



[View in Aladin](#) • [View in WorldWide Telescope](#)



[adsass.org](http://adsass.org)

here is a 180-degree heatmap of article density on **all** kinds of objects, on the Sky, over **all** time

The ADS All Sky Survey [About](#) [Watch videos](#) [Tour](#) [Open WWT version](#) Astronomy articles. In the sky.

**FILTER BY**

**Object**

All Stars Galaxies HII regions  
Nebulae Other

**Band**

Radio Infrared Ultraviolet X-ray

**Custom**

Harvard

Year

**TOGGLE BASE LAYER**

Optical Mellinger GALEX AIS  
DSS2 Red IRIS 2MASS Halpha  
VTSS

Select tool

J2000 07 25 35.99 -74 16 3.93

+

# let's zoom in (on Ophiuchus)

The ADS All Sky Survey

◀ About

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Astronomy articles. In the sky.

FILTER BY

Object

**All** Stars Galaxies HII regions  
Nebulae Other

Band

Radio Infrared Ultraviolet X-ray

Custom

Harvard

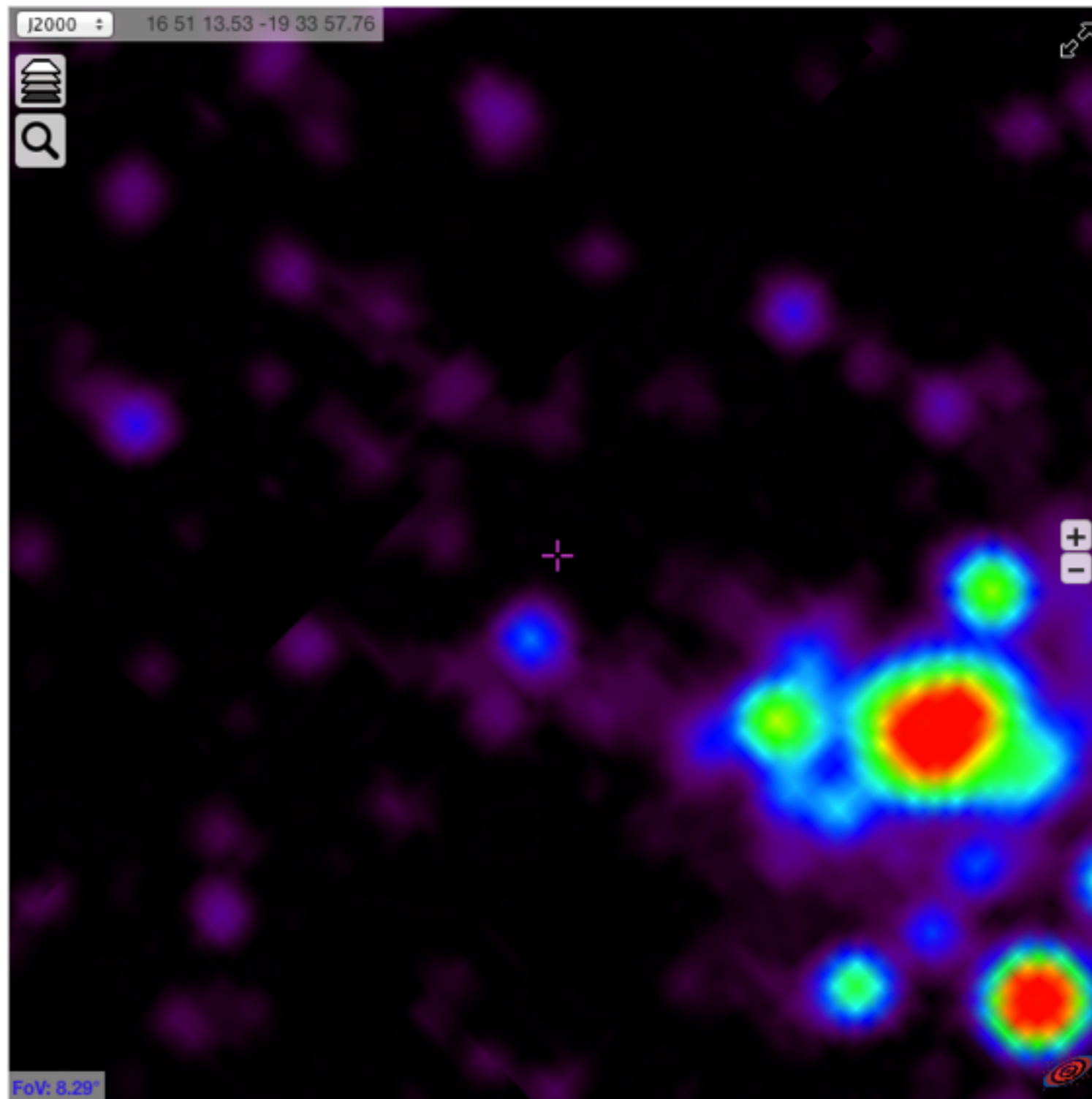
Year



TOGGLE BASE LAYER

Optical Mellinger GALEX AIS  
DSS2 Red IRIS 2MASS Halpha  
VTSS

Select tool



# now, let's toggle on the "Mellinger" view of the Sky ...to see a nice optical image of Ophiuchus

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Astronomy articles. In the sky.

## FILTER BY

### Object

All Stars Galaxies HII regions  
Nebulae Other

### Band

Radio Infrared Ultraviolet X-ray

### Custom

Harvard

### Year



## TOGGLE BASE LAYER

Optical **Mellinger** GALEX AIS  
DSS2 Red-IR K-MASS Halpha  
VTSS

Select tool



to add **markers** for SIMBAD sources, we can click the **Select Tool**

**FILTER BY**

**Object**  
[All Stars](#) [Galaxies](#) [HII regions](#)  
[Nebulae](#) [Other](#)

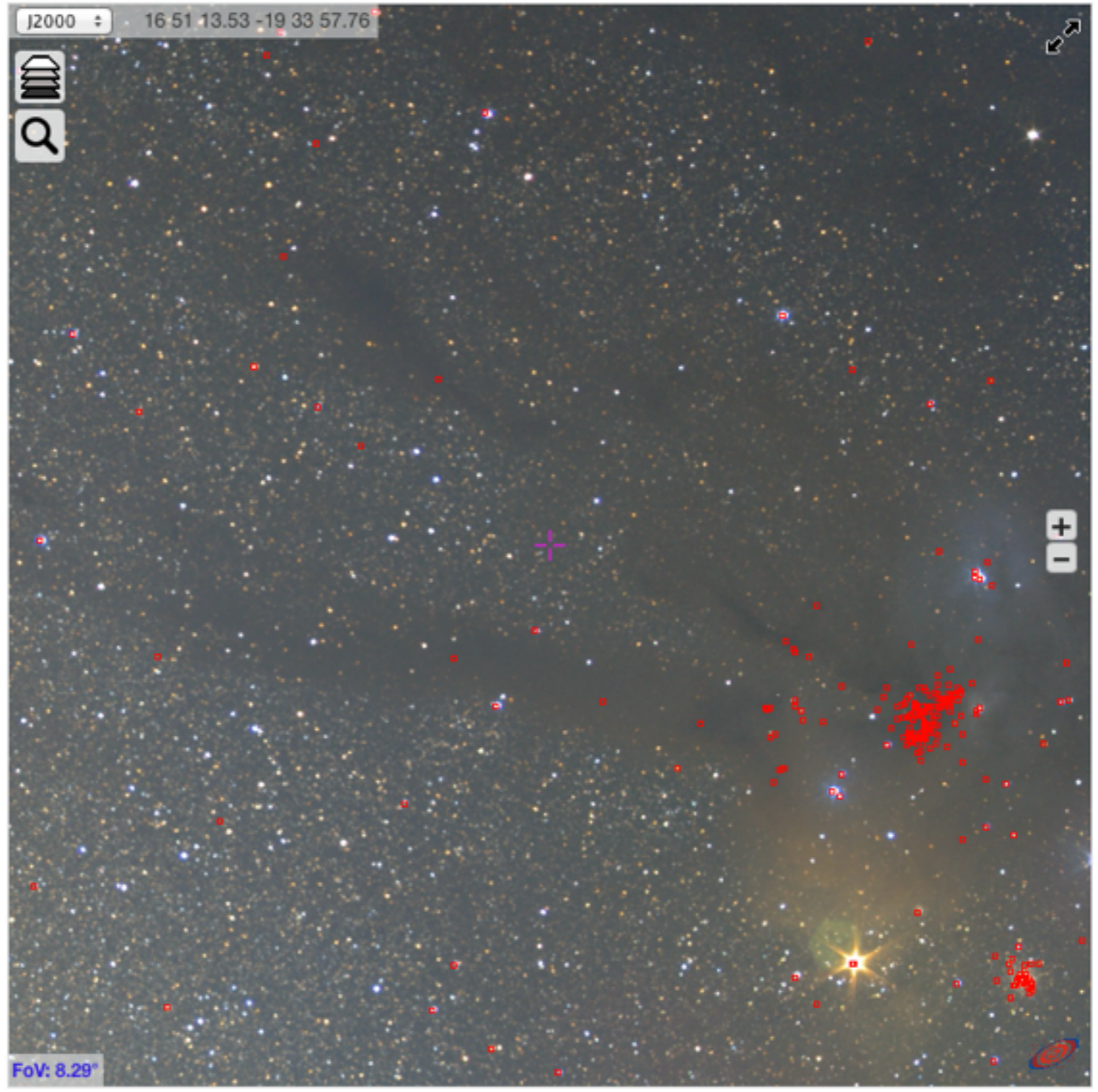
**Band**  
[Radio](#) [Infrared](#) [Ultraviolet](#) [X-ray](#)

**Custom**  
[Harvard](#)

**Year**

**TOGGLE BASE LAYER**  
[Optical](#) **Mellinger** [GALEX](#) [AIS](#)  
[DSS2](#) [Red](#) [IRIS](#) [ZMASS](#) [Halpha](#)  
[VTSS](#)

**Select tool**



now, if we re-select "All," we see **sources** on article distribution

**FILTER BY**

**Object**  
**All** Stars Galaxies HII regions  
Nebulae Other

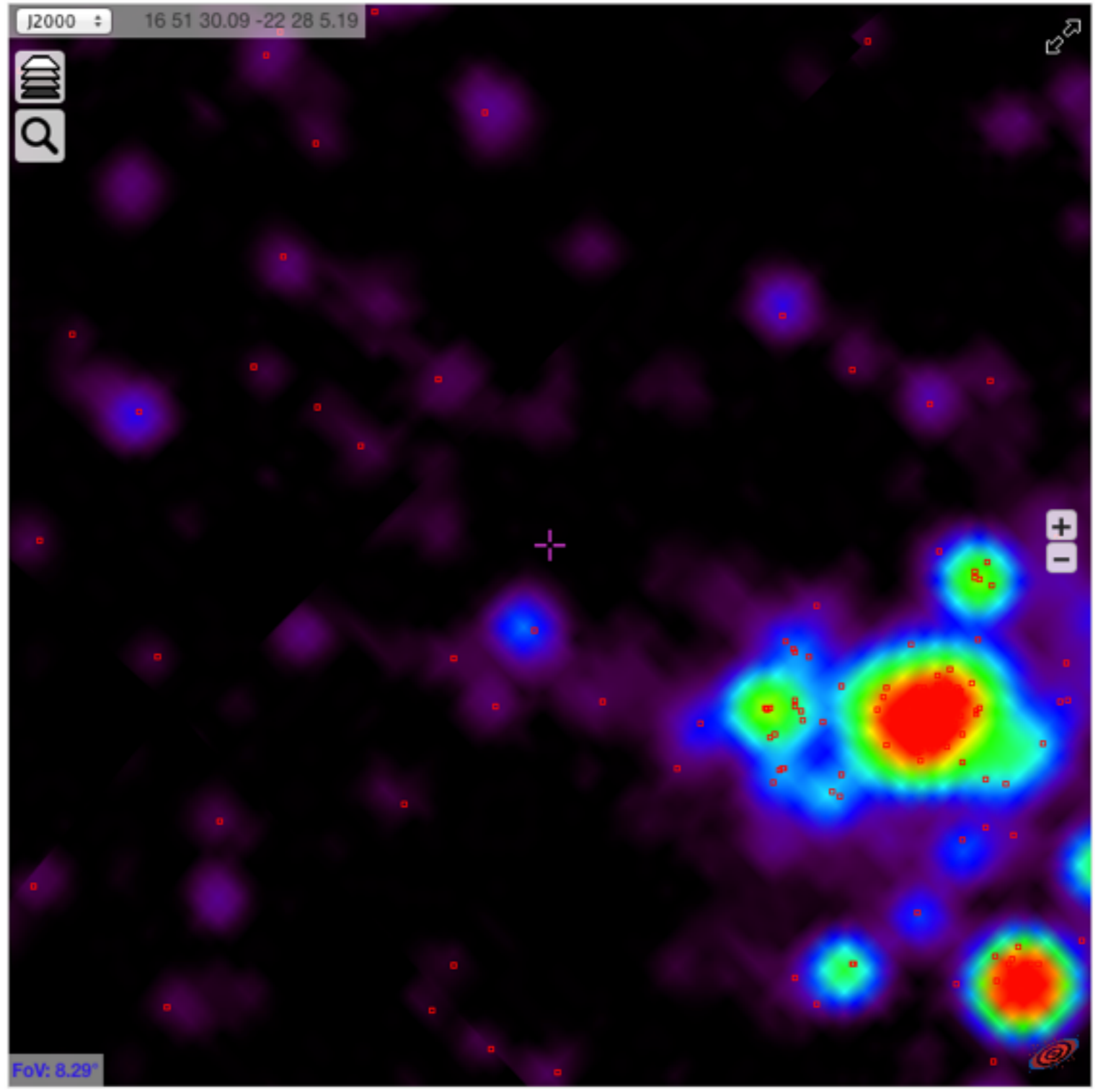
**Band**  
Radio Infrared Ultraviolet X-ray

**Custom**  
Harvard

**Year**  
[Slider]

**TOGGLE BASE LAYER**  
Optical Mellinger GALEX AIS  
DSS2 Red IRIS 2MASS Halpha  
VTSS

Select tool



panning over a bit, we can center our region of interest

**FILTER BY**

**Object**  
**All** Stars Galaxies HII regions  
Nebulae Other

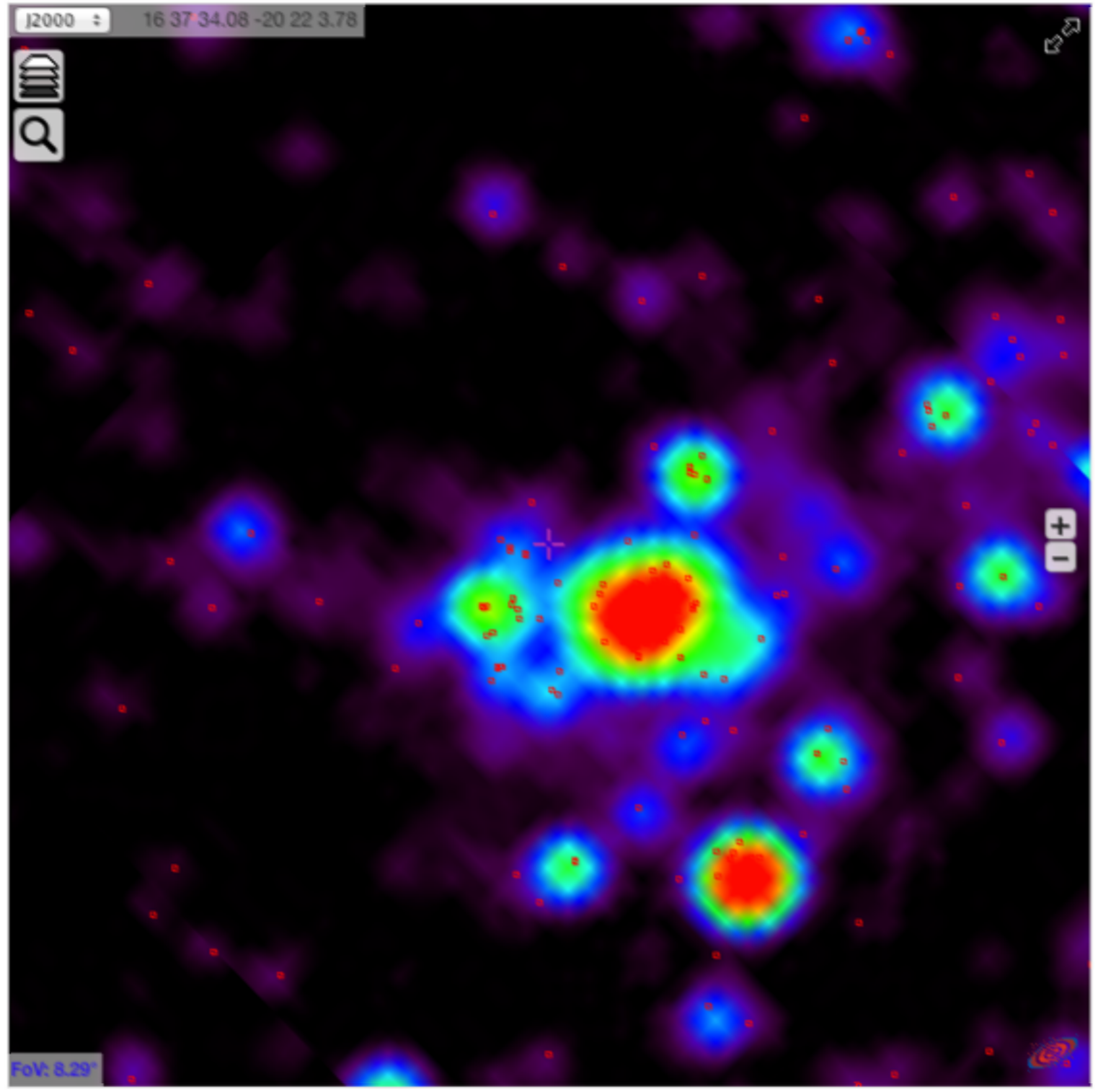
**Band**  
Radio Infrared Ultraviolet X-ray

**Custom**  
Harvard

**Year**  
[Slider]

**TOGGLE BASE LAYER**  
Optical Mellinger GALEX AIS  
DSS2 Red IRIS 2MASS Halpha  
VTSS

Select tool



let's change the **color table** from **rainbow** to greyscale to make **sources** more apparent

**FILTER BY**

**Object**  
**All** Stars Galaxies HII regions  
Nebulae Other

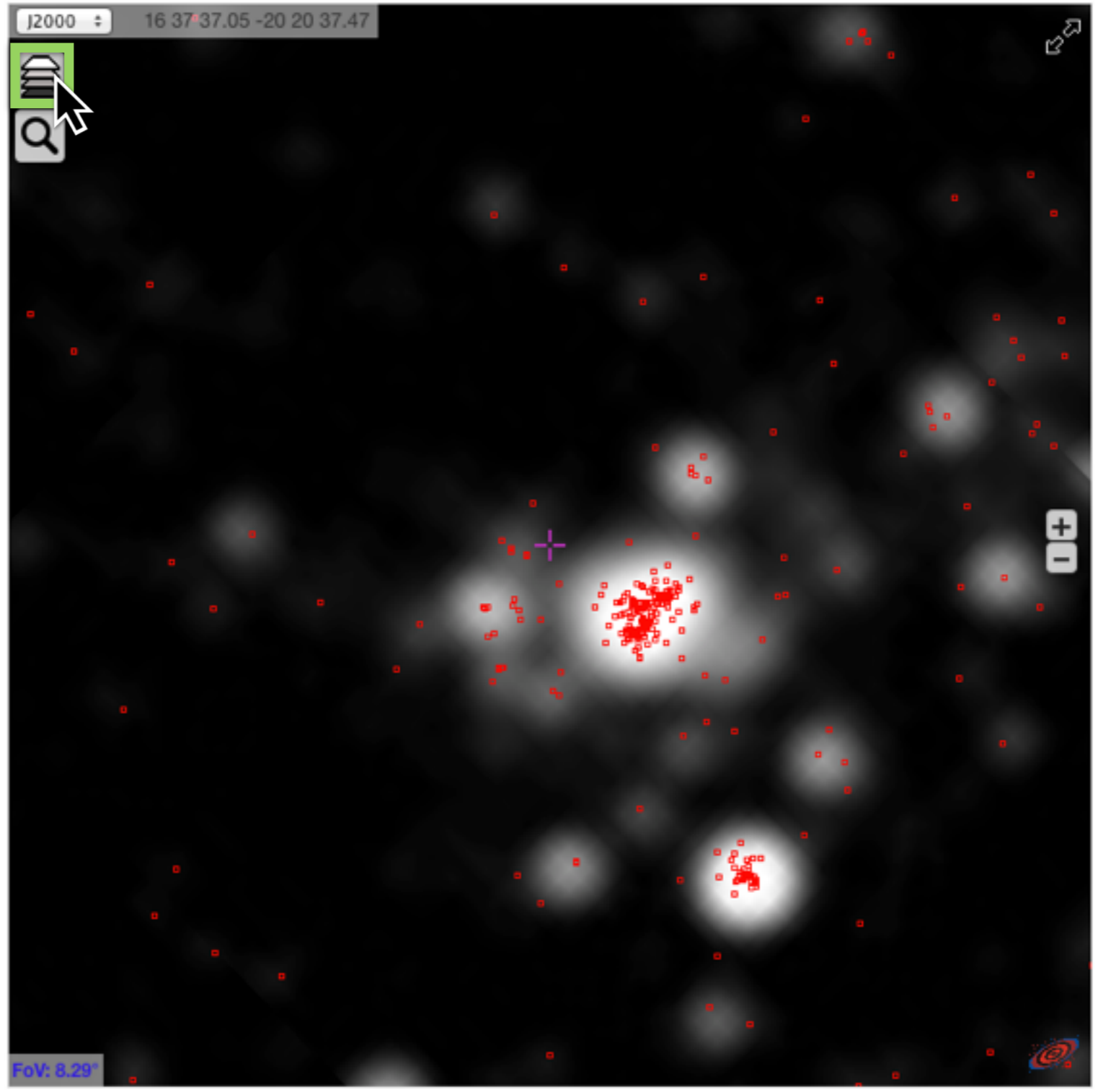
**Band**  
Radio Infrared Ultraviolet X-ray

**Custom**  
Harvard

**Year**

**TOGGLE BASE LAYER**  
Optical Mellinger GALEX AIS  
DSS2 Red IRIS 2MASS Halpha  
VTSS

Select tool





let's look now at the distribution of articles about "HII regions" and *select* an area we're curious about

FILTER BY

**Object**  
All Stars Galaxies **HII regions**  
Nebulae Other

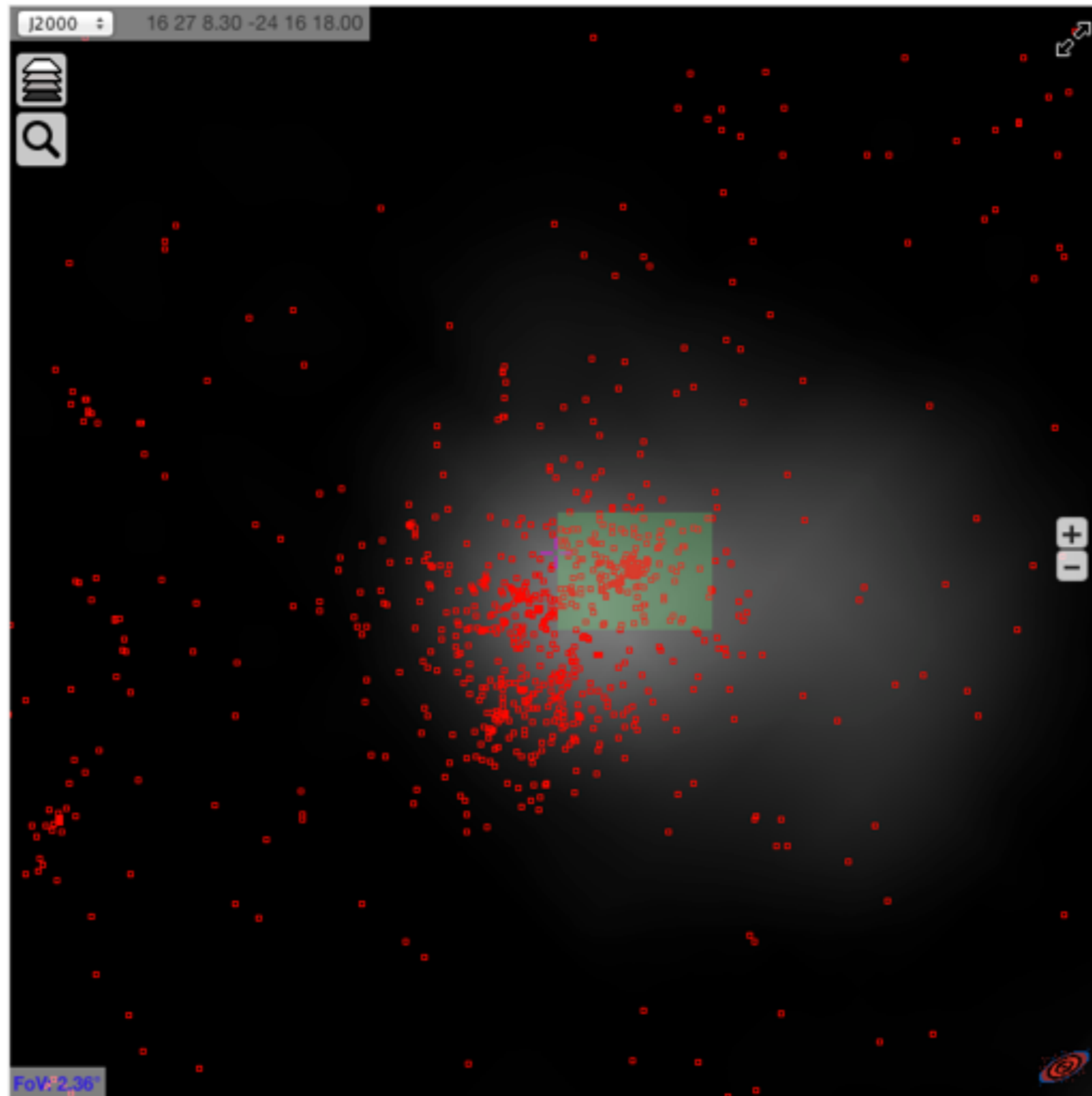
**Band**  
Radio Infrared Ultraviolet X-ray

**Custom**  
Harvard

**Year**  
[Slider]

TOGGLE BASE LAYER  
Optical Mellinger GALEX AIS  
DSS2 Red IRIS 2MASS Halpha  
VTSS

Select tool



when we *release* the selection rectangle, we get a pop-up list of papers (ADS) mentioning these objects, or a list of the objects (CDS/SIMBAD) we highlighted

The ADS All Sky Survey

About Watch videos Tour Open WWT version Astronomy articles. In the sky.

**Selected papers/objects** Open papers in ADS Open object list

Papers Objects

Note: List truncated to 200 most recent papers

NISINI B., et al. Astron. Astrophys., 549A, 16-16 (2013)  
TAFALLA M., et al. Astron. Astrophys., 551A, 116-116 (2013)  
BJERKELI P., et al. Astron. Astrophys., 552, L8-8 (2013)  
ZHANG M., et al. Astron. Astrophys., 553A, 41-41 (2013)  
VAN DER MAREL N., et al. Astron. Astrophys., 556A, 76-76 (2013)  
MURILLO N.M., et al. Astrophys. J., 764, L15 (2013)  
STUTZ A.M., et al. Astrophys. J., 767, 36 (2013)  
CHEN X., et al. Astrophys. J., 768, 110 (2013)  
HULL C.L.H., et al. Astrophys. J., 768, 159 (2013)  
GREEN J.D., et al. Astrophys. J., 770, 123 (2013)  
HSIEH T.-H., et al. Astrophys. J., Suppl. Ser., 205, 5 (2013)  
MAURY A., et al. Astron. Astrophys., 539A, 130-130 (2012)  
LISEAU R., et al. Astron. Astrophys., 541A, 73-73 (2012)  
ROBERTS J.F., et al. Astron. Astrophys., 544A, 150-150 (2012)  
BJERKELI P., et al. Astron. Astrophys., 546A, 29-29 (2012)  
PEZZUTO S., et al. Astron. Astrophys., 547A, 54-54 (2012)  
BOURKE T.L., et al. Astrophys. J., 745, 117 (2012)  
BARSONY M., et al. Astrophys. J., 751, 22 (2012)  
CHIANG H.-F., et al. Astrophys. J., 756, 168 (2012)  
NAKAMURA F., et al. Astrophys. J., 758, L25 (2012)  
BUSQUET G., et al. Astron. Astrophys., 525A, 141-141 (2011)  
BERGMAN P., et al. Astron. Astrophys., 527A, 39-39 (2011)  
NAKAMURA F., et al. Astrophys. J., 726, 46 (2011)  
GIANNINI T., et al. Astrophys. J., 738, 80 (2011)  
VELUSAMY T., et al. Astrophys. J., 741, 60 (2011)  
WARD-THOMPSON D., et al. Mon. Not. R. Astron. Soc., 415, 2812-2817 (2011)  
SIMPSON R.J., et al. Mon. Not. R. Astron. Soc., 417, 216-227 (2011)  
VAN DISHOECK E.F., et al. Publ. Astron. Soc. Pac., 123, 138-170 (2011)  
LISEAU R., et al. Astron. Astrophys., 510, A98-98 (2010)  
MAURY A.J., et al. Astron. Astrophys., 512, A40-40 (2010)  
LAHUIS F., et al. Astron. Astrophys., 519, A3-3 (2010)

Monday, January 6, 2014

# selecting "Open Papers in ADS" opens the paper list in ADS Labs

(From here, we can filter the list more, and more. e.g. clicking "SIMBAD Objects" lets us see particular objects in context on the Sky in WWT or Aladin.)

The screenshot shows the ADS Labs Streamlined Search interface. At the top, there is a navigation bar with links for Home, Labs Home, ADS Classic, and Help. The user is logged in as agoodman@cfa.harvard.edu. The main content area displays an advanced search query with 200 results. A sidebar on the left allows filtering by Authors, Keywords, Data, SIMBAD Objects, Vizier Tables, Refereed status, and Dates. A histogram at the bottom of the sidebar shows the distribution of results over time. The main list of results includes:

- 1. [2013A&A...556A..76V](#) [EF LXD R S U] **Outflow forces of low-mass embedded objects in Ophiuchus: a quantitative comparison of analysis methods**  
van der Marel, N.; Kristensen, L. E.; Visser, R.; Mottram, J. C.; and 2 coauthors
- 2. [2013ApJ...770..123G](#) Cited by 12 [EF LX RCS U] **Embedded Protostars in the Dust, Ice, and Gas In Time (DIGIT) Herschel Key Program: Continuum SEDs, and an Inventory of Characteristic Far-infrared Lines from PACS Spectroscopy**  
Green, Joel D.; Evans, Neal J., II; Jørgensen, Jes K.; Herczeg, Gregory J.; and 17 coauthors
- 3. [2013ApJ...768..159H](#) Cited by 21 [EF LX RCS U] **Misalignment of Magnetic Fields and Outflows in Protostellar Cores**  
Hull, Charles L. H.; Plambeck, Richard L.; Bolatto, Alberto D.; Bower, Geoffrey C.; and 21 coauthors
- 4. [2013ApJ...768..110C](#) Cited by 6 [EF LX RCS U] **SMA Observations of Class 0 Protostars: A High Angular Resolution Survey of Protostellar Binary Systems**  
Chen, Xuepeng; Arce, Héctor G.; Zhang, Qizhou; Bourke, Tyler L.; and 7 coauthors
- 5. [2013A&A...553A..41Z](#) [EF LXD R S U] **Proper motions of molecular hydrogen outflows in the  $\rho$  Ophiuchi molecular cloud**  
Zhang, M.; Brandner, W.; Wang, H.; Gennaro, M.; and 5 coauthors
- 6. [2013ApJ...767...36S](#) Cited by 6 [EF LXD RCS U] **A Herschel and APEX Census of the Reddest Sources in Orion: Searching for the Youngest Protostars**  
Stutz, Amelia M.; Tobin, John J.; Stanke, Thomas; Megeath, S. Thomas; and 12 coauthors
- 7. [2013A&A...552L...8B](#) Cited by 2 [EF X RCS U] **Physical properties of outflows. Comparing CO- and H<sub>2</sub>O-based parameters**

Let's try "Open WWT Version," so we can see this same view in WWT, and use a transparency slider

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**FILTER BY**

**Object**  
[All Stars](#) [Galaxies](#) [HII regions](#)  
[Nebulae](#) [Other](#)

**Band**  
[Radio](#) **Infrared** [Ultraviolet](#) [X-ray](#)

**Custom**  
[Harvard](#)

**Year**

**TOGGLE BASE LAYER**  
[Optical](#) [Mellinger](#) [GALEX](#) [AIS](#)  
[DSS2 Red](#) [IRIS](#) [2MASS](#) [Halpha](#)  
[VTSS](#)

Select tool

J2000 16 46 15.95 -23 37 36.69

FoV: 10.97°

# let's try the transparency (layer) slider in WorldWide Telescope

## CHOOSE HEATMAP

**Object** All Stars Galaxies HII regions Nebulae Other

**Band** Radio **Infrared** Ultraviolet X-ray

**Custom** Harvard/All

**Year**

Show Sources

Go to...



## BACKGROUND LAYER

Optical 2MASS **WISE** SFD IRIS GLIMPSE H-alpha ROSAT Fermi VLSS

**WISE**  **Infrared**

position slider  
move slider to  
"WISE" all the way to  
"infrared"

( $\alpha, \delta$ )=246.78°, -24.55° FOV= 11°



dust is nice, but we're curious about HII regions, let's change view to **H-alpha**

CHOOSE HEATMAP

**Object** All Stars Galaxies HII regions Nebulae Other

**Band** Radio Infrared Ultraviolet X-ray

**Custom** Harvard/All

**Year**

Show Sources

Go to...

BACKGROUND LAYER

Optical 2MASS WISE SFD IRIS GLIMPSE H-alpha ROSAT Fermi VLSS

H-alpha  X-ray



( $\alpha, \delta$ )=246.78°, -24.55° FOV= 11°



now we want to find **X-ray** observations and see if any are near the HII regions, so we can slide between H-alpha and X-ray

The ADS All Sky Survey [Open Aladin version](#) Astronomy articles. In the sky.

