



[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

FILTER BY

Object

**All** Stars Galaxies HII regions  
Nebulae Other

Band

Radio Infrared Ultraviolet X-ray

Custom

Harvard

**Year**

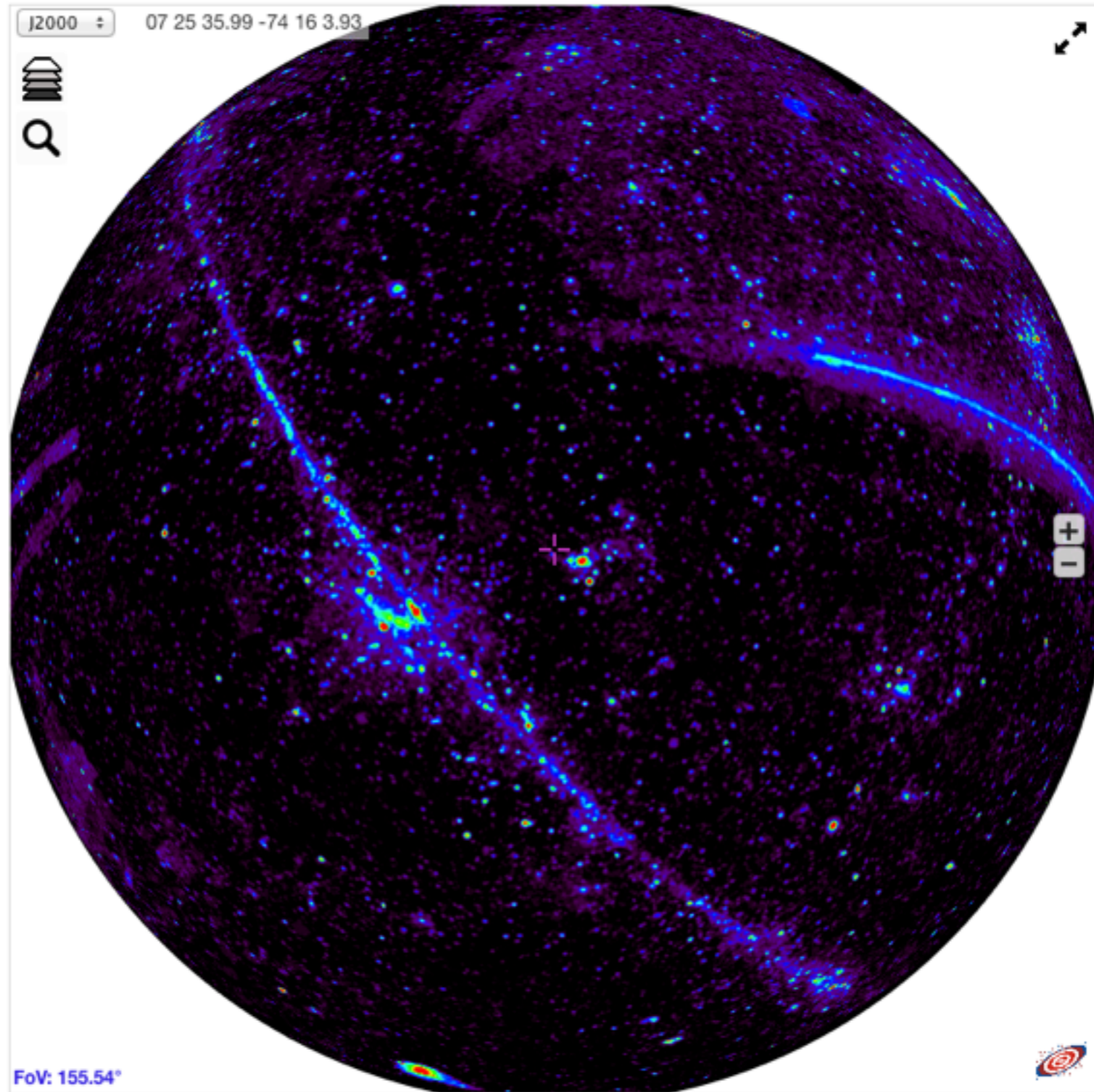


TOGGLE BASE LAYER

Optical Mellinger GALEX AIS  
DSS2 Red IRIS 2MASS Halpha  
VTSS

Select tool

J2000 07 25 35.99 -74 16 3.93



FoV: 155.54°





# let's zoom in (on Ophiuchus)

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

