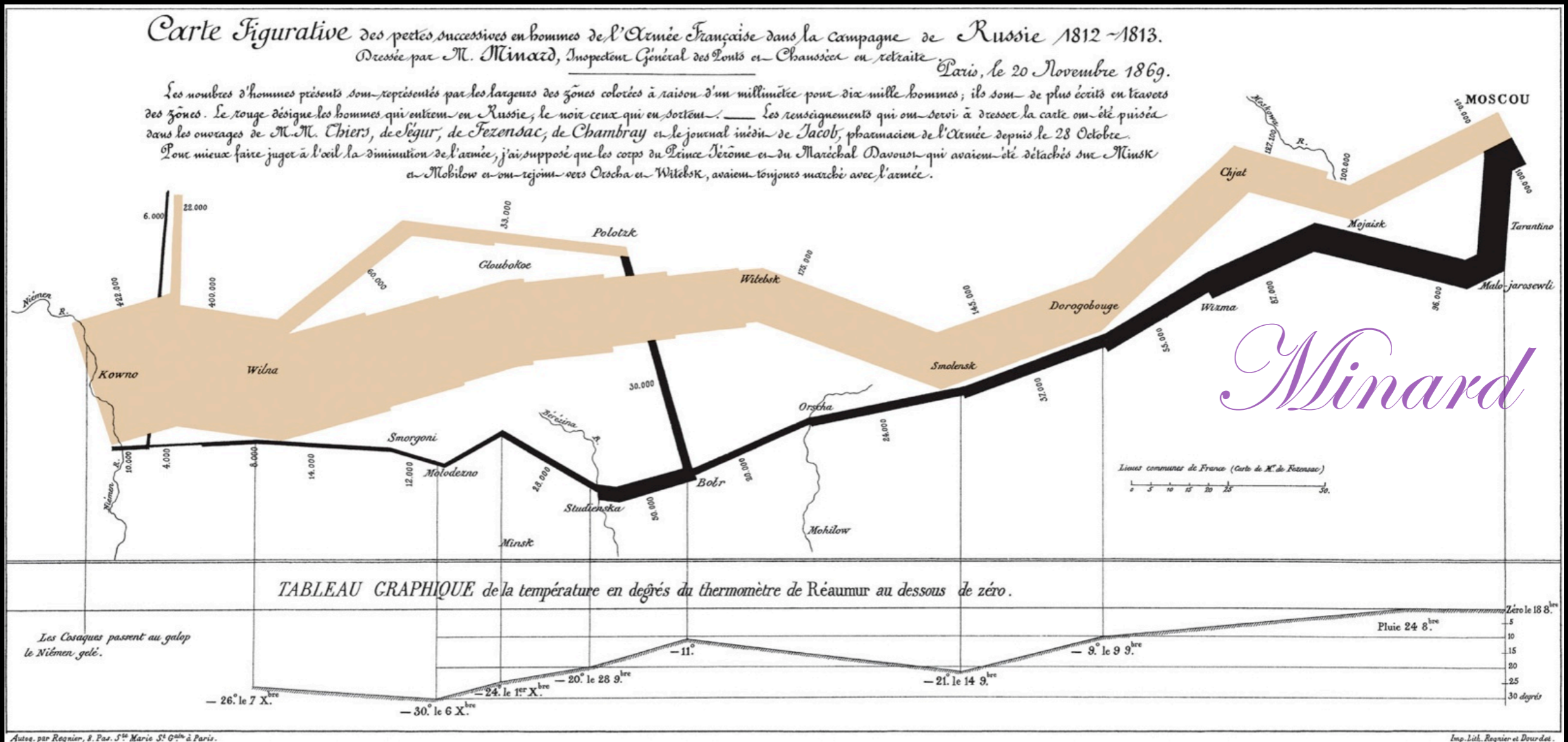
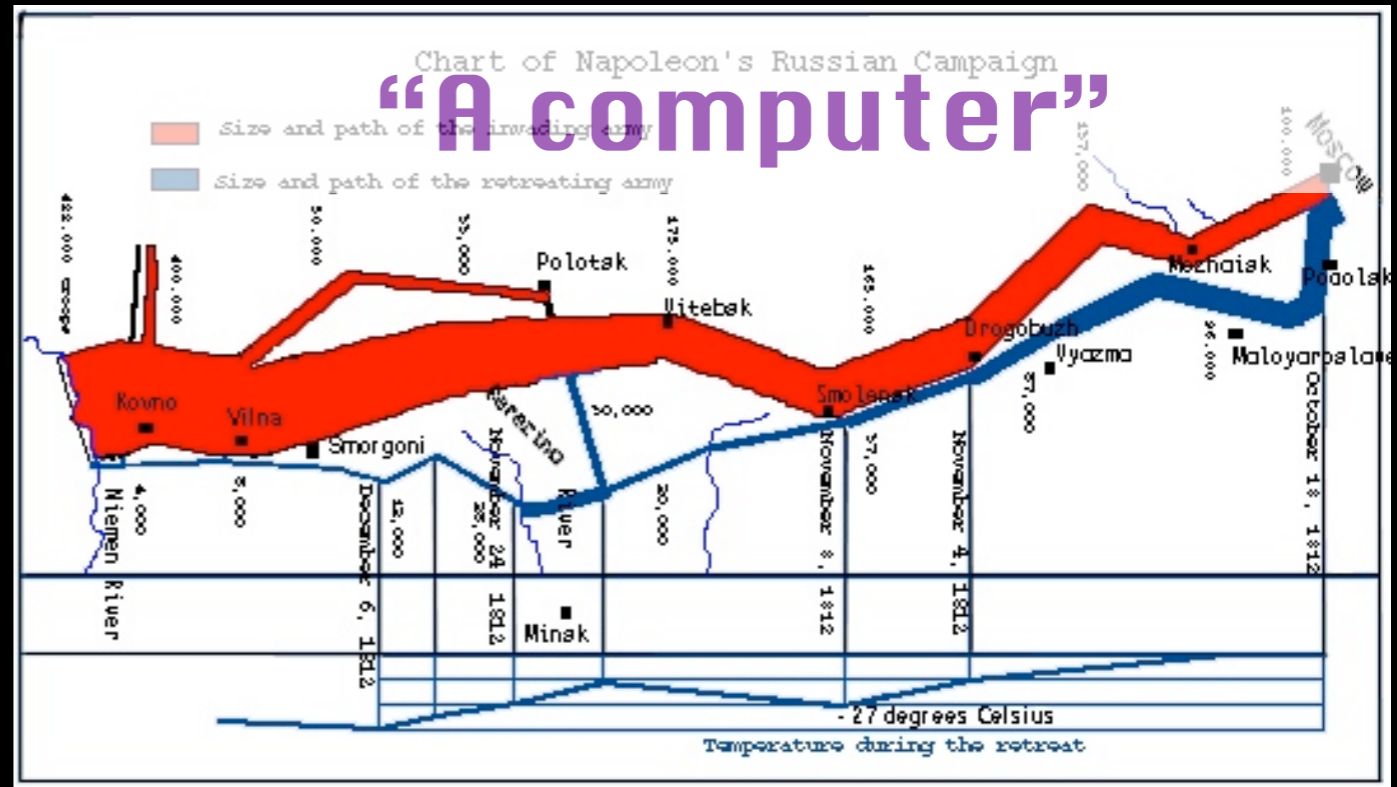
Click to rotate



LETTERS



How much are we held back today by digital tools?





Astronomical Medicine

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



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TED Fellows The TED Fellows Directory > Michelle Borkin

[Sign in to send Michelle an email »](#)



United States

3D Visualization Researcher + Astronomer + Applied Physicist, Harvard University

Websites
[Michelle Borkin's homepage](#)

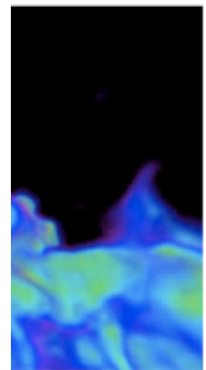
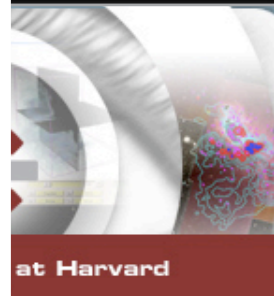
Bio

Michelle Borkin works on creating new approaches to interdisciplinary scientific imaging, data exploration and image analysis with a focus on 3D visualization. She wrote her undergraduate junior and senior theses on the application of medical imaging programs to astronomical data and has continued this research as part of the "Astronomical Medicine" project at Harvard's Initiative in Innovative Computing. She works with the developers of medical visualization tools to improve their effectiveness in multiple

Q&A

What projects are you working on now that are most meaningful to you?

My current primary focus is visualizing and analyzing data from the "Multiscale Hemodynamics" project, a collaboration of cardiologists, physicists, and computer scientists to combine fluid dynamics simulations of bloodflow with patient data to diagnose and treat heart disease. The "dream come true" outcome would be the development of a bedside supercomputer system that could be placed in a patient or operating room allowing a doctor to visualize a patient's coronary arteries in real-time 3D, overlaid with a bloodflow simulation. A physician could instantly identify areas of concern and take action such as inserting a stent to prevent a heart attack!