**CHOOSE HEATMAP**

**Object** All Stars Galaxies HII regions Nebulae Other

**Band** Radio Infrared Ultraviolet **X-ray**

**Custom** Harvard/All

**Year**

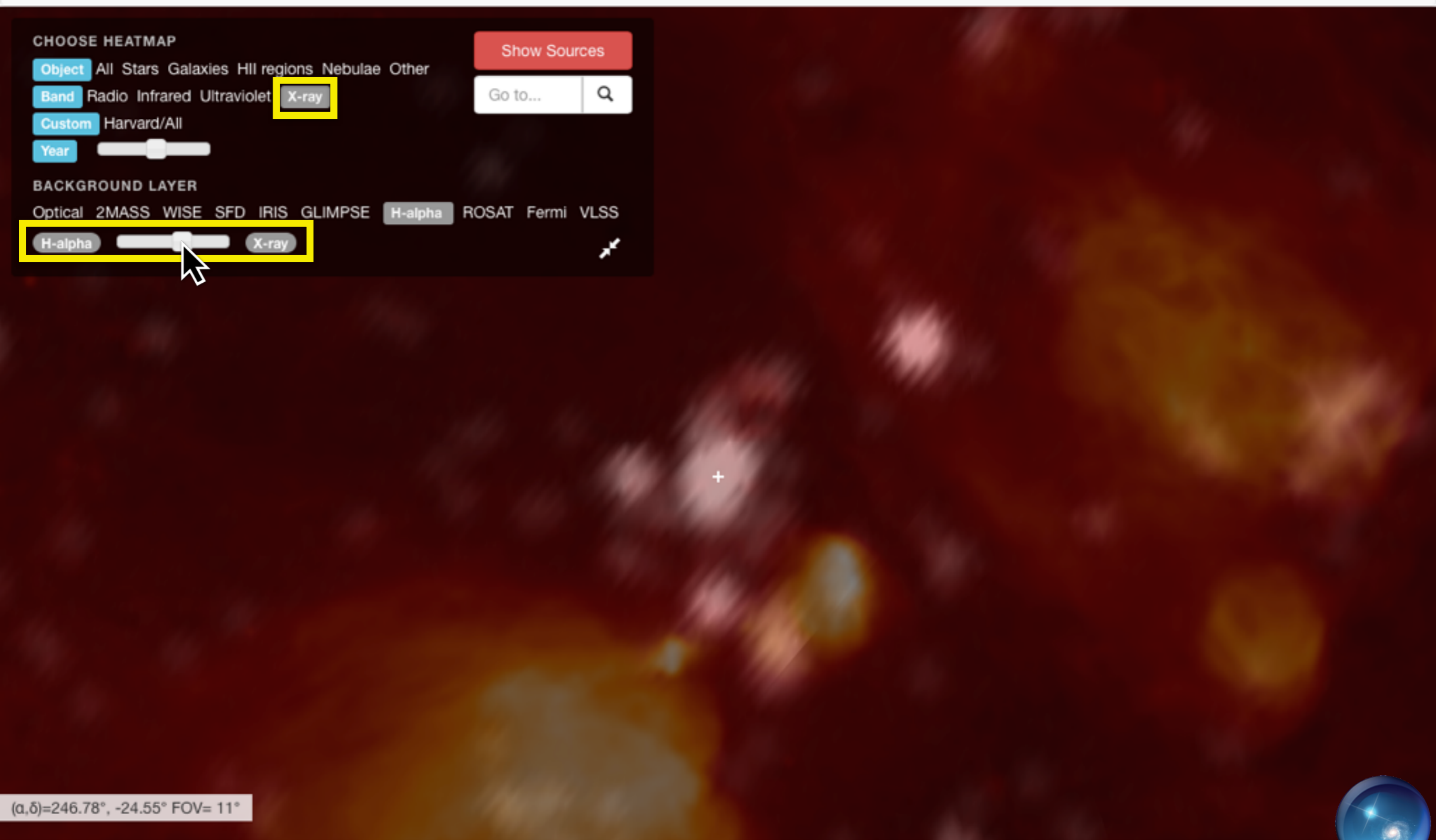
**BACKGROUND LAYER**

Optical 2MASS WISE SFD IRIS GLIMPSE **H-alpha** ROSAT Fermi VLSS

**H-alpha**  **X-ray**

[Show Sources](#)

Go to...



( $\alpha, \delta$ )=246.78°, -24.55° FOV= 11°



now let's zoom in, and try "Show Sources" to see what the SIMBAD X-ray sources really are

CHOOSE HEATMAP

**Object** All Stars Galaxies HII regions Nebulae Other

**Band** Radio Infrared Ultraviolet **X-ray**

**Custom** Harvard/All

**Year**

Show Sources

Go to...

BACKGROUND LAYER

Optical 2MASS WISE SFD IRIS GLIMPSE **H-alpha** ROSAT Fermi VLSS

**H-alpha**  X-ray

select an interesting source

( $\alpha, \delta$ )=246.72°, -23.97° FOV= 3°





and, we can have plenty of information on the source, via CDS/SIMBAD or via ADS.

The ADS All Sky Survey [Open Aladin version](#) Astronomy articles. In the sky.


**V\* V2503 Opt** [SIMBAD Entry](#) [Open papers in ADS](#)

**CHOOSE HEATMAP**  
Object: All Stars Galaxies HII regions Nebulae  
Band: Radio Infrared Ultraviolet X-ray  
Custom: Harvard/All  
Year:   
BACKGROUND LAYER  
Optical 2MASS WISE SFD IRIS GLIMPSE  
H-alpha  X-ray

**Papers**

- ESPAILLAT C., et al. *Astrophys. J.*, 762, 62 (2013)
- BROWN J.M., et al. *Astrophys. J.*, 770, 94 (2013)
- ARTEMENKO S.A., et al. *Astron. Lett.*, 38, 783-792 (2012)
- BAST J.E., et al. *Astron. Astrophys.*, 527A, 119-119 (2011)
- SALYK C., et al. *Astrophys. J.*, 731, 130 (2011)
- GUEDEL M., et al. *Astron. Astrophys.*, 519, A113-113 (2010)
- OLOFSSON J., et al. *Astron. Astrophys.*, 520, A39-39 (2010)
- PONTOPPIDAN K.M., et al. *Astrophys. J.*, 720, 887-903 (2010)
- McCLURE M.K., et al. *Astrophys. J., Suppl. Ser.*, 188, 75-122 (2010)
- VAN KEMPEN T.A., et al. *Astron. Astrophys.*, 498, 167-194 (2009)
- OLOFSSON J., et al. *Astron. Astrophys.*, 507, 327-345 (2009)
- FURLAN E., et al. *Astrophys. J.*, 703, 1964-1983 (2009)
- PADGETT D.L., et al. *Astrophys. J.*, 672, 1013-1037 (2008)
- GRANKIN K.N., et al. *Astron. Astrophys.*, 461, 183-195 (2007)
- GUENTHER E.W., et al. *Astron. Astrophys.*, 467, 1147-1155 (2007)
- LAHUIS F., et al. *Astrophys. J.*, 665, 492-511 (2007)
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- MONIN J.-L., et al. *Astron. Astrophys.*, 446, 201-210 (2006)
- CORREIA S., et al. *Astron. Astrophys.*, 459, 909-926 (2006)
- McCABE C., et al. *Astrophys. J.*, 636, 932-951 (2006)
- RATZKA T., et al. *Astron. Astrophys.*, 437, 611-626 (2005)
- DUCOURANT C., et al. *Astron. Astrophys.*, 438, 769-778 (2005)
- MAHESWAR G., et al. *Astron. Astrophys.*, 402, 963-970 (2003)
- SARTORI M.J., et al. *Astron. Astrophys.*, 404, 913-926 (2003)
- MELO C.H.F. *Astron. Astrophys.*, 410, 269-282 (2003)
- BARSONY M., et al. *Astrophys. J.*, 591, 1064-1074 (2003)
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- KAZAROVETS E.V., et al. *IAU Inform. Bull. Var. Stars*, 5135, 1 (2001)
- TEIXEIRA R., et al. *Astron. Astrophys.*, 361, 1143-1151 (2000)
- SHEVCHENKO V.S., et al. *Astron. J.*, 116, 1419-1431 (1998)
- JENSEN E.L.N., et al. *Astron. J.*, 114, 301-316 (1997)
- ASPIN C., et al. *Mon. Not. R. Astron. Soc.*, 284, 257-264 (1997)
- MONIN J.-L., et al. *The Messenger*, 89, 33-37 (1997)
- JENSEN E.L.N., et al. *Astrophys. J.*, 459, 312-326 (1996)

( $\alpha, \delta$ )=246.72°, -23.97° FOV= 3°



# Credits

funding **NASA ADAP** program

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Co-I: Alberto **Pepe**, Harvard-CfA & Authorea

Co-I: August **Muench**, Smithsonian-CfA

with

Alberto **Accomazzi**, Smithsonian Institution, NASA/ADS

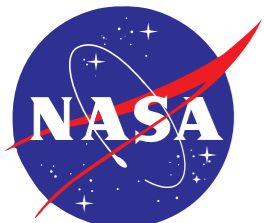
Christopher **Beaumont**, Harvard-CfA

Thomas **Boch**, CDS Strasbourg

Jonathan **Fay**, Microsoft Research

David **Hogg**, NYU, [astrometry.net](http://astrometry.net)

Alberto **Conti**, NASA/STScI, Northrup Grumman



**SEAMLESS  
ASTRONOMY**  
Linking scientific data, publications, and communities



Stephen

all lines

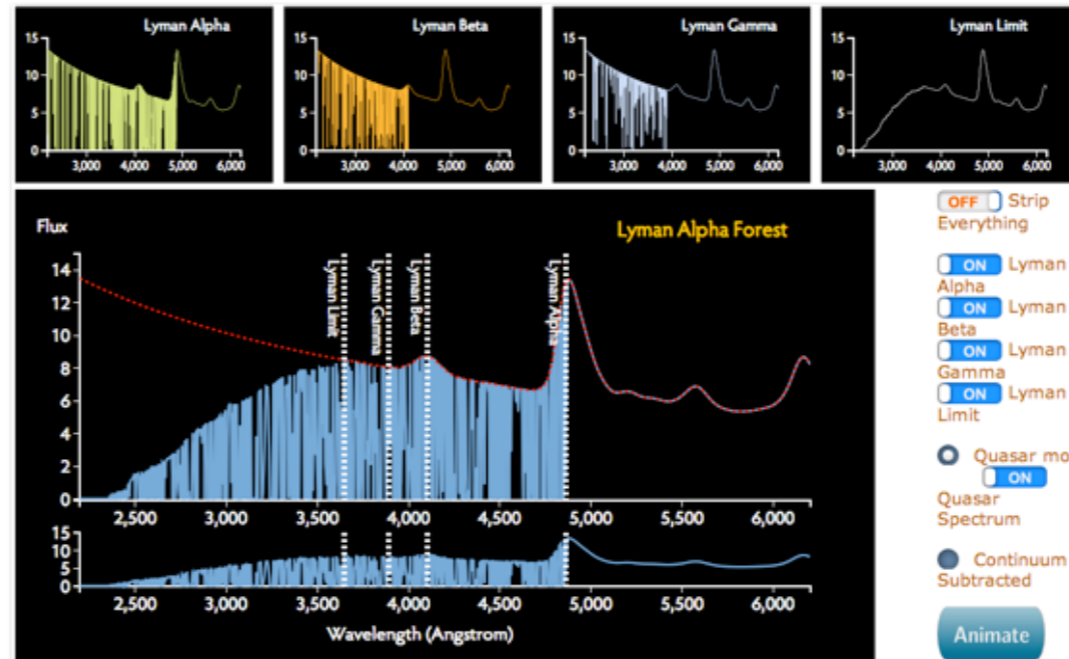
SII 6716/6731 Å

He 6563 Å

OIII 5007 Å

Yuan-Sen  
Ting

Interstellar  
Absorption  
and the  
Lyman Alpha  
Forest



JavaScript

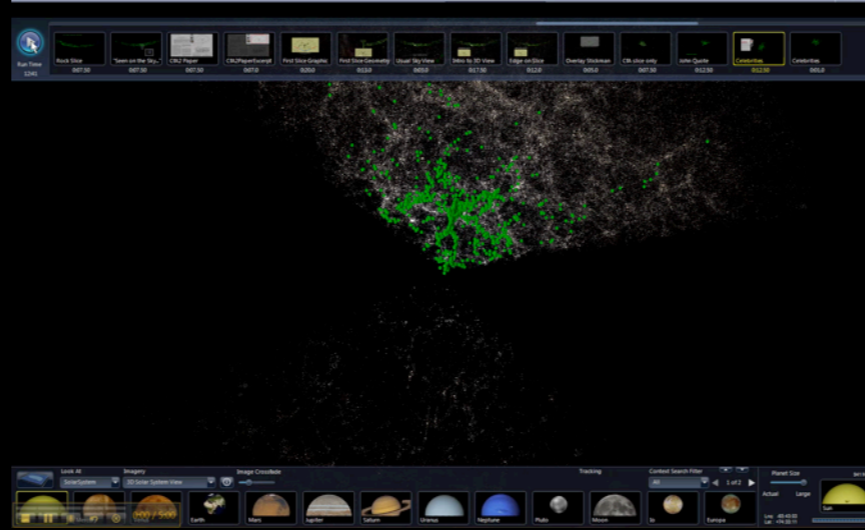
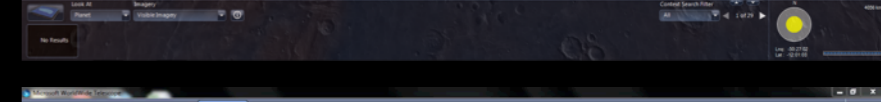
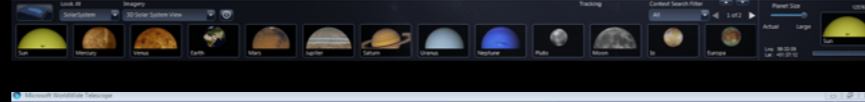
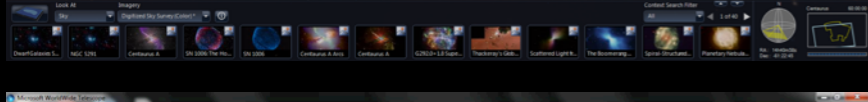
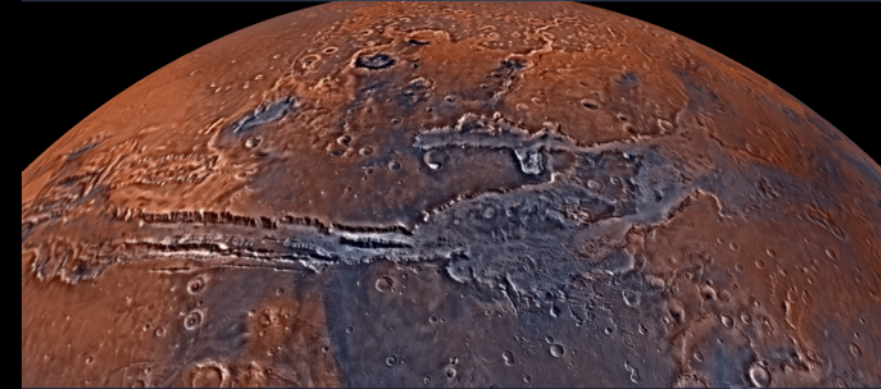
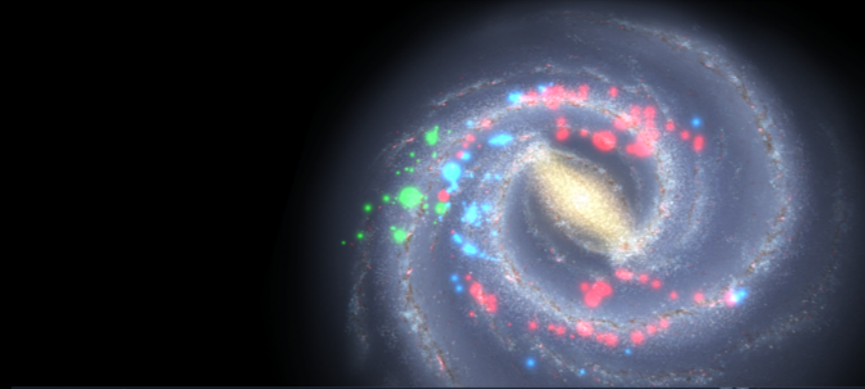
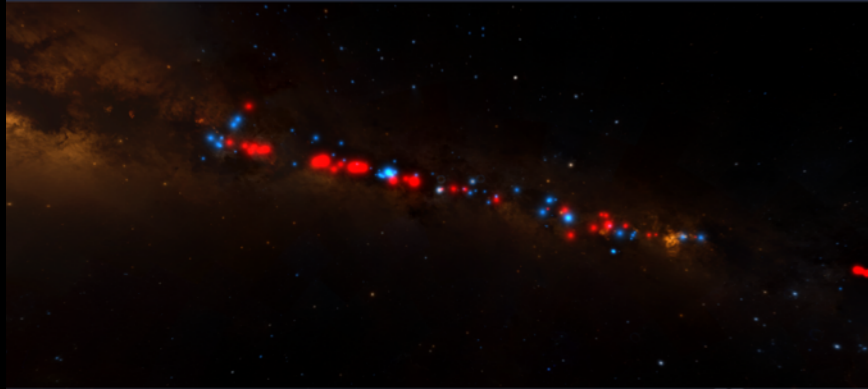
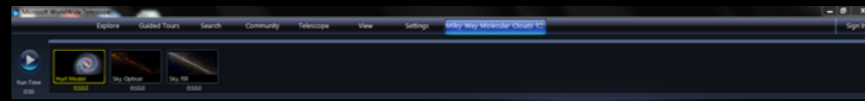
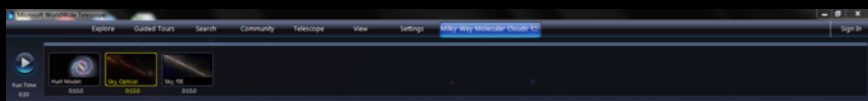
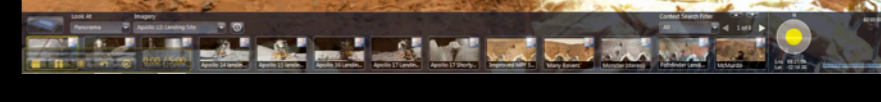
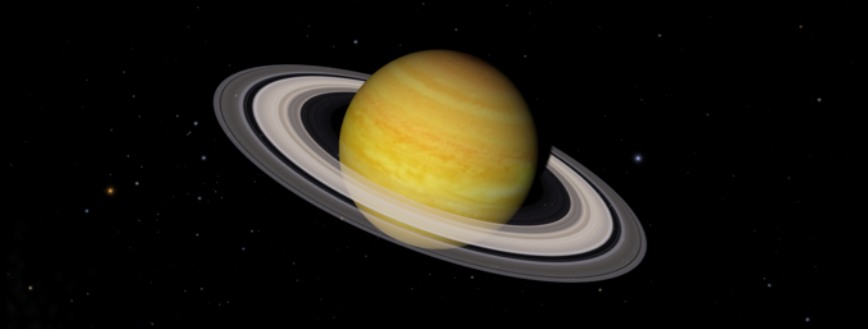
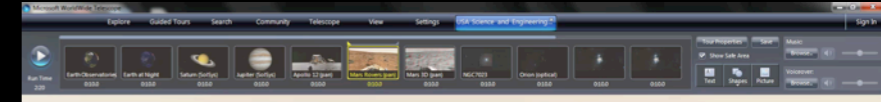
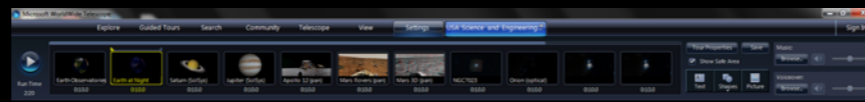
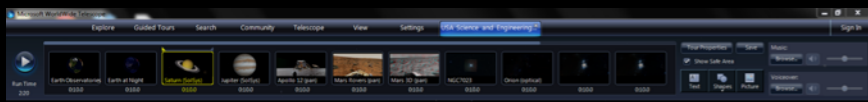
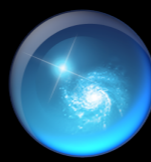
[https://www.cfa.harvard.edu/~yuan-sen.ting/lyman\\_alpha.html](https://www.cfa.harvard.edu/~yuan-sen.ting/lyman_alpha.html)



JavaScript

<http://portillo.ca/nebula/>

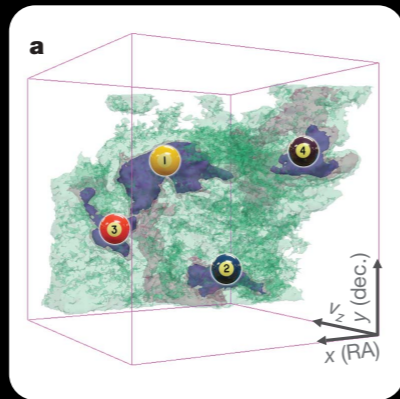
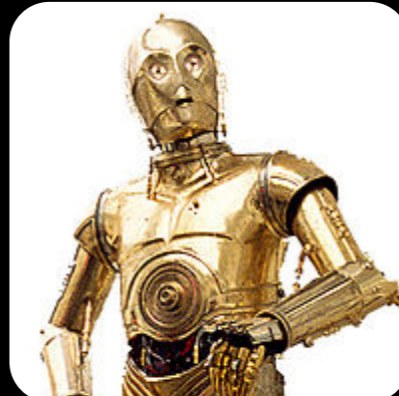
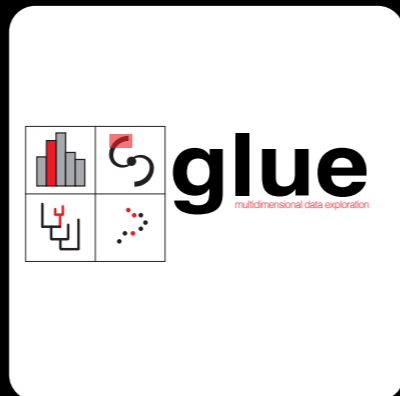
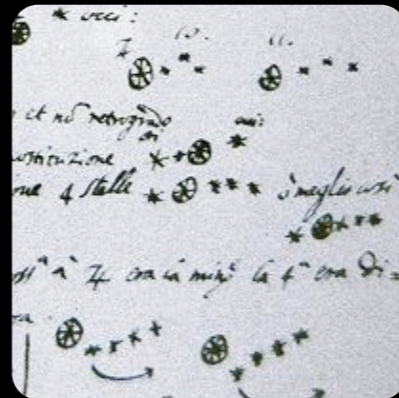
see: A New Approach to Developing Interactive Software Modules through Graduate Education, Sanders, Faesi & Goodman 2013



Experience WorldWide Telescope, free from Microsoft Research at [worldwidetelescope.org](http://worldwidetelescope.org)

# Linking Visualization & Understanding

Lyssa A. Goodman  
Harvard-Smithsonian  
Center for Astrophysics  
@AAGIE



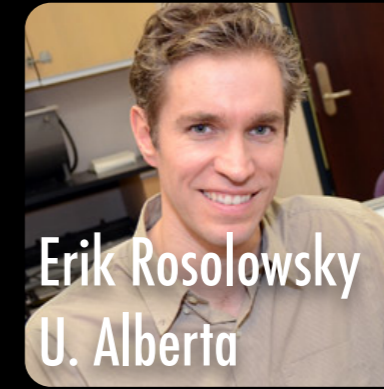
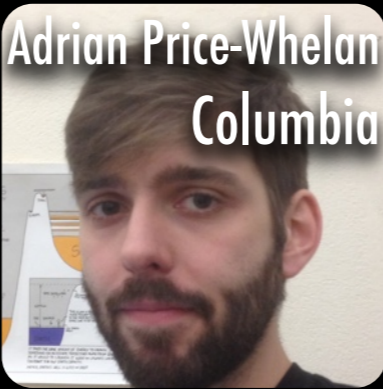
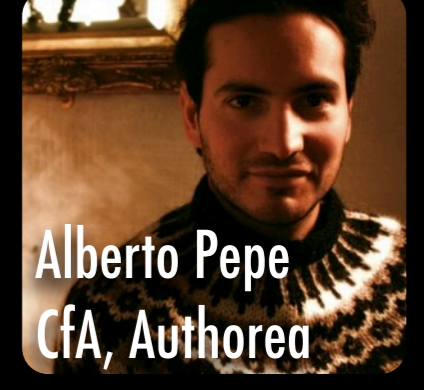
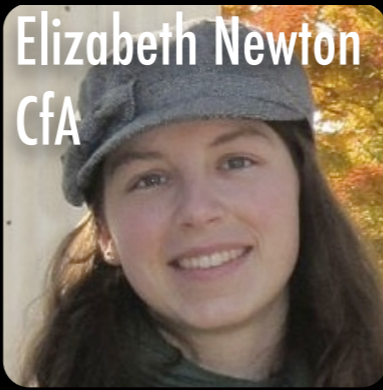
# Linking Visualization & Understanding

Lyssa A. Goodman  
Harvard-Smithsonian  
Center for Astrophysics



<http://www.astrobetter.com/linking-visualization-and-understanding-in-astronomy-aas223>

# Collaborat



**SEAMLESS  
ASTRONOMY**  
Linking scientific data, publications, and communities

[projects.iq.harvard.edu/seamlessastronomy](http://projects.iq.harvard.edu/seamlessastronomy)

...including ADS team (Alberto Accomazzi, Michael Kurtz, Edwin Henneken, et al.) and Wolbach Library staff (Christopher Erdmann et al.)

# Relative Strengths



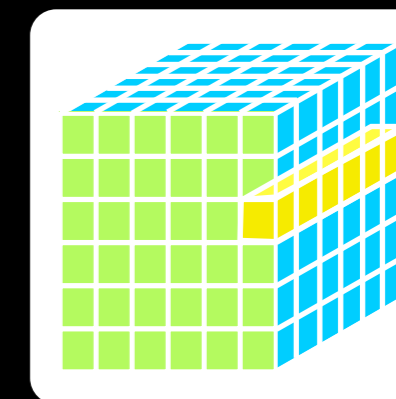
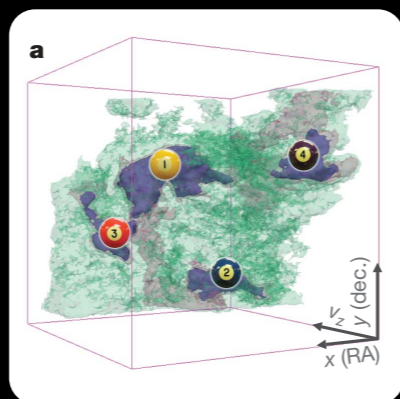
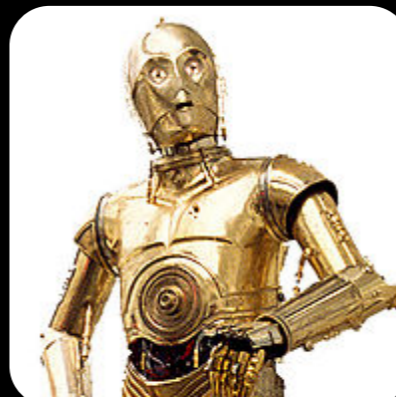
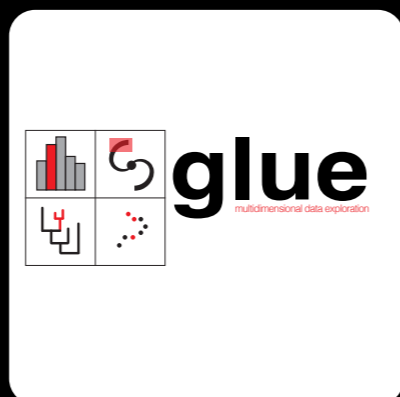
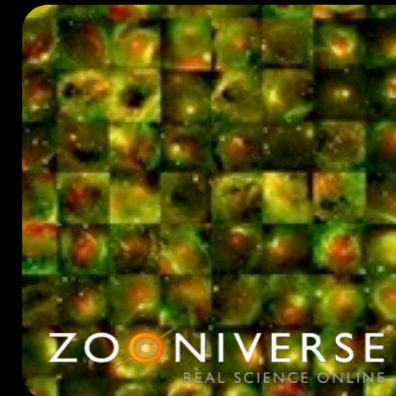
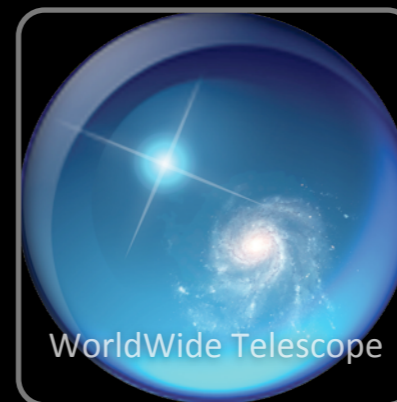
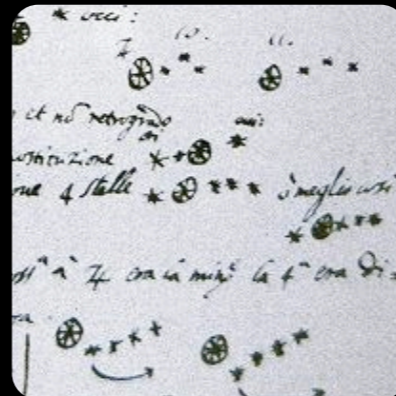
Pattern Recognition  
Creativity



Calculations



# Linking Visualization & Understanding





# Galileo Galilei (1564–1642)



*Sec<sup>mo</sup> Principe.*

*Galileo Galilei Humilis<sup>s</sup> Servus della Ser<sup>ma</sup> V.<sup>a</sup> invigilantissima  
 et de ogni spirito di buene no solam satisfac  
 alvario che nore della Accademia di Matematica nella sua  
 Vno di Padova,*

*Si viene da uero determinato di presentare al Sec<sup>mo</sup> Principe  
 l'Orchiale et di essere di giuramento inestimabile di ogni  
 negozio et in irea marittima o terrestre stimo di tenere per  
 ste nuovi artificio ne l'ingegno segreto et solam a disposizione  
 di v. ser<sup>ma</sup> l'Orchiale cauato dalle piu uide speculazioni di  
 prospettua na l'uantaggio di scoprire Legni et Vele dell'inimico  
 di uale hore et piu di tempo prima di essi suspra noi et distinguend  
 il numero et la qualita dei Vasselli giudicare le sue forze  
 ballastarsi alla caccia al combattimento o alla fuga, o pure uale  
 nella campagna aperta uedere et particolarmente distinguere ogni suo  
 moto et propriamento.*

*Adi 7. di gennaio*  
*Gioue si uide usti*  
*Adi 8. usti*  
*Adi 12. si uide in tale uisione*  
*Adi 13. si uide usti in Gioue 4 stelle*  
*Adi 14. si uide*  
*Adi 15. si uide*

7	* * ○ *	17	* ○
8	○ * * *	18	* ○
10	* * ○	19	* ○ * *
11	* * ○	19	* ○ * *
12	* ○ *	20	○ ○ ○ ○ ○
13	* ○ * *	21	... ○ *
15	○ * * * *	22	* ○ .. *
15	○ * * *	22	○ .. *
16	○ * *	23	* ○ * *
17	* ○ *	24	* ○
		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  
 e closest western one 2 minutes; and the other western one wa

East \* ○ \* \* West

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

On the fourth, at the second hour, there were four stars around  
 upiter, 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  
 rom Jupiter; Jupiter was 4 minutes from the nearest western one  
 d this one 6 minutes from the westernmost one. Their magnitude,  
 ere nearly equal; the one closest to Jupiter appeared a little smaller  
 an the rest. But at the seventh hour the eastern stars were only  
 o 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



# Galileo Galilei



## GALILEO'S "NEW ORDER"

Created by Alyssa Goodman, Curtis Wong  
with advice from Owen Gingerich and David



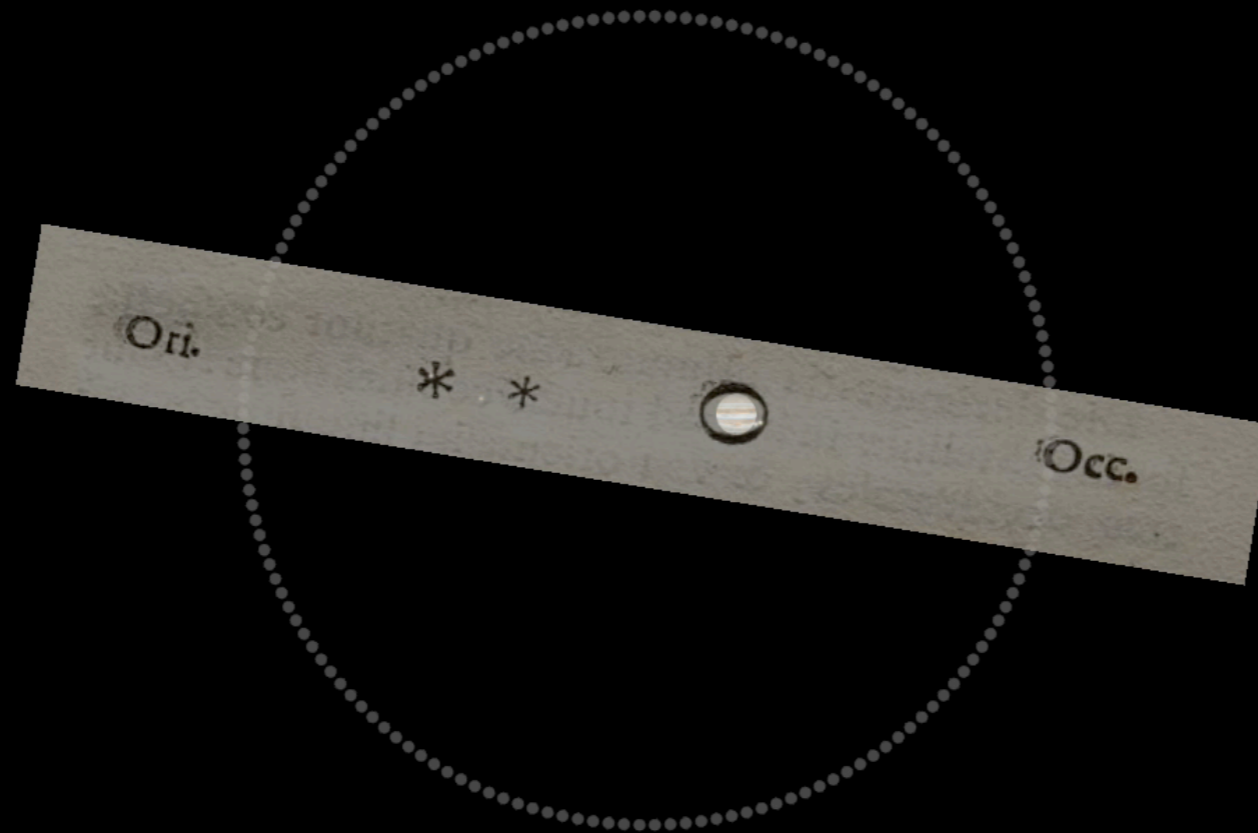
*Galileo's New Order, A WorldWide Telescope Tour by Goodman, Wong & Udomprasert 2010*