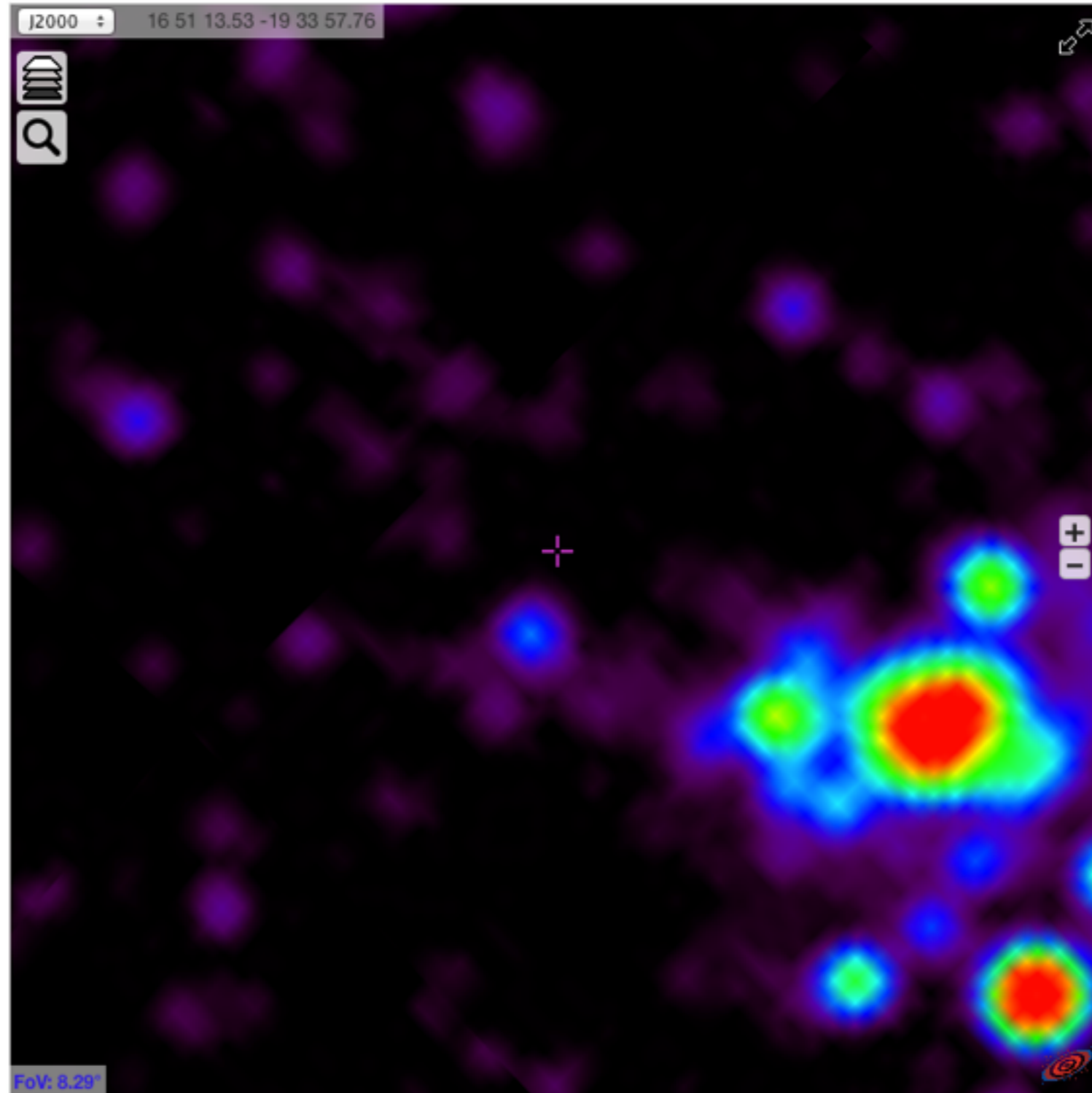
**Year**



TOGGLE BASE LAYER

Optical Mellinger GALEX AIS  
DSS2 Red IRIS 2MASS Halpha  
VTSS

Select tool



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

The ADS All Sky Survey

◀ About

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🔄 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-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