s (HMS/SPL of BWH), David

understanding in two very
ata exploration and








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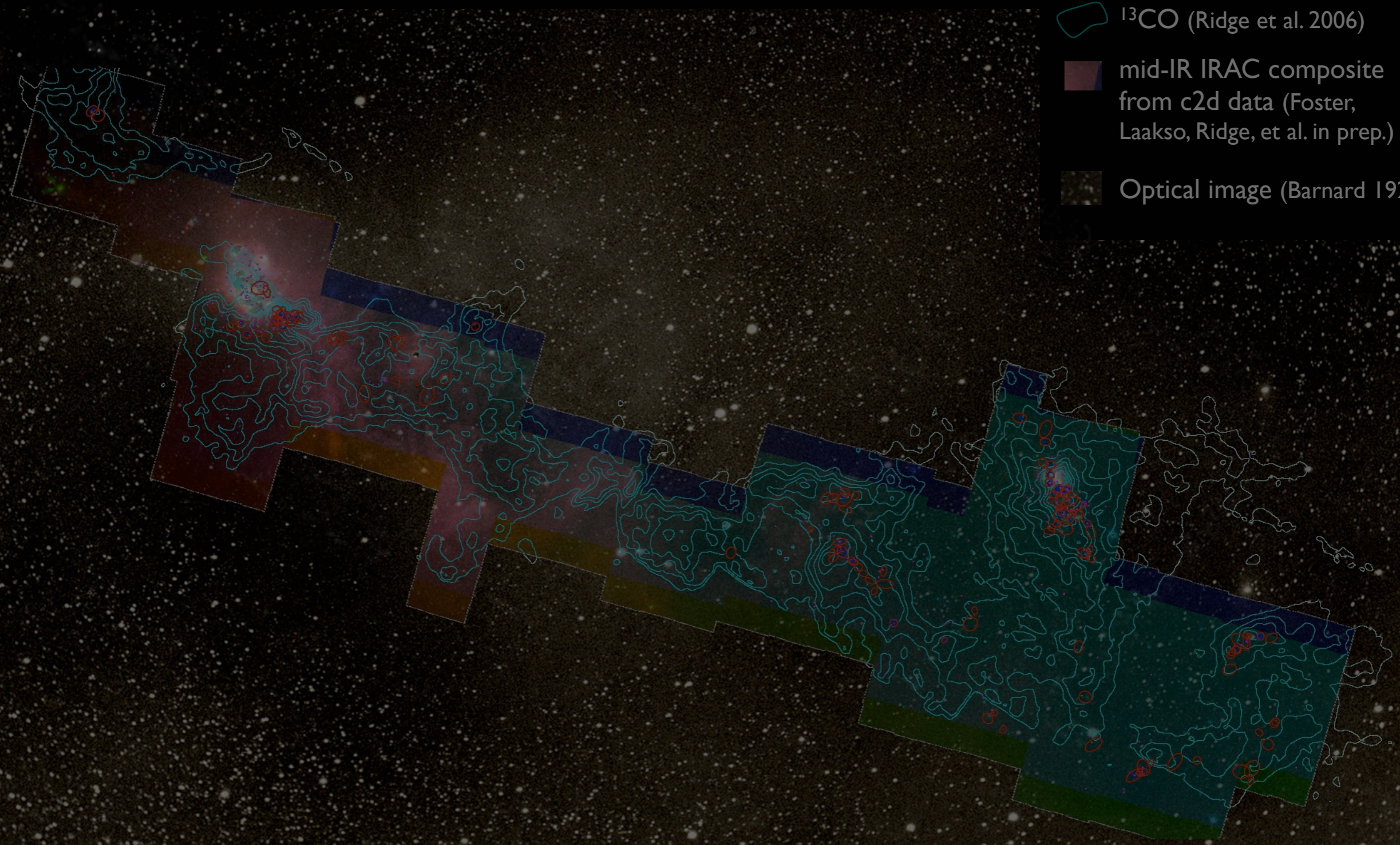
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com



COMPLETE Perseus

image size: 1305 x 733
WL: 63 WW: 127

-  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. in prep.)
-  Optical image (Barnard 1927)

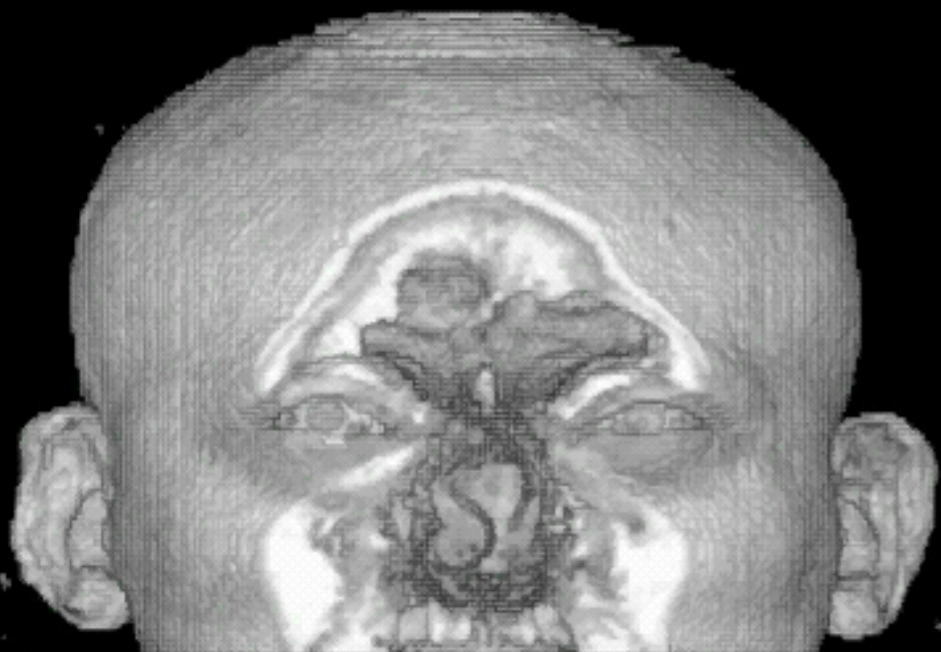


m: 17249
Zoom: 227% Angle: 0



“Astronomical Medicine”

“KEITH”



“z” is depth into head

“PERSEUS”








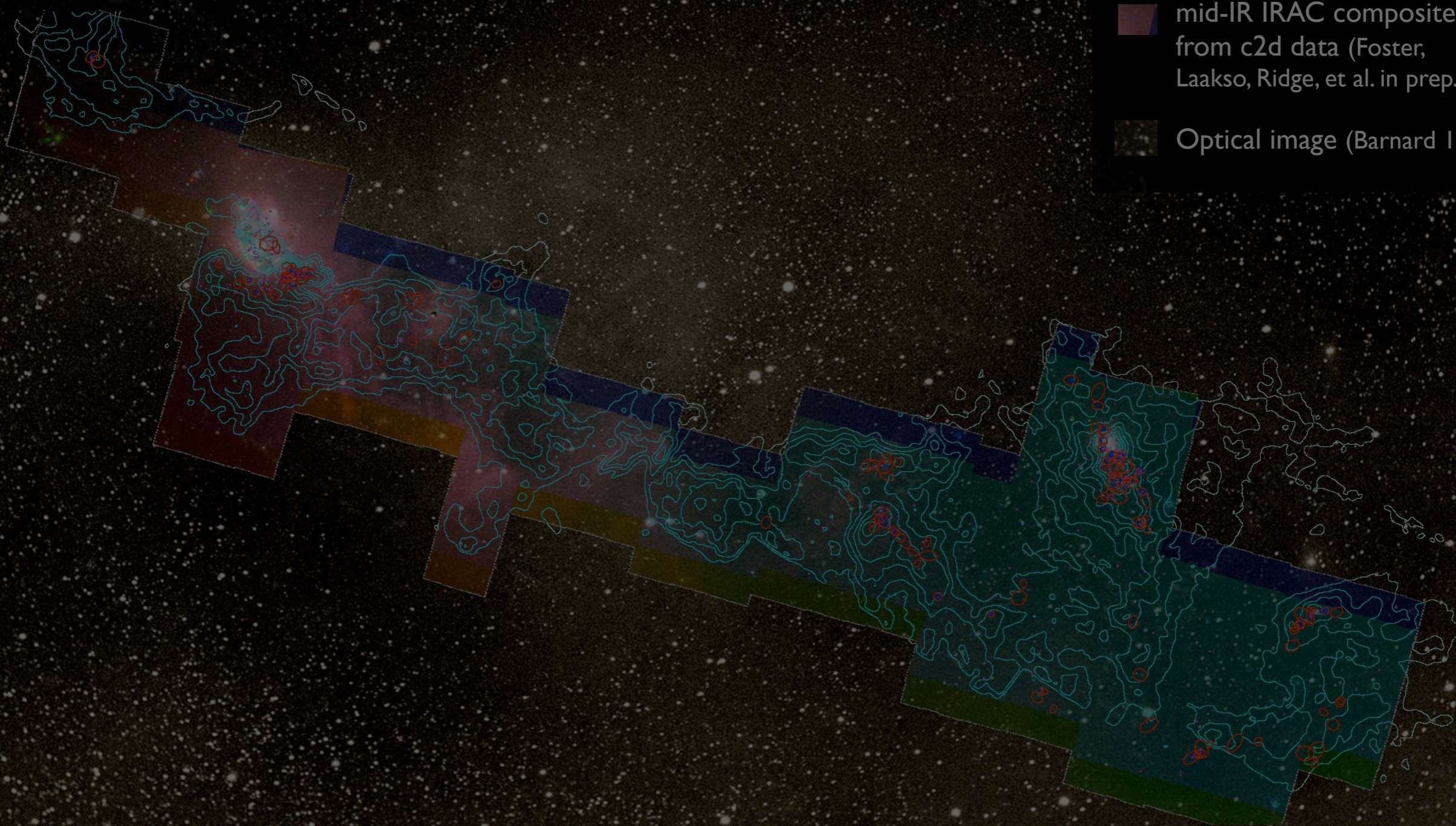
“z” is line-of-sight velocity

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

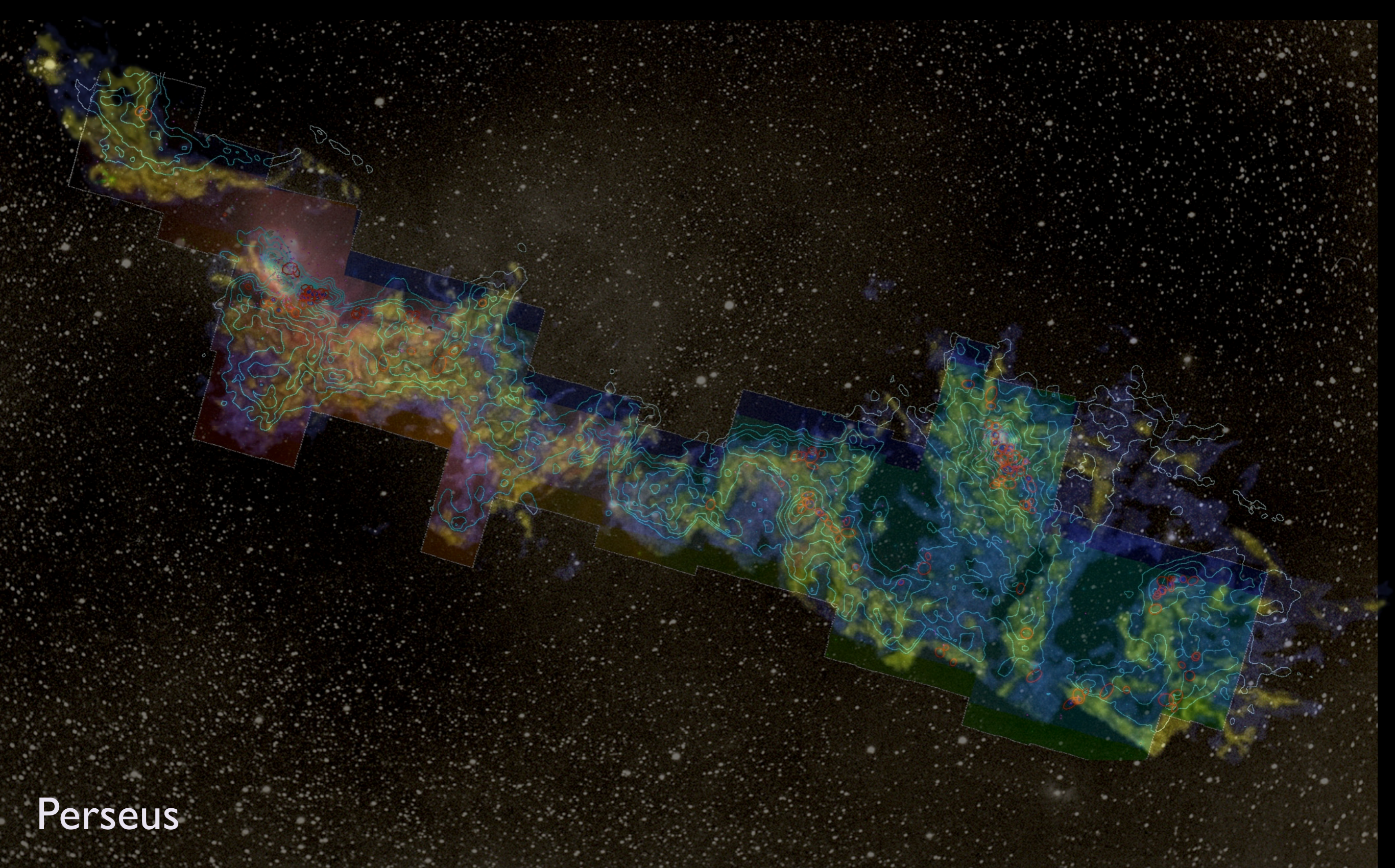
COMPLETE Perseus

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m: 17249
Zoom: 227% Angle: 0



Perseus

3D Viz made with VolView

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: Modular Craftsmanship

The Future we can see from “now”...