# Galileo Galilei

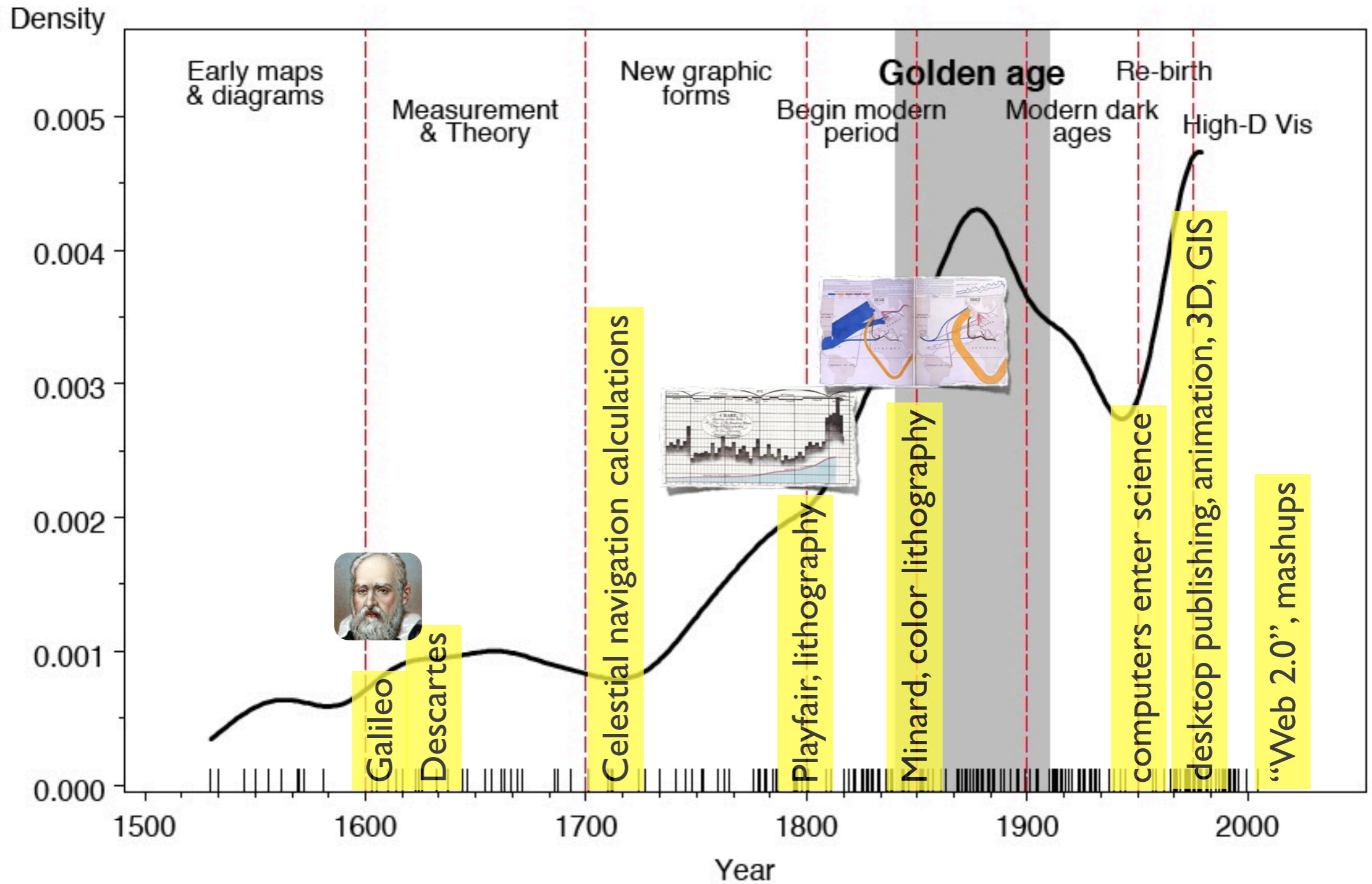


January 11, 1610

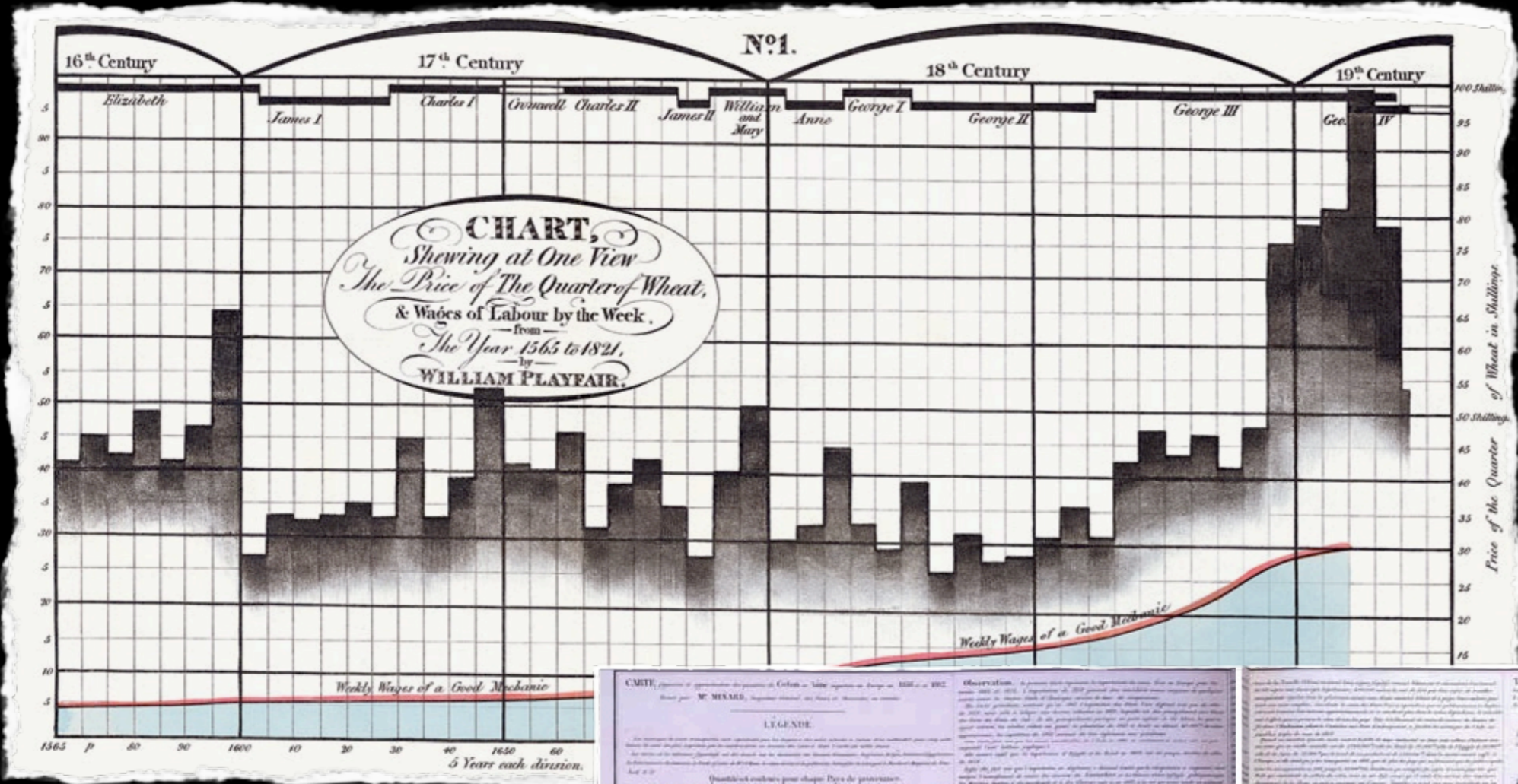


*Galileo's New Order, A WorldWide Telescope Tour by Goodman, Wong & Udomprasert 2010*

# Milestones: Time course of developments

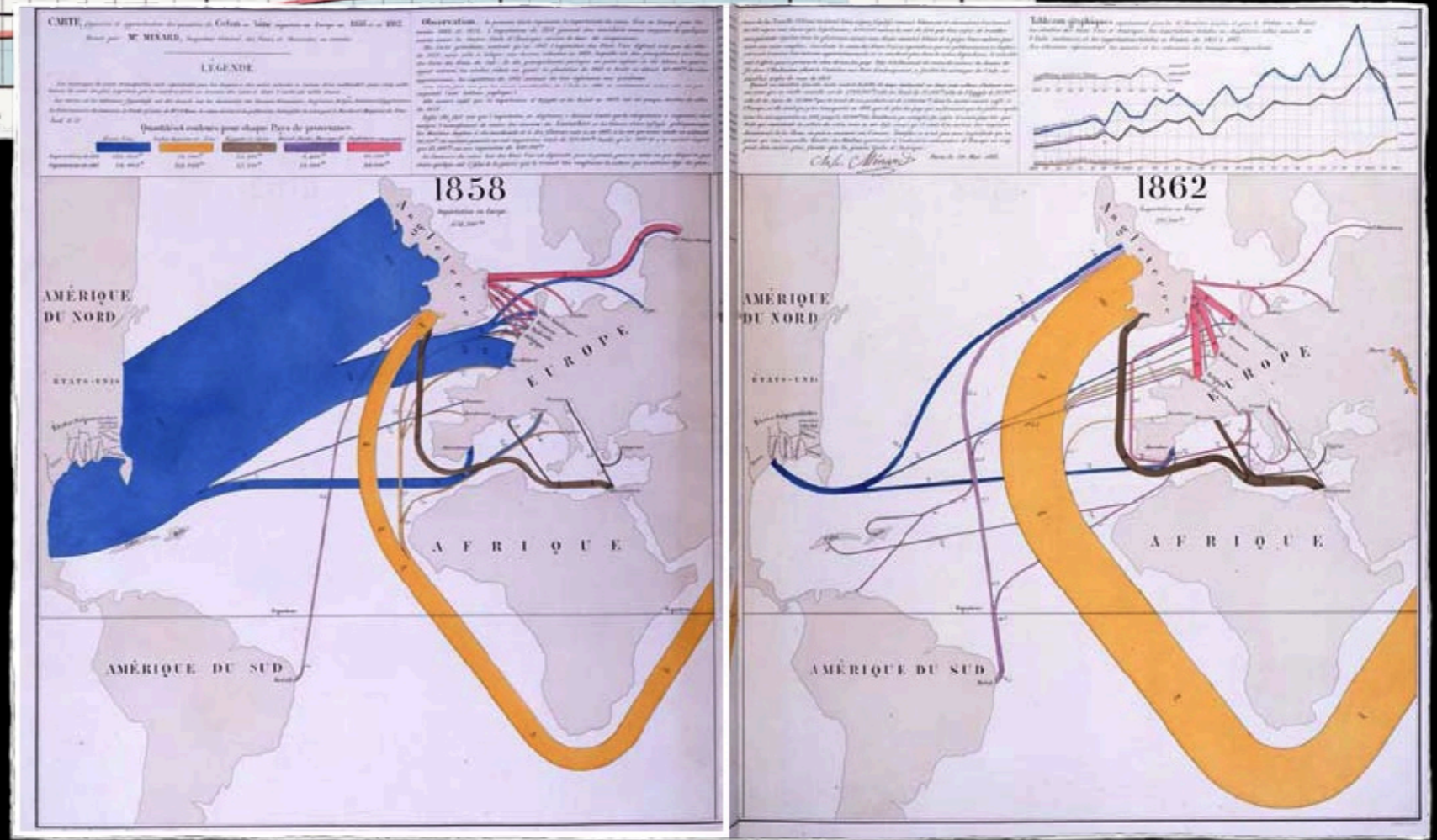


adapted from Friendly, "The Golden Age of Statistical Graphics," *Statistical Science*, 2009



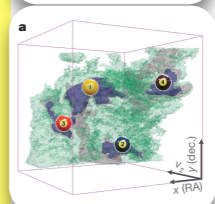
Playfair, lithography

William Playfair (1759-1823)

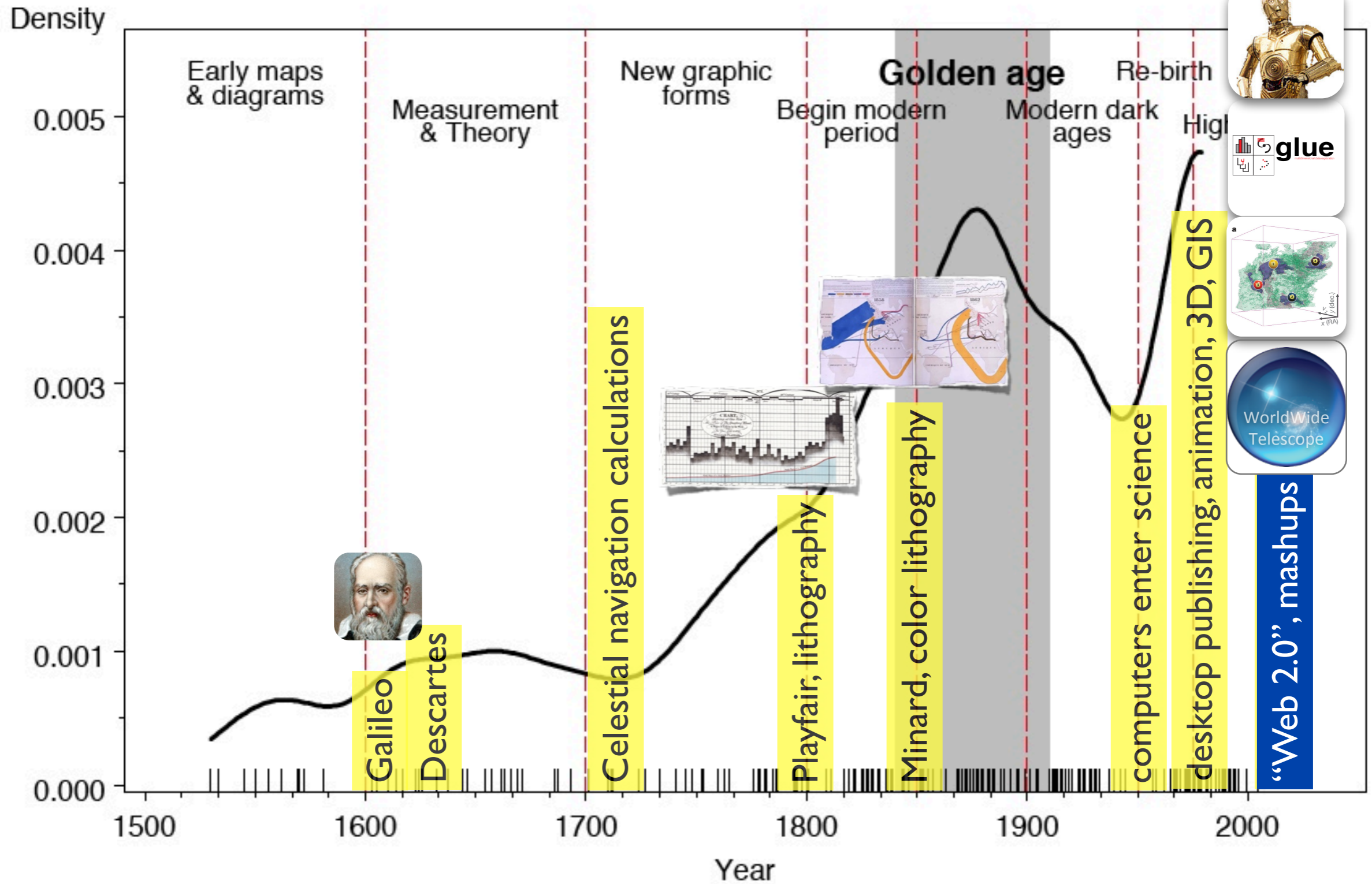


Minard, color lithography

Charles Joseph Minard (1781-1870)



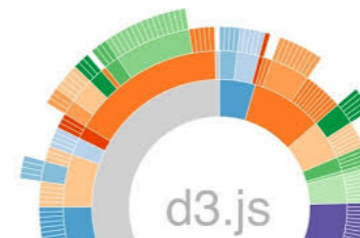
# Milestones: Time course of developments



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



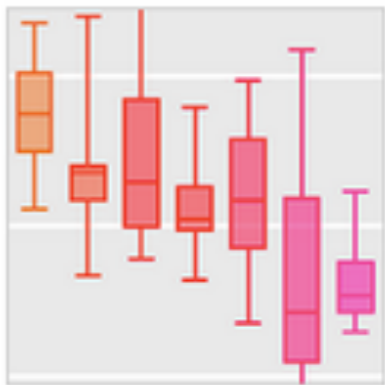
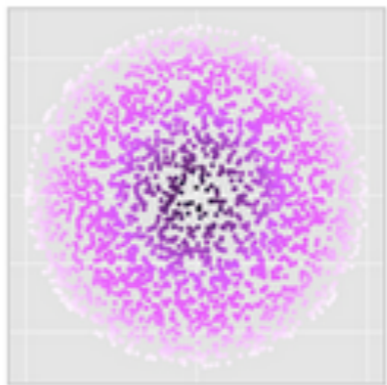
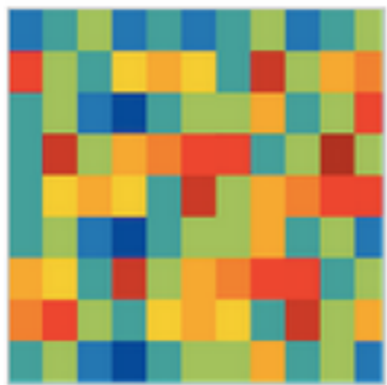
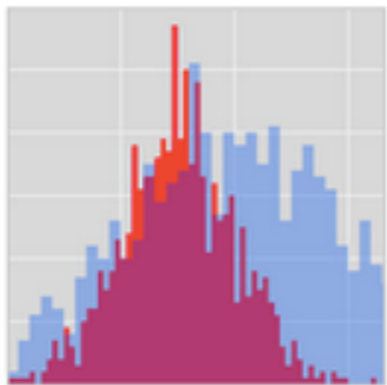
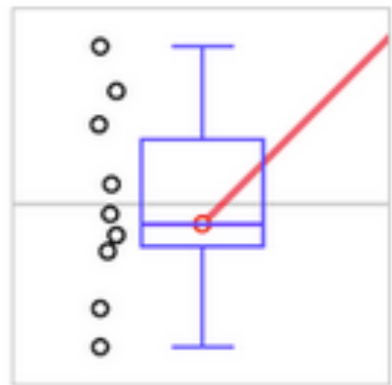
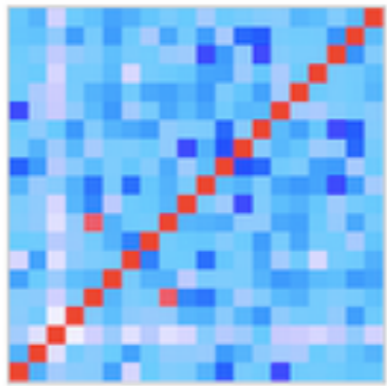
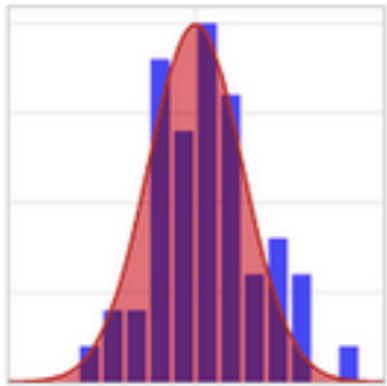
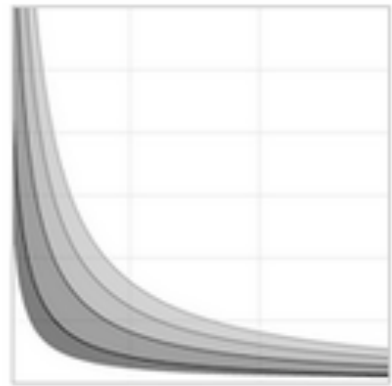
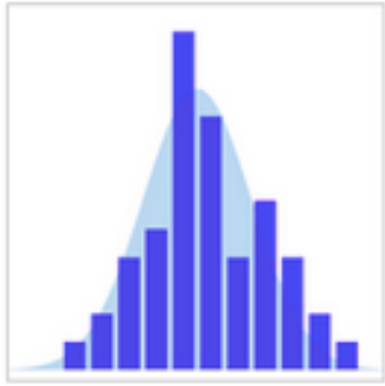
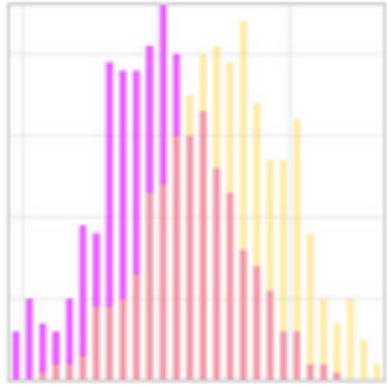
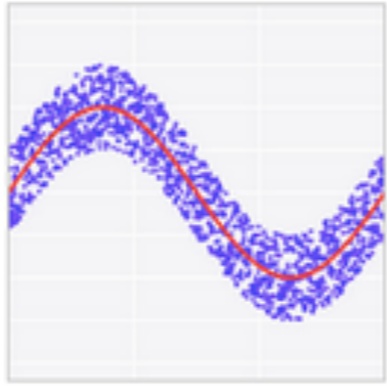
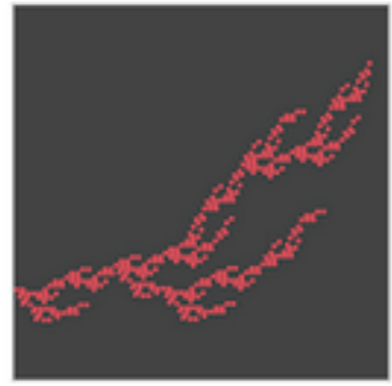
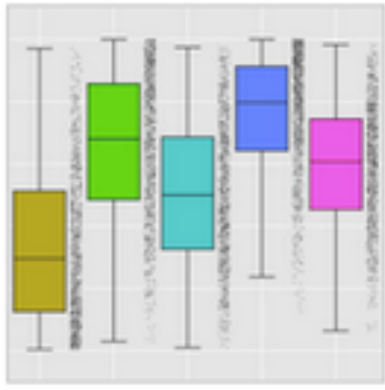
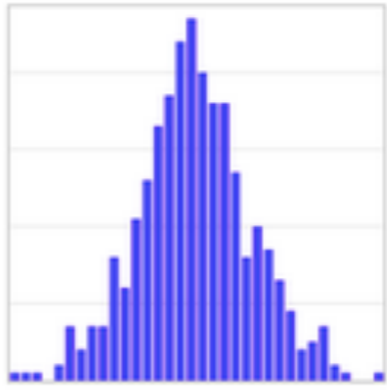
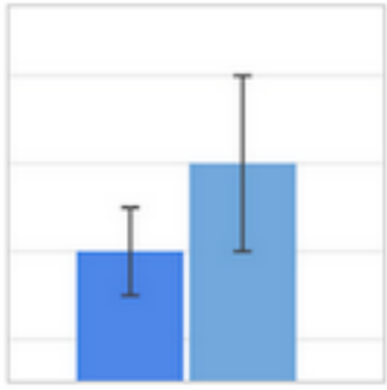
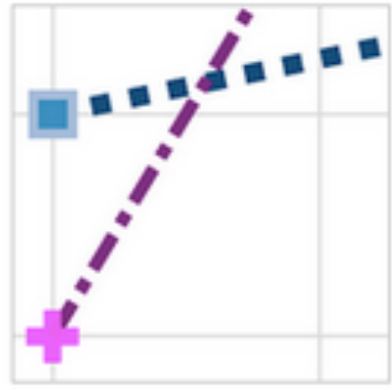
IP[y]: IPython  
Interactive Computing



“Web 2.0”, mashups



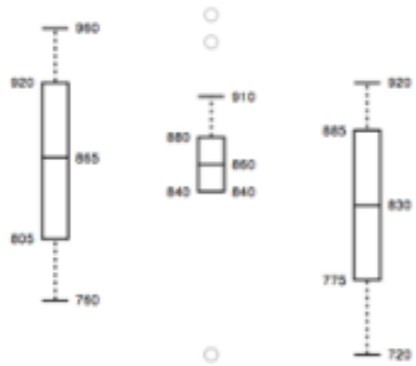
“Web 2.0”, mashups



plot.ly



Box Plots



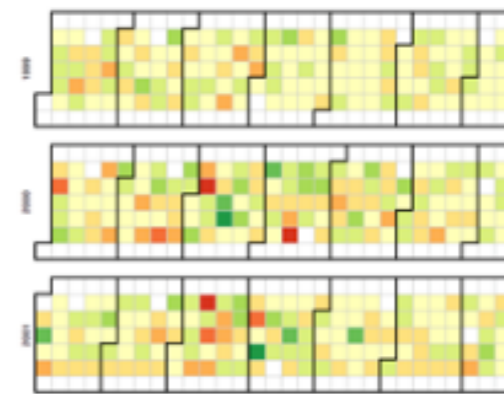
Bubble Chart



Bullet Charts



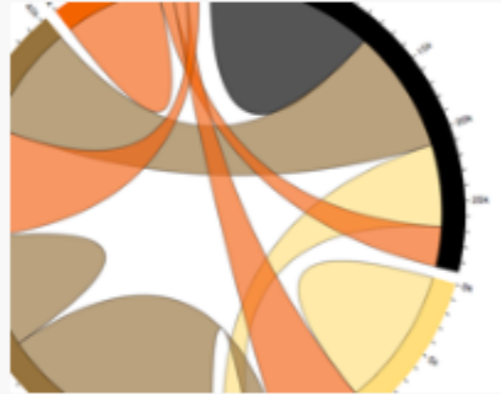
Calendar View



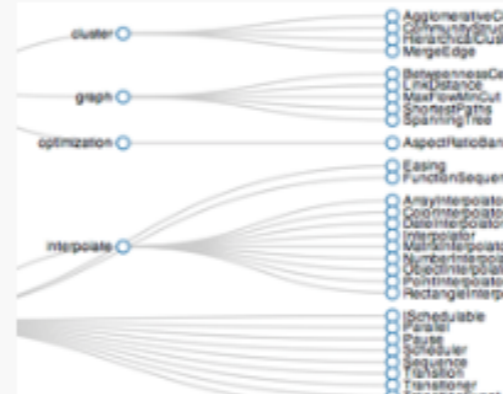
Non-contiguous Cartogram



Chord Diagram



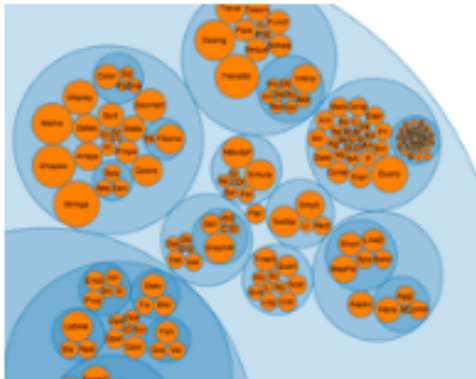
Dendrogram



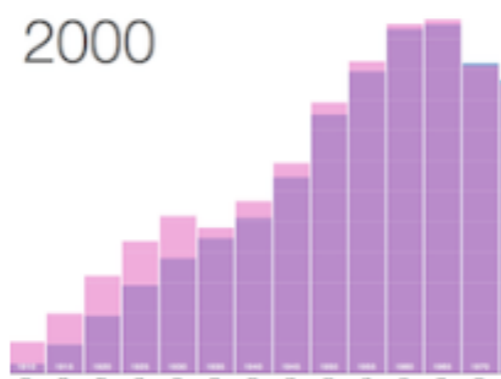
Force-Directed Graph



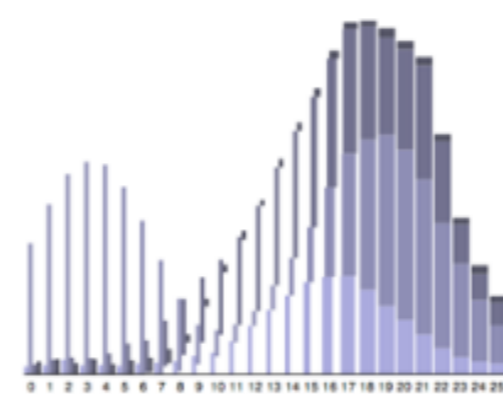
Circle Packing



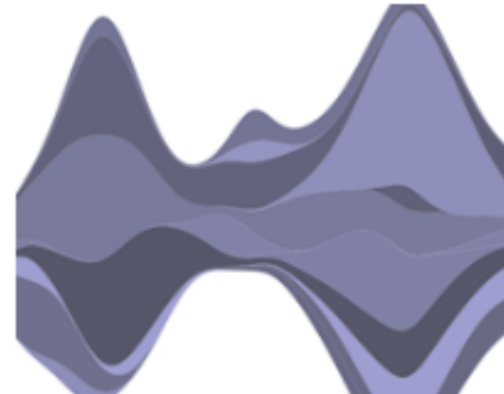
Population Pyramid  
2000



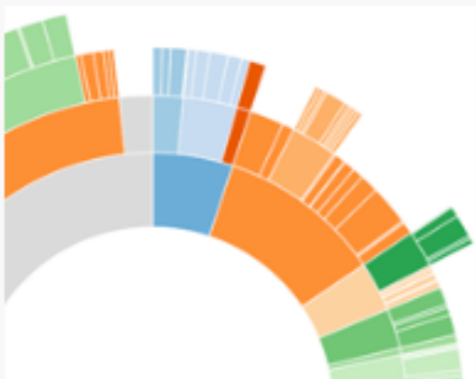
Stacked Bars



Streamgraph



Sunburst



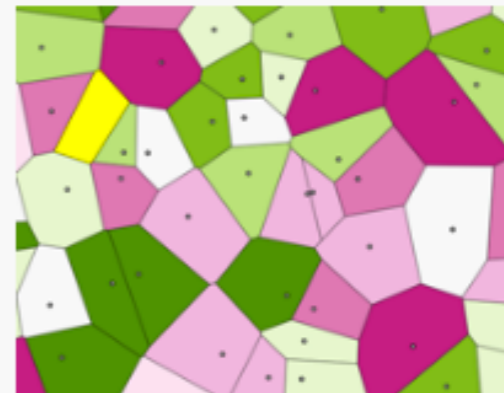
Node-Link Tree



Treemap



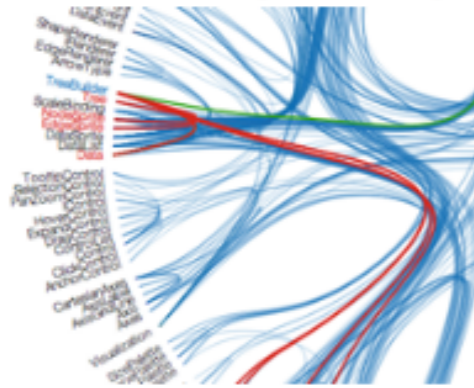
Voronoi Diagram



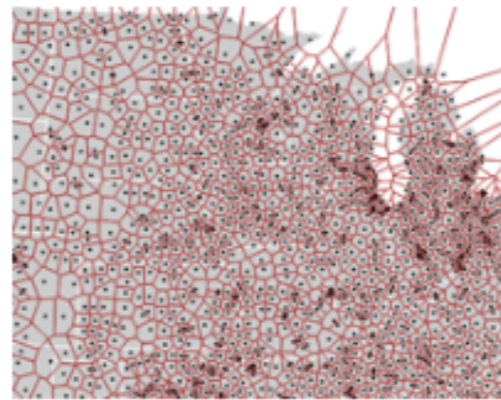
“Web 2.0”, mashups

d3.js

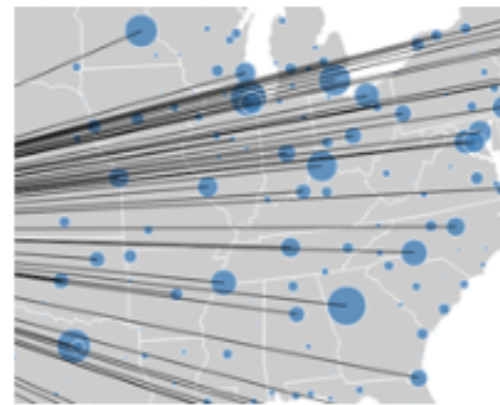
Hierarchical Edge Bundling



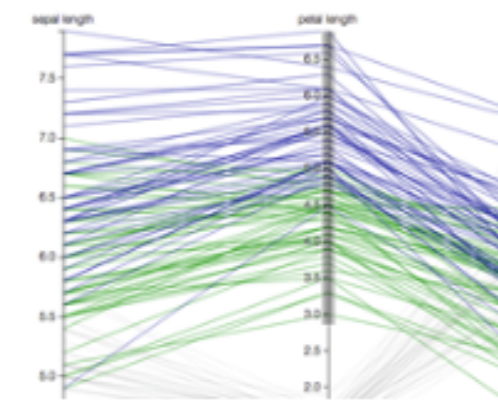
Voronoi Diagram



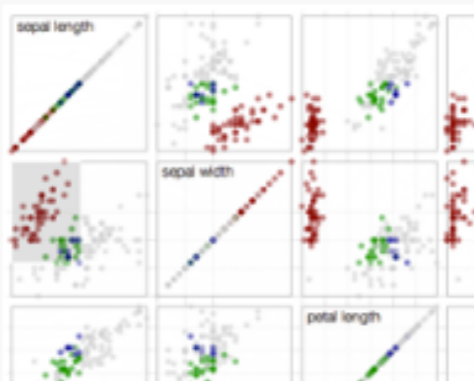
Symbol Map



Parallel Coordinates



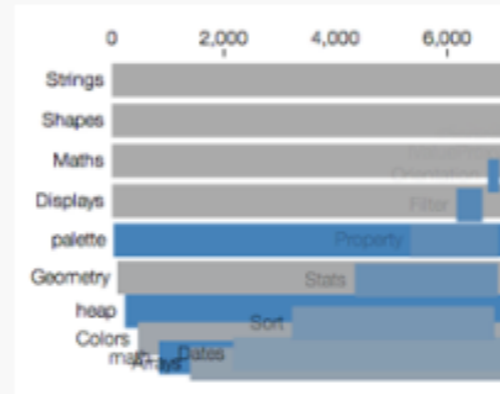
Scatterplot Matrix



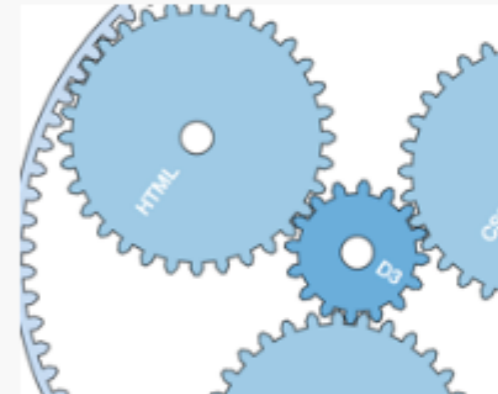
Zoomable Pack Layout



Hierarchical Bars



Epicyclical Gears



Collision Detection



Collapsible Force Layout



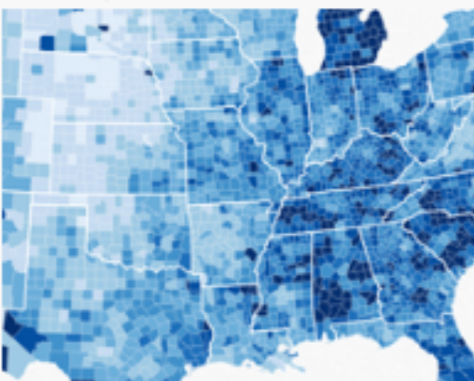
Force-Directed States



Azimuthal Projections



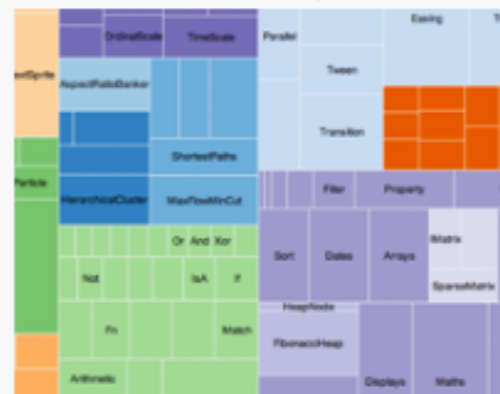
Choropleth



Collapsible Tree Layout



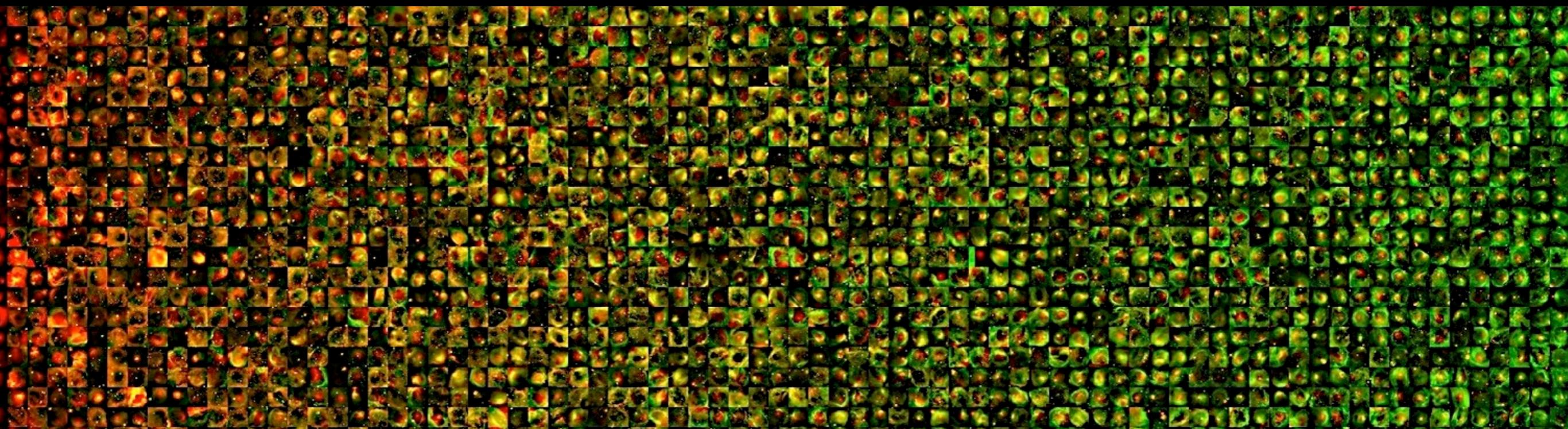
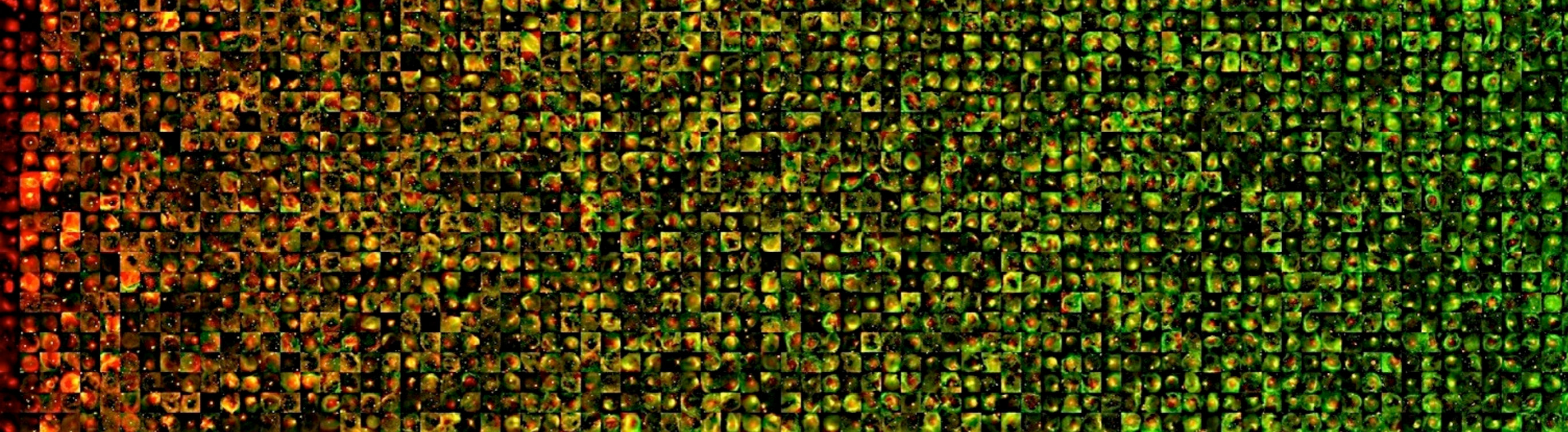
Zoomable Treemap



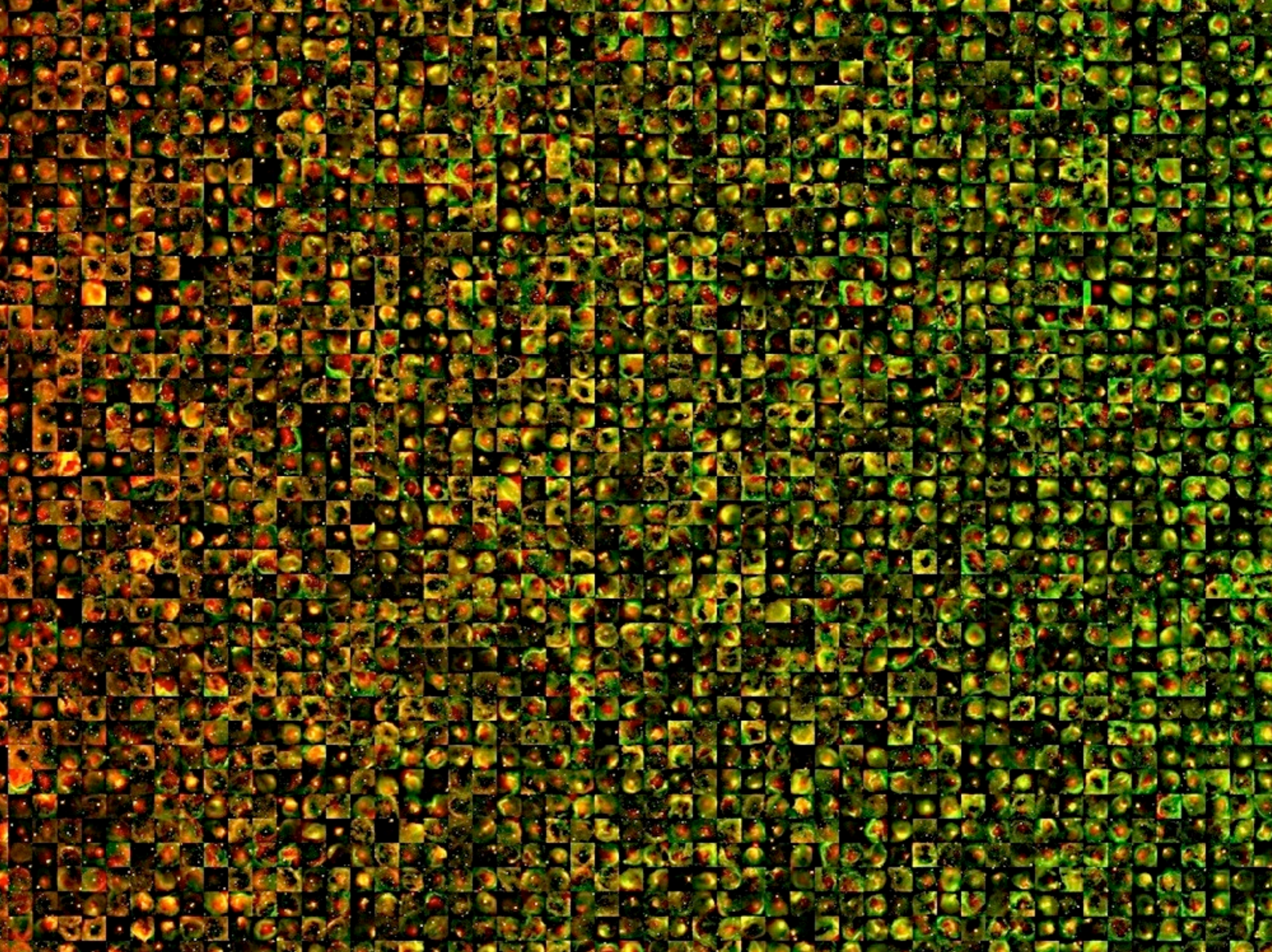
Zoomable Partition Layout







Monday, January 6, 2014



# BIG DATA and Human-Aided Computing

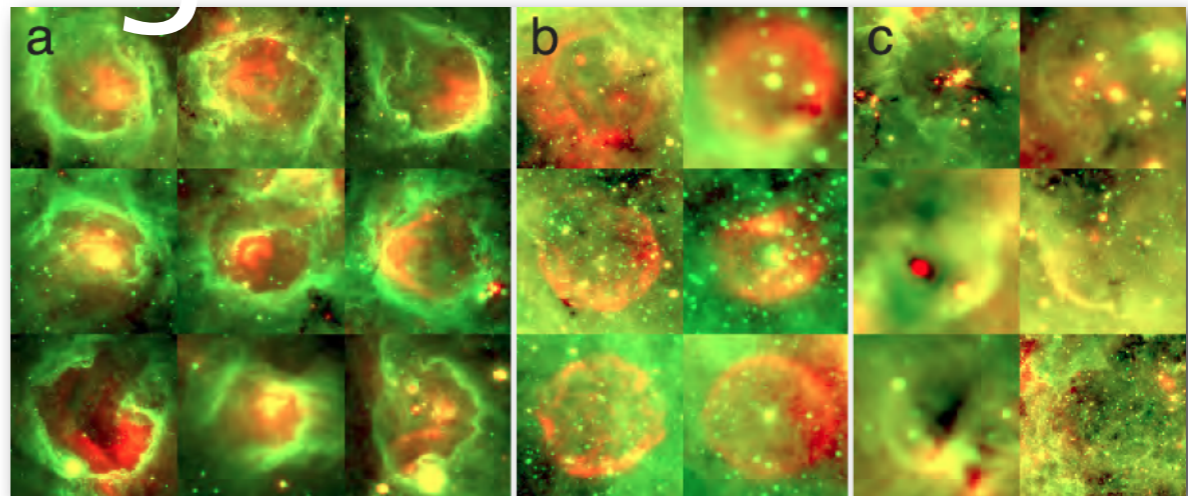
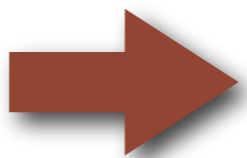


THE MILKY WAY PROJECT ZOONIVERSE REAL SCIENCE ONLINE

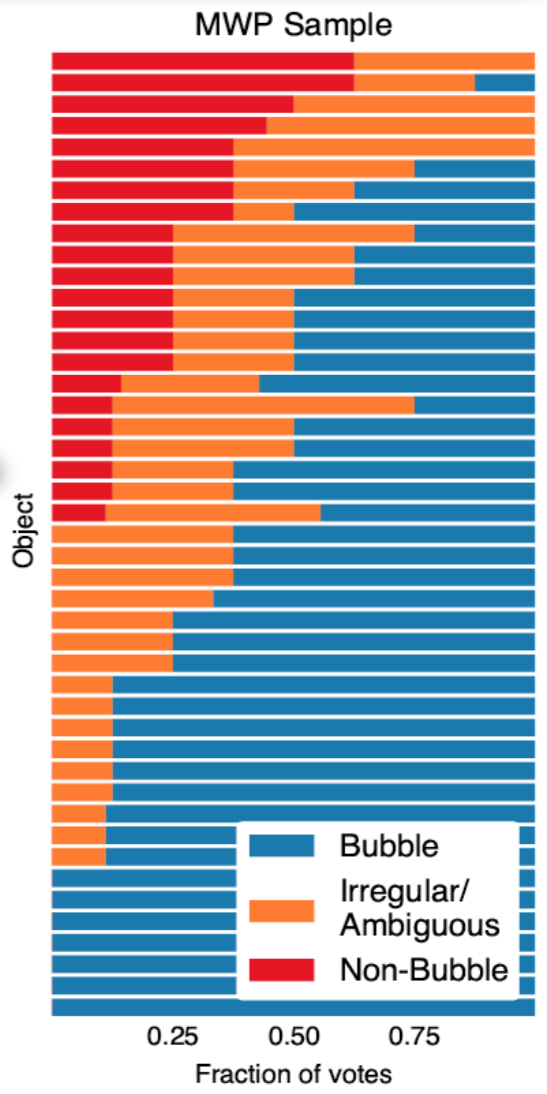
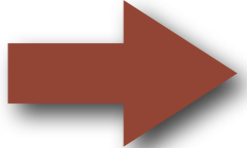
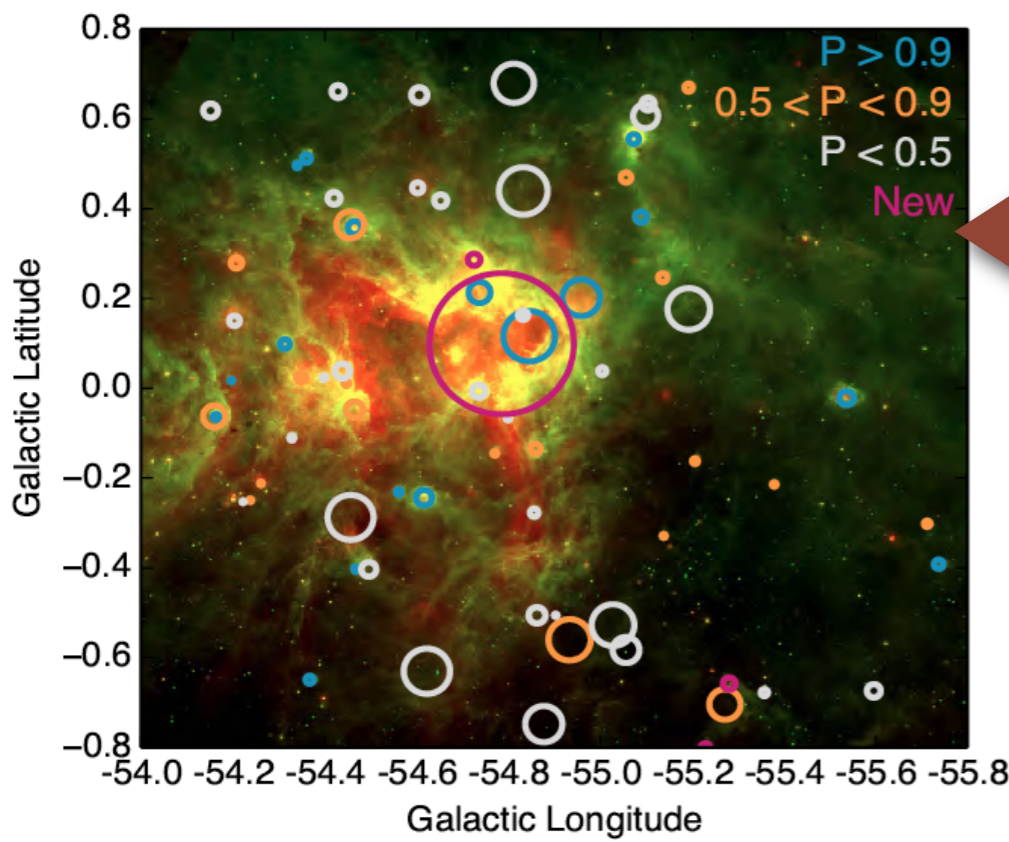
## mark bubbles

What do you see in this image?

Bubble Star Cluster EGO Galaxy Object I'm done!

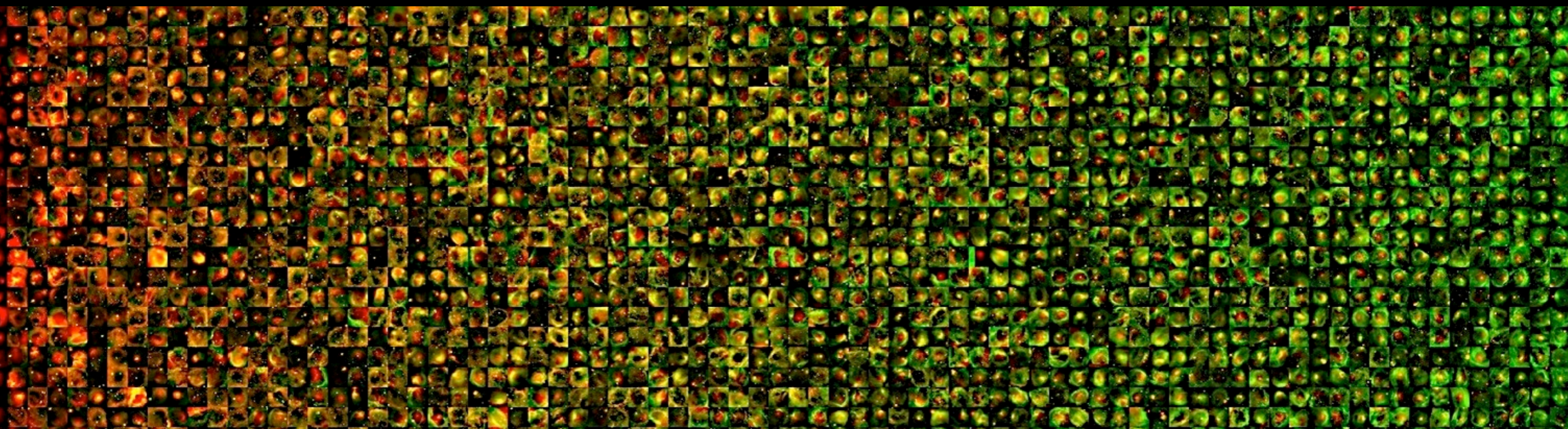
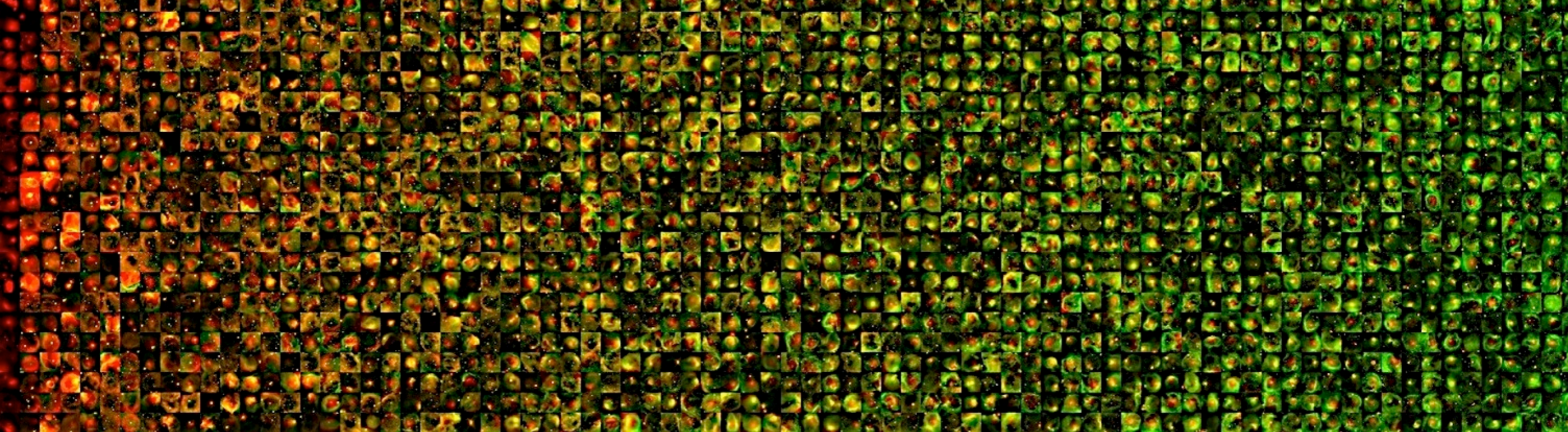


machine-learning algorithm (Brut)








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

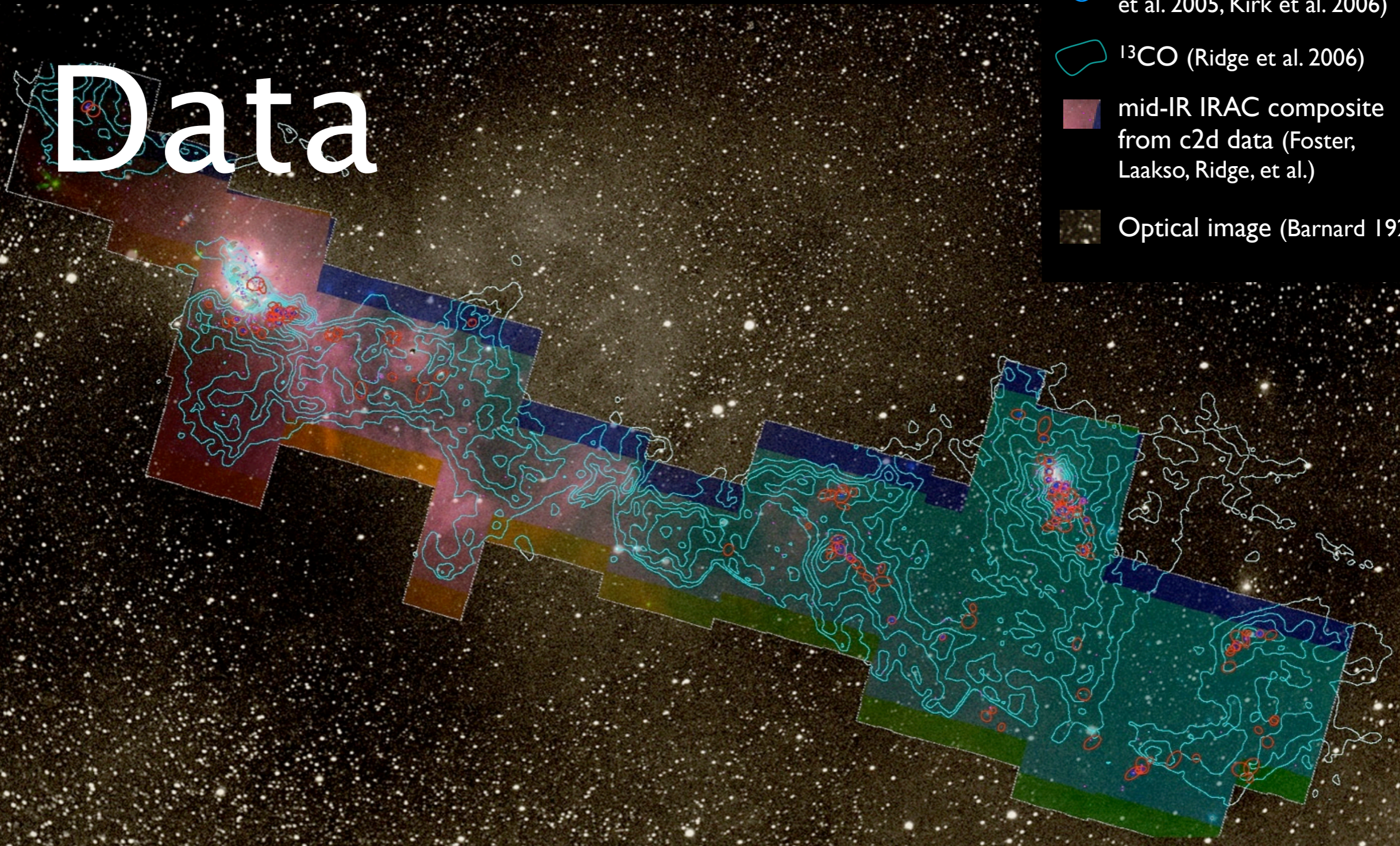


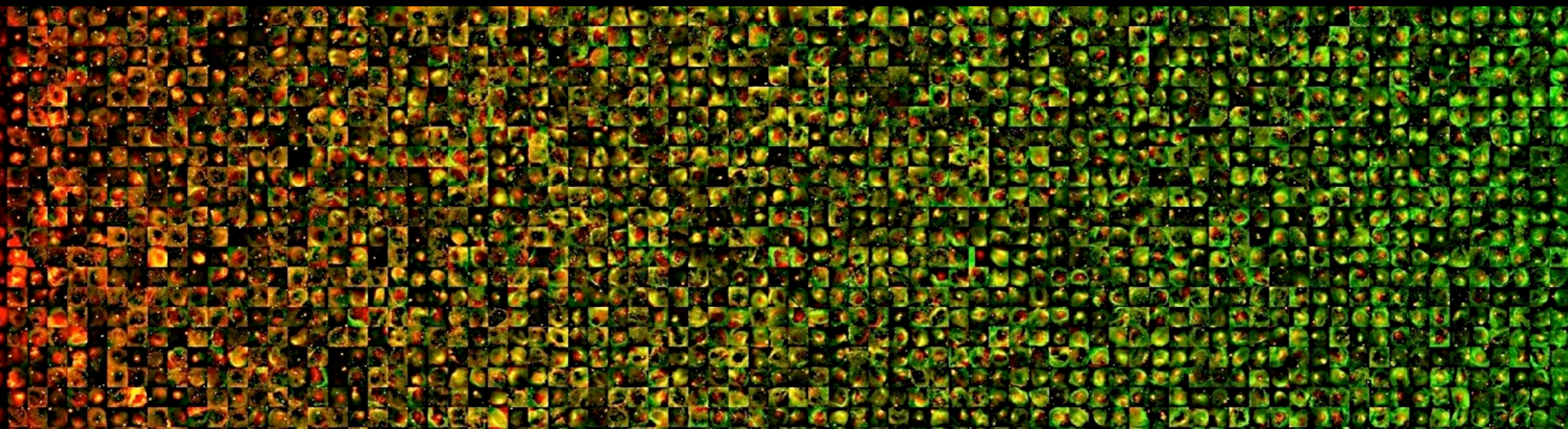
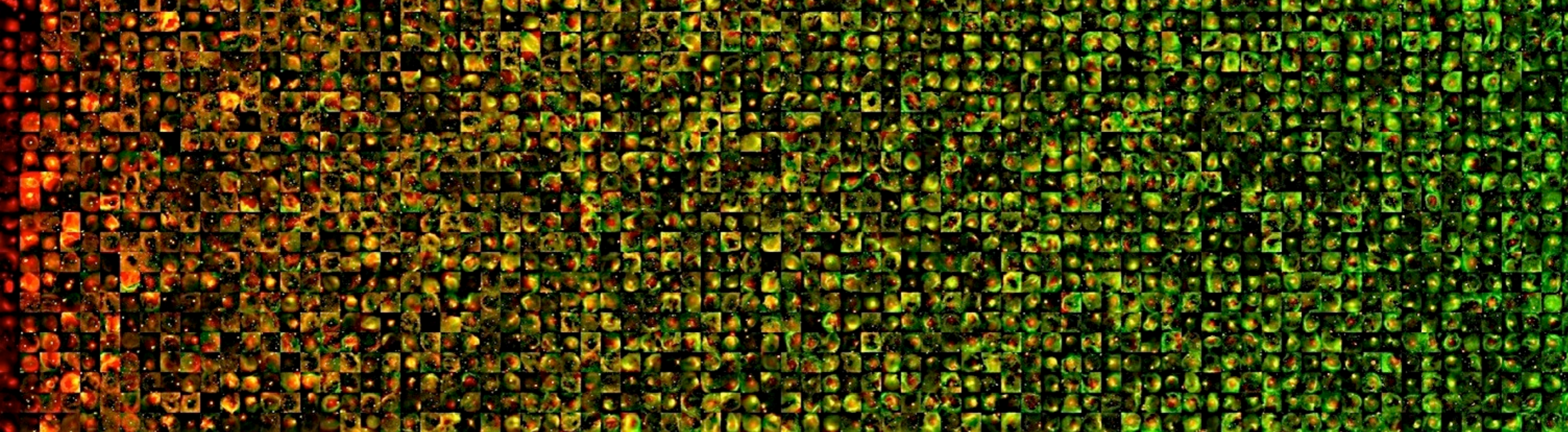


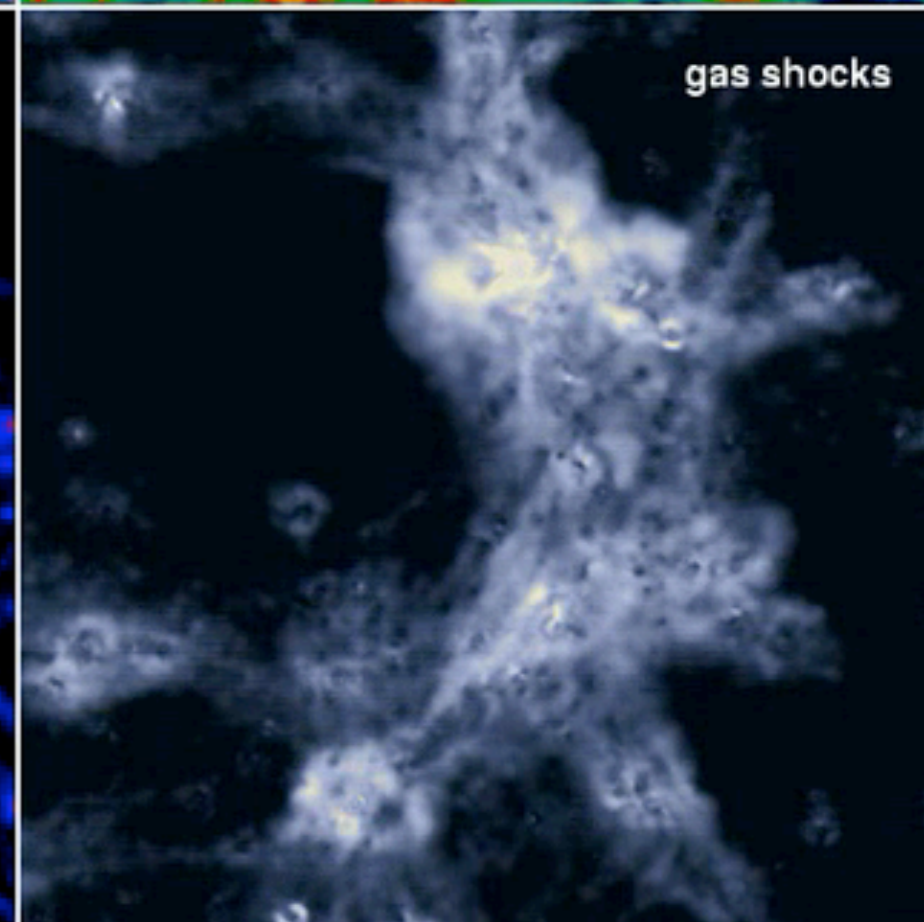
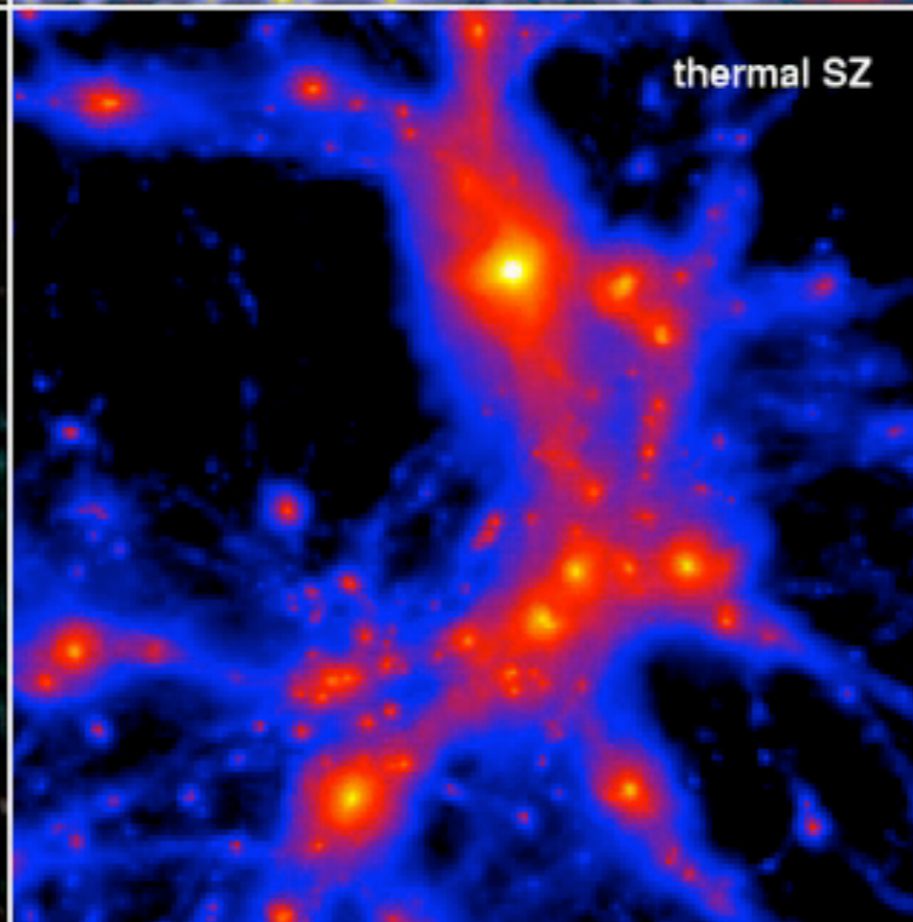
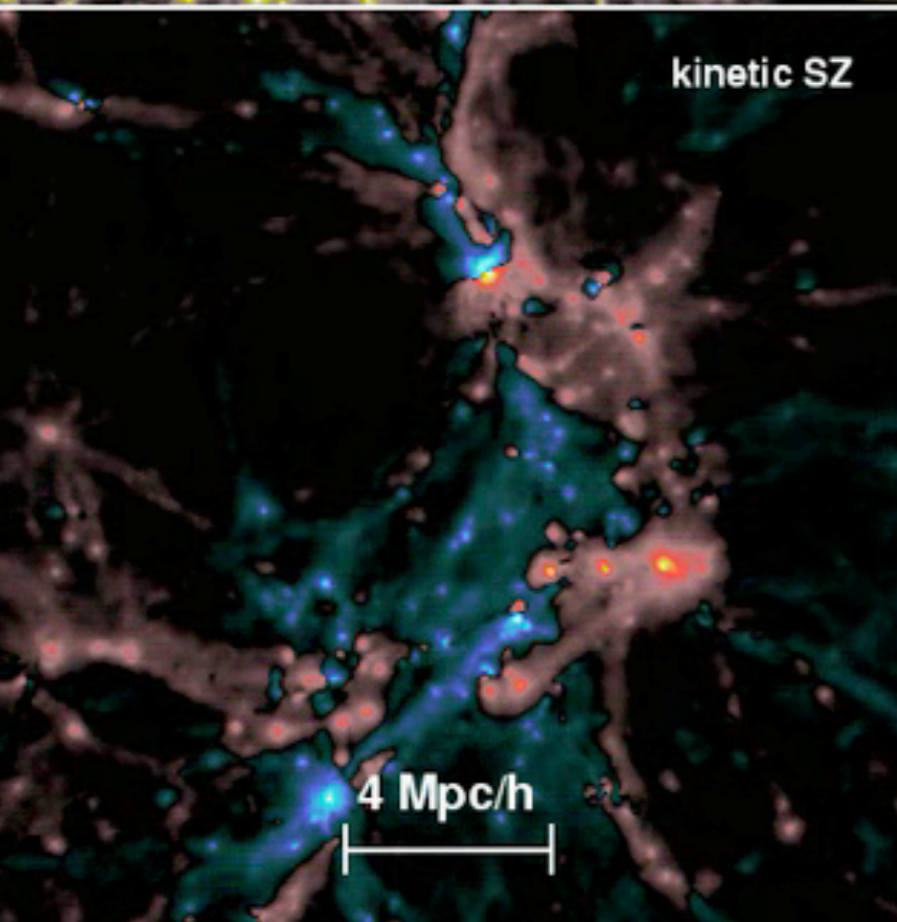
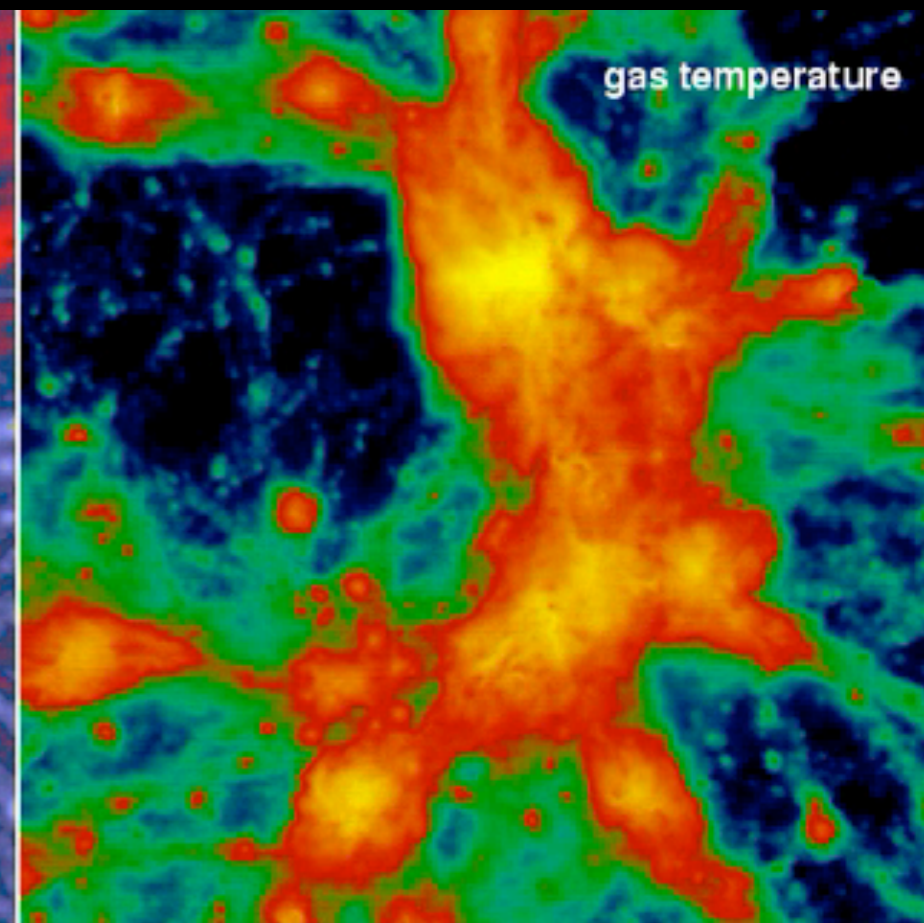
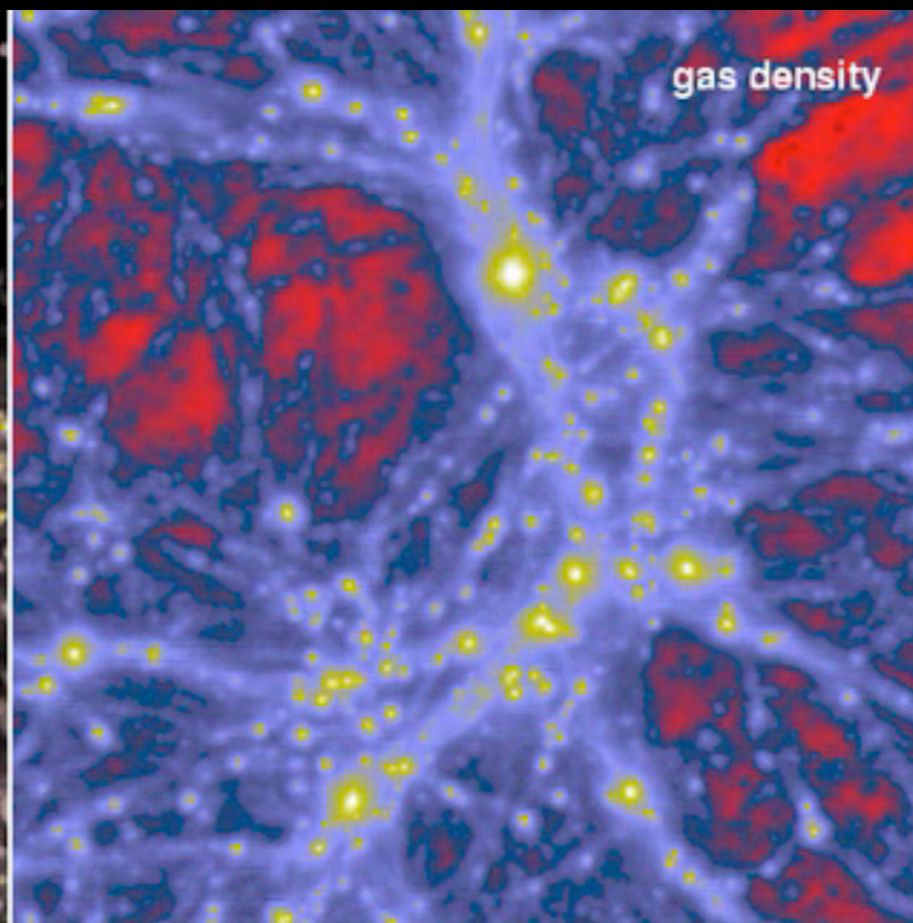
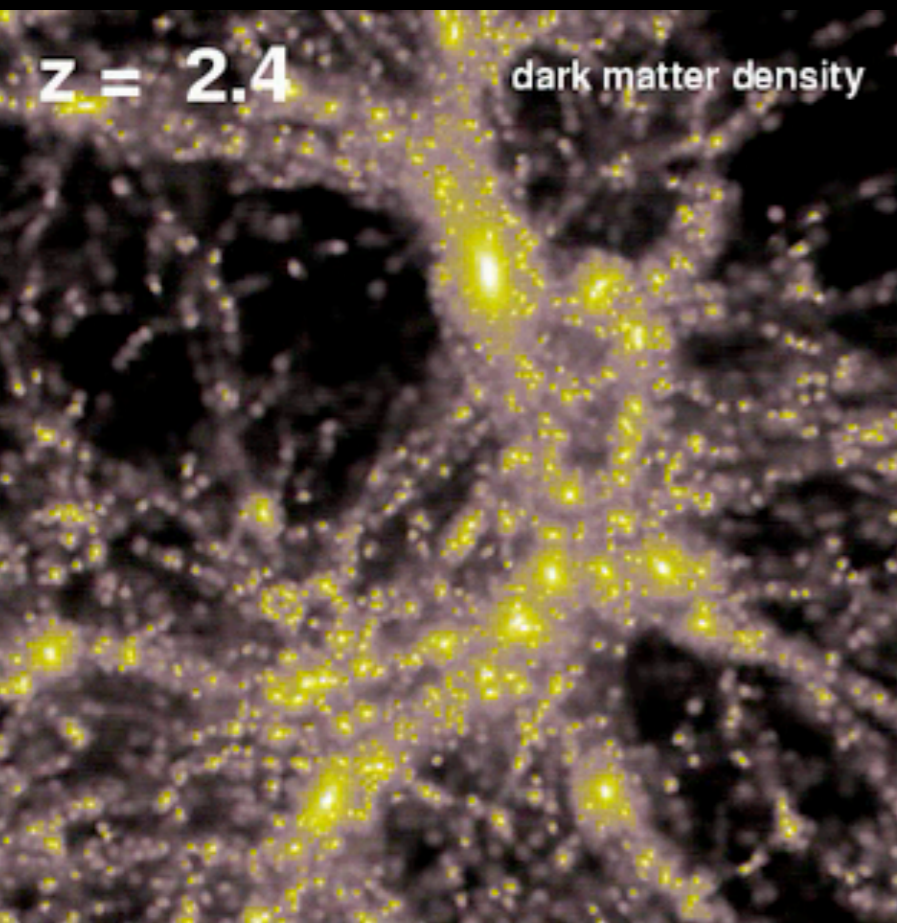
# Wide Data