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

re-usable tools/mashups (Many Eyes, crowdsourcing)

live, **interactive linked views** (DataDesk, GapMinder, WWT, Dendroviz)

Unsolved Questions...

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

improved graphical representation of **uncertainty**

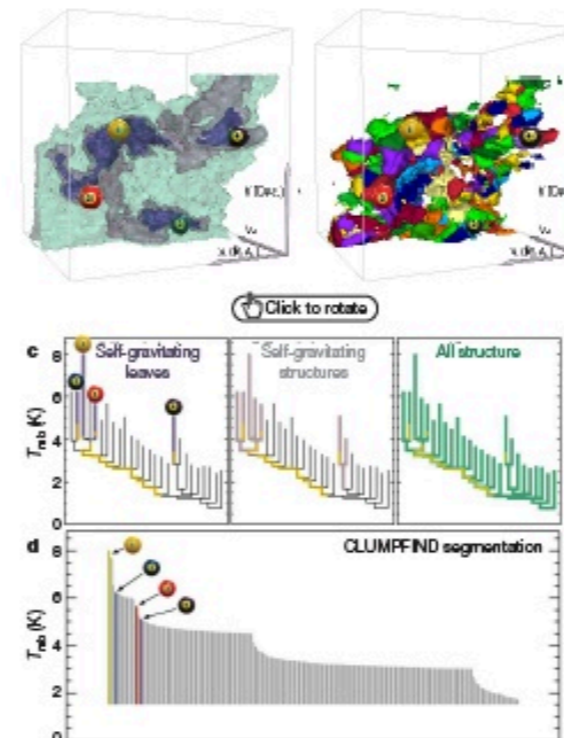


Figure 2 | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. **a**, 3D visualization of the surfaces indicated by colours in the dendrogram shown in **c**. Purple illustrates the smallest scale self-gravitating 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 set⁶ 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 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'¹⁰. Although well developed in other data-intensive fields^{11,12}, 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 frequency¹³.

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 (σ_v) and luminosity (L). The volumes can have any shape, and in other work¹⁴ 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 $M_{\text{gas}} = X_{13\text{CO}} L_{13\text{CO}}$, 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, $\alpha_{\text{obs}} = 5\sigma_v^2 R / GM_{\text{gas}}$. 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 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 fields⁶, its measured value should only be used as a guide to the longevity (boundedness) of any particular feature.

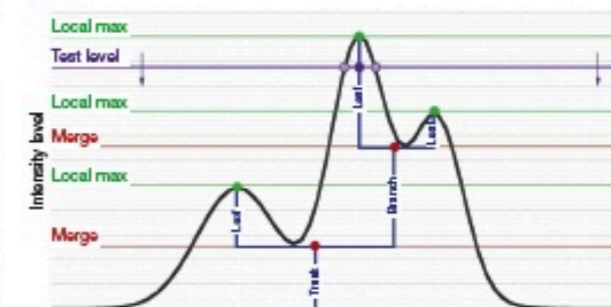


Figure 3 | Schematic illustration of the dendrogram process. Shown is the construction of a dendrogram from a hypothetical one-dimensional emission profile (black). The dendrogram (blue) can be constructed by 'dropping' a test constant emission level (purple) from above in tiny steps (exaggerated in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

3D PDF



Off the desktop

IIC Member login



Initiative in Innovative Computing at Harvard

home > research


scientists' discovery room lab (sdr lab)

Lead investigators
Chia Shen (IIC), Hanspeter Pfister (SEAS/IIC) and Robert Lue (FAS/Molecular and Cellular Biology)

Project staff
Michael Horn, Hao Jiang and Meekal Bajaj

Description

The Scientists' Discovery Room (SDR) is a next-generation visual digital laboratory for science discovery, collaborative learning and education. Our research focuses on experimenting with new modalities of human-computer interaction and visualization, to create a new genre of navigation, exploration and detailed analyses in multi-dimensional information spaces. All projects in SDR are in close collaboration with domain scientists and educators.



CThru, currently a collaborative endeavor with Molecular and Cellular Biology faculty, aims to develop a self-guided educational environment. In CThru, we examine methods for constructing interactive video-based educational modules. Using the animation "The Inner Life of the Cell" as a testbed, CThru addresses research issues of embedding interactive visible objects, extensive multimedia information and manipulatable 3D models within a video flow for self-explanatory learning, replacing sequential video viewing with the experience of exploring and manipulating in a multi-dimensional information space.

INVOLV is a generalizable multi-user interactive visualization framework for large hierarchical data sets. In this project, we address the visual layout of both the primary data representation and the overlay of alternate structures of the same data. Our first case study is the visualization of life on earth based on the Encyclopedia of Life (www.eol.org). We address the challenge of allowing free-form exploration of more than 1.2 million named species while communicating issues of biodiversity and phylogeny. The current visualization, designed for biodiversity science education settings, combines a Voronoi Treemap tessellation (see photo) with innovative human-computer interaction designs to support collaborative exploration and learning.

Slideshow: Tabletop Computers *Continued* By Meredith Ringel Morris

First Published December 2008

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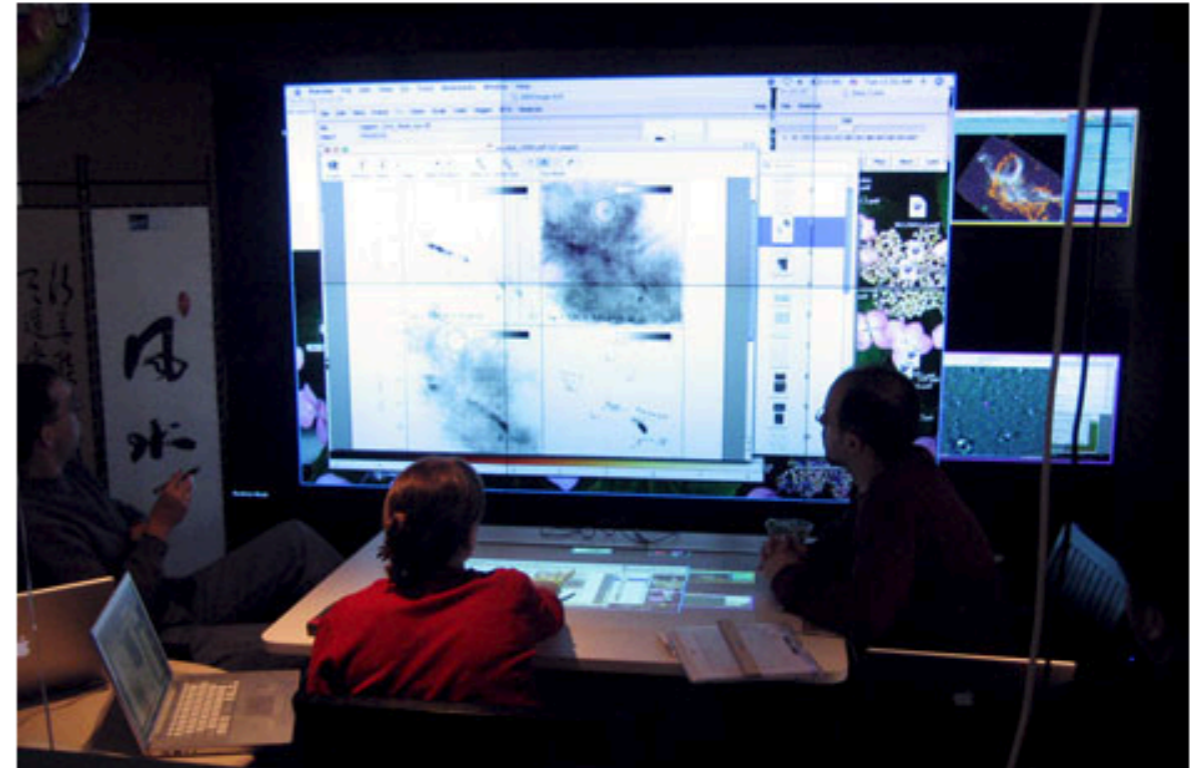


PHOTO: HAO JIANG, DANIEL WIGDOR, CLIFTON FORLINES, AND CHIA SHEN

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.