COMPLETE

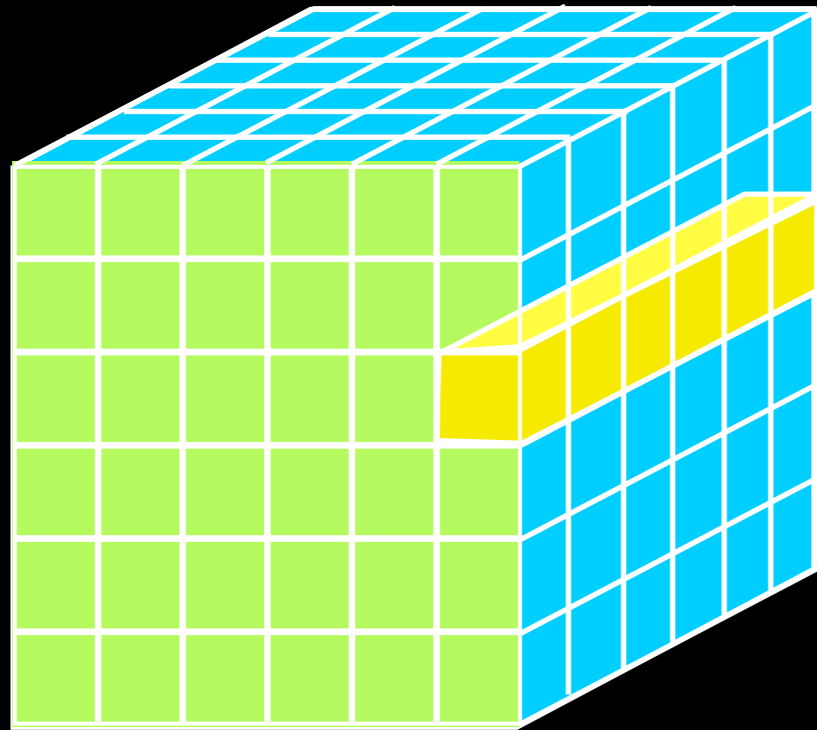
-  mm peak (Enoch et al. 2006)
-  sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)
-   $^{13}\text{CO}$  (Ridge et al. 2006)
-  mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al.)
-  Optical image (Barnard 1927)












*Movie: Volker Springel, formation of a cluster of galaxies*

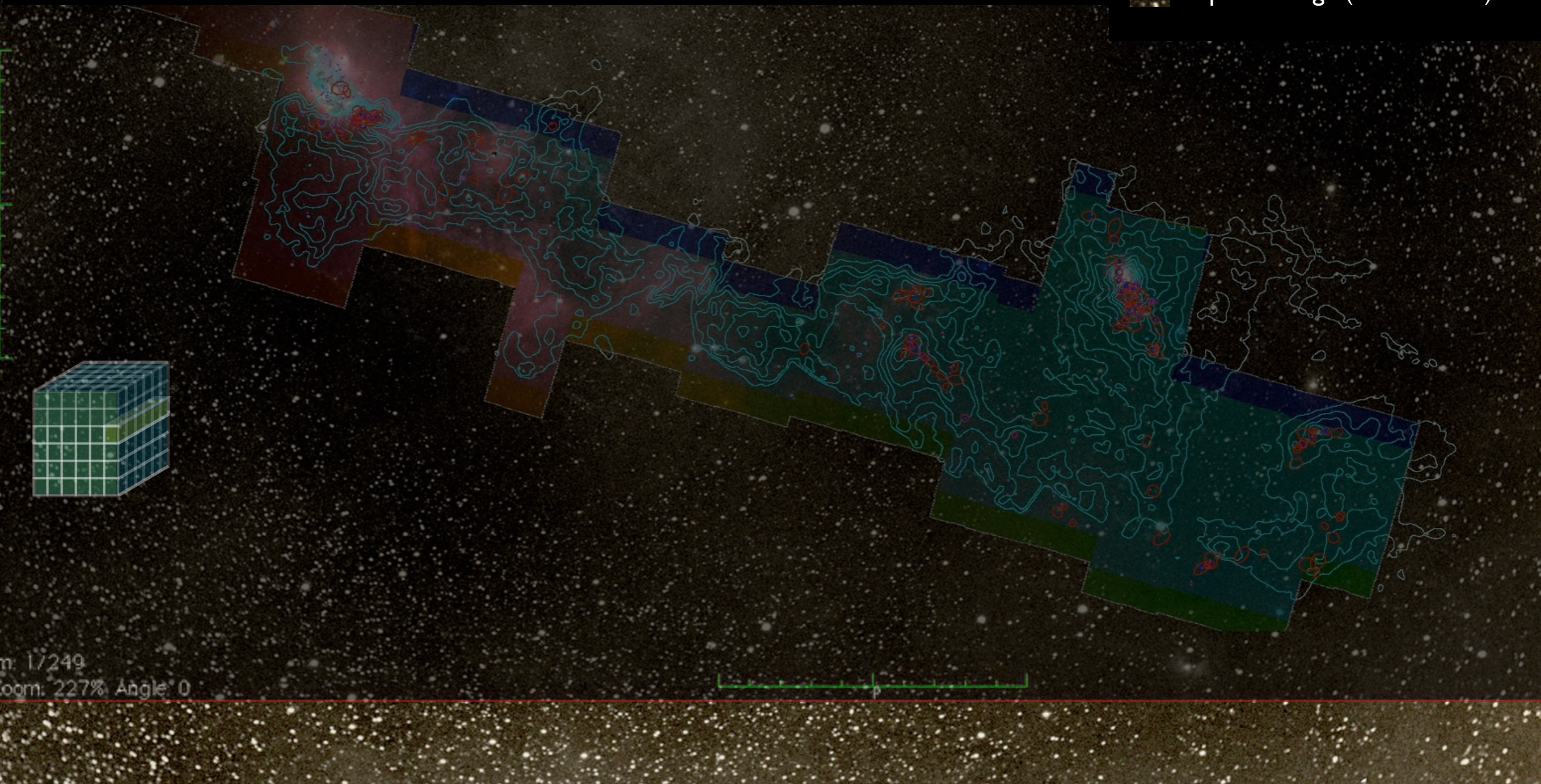


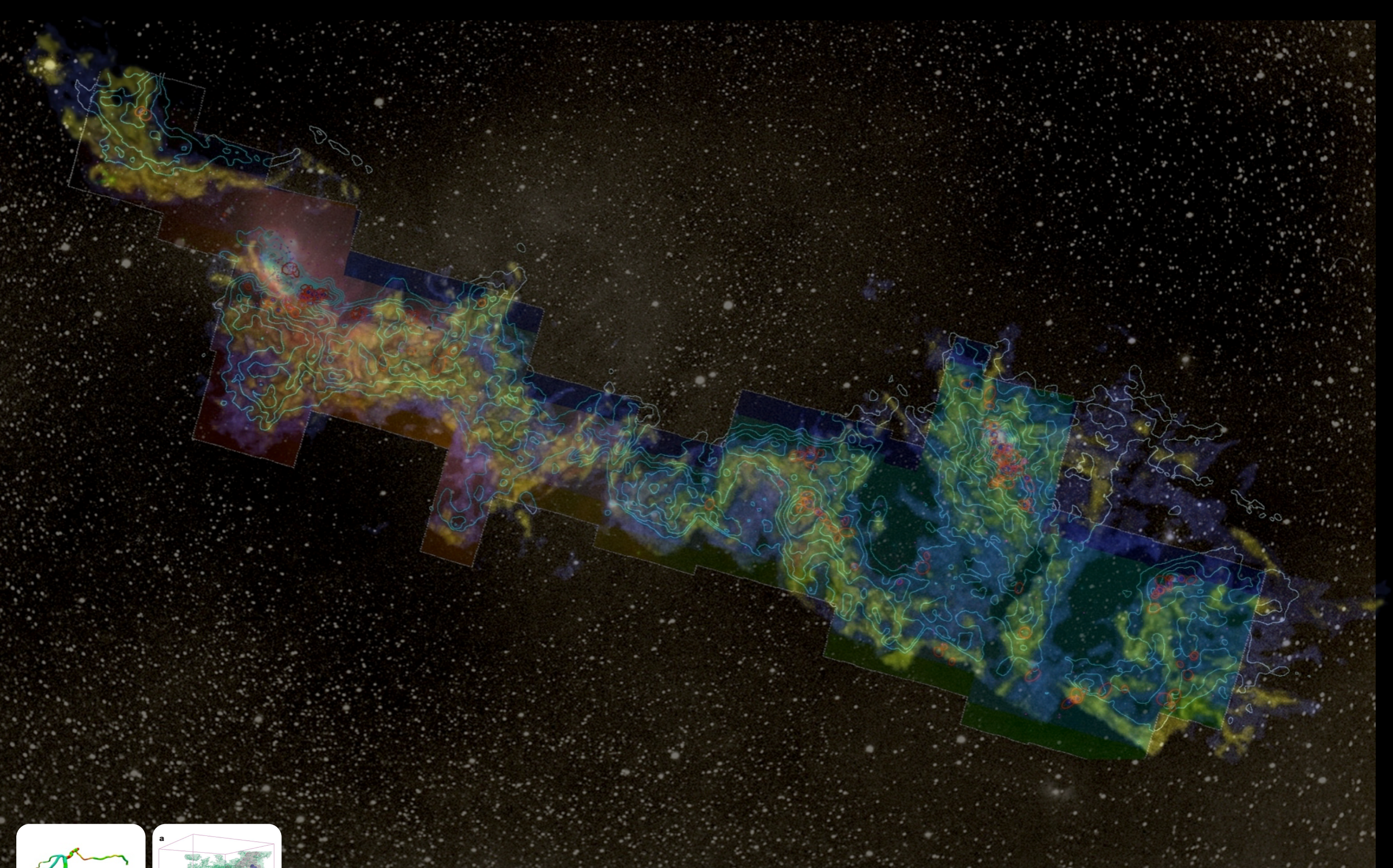
# “Data, Dimensions, Display”

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

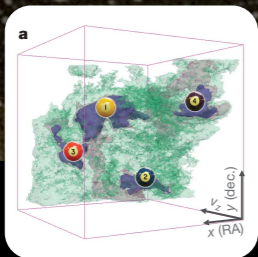
# Wide Data, “In 3D”

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





3D Viz made with VolView



AstronomicalMedicine@iig

COMPLETE

1610



SIDEREUS NUNCIUS

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

East \* ○ \* \* West

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

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

East \* ○ \* \* West

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

East \*\* ○ \*\*

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

On the fifth, the sky was cloudy.

On the sixth, only two stars appeared flanking Jupiter

East \* ○ \*

in the adjoining figure. The eastern one was 2 minutes from the next 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, but not on the same straight line.

# what do we publish?

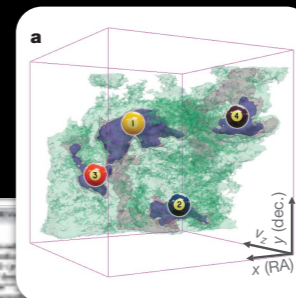
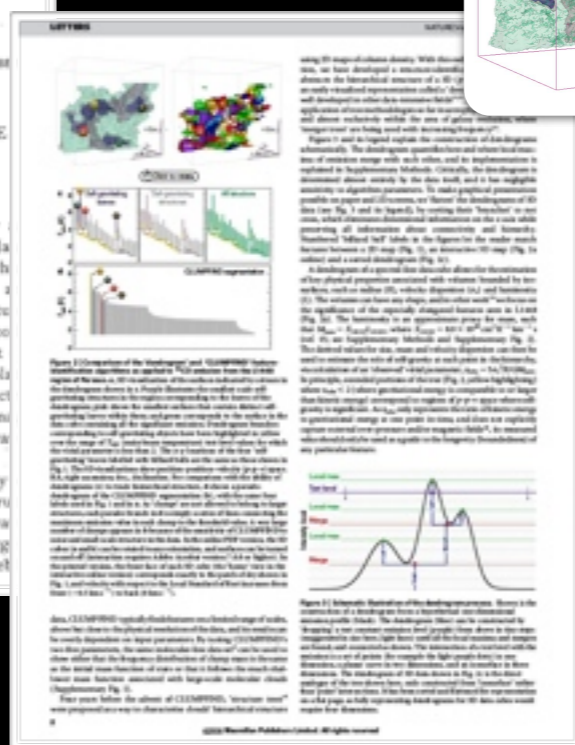
1665



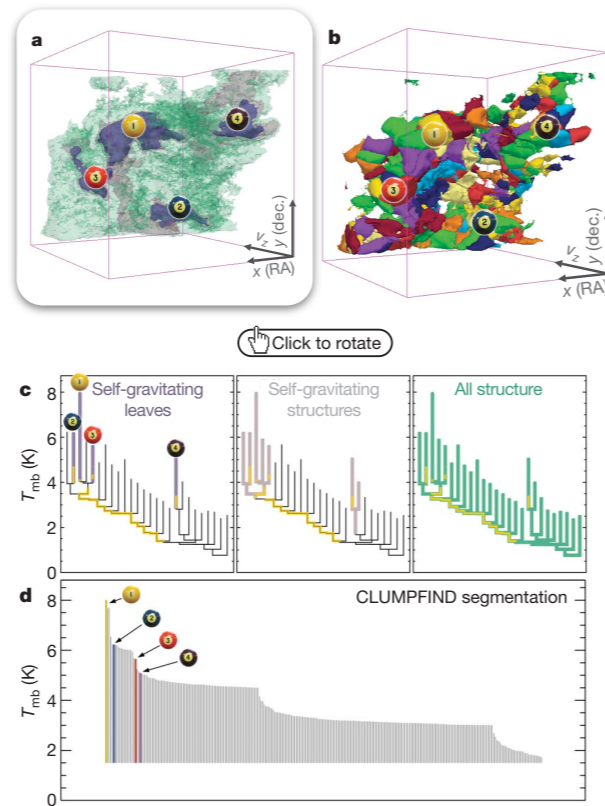
1895



2009







**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 ( $8 \text{ km s}^{-1}$ ).

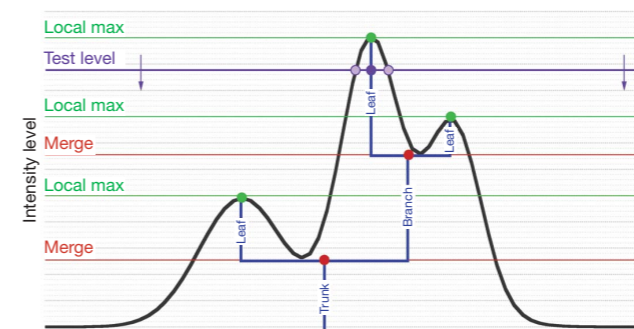
data, CLUMPFIND typically finds features on a limited range of scales, above but close to the physical resolution of the data, and its results can be overly dependent on input parameters. By tuning CLUMPFIND’s two free parameters, the same molecular-line data set<sup>8</sup> can be used to show either 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 the 2D work as inspiration, we have developed a structure-identification algorithm that abstracts the hierarchical structure of a data set into an easily visualized representation called a ‘merger tree’. This method, well developed in other data-intensive applications, is applied here and almost exclusively within the astrophysical context. ‘merger trees’ are being used with increasing frequency.

Figure 3 and its legend explain the dendrogram process schematically. The dendrogram was constructed by determining almost entirely by the sensitivity to algorithm parameters. The dendrogram is possible on paper and 2D screen data (see Fig. 3 and its legend). The dendrogram is a cross, which eliminates dimensions, preserving all information. Numbered ‘billiard ball’ labels are used to track features between a 2D map (see Fig. 1) and a sorted dendrogram.

A dendrogram of a spectrum of emission features, such as radius ( $r$ ), surface area ( $A$ ), and luminosity ( $L$ ). The volumes can have any shape, and the significance of the especially elongated features is highlighted (Fig. 2a). The luminosity is an approximate proxy for mass, so that  $M_{\text{lum}} = X_{13\text{CO}} L_{13\text{CO}}$ , where  $X_{13\text{CO}} = 8.0 \times 10^{20} \text{ cm}^2 \text{ K}^{-1} \text{ km}^{-1} \text{ s}$  (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,  $\alpha_{\text{obs}} = 5\sigma_v^2 R / GM_{\text{lum}}$ . 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  $\alpha_{\text{obs}}$  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.



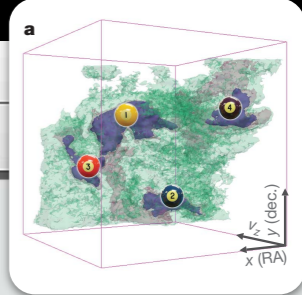
**Figure 3 | Schematic illustration of the dendrogram process.** Shown is the construction of a dendrogram from a hypothetical one-dimensional emission profile (black). The dendrogram (blue) can be constructed by ‘dropping’ a test constant emission level (purple) from above in tiny steps (exaggerated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

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

2009

3D PDF

interactivity in a “Paper”



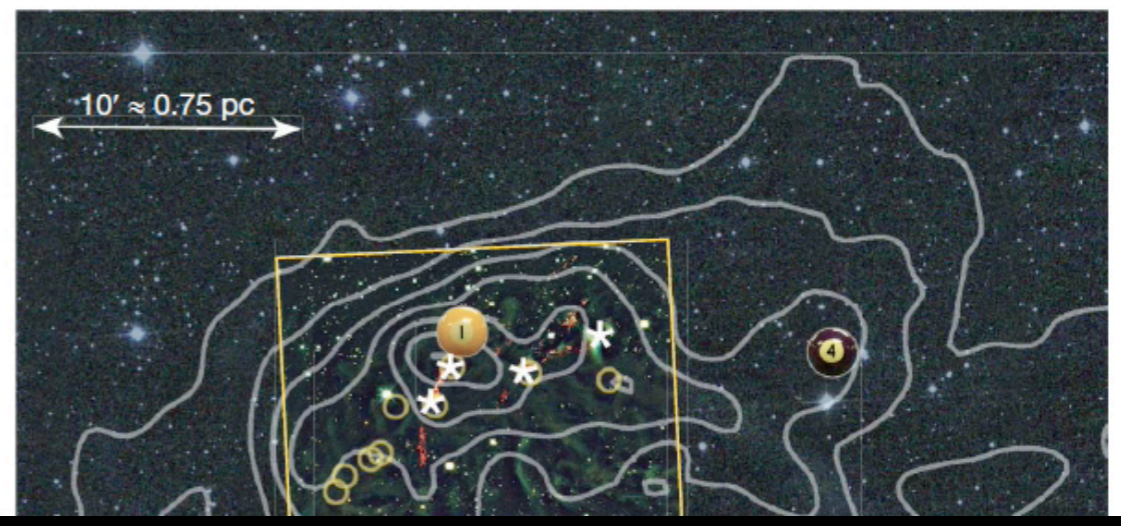
# LETTERS

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

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

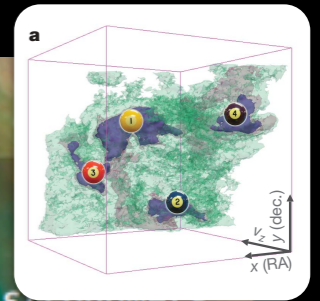
Self-gravity plays a decisive role in the final stages of star formation, where dense cores (size  $\sim 0.1$  parsecs) inside molecular clouds collapse to form star-plus-disk systems<sup>1</sup>. But self-gravity's role at earlier times (and on larger length scales, such as  $\sim 1$  parsec) is unclear; some molecular cloud simulations that do not include self-gravity suggest that 'turbulent fragmentation' alone is sufficient to create a mass distribution of dense cores that resembles, and sets, the stellar initial mass function<sup>2</sup>. Here we report a 'den-drogram' (hierarchical tree-diagram) analysis that reveals that self-gravity plays a significant role over the full range of possible scales traced by <sup>13</sup>CO observations in the L1448 molecular cloud, but not everywhere in the observed region. In particular, more than 90 per cent of the compact 'pre-stellar cores' traced by peaks of dust emission<sup>3</sup> are projected on the sky within one of the den-drogram's self-gravitating 'leaves'. As these peaks mark the locations of already-forming stars, or of those probably about to form, a self-gravitating cocoon seems a critical condition for their exist-

overlapping features as an option, significant emission found between prominent clumps is typically either appended to the nearest clump or turned into a small, usually 'pathological', feature needed to encompass all the emission being modelled. When applied to molecular-line



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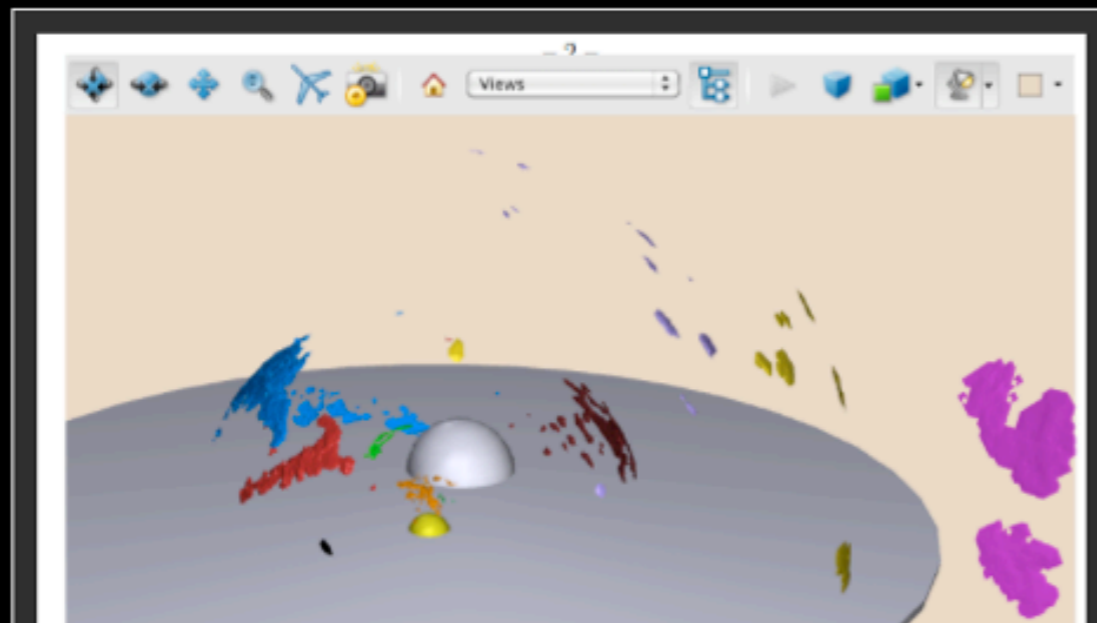
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## Tutorial for embedding 3D interactive graphics into PDF

by *Guest* on March 7, 2012

*Josh Peek (@joshuaegpeek) is a Hubble Fellow at Columbia University, specializing in the ISM in and around disk galaxies. He has a fascination with data presentation and design.*


As an astronomer studying the complex three-dimensional structures of the interstellar medium, I've been taken with the idea of presenting that information in a compelling and interactive way to readers. The major mode of communication for astronomers is the refereed journal article, as distributed through PDF, so I got interested in how one can package interactive 3D scenes with the papers we write. Interactive graphics can be embedded in PDFs that can be rotated, panned, and zoomed.





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- [Laura Trouille](#) (8)
- [contentmgr](#) (2)
- [Jess K](#) (1)

Josh Peek  
Columbia

# Riveting Sequel to come, but, first...

1610



SIDEREUS NUNCIUS

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

East \* ○ \* \* West

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

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

East \* ○ \* \* West

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

East \*\* ○ \*\*

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On the fifth, the sky was cloudy.

On the sixth, only two stars appeared flanking Jupiter

East \* ○ \*

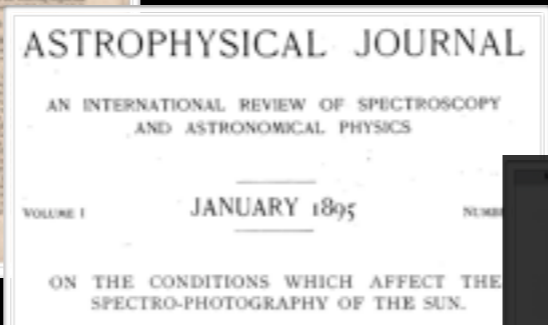
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1665



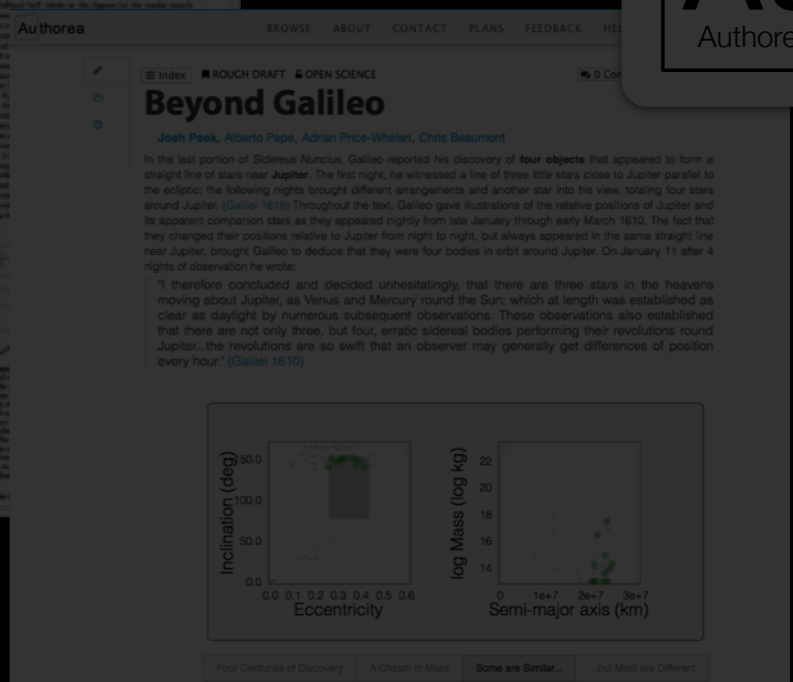
1895



2009



2014



PHOTOGRAPHS OF THE MILKY WAY.

By E. E. BARNARD.

In my photographic survey of the Milky Way with the 6-inch Willard lens of this Observatory, I have come across many very remarkable regions. Some of these, besides being remarkable for showing the peculiar structure of the Milky Way, are singularly beautiful as simple pictures of the stars. I have selected two of these for illustration in THE ASTROPHYSICAL JOURNAL.

Photography of the Milky Way is not a new thing. It has been done since the first days of the photographic process. The first photograph of the Milky Way was made by William Herschel in 1784. It was a very faint and indistinct picture. The first really good photograph of the Milky Way was made by John Herschel in 1827. It was a much better picture, but still very faint. The first really good photograph of the Milky Way was made by E. E. Barnard in 1890. It was a very bright and clear picture. It showed the structure of the Milky Way in a way that had never been seen before. It showed the spiral arms of the Milky Way, and the dark lanes of dust. It showed the stars of the Milky Way in a way that had never been seen before. It showed the Milky Way as a whole, and not just as a collection of stars.

Evidently the process is not limited to the photography of the prominences, but extends to all other peculiarities of structure which emit radiations of approximately constant wavelength; and the efficiency of the method depends very largely upon the contrast which can be obtained by the greater effect



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East \* \* ○ \* \* West

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East \*\* ○ \*\*

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On the sixth, only two stars appeared flanking Jupiter.

East \* ○ \*

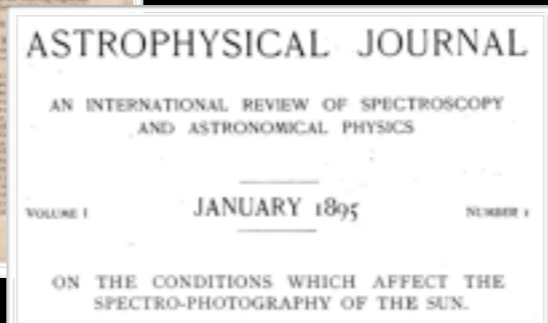
in the adjoining figure. The eastern one was 2 minutes from Jupiter, the western one 3 minutes from Jupiter. They were on the same straight line with Jupiter and equal in magnitude.