Touch Interfaces

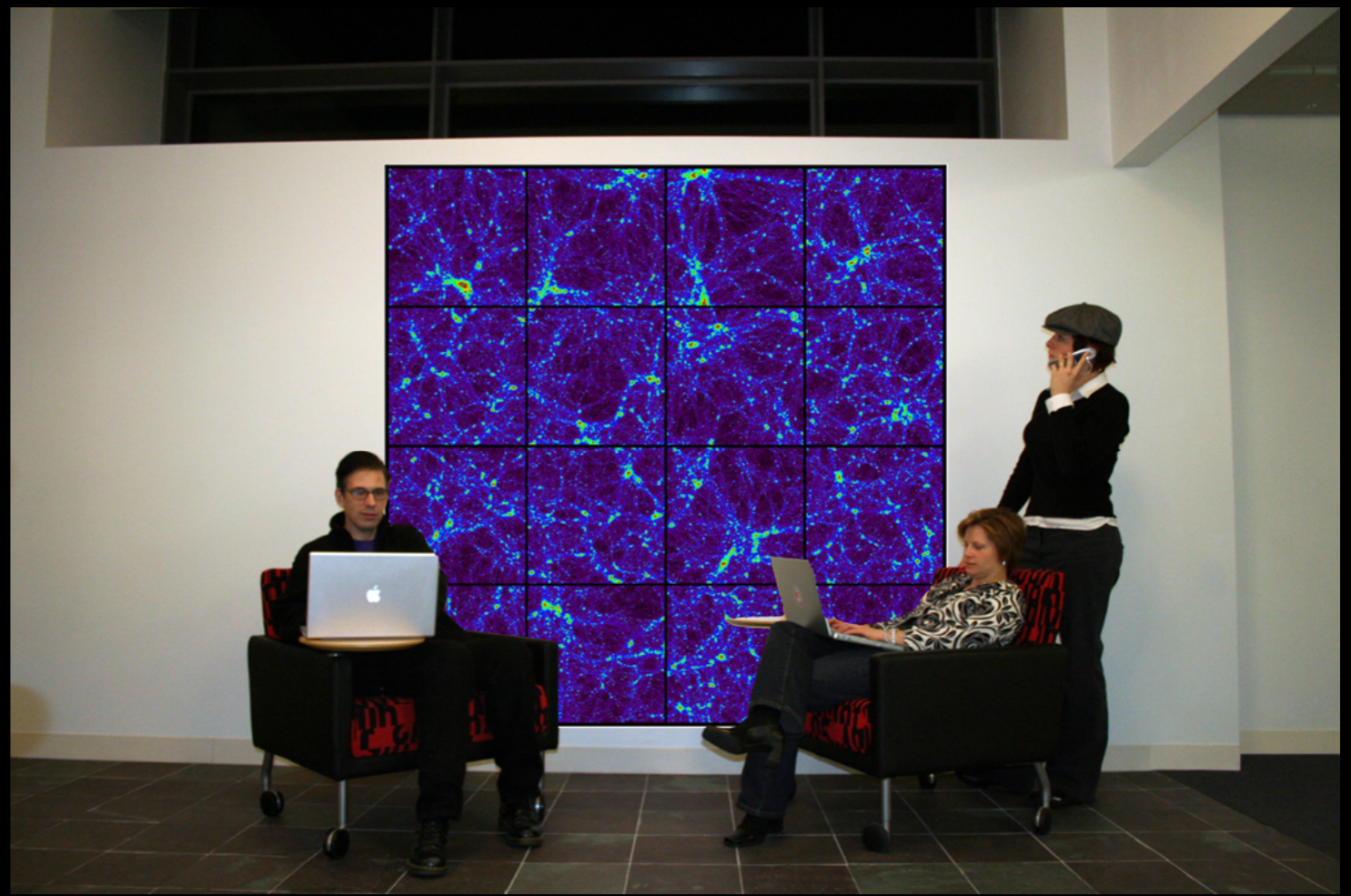


movie courtesy Daniel Wigdor, taken at MERL, Kendall Square, Cambridge

display modes

...why we must explain that...

“This is not art.”





The Baby Name Wizard's NameVoyager

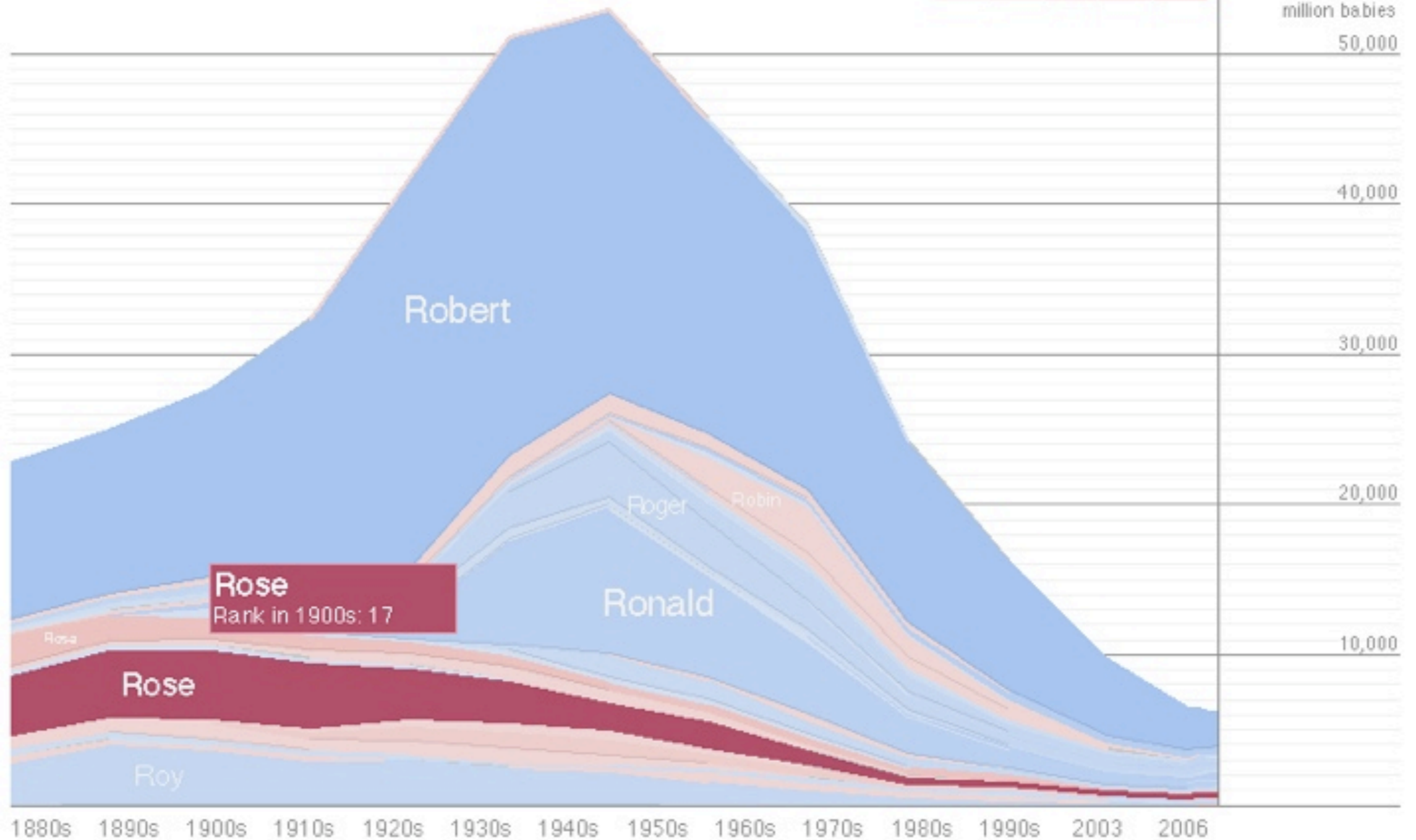
[Try Nymbler!](#) | [Read the Name Wizard Blog](#)
[NameVoyager FAQ](#) | [Buy the Book](#)

>RO

boys girls both

2005 rank, boys	1000	500	100	25	1
girls	1000	500	100	25	1

Names starting with
"RO", per
million babies
50,000



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Data Viz at its Best: Baby Name Wizard's Name Voyager from Martin Wattenberg

Many Eyes:

re-usable tools + crowdsourcing

Martin Wattenberg & Fernanda Viegas (now Google, formerly IBM)

The screenshot shows the Many Eyes website interface. At the top, the browser address bar displays `http://manyeeyes.alphaworks.ibm.com/manyeeyes/`. The page features a navigation menu on the left with sections for 'explore', 'participate', and 'learn more'. The main content area is titled 'Try Our Featured Visualizations' and includes four featured items: 'World Cup Finals Facts' (a bar chart), 'Leaves of Grass' (a wordle), 'OECD Economic Outlook' (a map), and 'Bhagavad Gita' (a word tree). Below this is a 'Featured Topic Hubs' section with three items: 'Convention Coverage 2008', 'Sports', and 'OECD Factbook 2007'. The footer contains the 'many eyes beta' logo, the tagline 'for shared visualization and discovery', and the IBM logo.

Many Eyes

http://manyeeyes.alphaworks.ibm.com/manyeeyes/

Welcome, AAGie | Logout

visualizations search

explore

- visualizations
- data sets
- comments
- topic hubs
- my stuff
- my topic hubs
- my watchlist
- my contributions
- messages to me

participate

- create visualization
- upload data set
- create topic hub

learn more

- quick start
- visualization types
- about Many Eyes
- blog

Try Our Featured Visualizations

World Cup Finals Facts

Compare soccer stats across countries.

by Kyle C

Leaves of Grass

Wordle of Walt Whitman's classic.

by amyp

OECD Economic Outlook

GDP growth projections for 40 countries over 2008-2010.

by OECD

Bhagavad Gita

Word tree of the Hindu sacred text.

by I Love GOD (www.ishwar.com)

Featured Topic Hubs

Convention Coverage 2008

For the US presidential election

Sports

All things sports.

OECD Factbook 2007

Official statistics.

WORDLE!

debuts on many eyes


Alice


many eyes beta


for shared visualization and discovery

brought to you by **IBM**

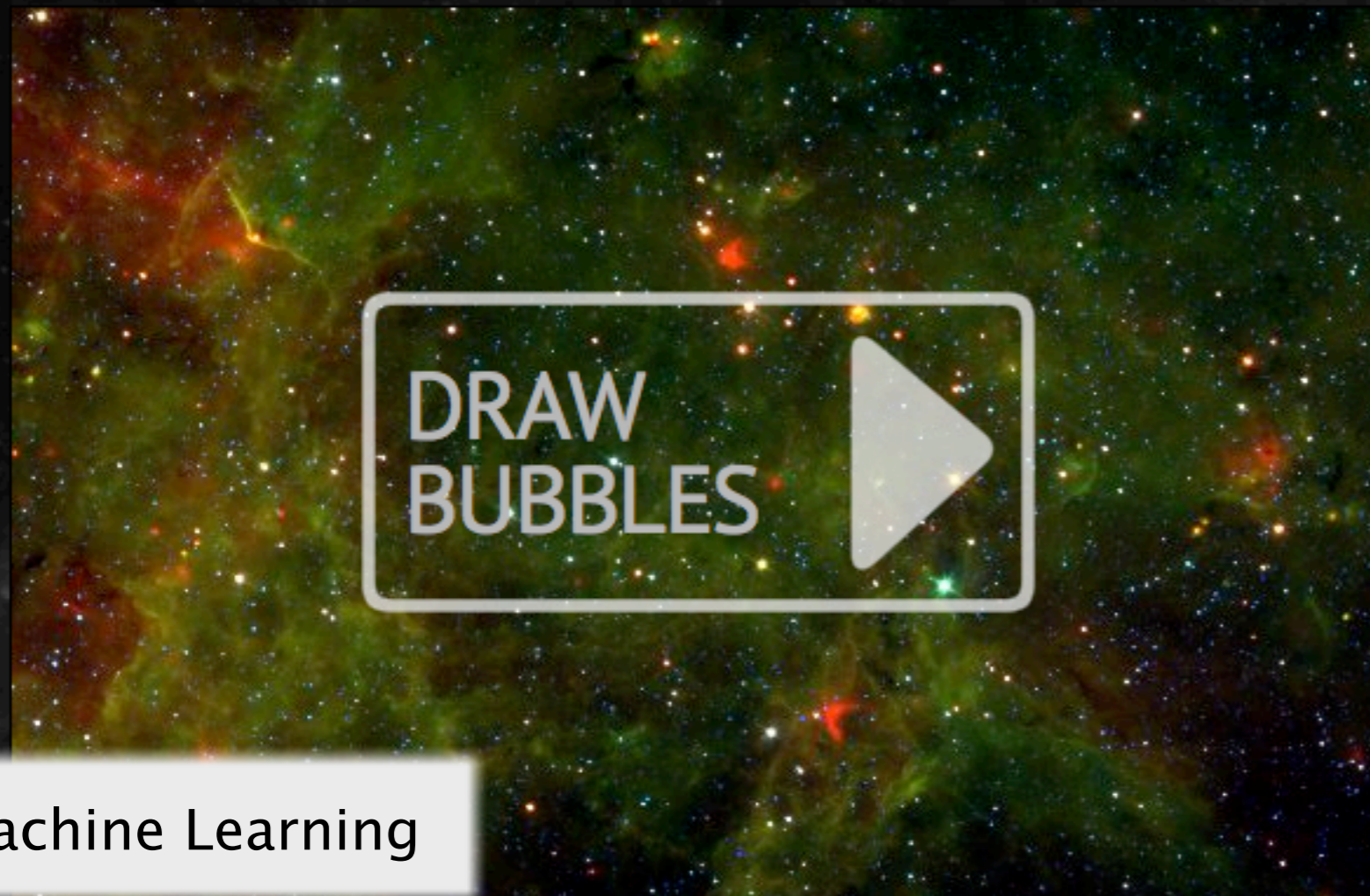
THE MILKY WAY PROJECT

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MILKY WAY TALK 

HOME TAKE PART ABOUT TUTORIAL LOG IN GALACTOMETER™



WELCOME

The Milky Way Project aims to sort and measure our galaxy, the Milky Way. Initially we're asking you to help us find and draw bubbles in beautiful infrared data from the Spitzer Space Telescope.