On the seventh, two stars stood near Jupiter, but not on the same straight line with it, as arranged in this manner.

1665



1895



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photography are... ted by Janens... ns of which... ined at any... tial features... f the colli-... cond slit (at... aphic plate... me spectral... use always falls on the second slit, then a photographic image of the Sun will be reproduced by light of this particular wavelength.

Evidently the process is not limited to the photography of the prominences, but extends to all other peculiarities of structure which emit radiations of approximately constant wavelength; and the efficiency of the method depends very largely upon the contrast which can be obtained by the greater exte-

# .....How to “Un”publish Graphical Data





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$\alpha$  (1875) 3h 30m 30s,  $\delta$  (1875) +31° 00'

Area  
In Perseus and Taurus

Galactic Coordinates  
127°, -18°

Scale  
1 cm = 18'.2 or 1 in = 46'.2



Chart



Plate & Chart

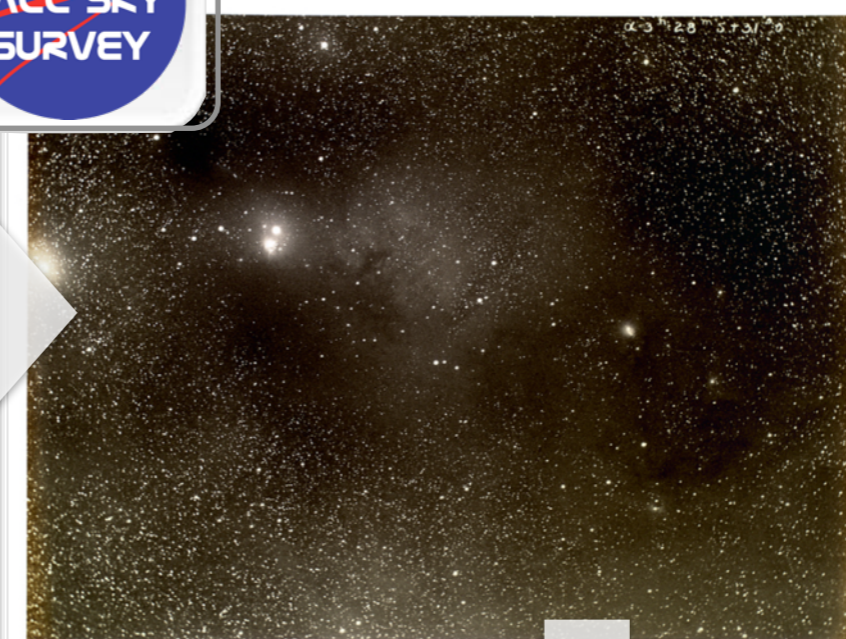
Star	Mag.
AD-54910	6.9
NGC 549	5.5
BD-54908	5.2
BD-54909	5.3
BD-54910	5.4
BD-54911	5.5
BD-54912	5.6

Table

Text

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Bar-pt1-pl003\_sm  
Barnard's Image of Perseus, from [www.library.gatech.edu/bpdi/bpdi.php](http://www.library.gatech.edu/bpdi/bpdi.php)

December 17, 2003

astrometry.net  
Hello, this is the blind astrometry solver. Your results are: (RA, Dec) center: (54.3098782184, 31.431266374) degrees Orientation: 5.21349891764 deg E of N Pixel scale: 18.5163711997 arcsec/pixel Your field contains: NGC 1465 IC 1985  $\zeta$  Per / Atik o Per 40Per 42Per NGC 1333 IC 348 IC 2003 [View in WorldWide Telescope](#) — If you would like to have other images solved, please submit them to the



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# And, soon...humans will see the invisible!



+



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ORIGIN AND EVOLUTION OF THE CEPHEUS BUBBLE

243

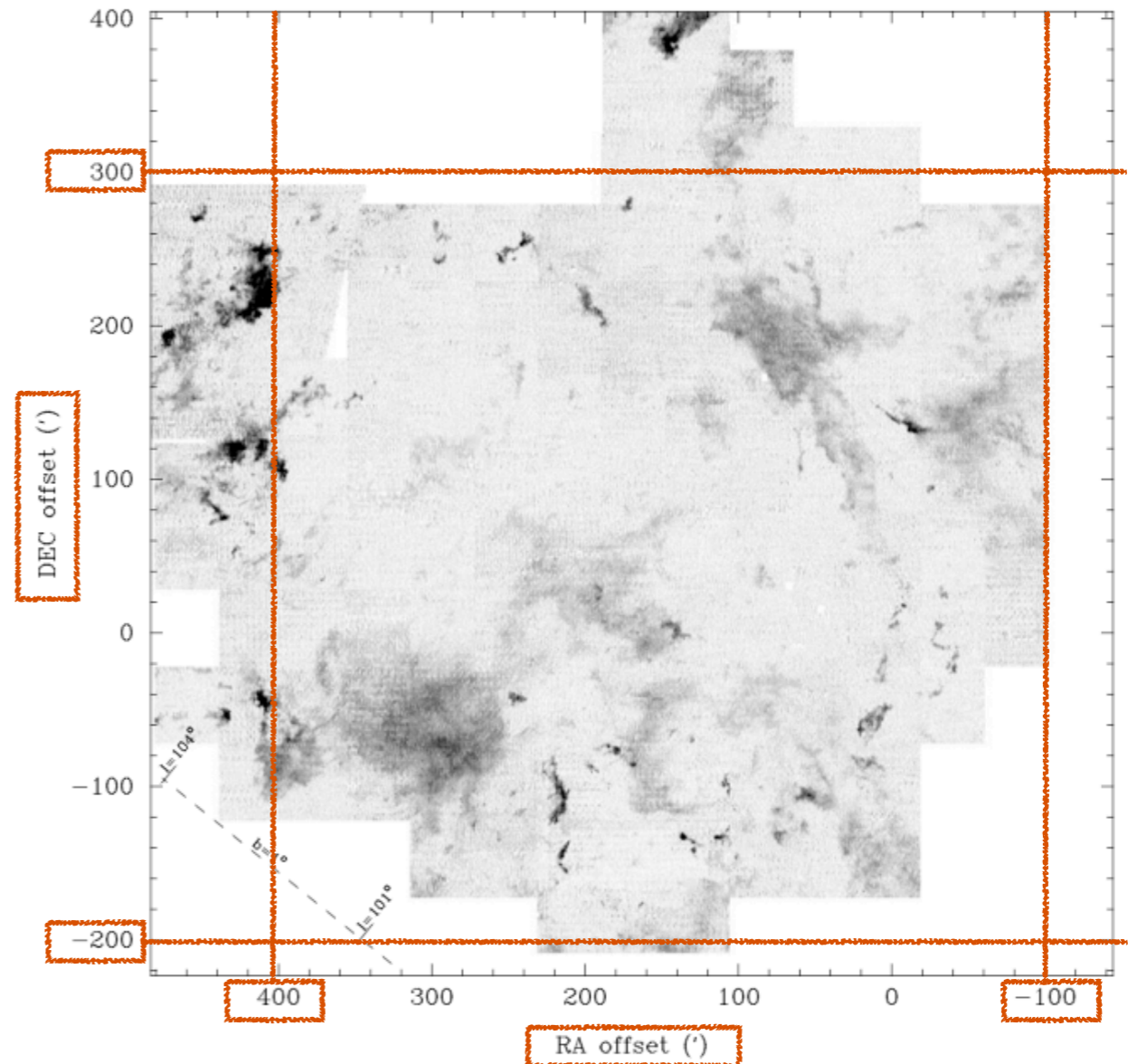
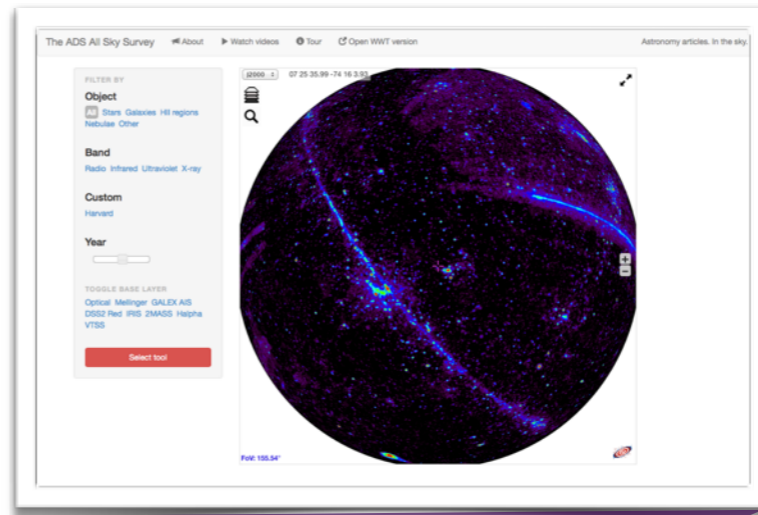

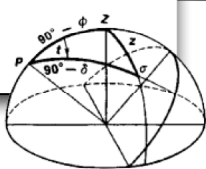


FIG. 1.—Peak intensity of CO 1–0 emission. The gray scale represents antenna temperature values scaled linearly between 0 and 3.5 K. The strongest emission occurs at the S140 region and globule A of IC 1396, where the peak antenna temperature is about 10 K. The position offsets are measured from  $\alpha(1950) = 21^{\text{h}}18^{\text{m}}00^{\text{s}}$ ,  $\delta(1950) = 59^{\circ}30'00''$ , near S129.

Patel et al. 1998, page 243, Figure 1, with markup (orange) to be made by a citizen scientist using oldAstronomy tools.


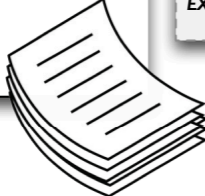


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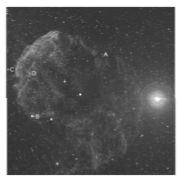
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Literature

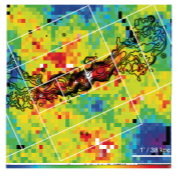



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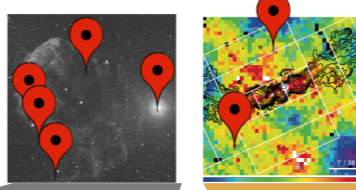
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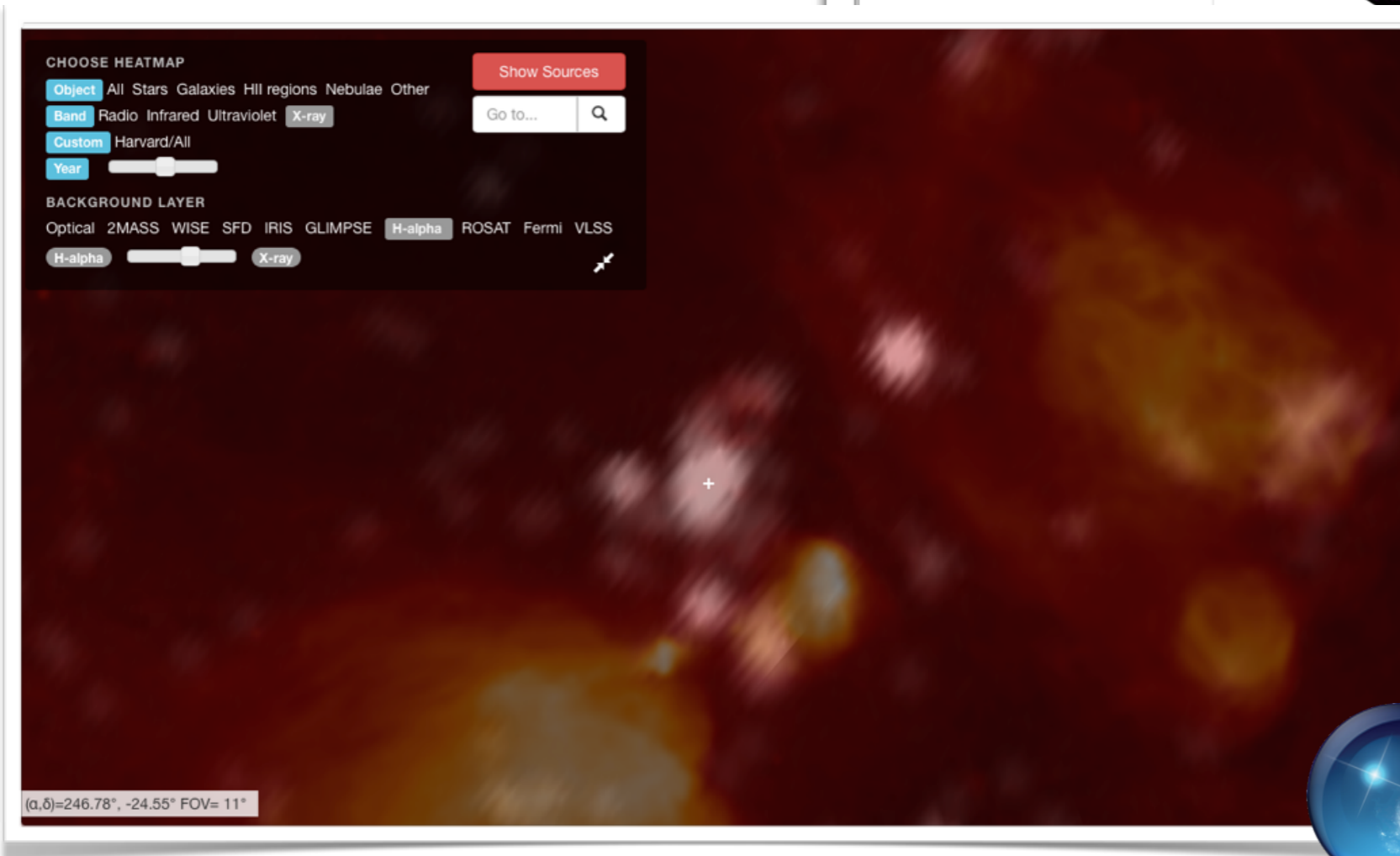
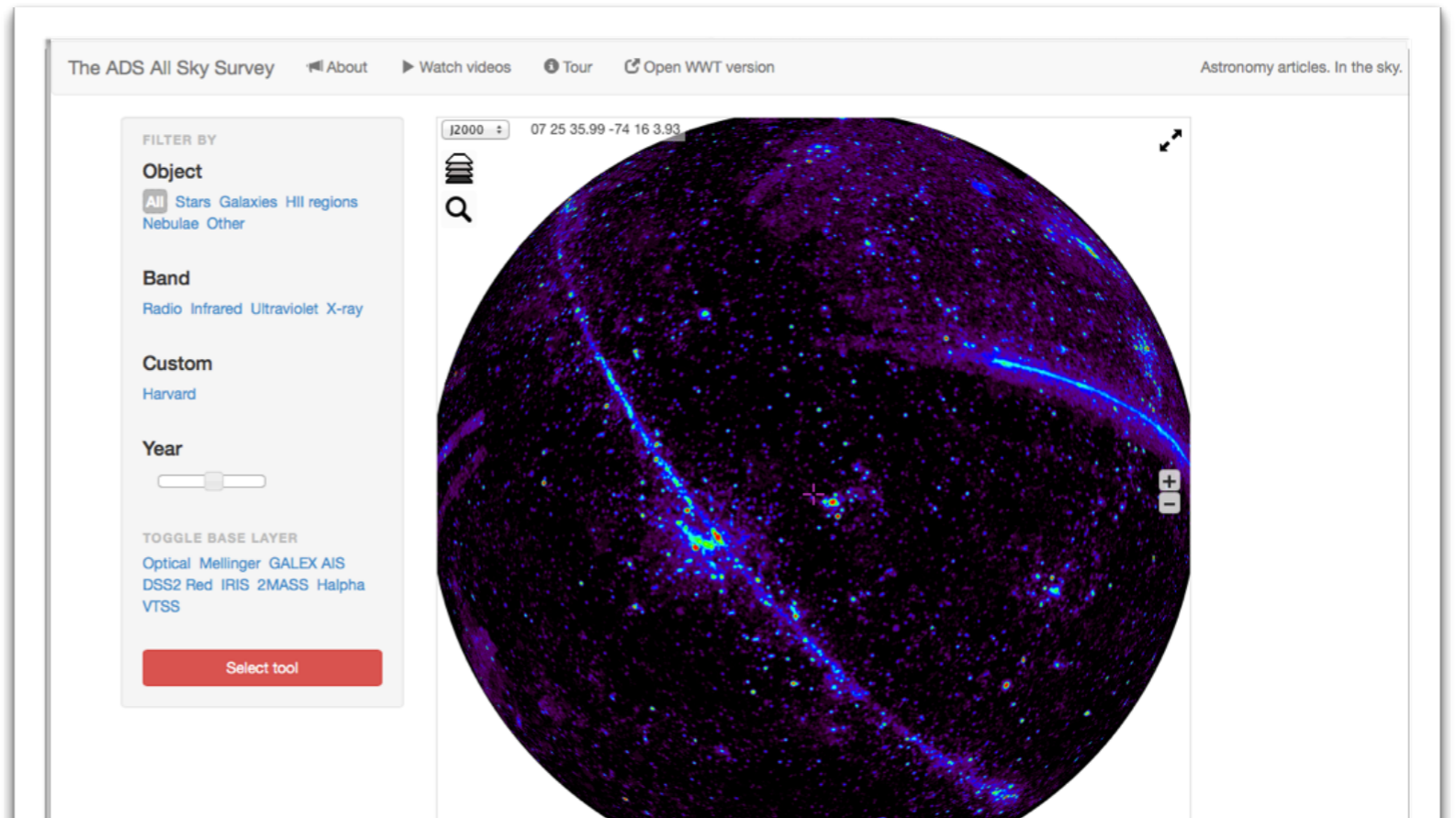


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browser, any platform*

1610



SIDEREUS NUNCIIUS

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

East \* ○ \* \* West

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East \* ○ \*

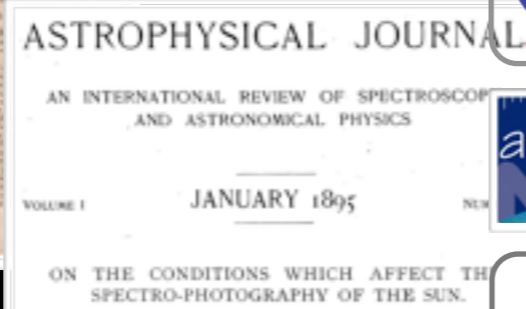
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1665



1895



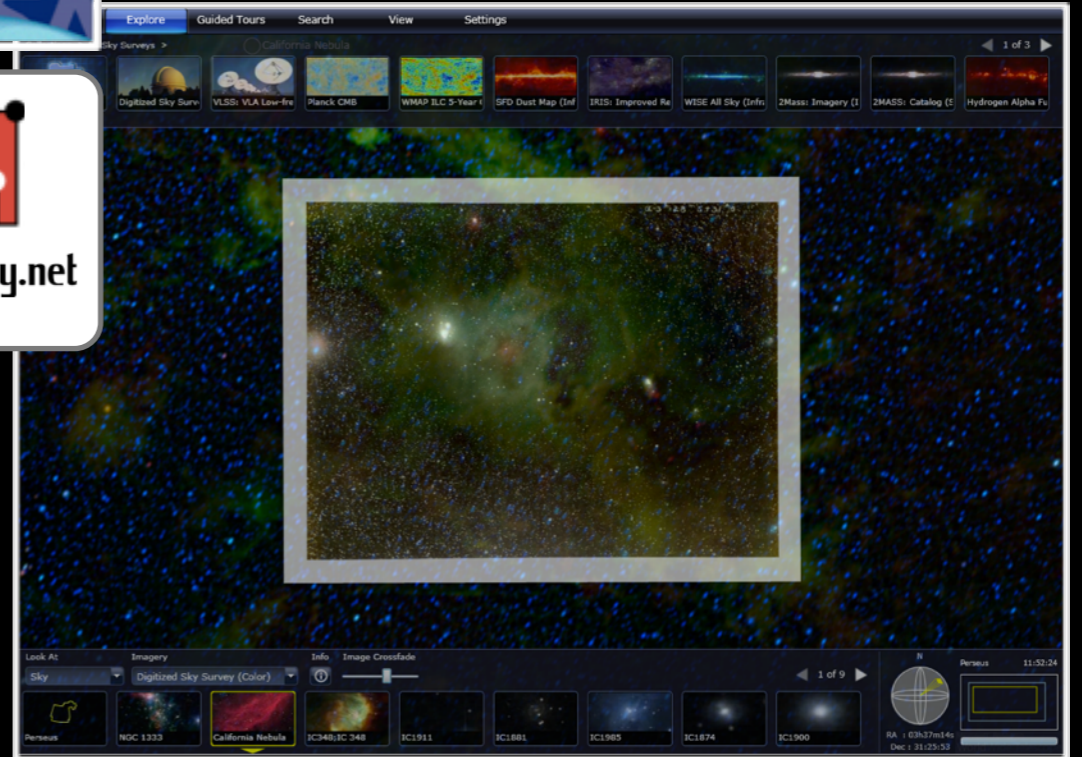
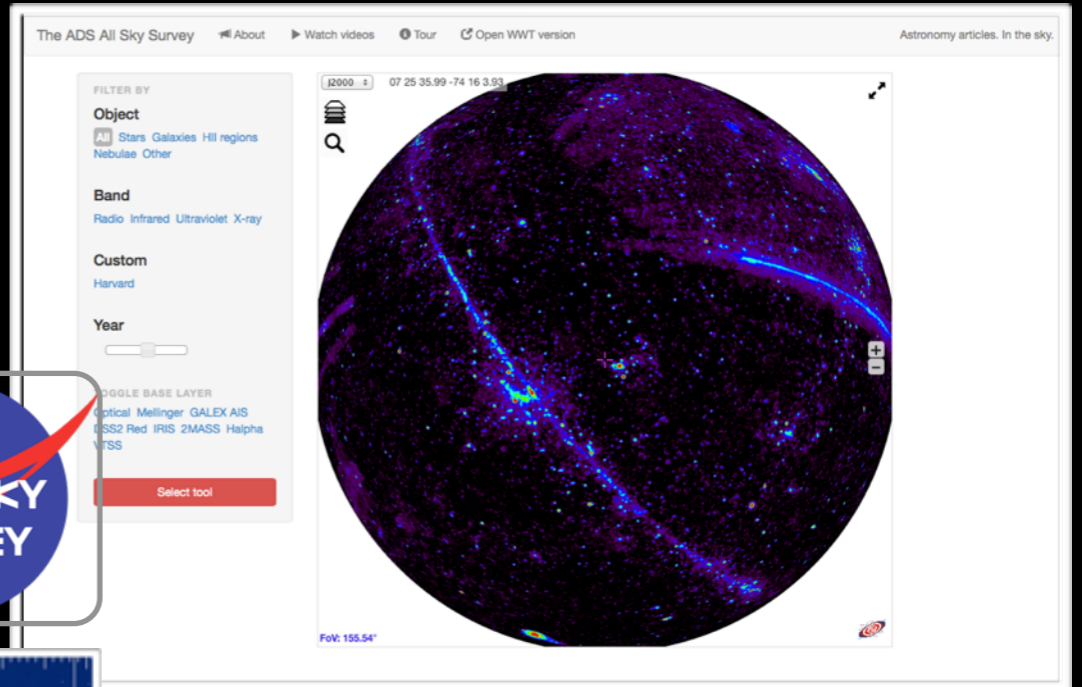
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By E. E. BARNARD.

In my photographic survey of the Milky Way with the 6-inch Willard lens of this Observatory, I have come across many very remarkable regions. Some of these, besides being remarkable for showing the peculiar structure of the Milky Way, are singularly beautiful as simple pictures of the stars. I have selected two of these for illustration in THE ASTROPHYSICAL JOURNAL.

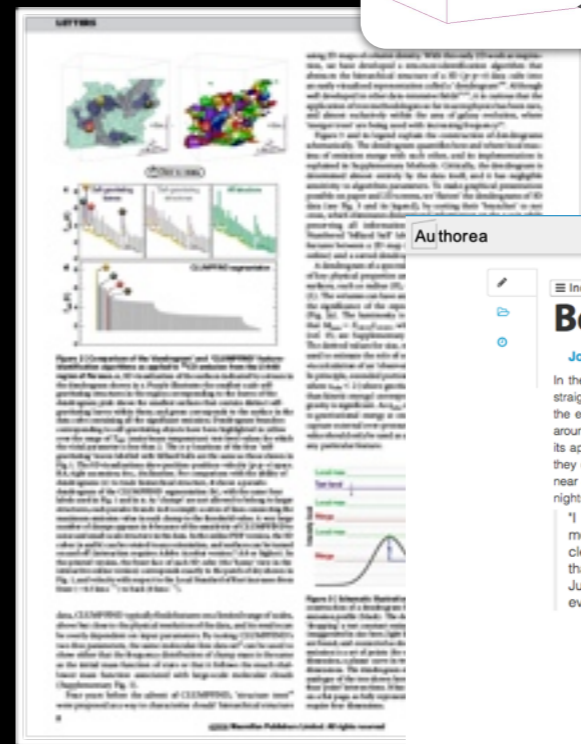
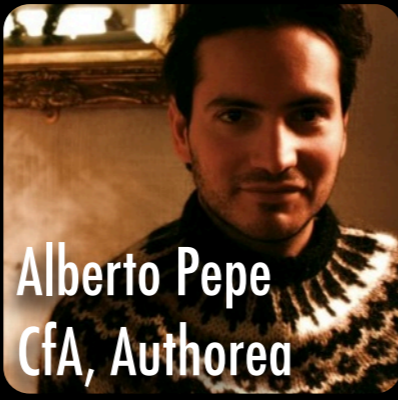
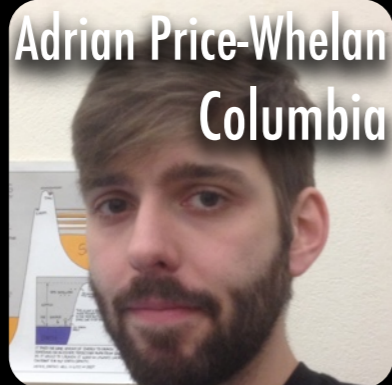
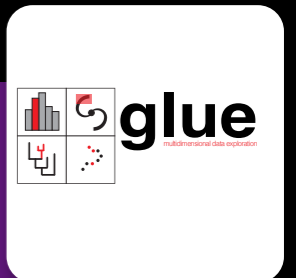
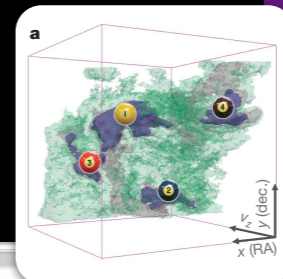
...photographed by means of a photographic camera... the image of the Sun will be reproduced by light of this particular wavelength.

Evidently the process is not limited to the photography of the prominences, but extends to all other peculiarities of structure which emit radiations of approximately constant wavelength; and the efficiency of the method depends very largely upon the contrast which can be obtained by the greater exte-

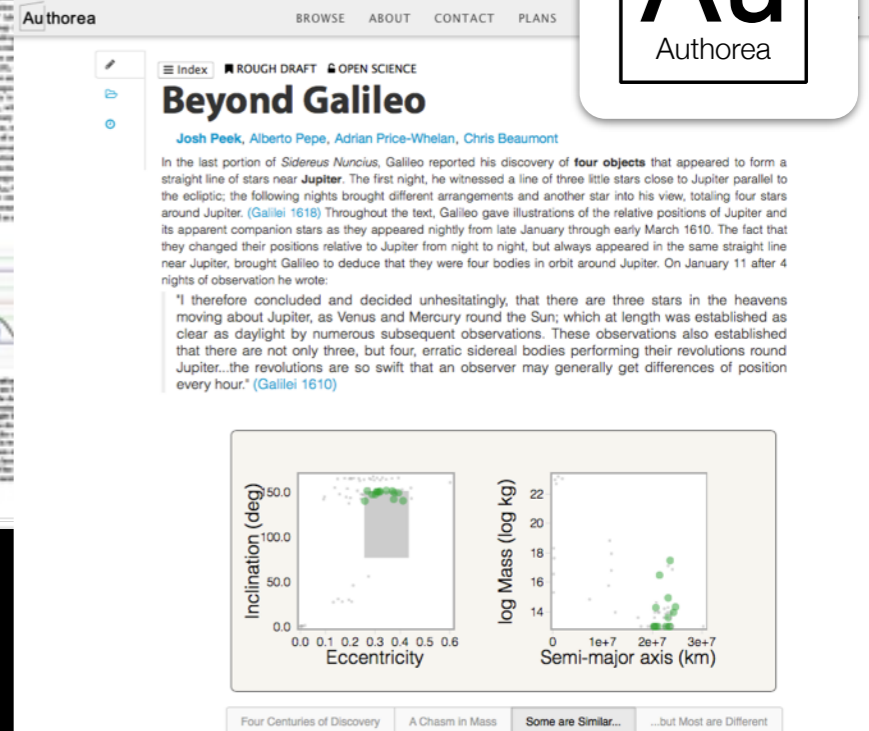


# the Riveting sequel

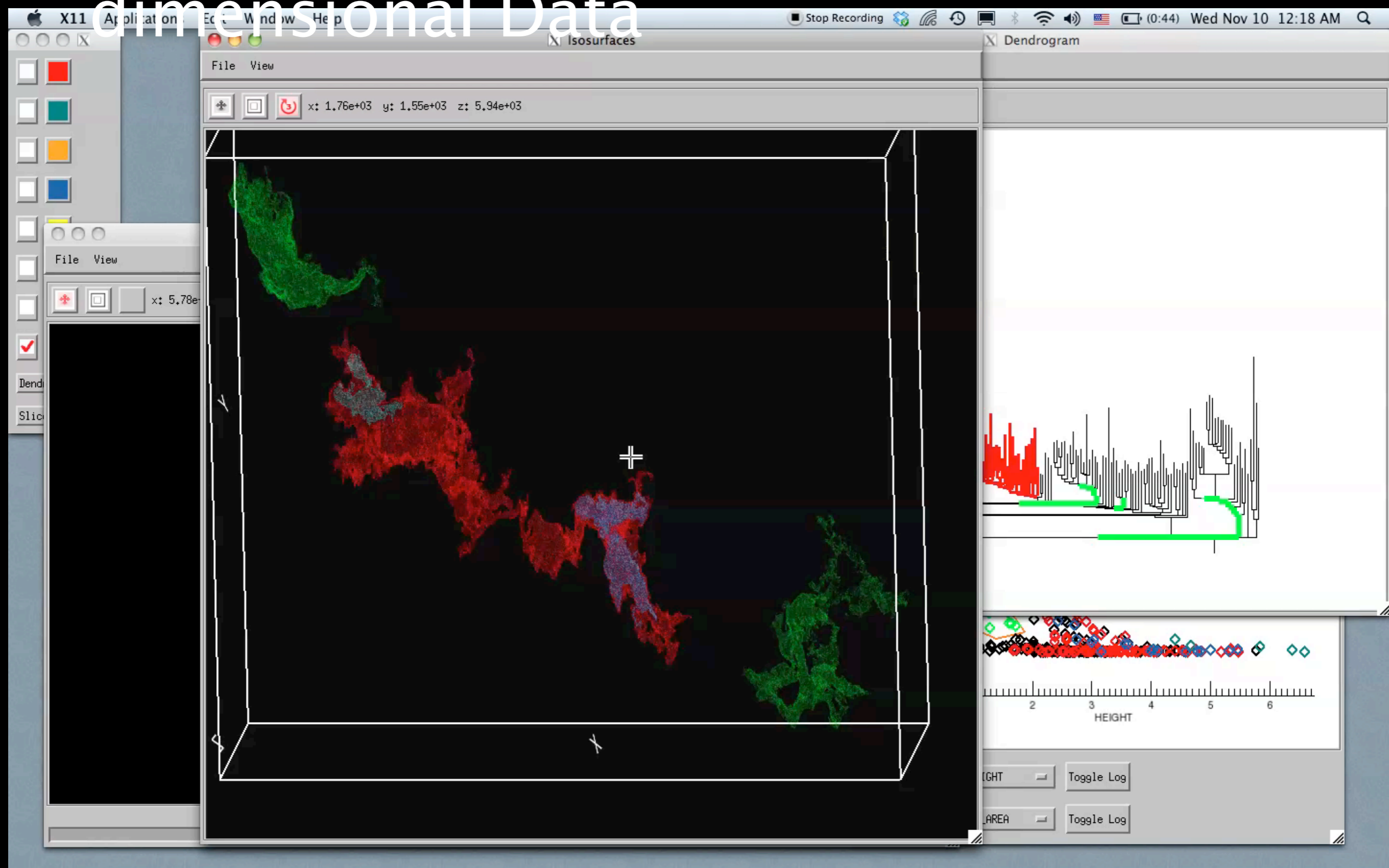
2009



2014



# Linked Views of High-dimensional Data

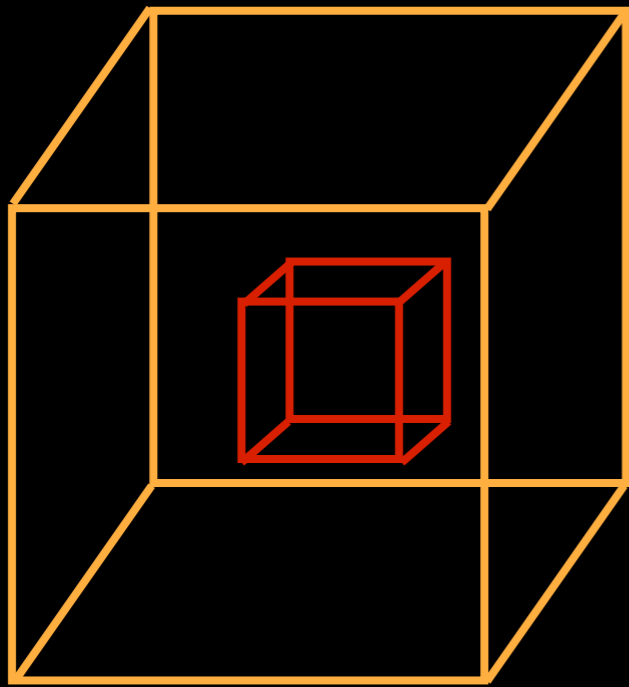


Video & implementation: **Christopher Beaumont, CfA**;  
inspired by AstroMed work of Douglas Alan, Michelle Borkin, AG, Michael Halle, Erik Rosolowsky

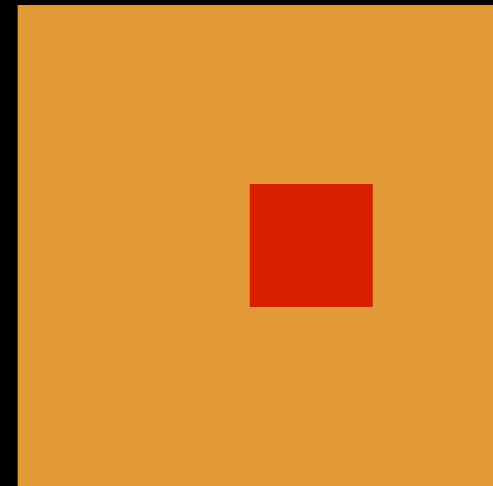
# Linked Views of High-dimensional Data



John Tukey

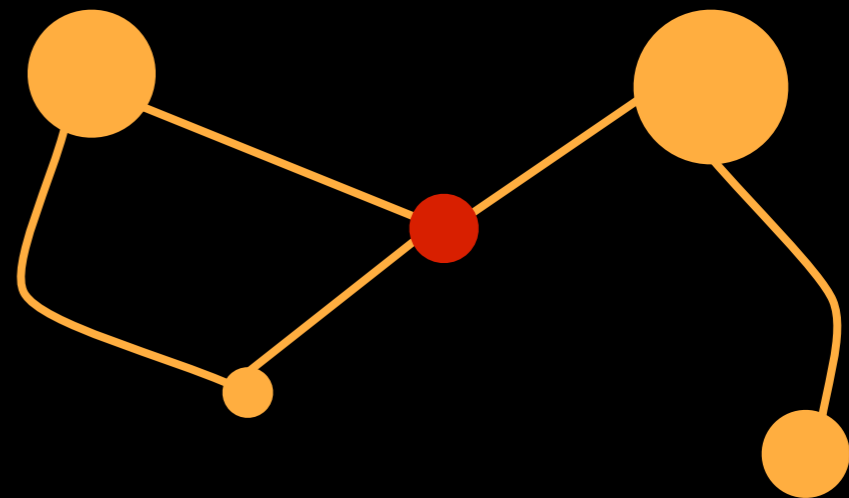


3D

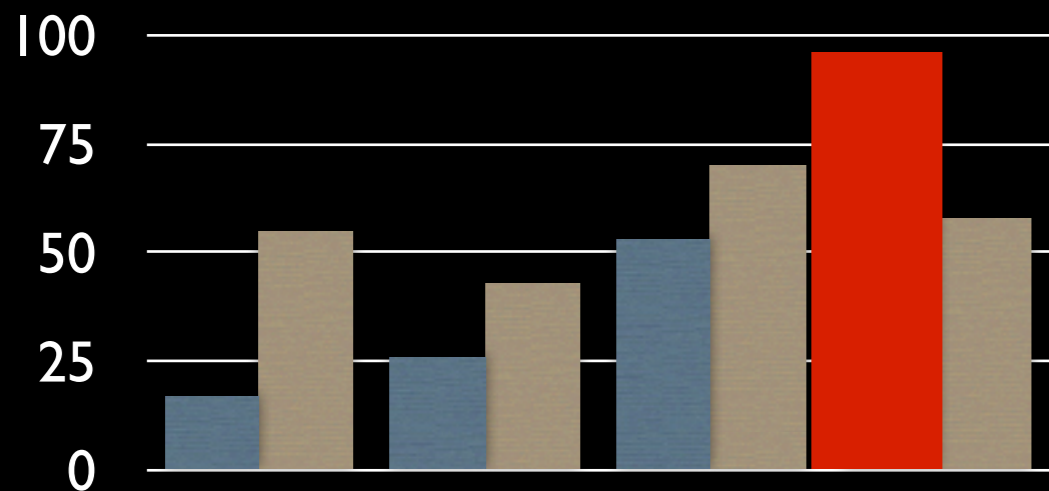


2D

## Data Abstraction

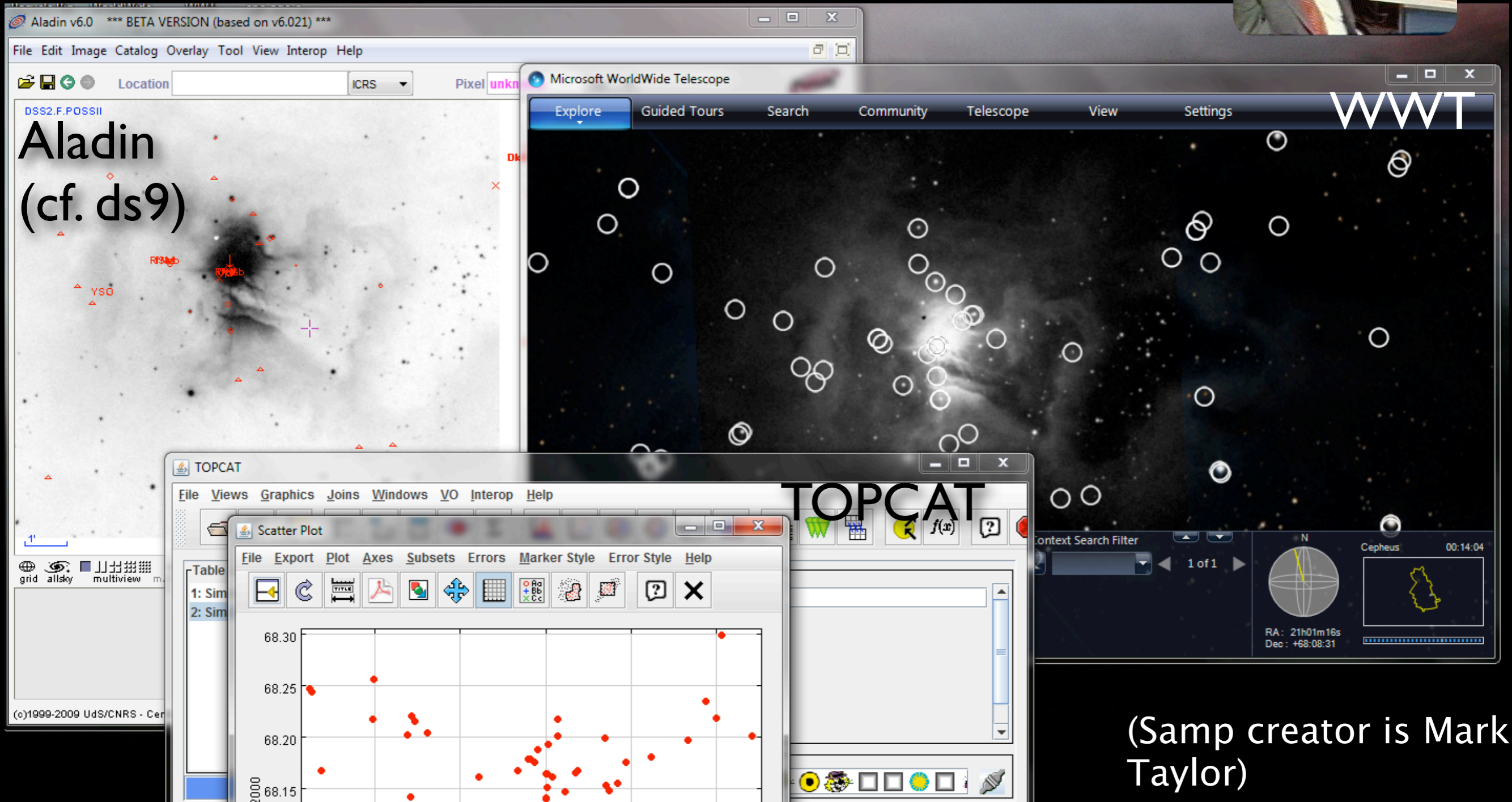
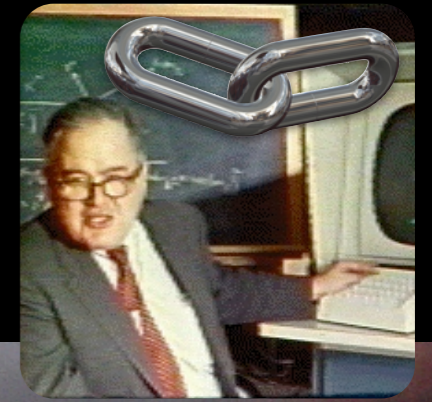


## Statistics



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

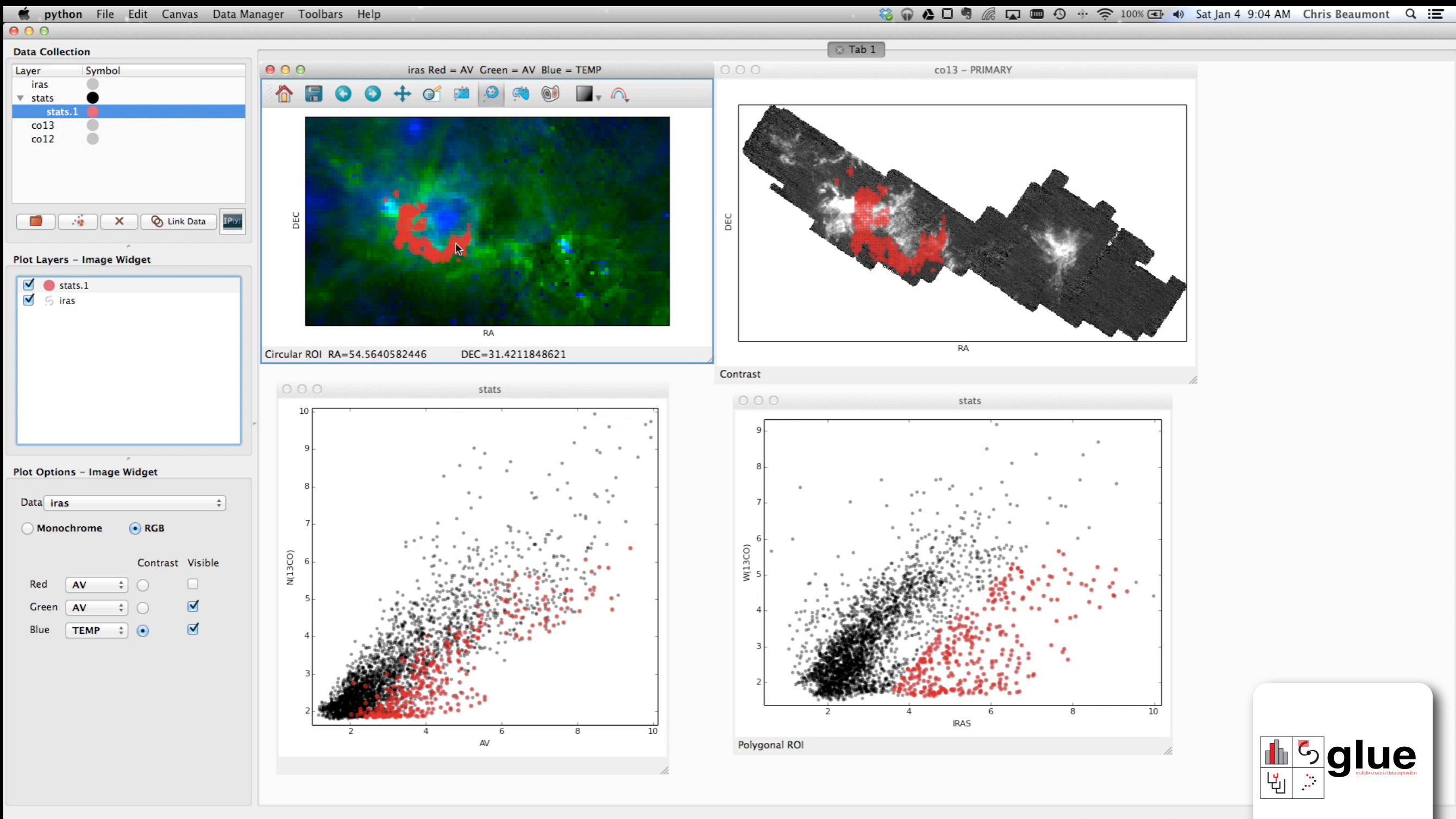
# Linked Views of High-dimensional Data



(Samp creator is Mark Taylor)

figure, showing SAMP screenshot, reproduced from [Goodman 2012](#), "Principles of High-Dimensional Data Visualization in Astronomy"

# Linked Views of High-dimensional Data Glue

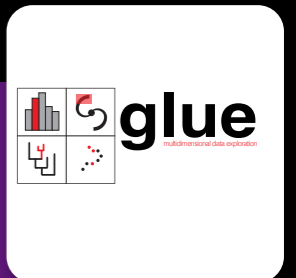
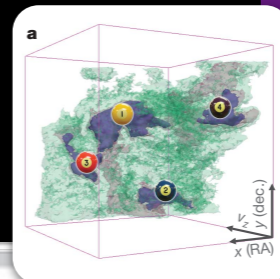


Beaumont, w/Goodman, Robitaille & Borkin

Monday, January 6, 2014

# the Riveting sequel

2009



2014

**Beyond Galileo**

Josh Peek, Alberto Pepe, Adrian Price-Whelan, Chris Beaumont

In the last portion of *Sidereus Nuncius*, Galileo reported his discovery of **four objects** that appeared to form a straight line of stars near **Jupiter**. The first night, he witnessed a line of three little stars close to Jupiter parallel to the ecliptic; the following nights brought different arrangements and another star into his view, totaling four stars around Jupiter. (Galilei 1610) Throughout the text, Galileo gave illustrations of the relative positions of Jupiter and its apparent companion stars as they appeared nightly from late January through early March 1610. The fact that they changed their positions relative to Jupiter from night to night, but always appeared in the same straight line near Jupiter, brought Galileo to deduce that they were four bodies in orbit around Jupiter. On January 11 after 4 nights of observation he wrote:

"I therefore concluded and decided unhesitatingly, that there are three stars in the heavens moving about Jupiter, as Venus and Mercury round the Sun; which at length was established as clear as daylight by numerous subsequent observations. These observations also established that there are not only three, but four, erratic sidereal bodies performing their revolutions round Jupiter...the revolutions are so swift that an observer may generally get differences of position every hour." (Galilei 1610)

**Figure 1** Shows the relative positions of the four objects near Jupiter as reported by Galileo in 1610. The objects are labeled 1 through 4. The plot shows their positions in the sky relative to Jupiter and the ecliptic.

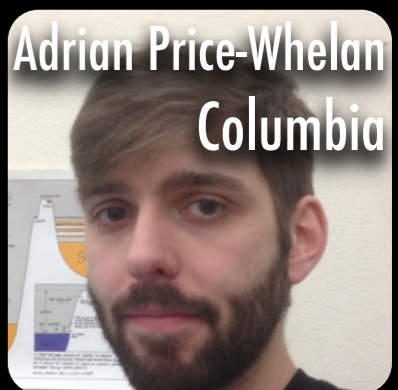
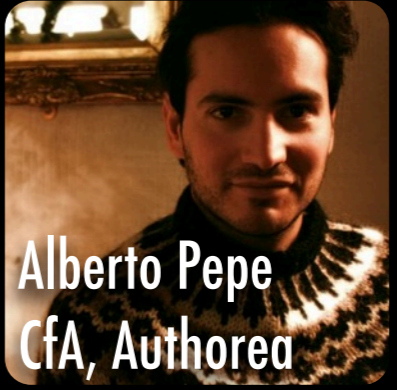
**Figure 2** Shows the inclination (deg) versus eccentricity of the four objects. The plot shows that the objects have low eccentricities and low inclinations.

**Figure 3** Shows the log Mass (log kg) versus Semi-major axis (km) for the four objects. The plot shows that the objects have low masses and small semi-major axes.





# “The Story & the Sandbox” (Glue:D3PO:Authorea)



Authorea

BROWSE ABOUT CONTACT PLANS FEEDBACK HELP JOSH PEEK ▾

Index ROUGH DRAFT OPEN SCIENCE Settings Fork Quick edit Tour 0 Comments Export

## Beyond Galileo

Josh Peek, Alberto Pepe + Add author

In the last portion of *Sidereus Nuncius*, Galileo reported his discovery of **four objects** that appeared to form a straight line of stars near **Jupiter**. The first night, he witnessed a line of three little stars close to Jupiter parallel to the ecliptic; the following nights brought different arrangements and another star into his view, totaling four stars around Jupiter. (Galilei 1618) Throughout the text, Galileo gave illustrations of the relative positions of Jupiter and its apparent companion stars as they appeared nightly from late January through early March 1610. The fact that they changed their positions relative to Jupiter from night to night, but always appeared in the same straight line near Jupiter, brought Galileo to deduce that they were four bodies in orbit around Jupiter. On January 11 after 4 nights of observation he wrote:

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glue d3po Au Authorea

# The future is in line




**10 Simple Rules for the Care and Feeding of Scientific Data**

Alyssa Goodman, Alberto Pepe, Alexander W. Blocker, Christine L. Borgman, Kyle Cranmer, Merce Crosas, Rosanne Di Stefano, Yolanda Gil, Paul Groth, Margaret Hedstrom, David W. Hogg, Vinay Kashyap, Ashish Mahabal, Aneta Siemiginowska, Aleksandra Slavkovic

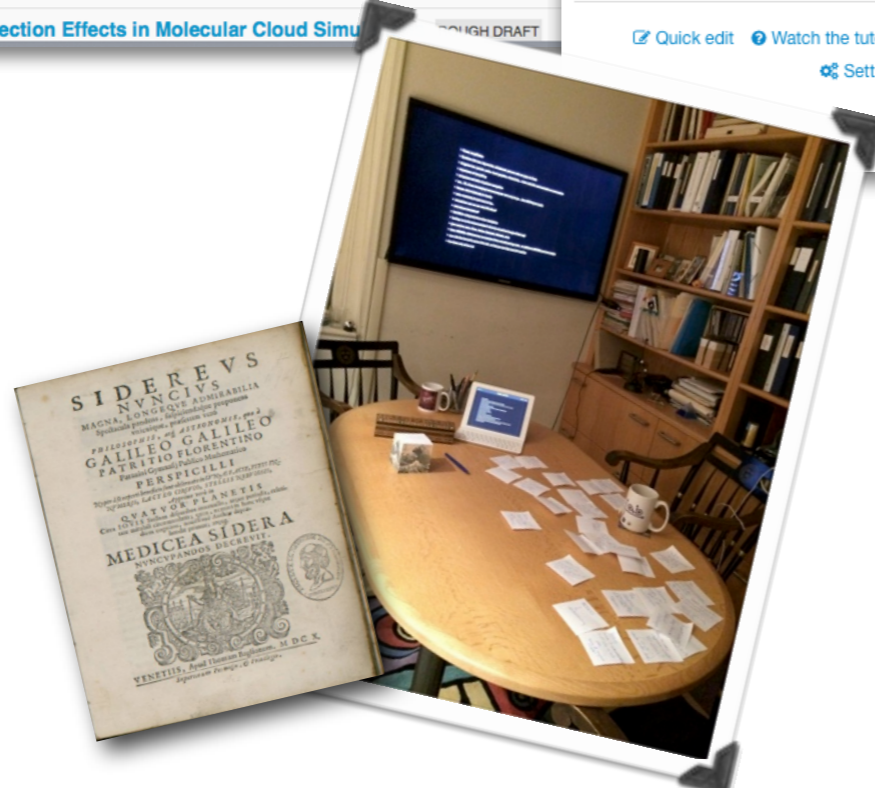
**Introduction**

In the early 1600s, Galileo Galilei turned a telescope toward Jupiter. In his log book each night, he drew to-scale schematic diagrams of Jupiter and some oddly-moving points of light near it. Galileo labeled each drawing with the date. Eventually he used his observations to conclude that the Earth orbits the Sun, just as the four Galilean moons orbit Jupiter. History shows Galileo to be much more than an astronomical hero, though. His clear and careful record keeping and publication style not only let Galileo understand the Solar System, it continues to let *anyone* understand *how* Galileo did it. Galileo's notes directly integrated his **data** (drawings of Jupiter and its moons), key **metadata** (timing of each observation, weather, telescope properties), and **text** (descriptions of methods, analysis, and conclusions). Critically, when Galileo included the information from those notes in *Siderius Nuncius* (Galilei 1610), this integration of text, data and metadata was preserved, as shown in Figure 1. Galileo's work advanced the "Scientific Revolution," and his approach to observation and analysis contributed significantly to the shaping of today's modern "Scientific Method" (Galilei 1618, Drake 1957).

Today most research projects are considered complete when a journal article based on the analysis has been written and published. Trouble is, unlike Galileo's report in *Siderius Nuncius*, the amount of real data and data description in modern publications is almost never sufficient to repeat or even statistically verify a study being presented. Worse, researchers wishing to build upon and extend work presented in the literature often have trouble recovering data associated with an article after it has been published. More often than scientists would like to admit, they cannot even recover the data associated with their own published works.

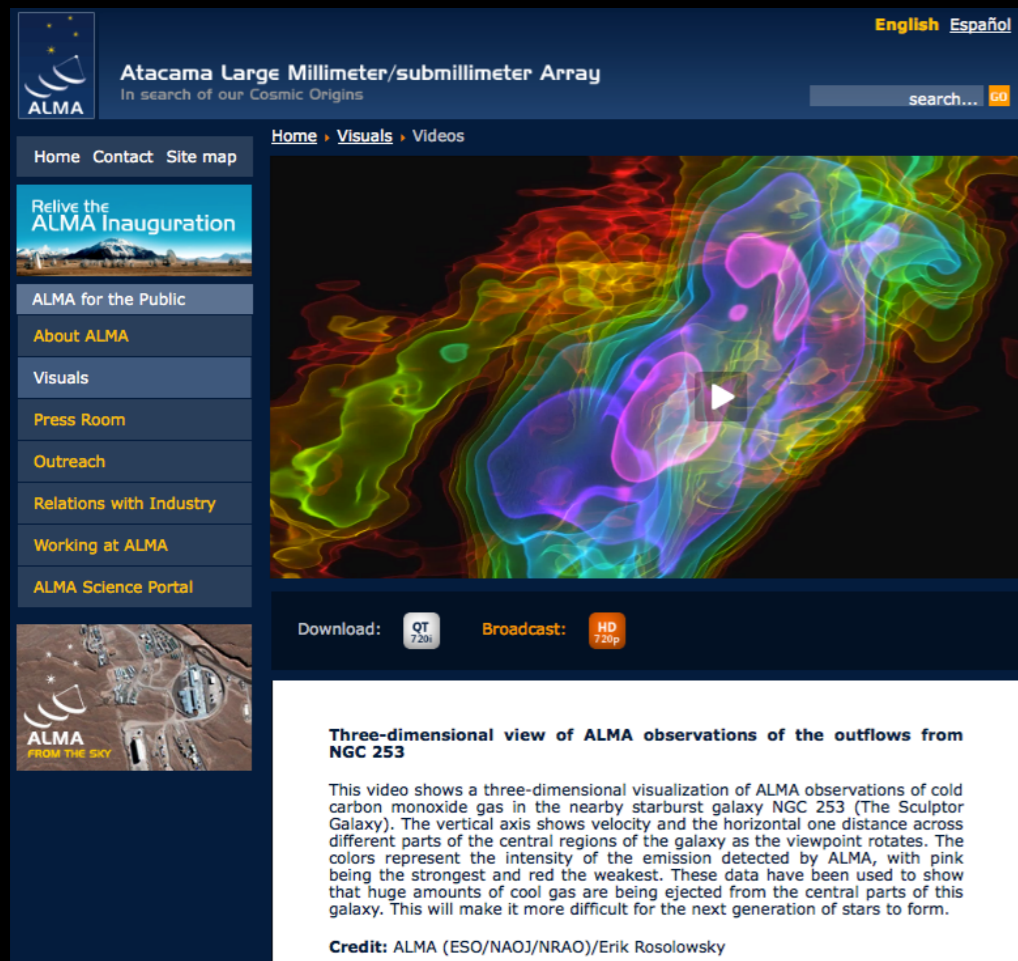
But we do need to figure out how to

What's an "Acid-Free" digital Record?



tinyurl.com/acidfreedigital

# The future is in 3D



Atacama Large Millimeter/submillimeter Array  
In search of our Cosmic Origins

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Relive the ALMA Inauguration

ALMA for the Public

About ALMA

Visuals

Press Room

Outreach

Relations with Industry

Working at ALMA

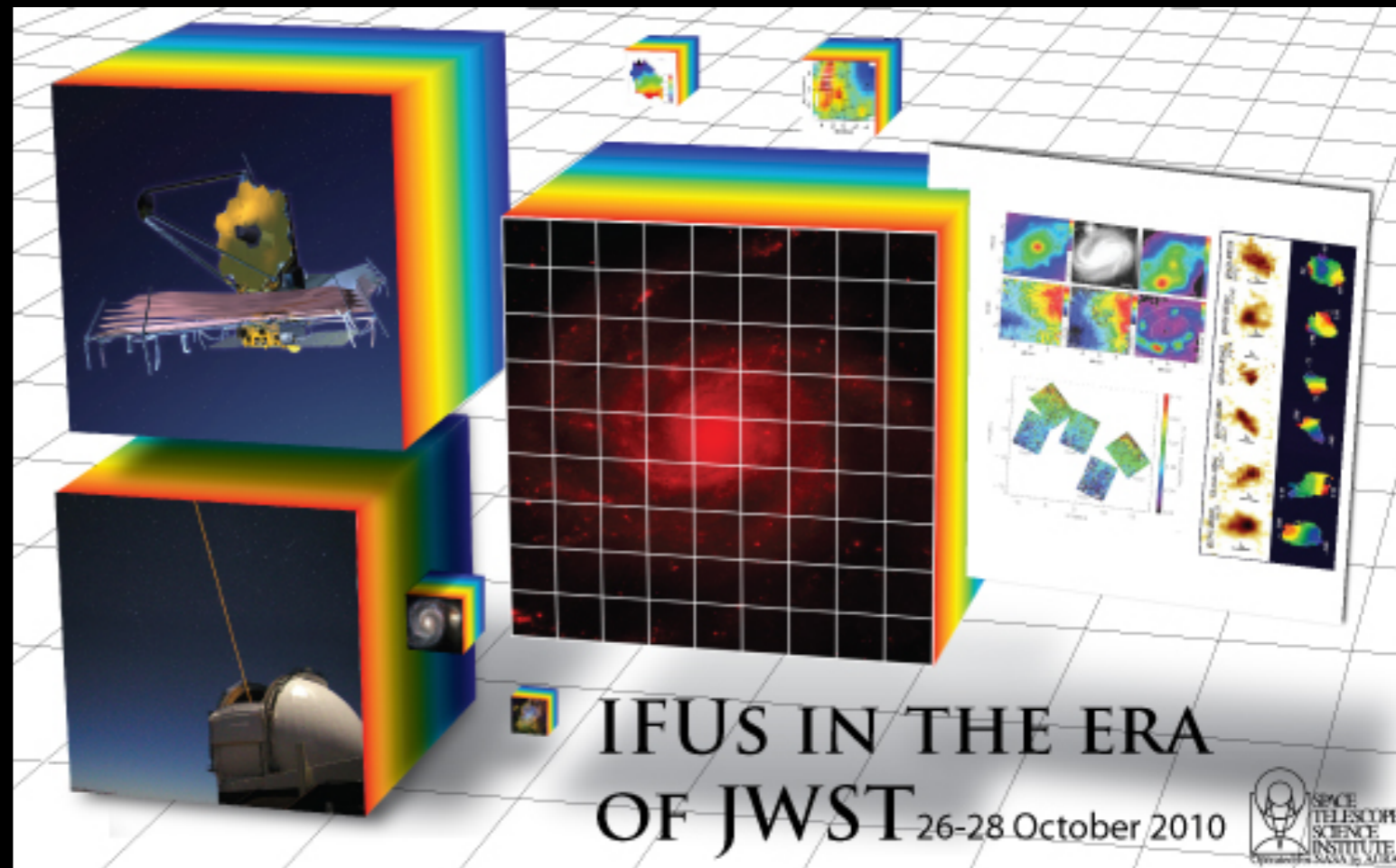
ALMA Science Portal

Download: QT 720p Broadcast: HD 720p

**Three-dimensional view of ALMA observations of the outflows from NGC 253**

This video shows a three-dimensional visualization of ALMA observations of cold carbon monoxide gas in the nearby starburst galaxy NGC 253 (The Sculptor Galaxy). The vertical axis shows velocity and the horizontal one distance across different parts of the central regions of the galaxy as the viewpoint rotates. The colors represent the intensity of the emission detected by ALMA, with pink being the strongest and red the weakest. These data have been used to show that huge amounts of cool gas are being ejected from the central parts of this galaxy. This will make it more difficult for the next generation of stars to form.

Credit: ALMA (ESO/NAOJ/NRAO)/Erik Rosolowsky



IFUS IN THE ERA OF JWST 26-28 October 2010

SPACE TELESCOPE SCIENCE INSTITUTE

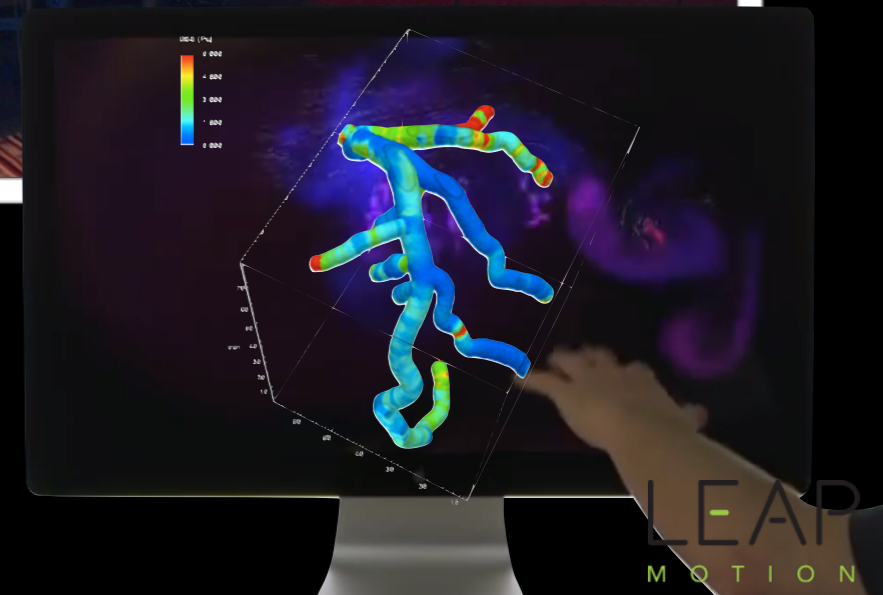
yt viz from ALMA data  
(Turk, Rosolowsky)

IFUs on JWST...with Glue!  
(coming soon)

# The future is modular, Open-Source,

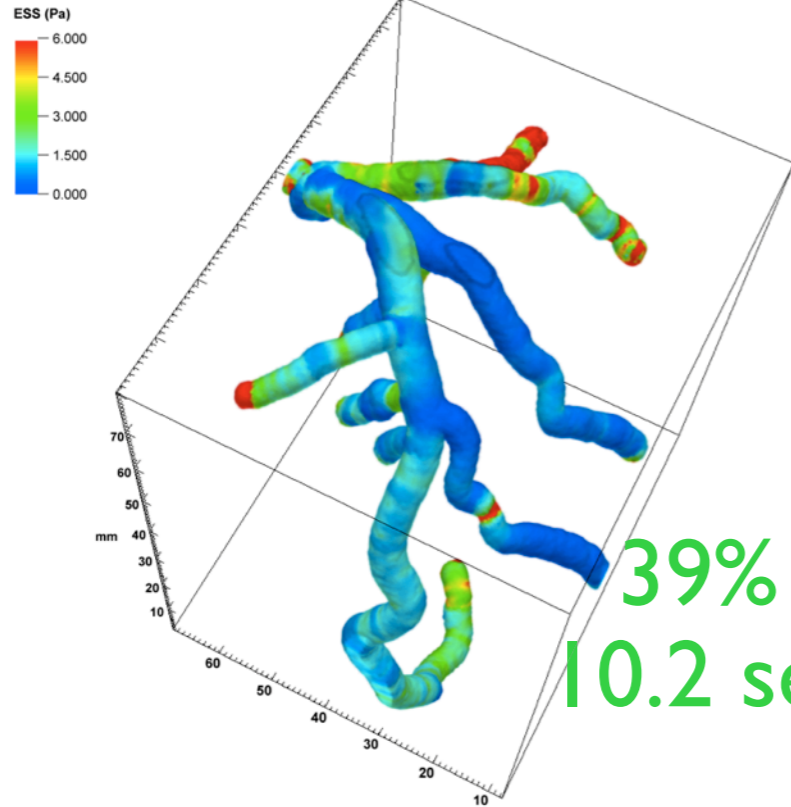


**HACK  
TO THE FUTURE**

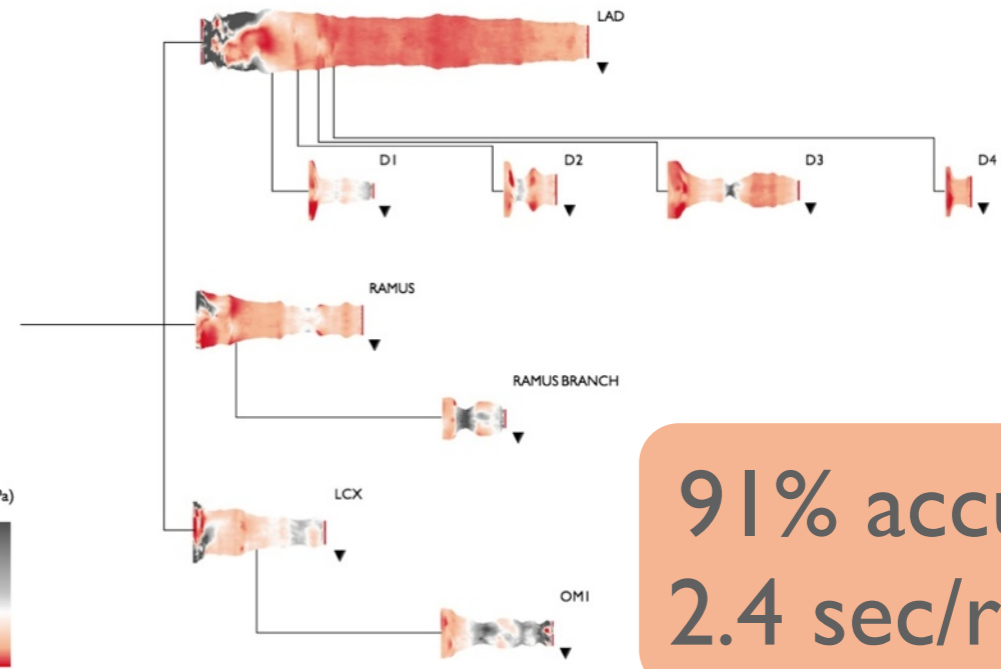


LEAP  
MOTION

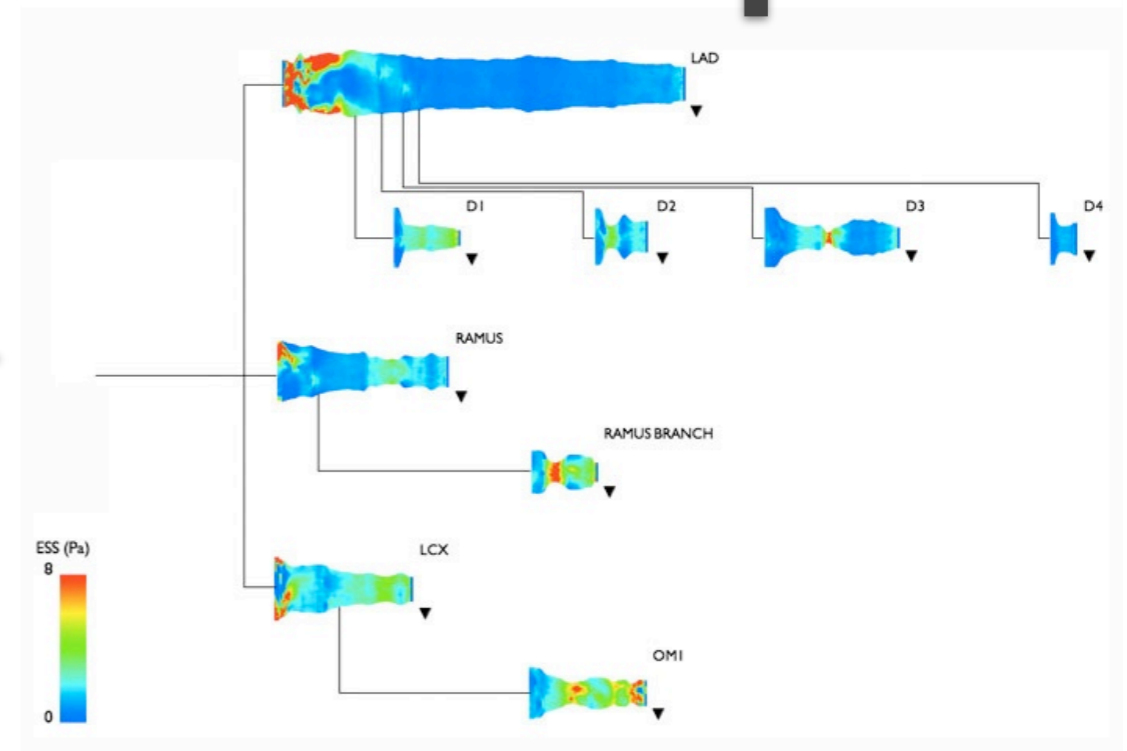
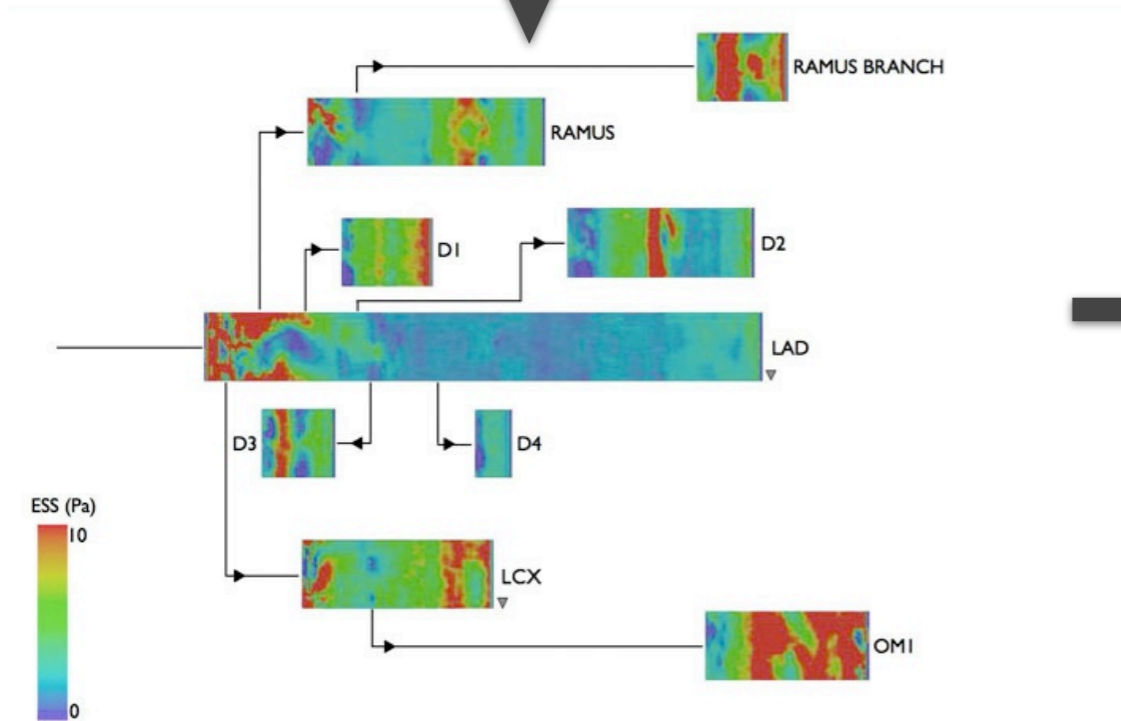
# Dimensionality and Color