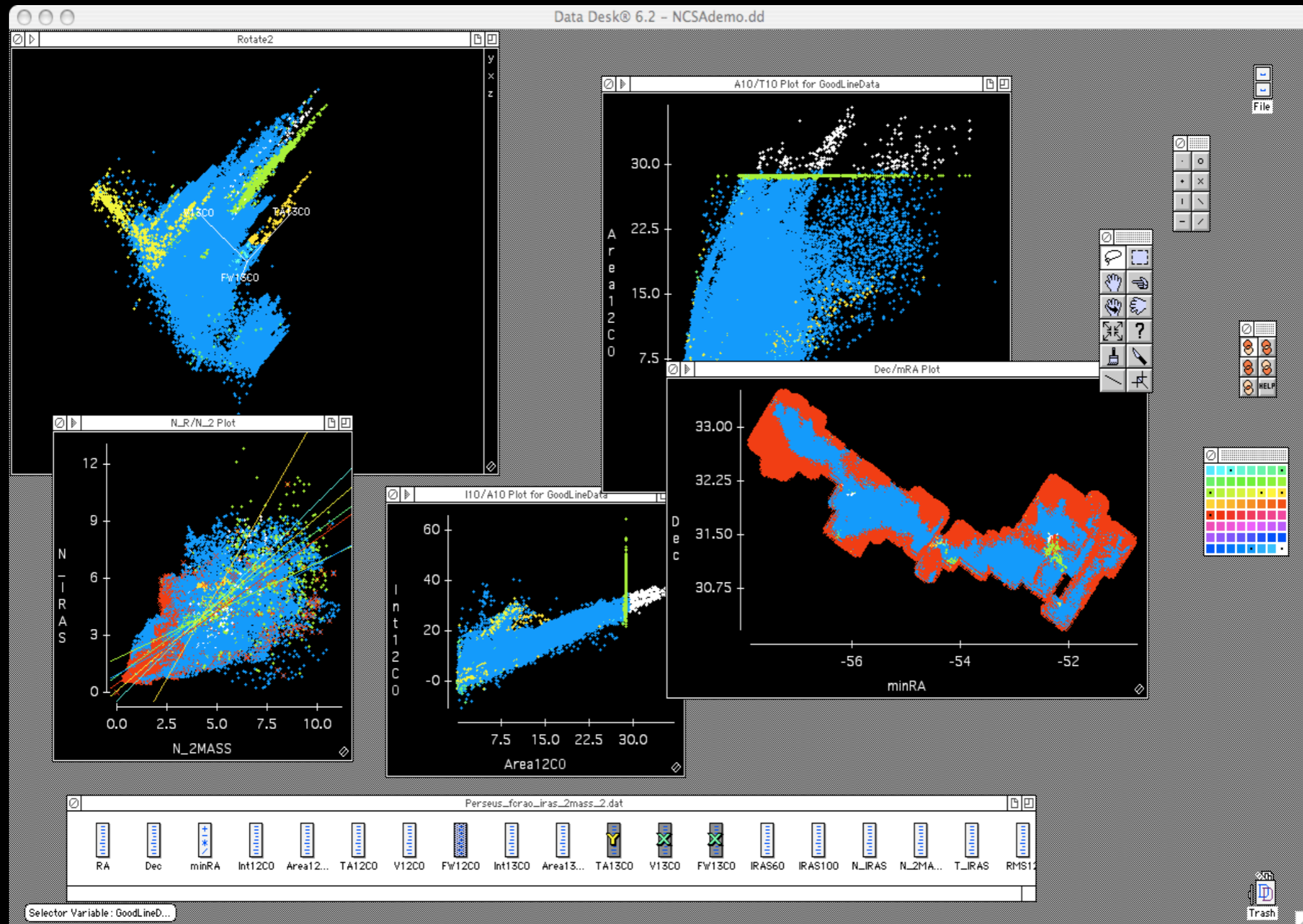
Understanding the cold, dusty material that we see in these images, helps scientists to learn how stars form and how our galaxy changes and evolves with time.

[Click here](#) to see the full tutorial or browse the site to find out more about the science behind the Milky Way Project.

Machine Learning

What riles up
the ISM?

Data Desk, c. 1986(!)



If only **DataDesk** were >2D...??

Gapminder (today)



Gapminder for All = Google Motion Charts



google motion charts

Search

SafeSearch moderate

About 2,380,000 results (0.41 seconds)

Advanced search

Everything

Images

Videos

News

Shopping

More

Any size

Large

Medium

Icon

Larger than...

Exactly...

Any type

Face

Photo

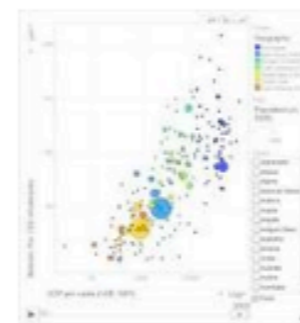
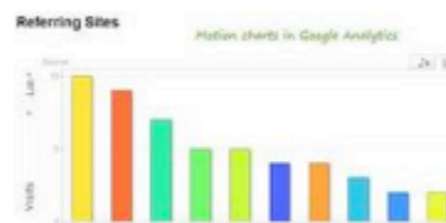
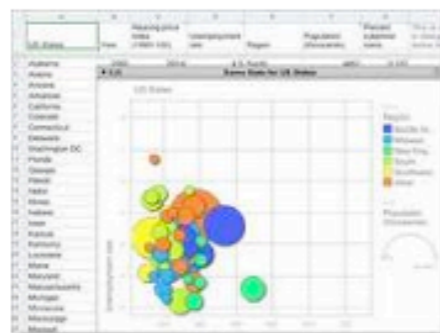
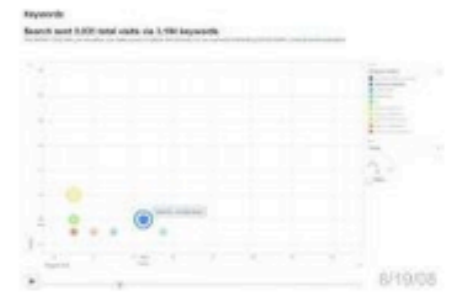
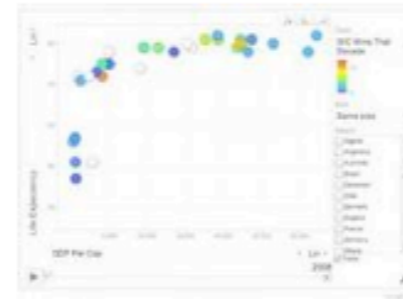
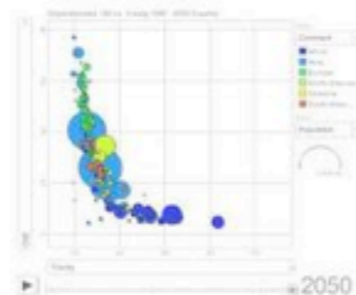
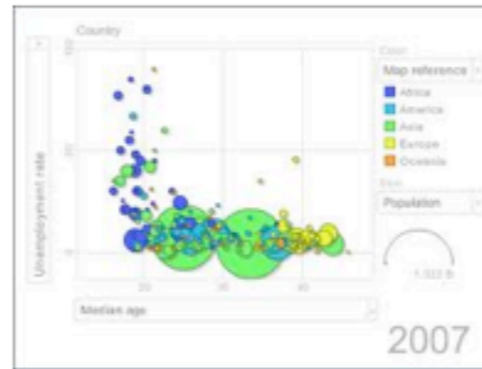
Clip art