39% accurate  
10.2 sec/region



91% accurate  
2.4 sec/region



Borkin et al. 2011  
cf. colorbrewer2.org

# The Future offers new Ways to learn

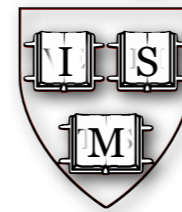
## WorldWide Telescope Ambassadors

## Higher Ed



the 2013 experiment

HARVARD UNIVERSITY  
ASTRONOMY 201B  
DEMOFEST



LOCATION

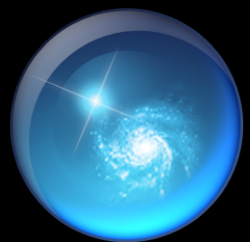
Perkin Lobby and Wolbach Library, 60 Garden Street

TIME

11-12 for drop-in demos  
12-12:45 lunch for students & their guests

PREVIEW

<http://ay201b.wordpress.com/topical-modules>



# Microsoft® Research WorldWide Telescope



Experience WWT at [worldwidetelescope.org](http://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 grid of image thumbnails: 'Digitized Sky Survey', 'VLSS: VLA Low-frequency Sky Survey', 'WMAP ILC 5-Year Cosmic Microwave Background', 'SFD Dust Map (Infrared)', 'IRIS: Improved Resolution', '2MASS: Two Micron All Sky Survey', and 'Hydrogen Alpha Filter'. The main view shows a 3D rendering of the Andromeda galaxy with a circular 'Finder Scope' overlaid. A 'Finder Scope' window is open, showing a thumbnail of NGC224, its classification as a 'Spiral Galaxy in Andromeda', and various astronomical coordinates (RA, Dec, Alt, Az, Rise, Transit, Set) and image credits. At the bottom, there is a 'Look At' dropdown set to 'Sky', an 'Imagery' section with 'Digitized Sky Survey' and 'Three Faces of Andromeda' thumbnails, a 'Context bar' with thumbnails for 'NGC221' and 'M31', a 'Context globe' showing the current field of view, and a 'Context globe' showing the location of the current field of view on a larger celestial map.

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.

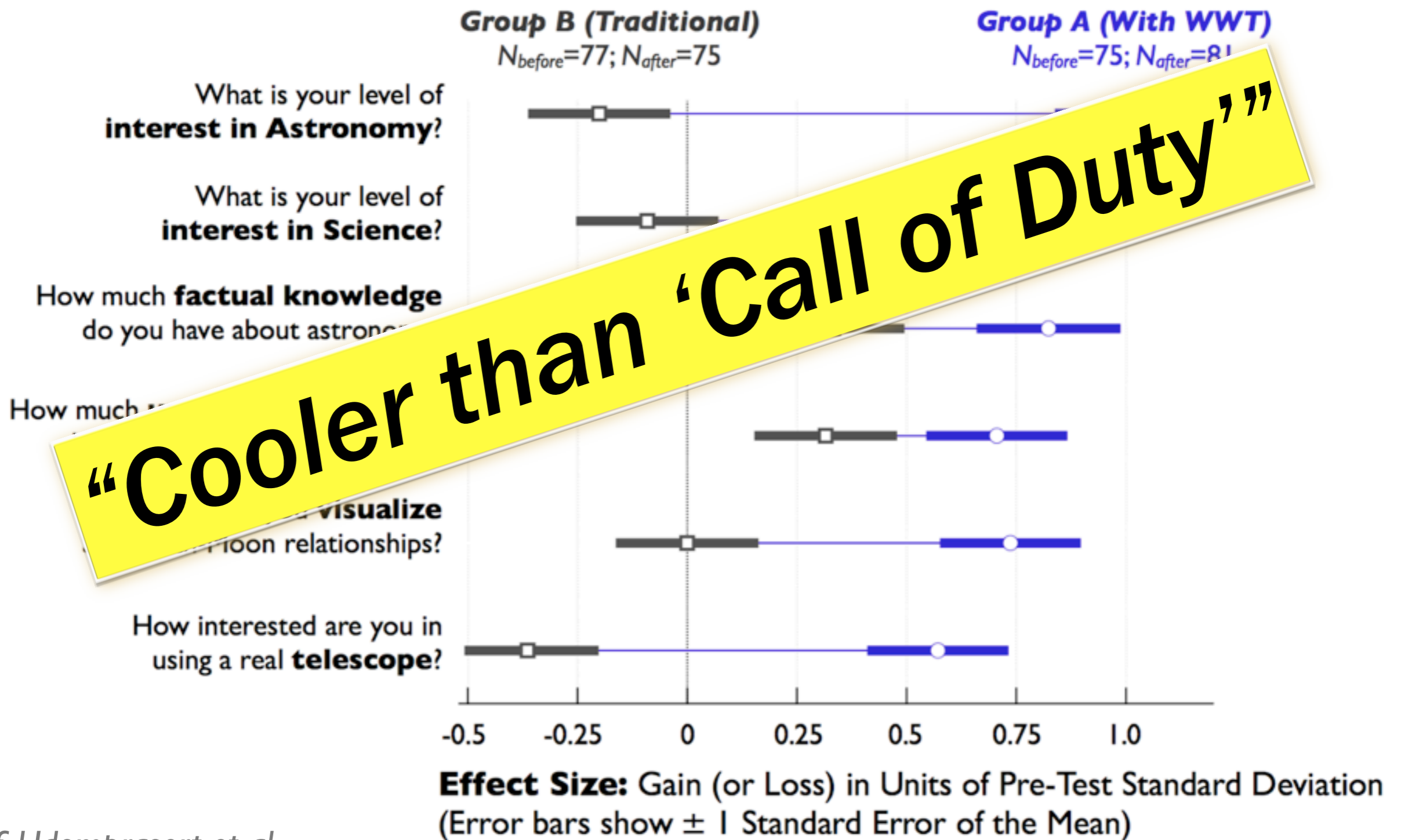
Finder Scope links to Wikipedia, publications, and data, so you can learn more

Context bar shows items of interest in current field of view

Context globe shows where you're looking.

WWT created by Curtis Wong & Jonathan Fay

# Gains in Student Interest and Understanding

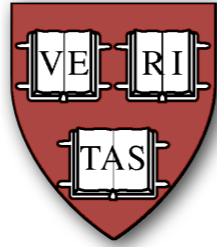
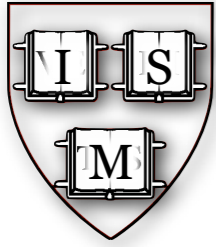


cf. Udomprasert et al.



the 2013 experiment

# HARVARD UNIVERSITY ASTRONOMY 201B DEMOFEST



## LOCATION

Perkin Lobby and Wolbach Library, 60 Garden Street

## TIME

11-12 for drop-in demos  
12-12:45 lunch for students & their guests

## PREVIEW

<http://ay201b.wordpress.com/topical-modules>



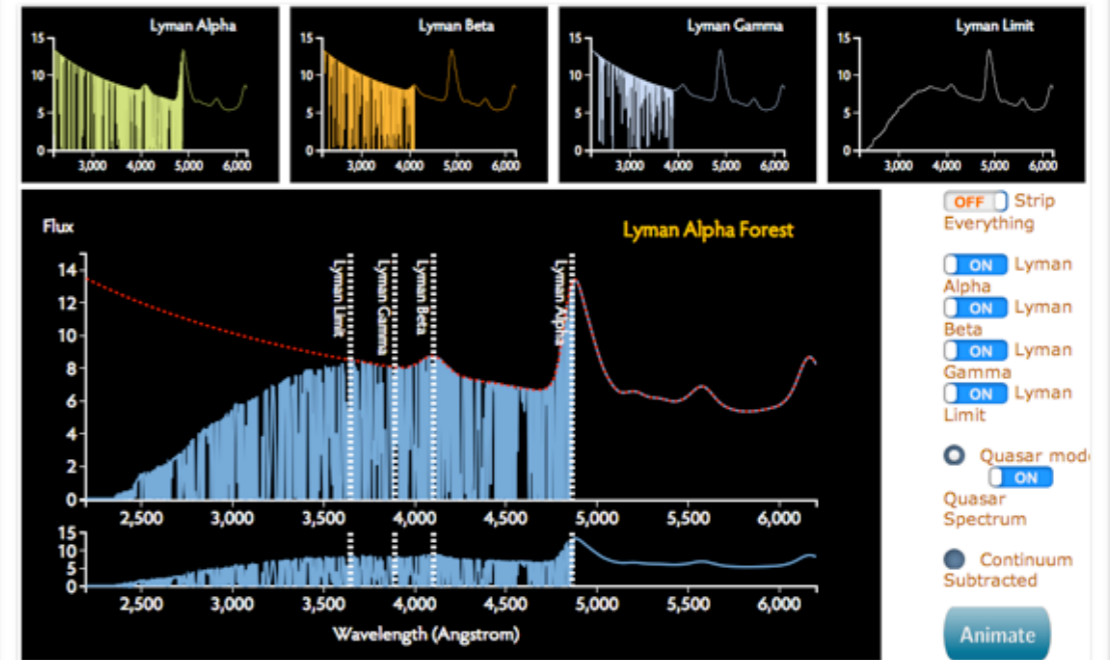
# Viz in Higher-Ed

Stephen

all lines SII 6716/6731 A He 6553 A OIII 5007 A

Yuan-Sen  
Ting

## Interstellar Absorption and the Lyman Alpha Forest



 JavaScript

[https://www.cfa.harvard.edu/~yuan-sen.ting/lyman\\_alpha.html](https://www.cfa.harvard.edu/~yuan-sen.ting/lyman_alpha.html)

 JavaScript

<http://portillo.ca/nebula/>

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

# Challenges

What can we afford?

What do we teach?

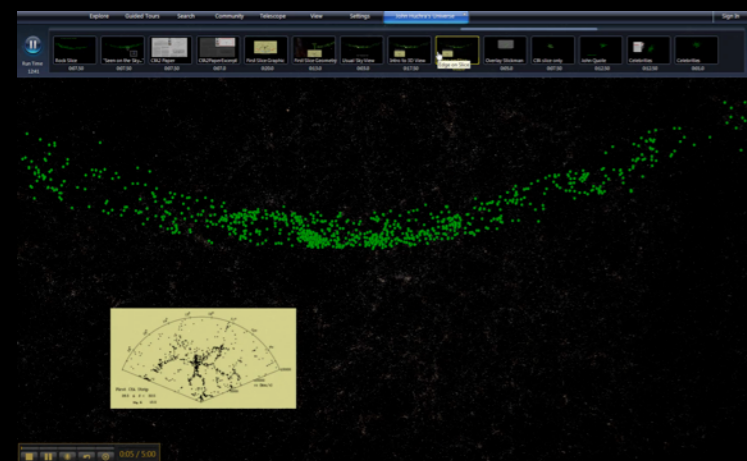
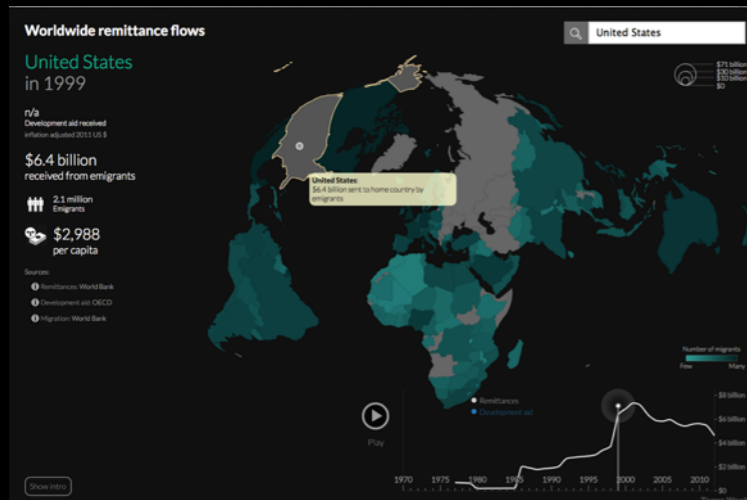
Is visualization, and computation more generally, the new "instrumentation"?

How do we value visualization specialists?

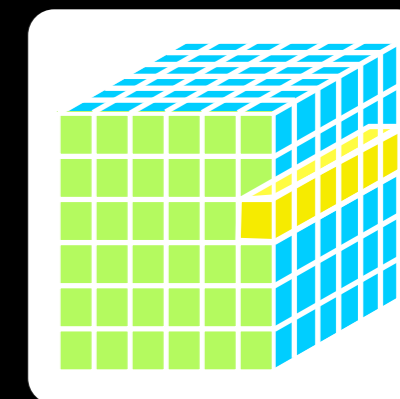
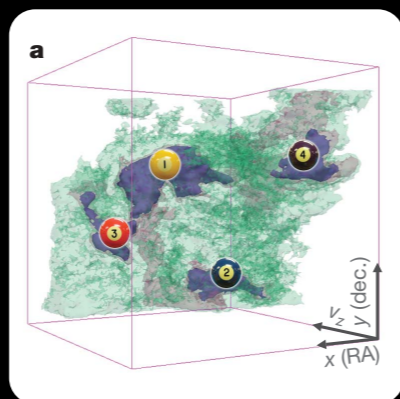
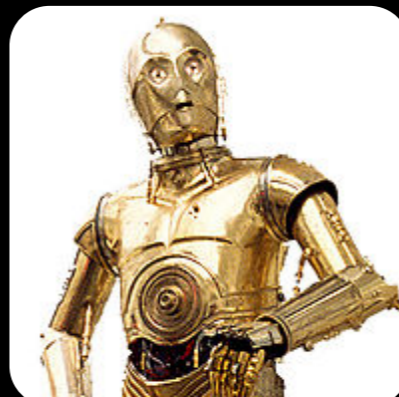
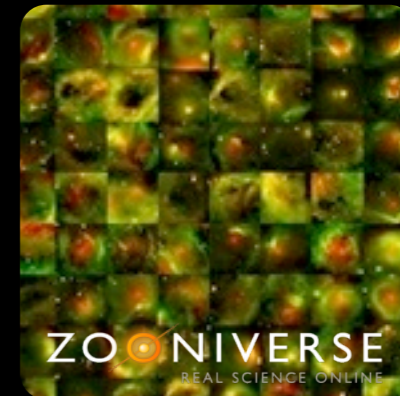
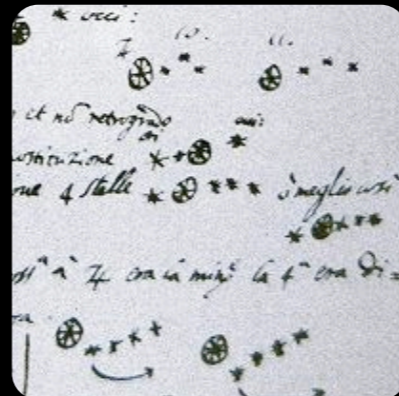
How much customization?

Will tools be preserved?

How much organization (orchestration) is too much?



# Linking Visualization & Understanding



# Linking Visualization & Understanding

Lyssa A. Goodman  
Harvard-Smithsonian  
Center for Astrophysics

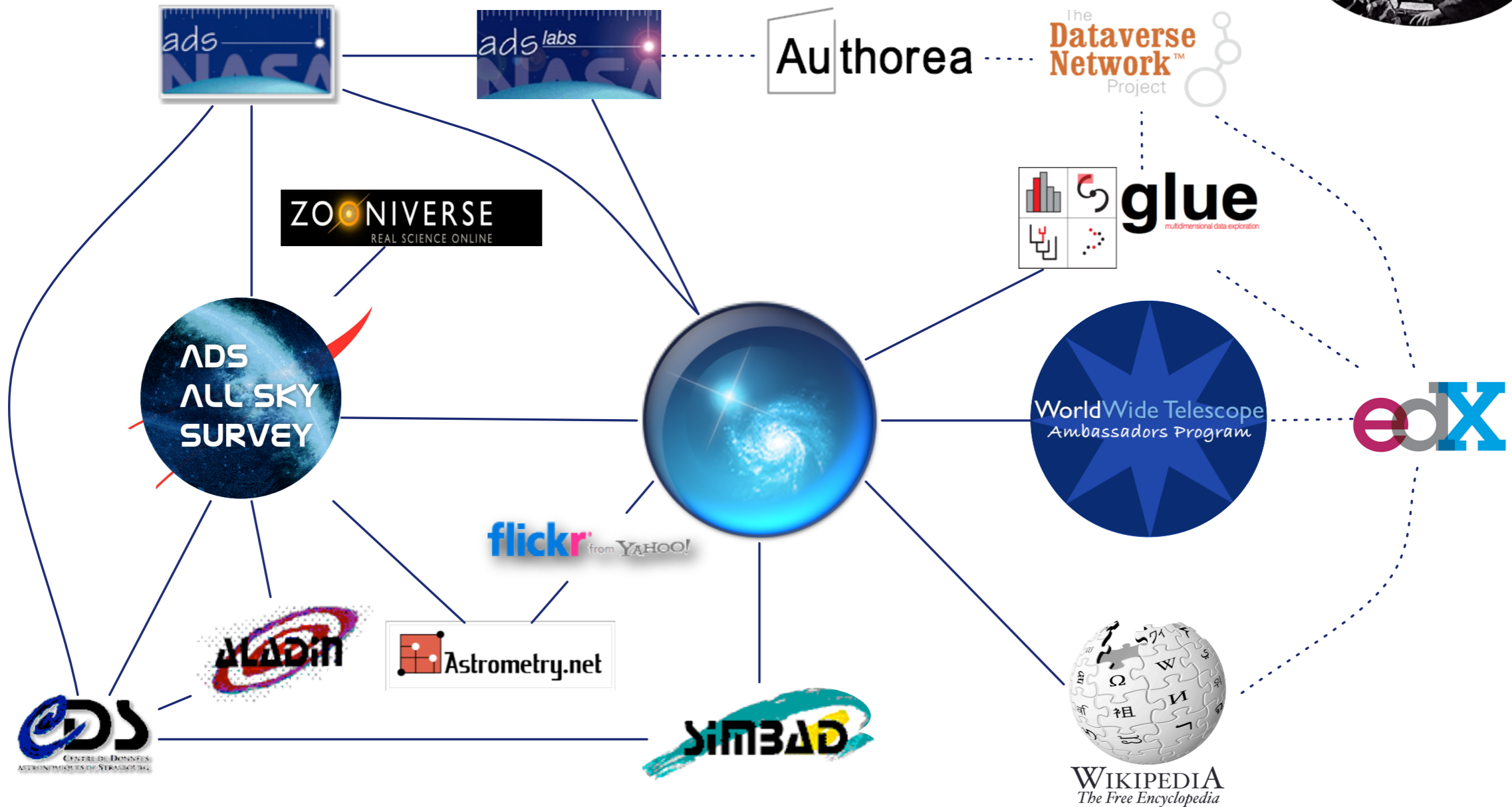






# SEAMLESS ASTRONOMY

Linking scientific data, publications, and communities



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

Supported by

Microsoft Research



Made possible by MANY collaborators, listed at [projects.iq.harvard.edu/seamlessastronomy](http://projects.iq.harvard.edu/seamlessastronomy)

1610



SIDEREUS NUNCIUS

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

East \* ○ \* \* West

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

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

East \* ○ \* \* West

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

East \*\* ○ \*\*

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

On the fifth, the sky was cloudy.

On the sixth, only two stars appeared flanking Jupiter

East \* ○ \*

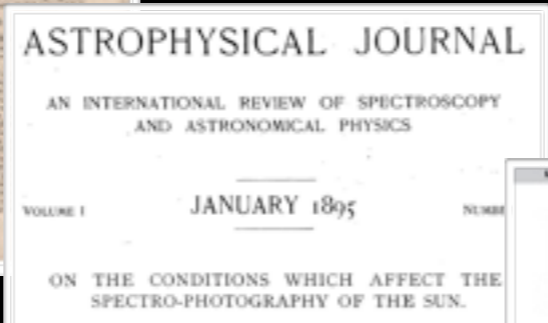
in the adjoining figure. The eastern one was 2 minutes from the next western one 3 minutes from Jupiter. They were on the same straight line with Jupiter and equal in magnitude.

On the seventh, two stars stood near Jupiter, but not on the same straight line.

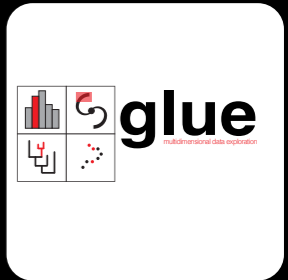
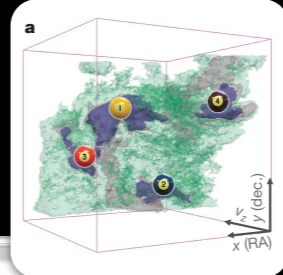
1665



1895



2009



2014



PHOTOGRAPHS OF THE MILKY WAY.

By E. E. BARNARD.

In my photographic survey of the Milky Way with the 6-inch Willard lens of this Observatory, I have come across many very remarkable regions. Some of these, besides being remarkable for showing the peculiar structure of the Milky Way, are singularly beautiful as simple pictures of the stars. I have selected two of these for illustration in THE ASTROPHYSICAL JOURNAL.

... photography is not limited to the photography of the prominences, but extends to all other peculiarities of structure which emit radiations of approximately constant wavelength; and the efficiency of the method depends very largely upon the contrast which can be obtained by the greater effect

Au thorea

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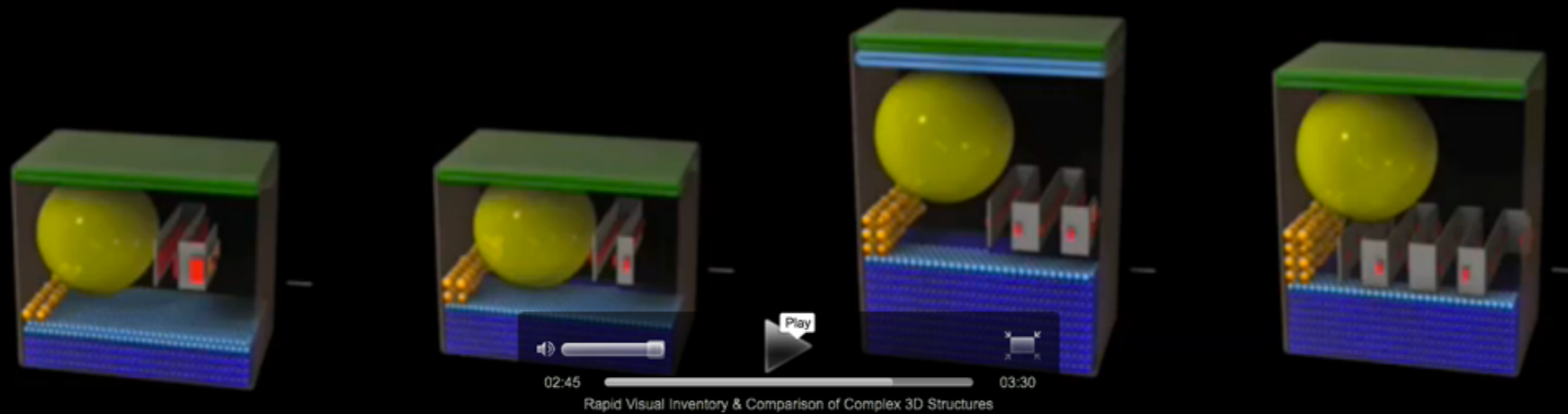
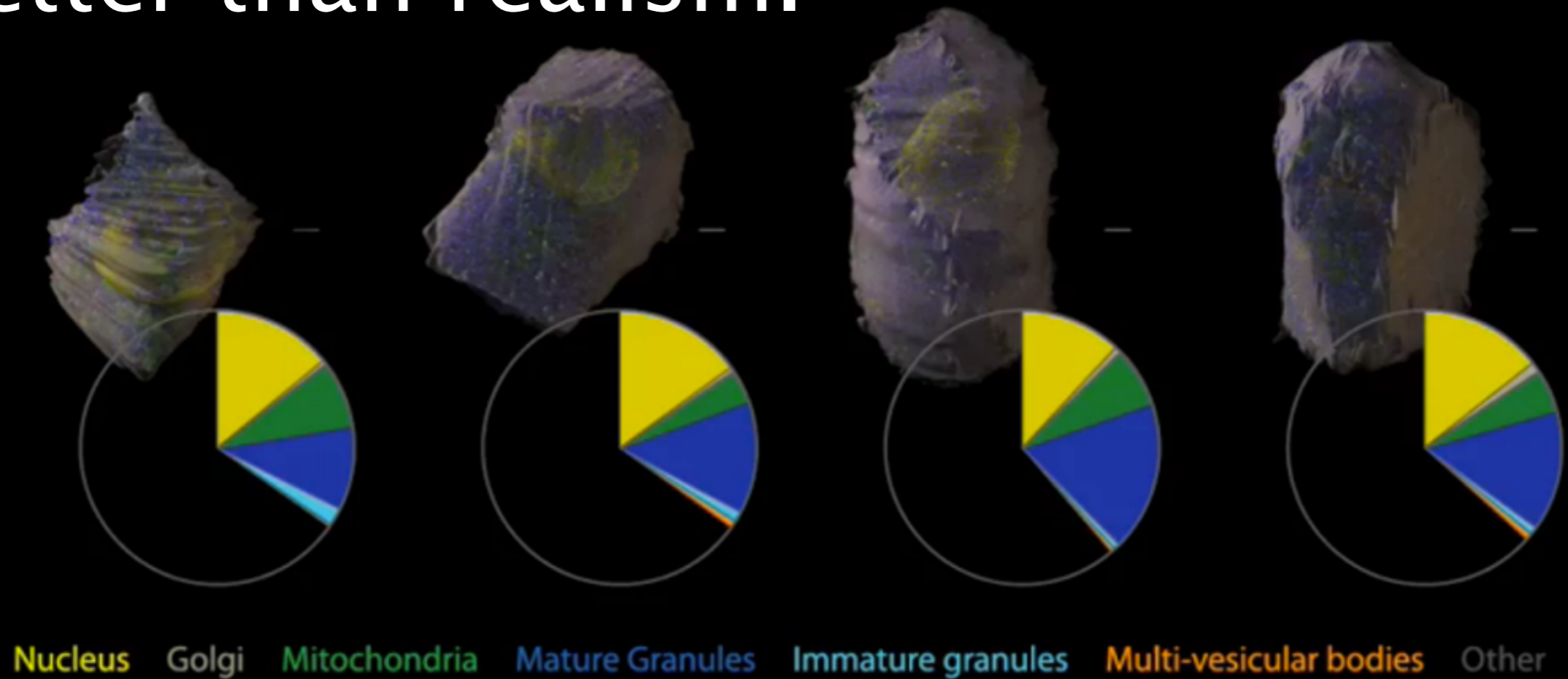
### Four centuries of discoveries

Alberto Pepe, Josh Peek

Four Centuries of Discovery | A Chasm in Mass | Some are Similar... | ...but Most are Different

The Inner moons resemble the Galilean moons: close, prograde, with little inclination or eccentricity.

# Meaningful abstraction is often better than realism.



G. Johnson et al. 2011: <http://video.sciencemag.org/VideoLab/1423692/3000111>





# A great photographic nebula near pi and delta Scorpii.

Barnard, E. E.

*Astrophysical Journal*, 23, 144-147 (1906)

Published in Mar 1906

DOI: [10.1086/141311](https://doi.org/10.1086/141311)



## A GREAT PHOTOGRAPHIC NEBULA NEAR $\pi$ AND $\delta$ SCORPII

By E. E. BARNARD

Through the courtesy of Professor Hale and the generosity of Mr. John D. Hooker, of Los Angeles, I spent the past spring and summer in photographic work at the Solar Observatory of the Carnegie Institution on Mount Wilson, California, at an altitude of 6000 feet. Mr. Hooker's generous grant made it possible to transport the Bruce Photographic Telescope of the Yerkes Observatory to Mount Wilson, where it was installed from February until September, 1905. It is hoped that the results may later be published in full, with reproductions of the principal photographs. At this time I wish to call attention to an especial region in *Scorpio*.

The main object of the work at Mount Wilson was to secure the best possible photographs of the Milky Way as far south as the latitude would permit. But little time was available for independent investigations in other parts of the sky, though the conditions for such work were often superb.

A few exposures were made, however, at various points in a search for diffused nebulosities. The extraordinary nebulosities in *Scorpio* and *Ophiuchus* which I found by photography in 1894—those of  $\rho$  *Ophiuchi*,  $\nu$  *Scorpii*, etc.—suggested the immediate region of the upper part of the Scorpion as a suitable hunting-ground. Trial plates were exposed on  $\rho$  *Scorpii*, and  $\pi$  *Scorpii*, and elsewhere. The photographs of the region of  $\pi$  showed a very remarkable, large, straggling nebula extending from  $\pi$  to  $\delta$  *Scorpii*, with branches involving several other naked-eye stars near.

With the exception of the great curved nebula in *Orion* and some of the exterior nebulosities of the *Pleiades*, this nebula is quite exceptional in its extent, and in the peculiarities of its various branches. A simple description of it would be inadequate to give a fair conception of these features.

The screenshot shows the WorldWideTelescope web client interface. At the top, there are navigation tabs: Explore, Guided Tours, Search, View, and Settings. Below this is a 'Collections' bar with various survey thumbnails like 'More Surveys', 'Digitized Sky Survey', 'VLSS: VLA Low-fre', 'Planck CMB', 'WMAP ILC 5-Year', 'SFD Dust Map (Inf)', 'IRIS: Improved Re', 'WISE All Sky (Infr)', '2Mass: Imagery (I)', '2MASS: Catalog (S)', 'Hydrogen Alpha Fu', and 'SDSS: Sloan Digit'. The main view is a colorful star field with a 'Finder Scope' overlay showing a zoomed-in view of a star. A data panel for the star NGC5998 is visible, containing the following information:

Classification:	Star
	in Scorpius
	Pi Scorpii; 6 Scorpii; HR5944;
	SAO183987; HD143018; DM
RA:	15h58m51s
Magnitude:	2.89
Dec:	-26 : 06 : 51
Distance:	n/a
Alt:	-32 : 20 : 42
Rise:	04:54
Az:	262 : 42 : 42
Transit:	09:11
Set:	13:28

Below the data panel, there are 'Image Credits' (NASA/JPL-Caltech/UCLA) and a URL: <http://wise.ssl.berkeley.edu/>. At the bottom, there are buttons for 'Research', 'Show Object', and 'Close'. The interface also includes a 'Look At' dropdown set to 'Sky', an 'Imagery' dropdown set to 'Digitized Sky Survey (Color)', and a 'Info' icon. A bottom bar shows 'Scorpius' and '17:30:13'.

[http://www.worldwidetelescope.org/webclient/default.aspx?wtm=http%3a%2f%2fwww.worldwidetelescope.org%2fwww%2fshowimage.aspx%3freverseparity%3dTrue%26scale%3d13.4575%26name%3d1906ApJ...23%2b\(Page%3a%2b%2b%2bimage%3a%2b1\)%26imageurl%3dhttp%3a%2f%2fwww.adsass.org%2foldastro%2fdata%2f1906ApJ...23..144B-002-001.png%26credits%3dADS%2bAll%2bSky%2bSurvey%26creditsUrl%3dhttp%2fadsass.org%26ra%3d239%26y%3d948%26x%3d756%26rotation%3d179.892%26dec%3d-25.06%26thumb%3d%26wtm%3dtrue](http://www.worldwidetelescope.org/webclient/default.aspx?wtm=http%3a%2f%2fwww.worldwidetelescope.org%2fwww%2fshowimage.aspx%3freverseparity%3dTrue%26scale%3d13.4575%26name%3d1906ApJ...23%2b(Page%3a%2b%2b%2bimage%3a%2b1)%26imageurl%3dhttp%3a%2f%2fwww.adsass.org%2foldastro%2fdata%2f1906ApJ...23..144B-002-001.png%26credits%3dADS%2bAll%2bSky%2bSurvey%26creditsUrl%3dhttp%2fadsass.org%26ra%3d239%26y%3d948%26x%3d756%26rotation%3d179.892%26dec%3d-25.06%26thumb%3d%26wtm%3dtrue)