Line drawing

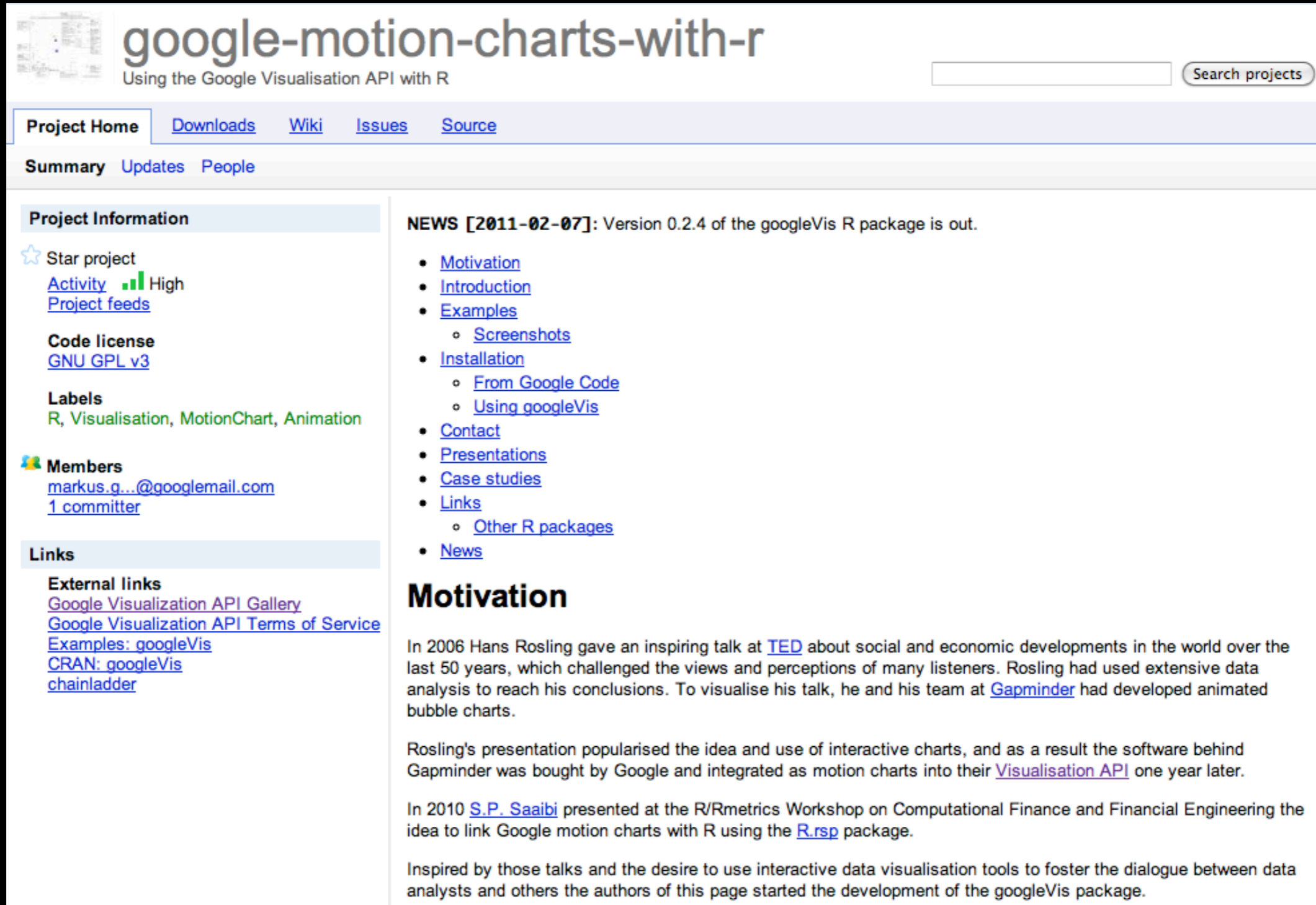
Any color

Full color

Black and white




“Modular Craftsmanship” = Google Motion Charts with R



The screenshot shows the SourceForge project page for "google-motion-charts-with-r". The page title is "google-motion-charts-with-r" with the subtitle "Using the Google Visualisation API with R". There is a search bar and a "Search projects" button. The navigation menu includes "Project Home", "Downloads", "Wiki", "Issues", and "Source". Below the navigation, there are tabs for "Summary", "Updates", and "People".

Project Information

- ★ Star project
- Activity  High
- Project feeds
- Code license: [GNU GPL v3](#)
- Labels: R, Visualisation, MotionChart, Animation
- Members: [markus.g...@googlemail.com](#), 1 committer

Links

External links

- [Google Visualization API Gallery](#)
- [Google Visualization API Terms of Service](#)
- Examples: [googleVis](#)
- CRAN: [googleVis](#)
- [chainladder](#)

NEWS [2011-02-07]: Version 0.2.4 of the googleVis R package is out.

- [Motivation](#)
- [Introduction](#)
- [Examples](#)
 - [Screenshots](#)
- [Installation](#)
 - [From Google Code](#)
 - [Using googleVis](#)
- [Contact](#)
- [Presentations](#)
- [Case studies](#)
- [Links](#)
 - [Other R packages](#)
- [News](#)

Motivation

In 2006 Hans Rosling gave an inspiring talk at [TED](#) about social and economic developments in the world over the last 50 years, which challenged the views and perceptions of many listeners. Rosling had used extensive data analysis to reach his conclusions. To visualise his talk, he and his team at [Gapminder](#) had developed animated bubble charts.

Rosling's presentation popularised the idea and use of interactive charts, and as a result the software behind Gapminder was bought by Google and integrated as motion charts into their [Visualisation API](#) one year later.

In 2010 [S.P. Saaibi](#) presented at the R/Rmetrics Workshop on Computational Finance and Financial Engineering the idea to link Google motion charts with R using the [R.rsp](#) package.

Inspired by those talks and the desire to use interactive data visualisation tools to foster the dialogue between data analysts and others the authors of this page started the development of the googleVis package.



Spitzer Space Telescope

• Jet Propulsion Laboratory
• California Institute of Technology
• Vision for Space Exploration

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NEWSROOM

Press Releases

- Chronological
- By Subject
- Outside Institutions

What's Happening Archive

Visuals

- Image Use Policy

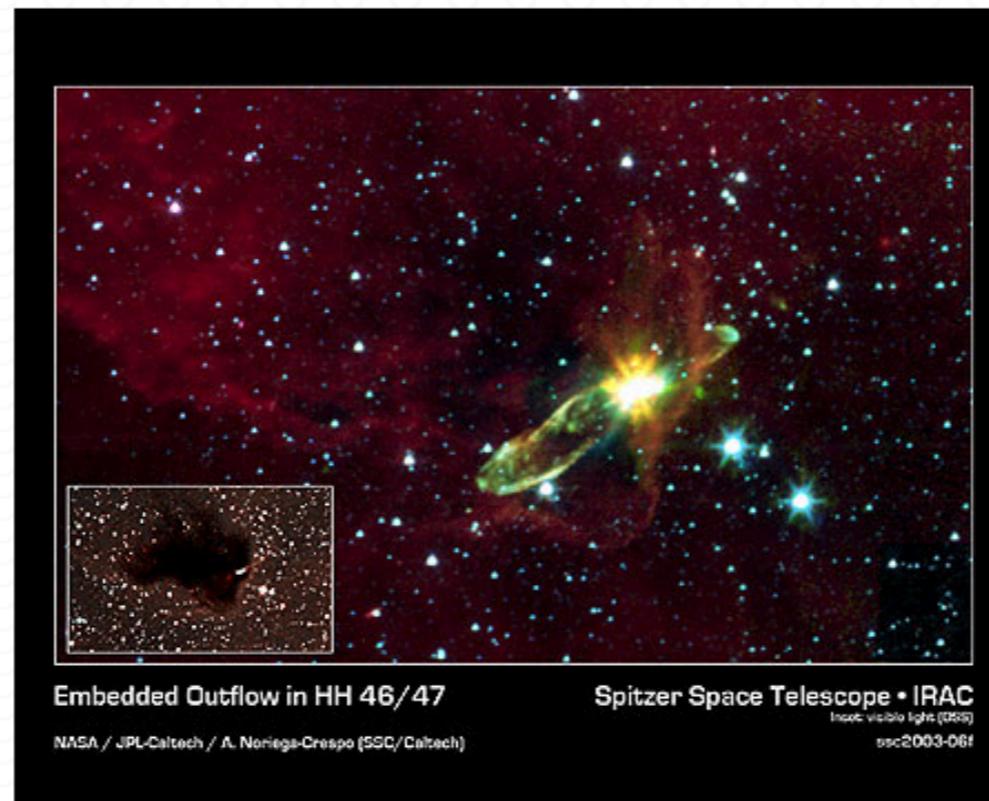
Update Notifications

- Mailing List
- RSS Feed (XML)

References

- Fast Facts
- Press Kit (.pdf)
- Fact Sheet (.pdf)
- Field Guides
- Glossary

Media Contacts



Embedded Outflow in HH 46/47

Spitzer Space Telescope • IRAC

NASA / JPL-Caltech / A. Noriega-Crespo (SSC/Caltech)

Inset: visible light (DSS)
ssc2003-06f

Credit: NASA/JPL-Caltech/A. Noriega-Crespo (SSC/Caltech), Digital Sky Survey

HH46/47

This image from NASA's Spitzer Space Telescope transforms a dark cloud into a silky translucent veil, revealing the molecular outflow from an otherwise hidden newborn star. Using near-infrared light, Spitzer pierces through the dark cloud to detect the embedded outflow in an object called HH 46/47. Herbig-Haro (HH) objects are bright, nebulous regions of gas and dust that are usually buried within dark clouds. They are formed when supersonic gas ejected from a forming protostar, or embryonic star, interacts with the surrounding interstellar medium. These young stars are often detected only in the infrared.

The Spitzer image was obtained with the infrared array camera. Emission at 3.6 microns is shown as blue, emission from 4.5 and 5.8 microns has been combined as green, and 8.0 micron emission is depicted as red.

HH 46/47 is a striking example of a low-mass protostar ejecting a jet and creating a bipolar or two-sided outflow. The central

HH4647

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Embedded Outflow in HH 46/47 **Spitzer Space Telescope • IRAC**
Inset: visible light (DSS) bsc2003-06f
 NASA / JPL-Caltech / A. Noriega-Crespo (SSC/Caltech)

Uploaded on January 6, 2009 by [Alyssa_Goodman](#)

Alyssa_Goodman's photostream

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Making Sense of High-Dimensional Data and Visualizations

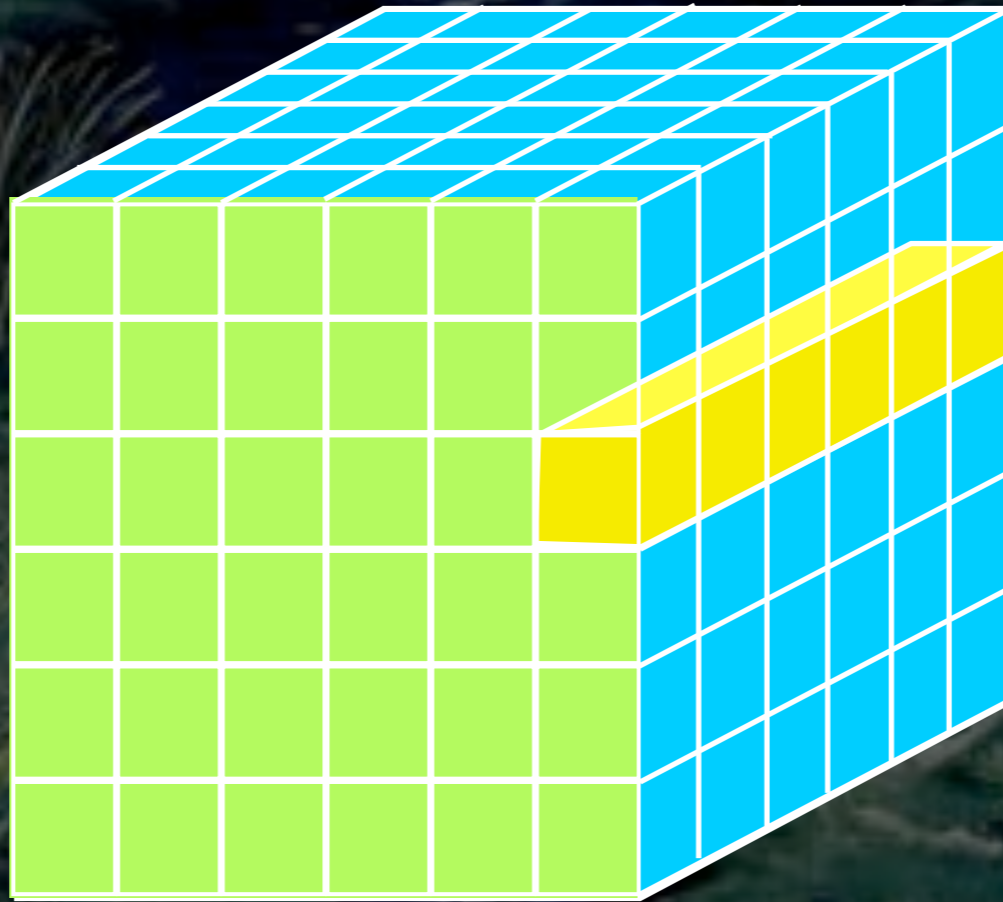


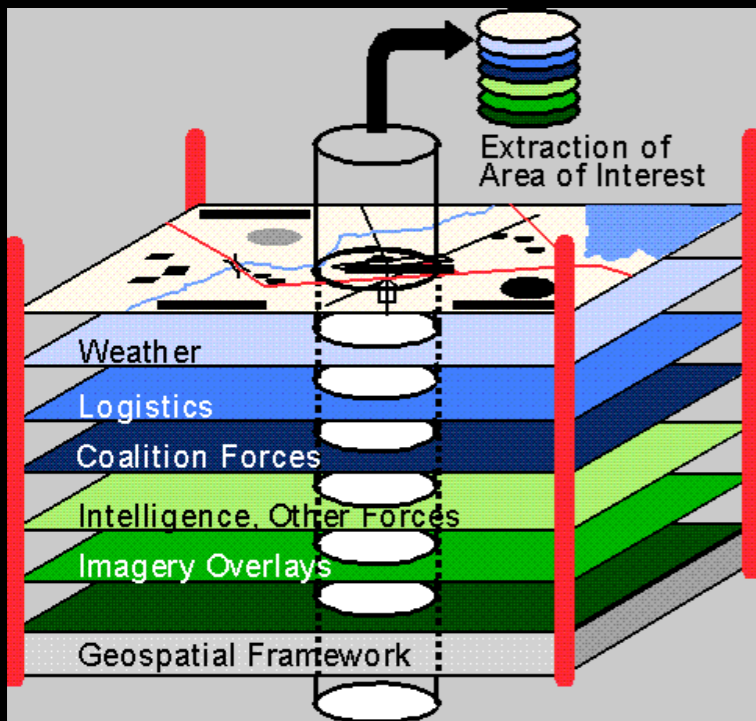
Alyssa A. Goodman

Harvard-Smithsonian Center for Astrophysics

Key Collaborators: H. Arce, C. Beaumont, M. Borkin, M. Halle, J. Kauffmann, J. Pineda, E. Rosolowsky, R. Shetty

The dream scenario...





COMPLETE

COMPLETE Data Available

Center on Perseus Center on Ophiuchus Center on Serpens

Full-Cloud Data (Phase I, All Data Available)

Dataset	Show	Perseus	Ophiuchus	Serpens	Link
GBT: HI Data Cube	<input checked="" type="checkbox"/>	✓	✓	∅	Data
IRAS: Av/Temp Maps	<input checked="" type="checkbox"/>	✓	✓	✓	Data
FCRAO: 12CO	<input checked="" type="checkbox"/>	✓	✓	✓	Data
FCRAO: 13CO	<input checked="" type="checkbox"/>	✓	✓	✓	Data
JCMT: 850 microns	<input checked="" type="checkbox"/>	✓	✓	∅	Data
Spitzer c2d: IRAC 1,3 (3.6,5.8 μm)	<input checked="" type="checkbox"/>	✓	✓	✓	Data
Spitzer c2d: IRAC 2,4 (4.5,8 μm)	<input checked="" type="checkbox"/>	✓	✓	✓	Data
CSO/Bolocam: 1.2-mm	<input checked="" type="checkbox"/>	✓	∅	∅	Data
Spitzer MIPS: Derived Dust Map	<input checked="" type="checkbox"/>	✓	∅	∅	Data

Targeted Regions (Phase II, Some Data Not Yet Available)

CTIO/Calar Alto: NIR (J,H,Ks)	<input checked="" type="checkbox"/>	✓	✓	∅	Data
IRAM 30-m: N2H+ and C18O	<input checked="" type="checkbox"/>	✓	∅	∅	Data
IRAM 30-m: 1.1-mm continuum	<input checked="" type="checkbox"/>	✓	∅	∅	Data
Megacam/MMT: r,i,z images	<input checked="" type="checkbox"/>	✓	∅	∅	Data

Catalogs & Pointed Surveys

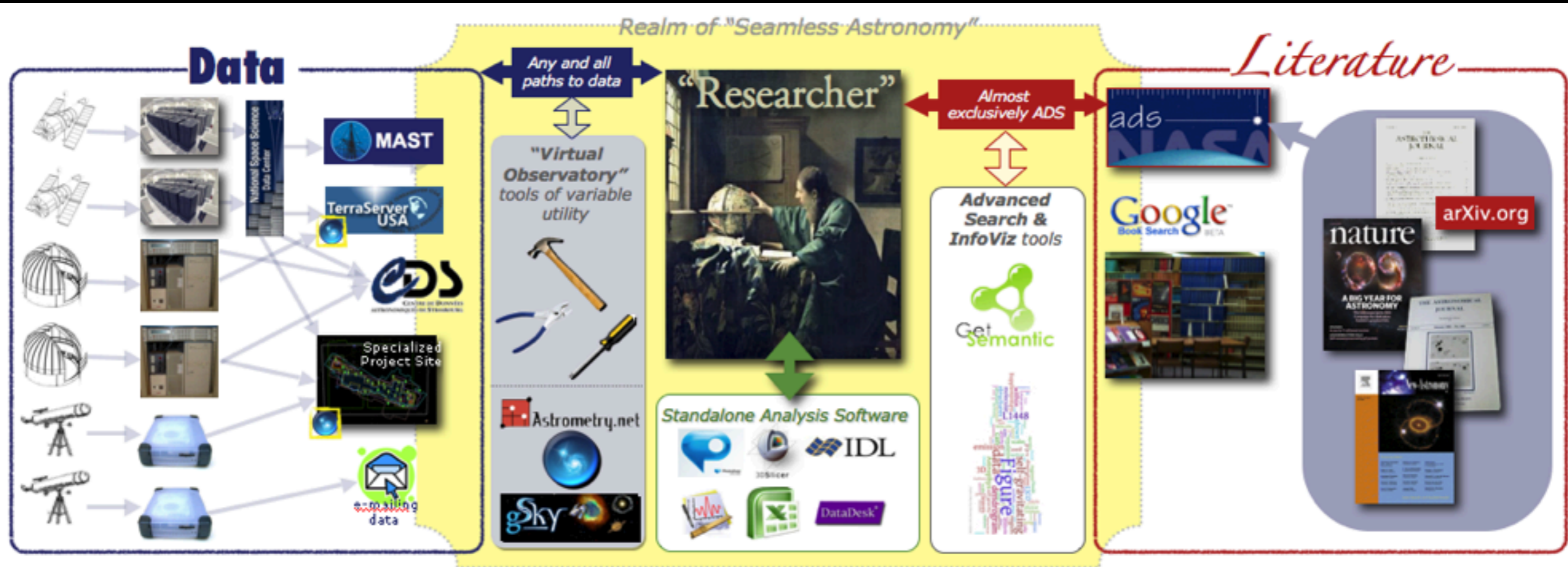
NH3 Pointed Survey	<input checked="" type="checkbox"/>	✓	∅	∅	Data
YSO Candidate list (c2d)	<input checked="" type="checkbox"/>	✓	✓	✓	Data



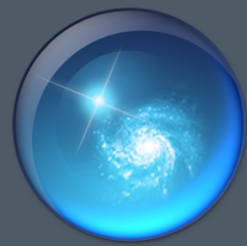
WWT—"NUIs"—Seamless Astronomy

Seamless Astronomy

Alberto Accomazzi, Doug Burke, Alberto Conti, Carol Christian, Mercé Crosas, Raffaele D'Abrusco, Rahul Davé, Christopher Erdmann, Jonathan Fay, Jay Luker, Alyssa Goodman, Michael Kurtz, Gus Muench, Alberto Pepe, Curtis Wong



WWT-"NUIs"-Seamless Astronomy



Microsoft® Research WorldWide Telescope

Experience WWT at worldwidetelescope.org

The screenshot displays the WWT interface with a top navigation bar containing 'Explore', 'Guided Tours', 'Search', 'View', and 'Settings'. Below this is a 'Collections > All-Sky Surveys >' section with a row of image thumbnails: 'Digitized Sky Survey', 'VLSS: VLA Low-fre', 'WMAP ILC 5-Year', 'SFD Dust Map (Inf', 'IRIS: Improved Re', '2MASS: Two Micro', and 'Hydrogen Alpha Fu'. The main view shows a large galaxy with a 'Finder Scope' overlay. A 'Context bar' at the bottom shows 'NGC221' and 'M31'. A 'Context globe' on the right shows the current field of view. A 'Look At' dropdown is set to 'Sky'. A 'Finder Scope' window is open, displaying details for 'NGC224'.

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.

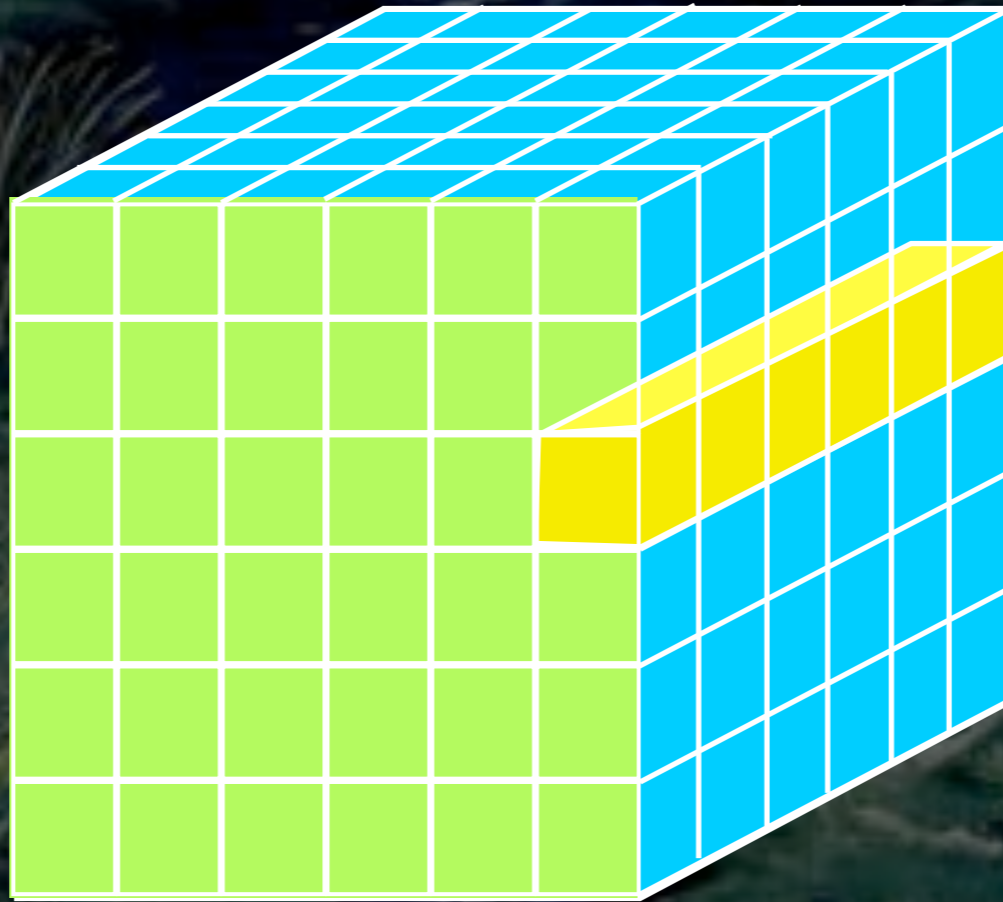
Finder Scope links to Wikipedia, publications, and data, so you can learn more

Context bar shows items of interest in current field of view

Context globe shows where you're looking.

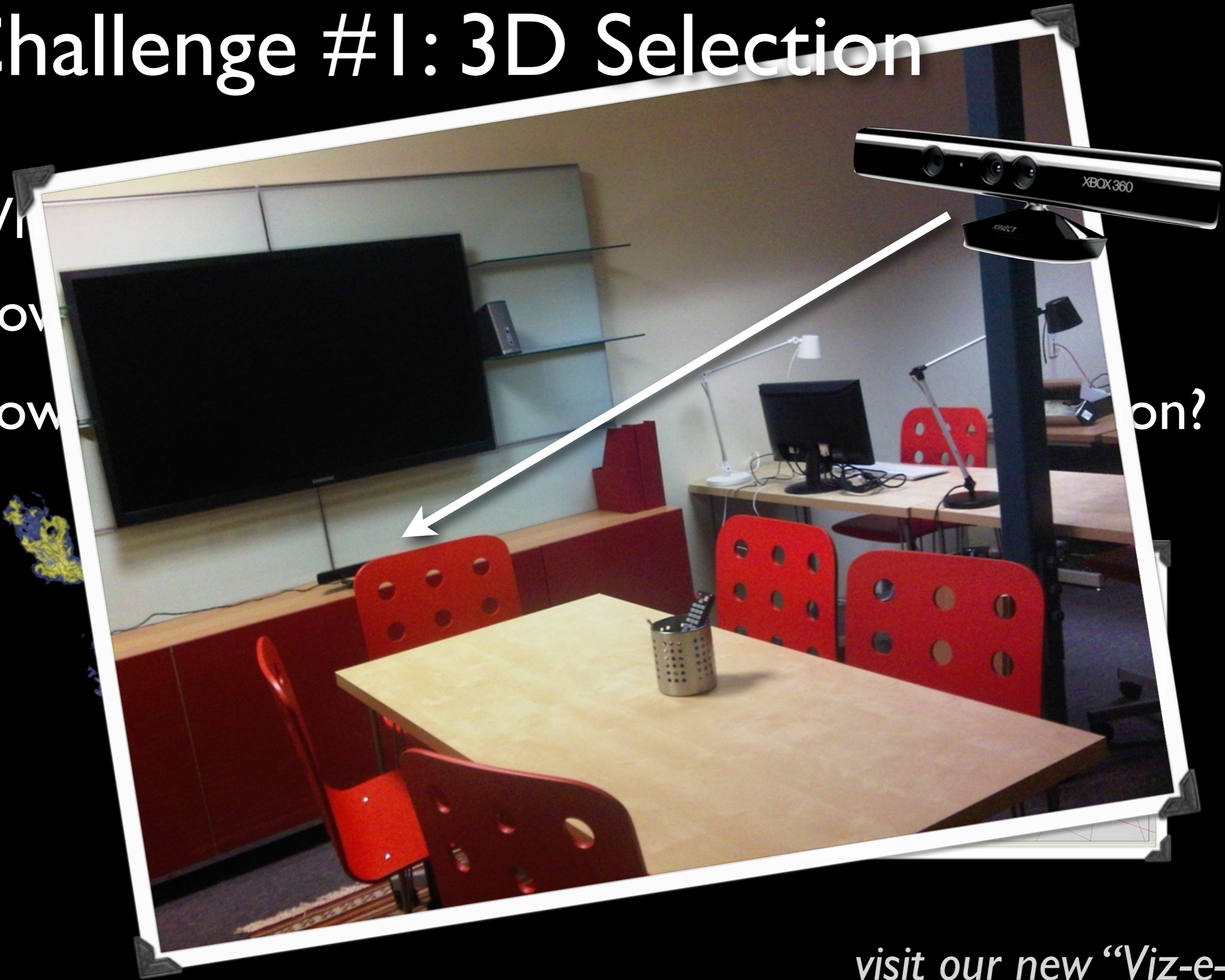
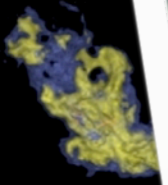
WWT—"NUIs"—Seamless Astronomy

The dream scenario...



Challenge #1: 3D Selection

Why?
How?
How?



on?

visit our new "Viz-e-Lab"!

Challenge #2: Too many windows...

The image displays a desktop environment with several overlapping windows from astronomical software. The windows are:

- Aladin v6.0**: A window titled "Aladin v6.0 *** BETA VERSION (based on v6.021) ***". It shows a grayscale astronomical image of a star-forming region with red triangles and a purple cross marking specific stars. The menu bar includes File, Edit, Image, Catalog, Overlay, Tool, View, Interop, and Help.
- Microsoft WorldWide Telescope**: A window titled "Microsoft WorldWide Telescope". It displays a color astronomical image of a star-forming region with numerous white circles highlighting stars. The menu bar includes Explore, Guided Tours, Search, Community, Telescope, View, and Settings.
- TOPCAT**: A window titled "TOPCAT". It shows a "Scatter Plot" window with a grid of red dots. The menu bar includes File, Views, Graphics, Joins, Windows, VO, Interop, and Help. The plot has a y-axis ranging from 68.15 to 68.30.
- Context Search Filter**: A small window in the bottom right corner showing a globe and a map of Cepheus. It displays coordinates: RA: 21h01m16s, Dec: +68:08:31, and a timestamp of 00:14:04.

The overlapping nature of these windows illustrates the challenge of managing multiple windows in a complex software environment.

Challenge #3:

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

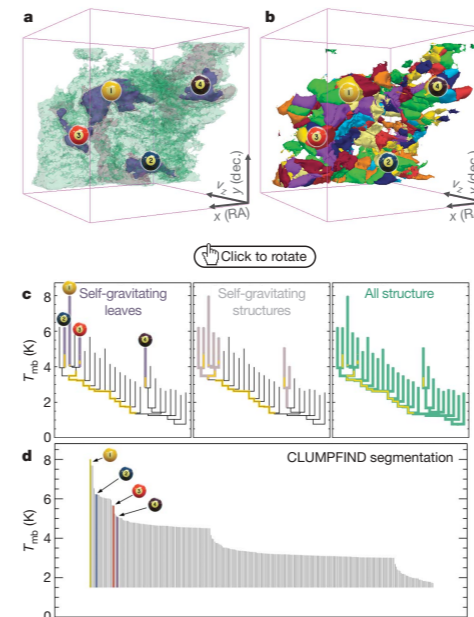


Figure 2 | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. **a**, 3D visualization of the surfaces indicated by colours in the dendrogram shown in **c**. Purple illustrates the smallest scale self-gravitating 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 set⁸ 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 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'¹⁰. Although well developed in other data-intensive fields^{11,12}, 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 frequency¹³.

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 (σ_v) and luminosity (L). The volumes can have any shape, and in other work¹⁴ 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 $M_{\text{lum}} = X_{13\text{CO}} L_{13\text{CO}}$, where $X_{13\text{CO}} = 8.0 \times 10^{20} \text{ cm}^{-2} \text{ K}^{-1} \text{ s}$ (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, $\alpha_{\text{obs}} = 5\sigma_v^2 R/GM_{\text{lum}}$. 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 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 fields⁶, its measured value should only be used as a guide to the longevity (boundedness) of any particular feature.

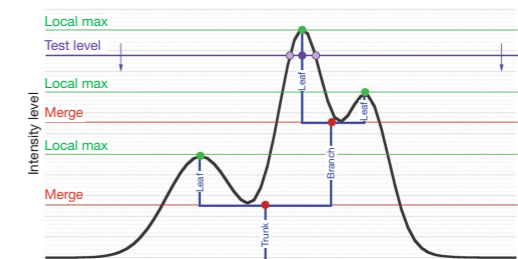


Figure 3 | Schematic illustration of the dendrogram process. Shown is the construction of a dendrogram from a hypothetical one-dimensional emission profile (black). The dendrogram (blue) can be constructed by 'dropping' a test constant emission level (purple) from above in tiny steps (exaggerated in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

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

The Art of Numbers



The Art of Numbers

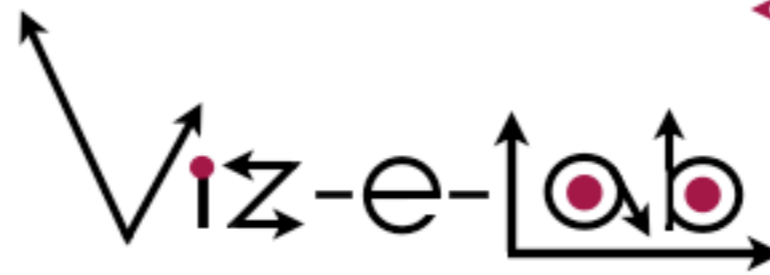
Empirical and Mathematical Reasoning 19. The Art of Numbers: The Visual Display of Information

Professor Alyssa A. Goodman (Astronomy)

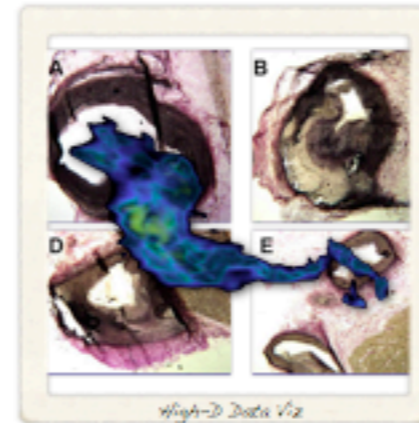
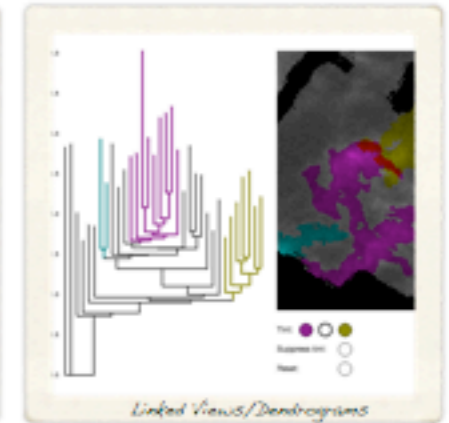
[Course website](#)

Duration: 05:30

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



Projects
2011



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