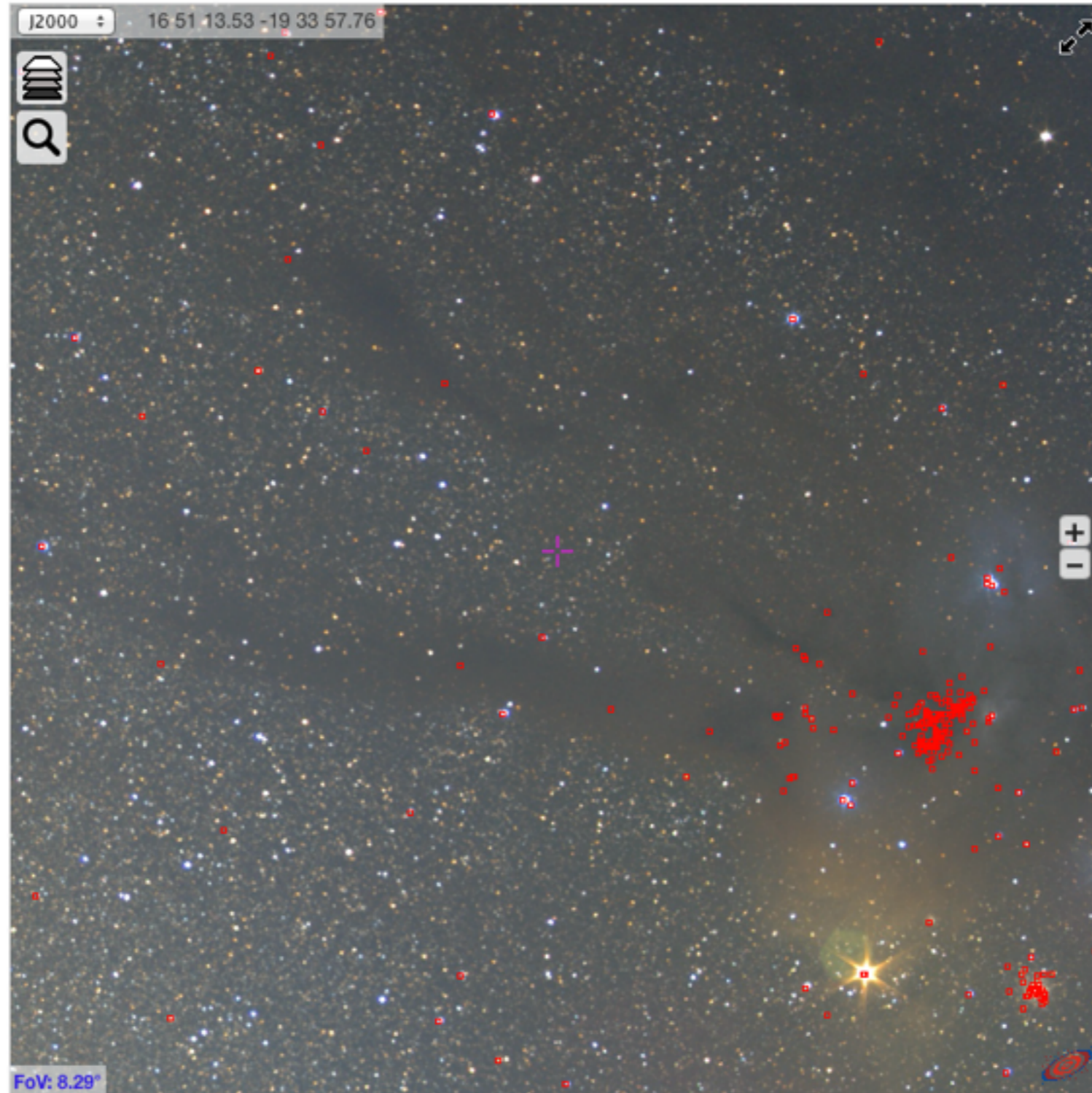
Year



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

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**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

J2000 16 51 30.09 -22 28 5.19

FoV: 8.29°

ALADiN



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

**FILTER BY**

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

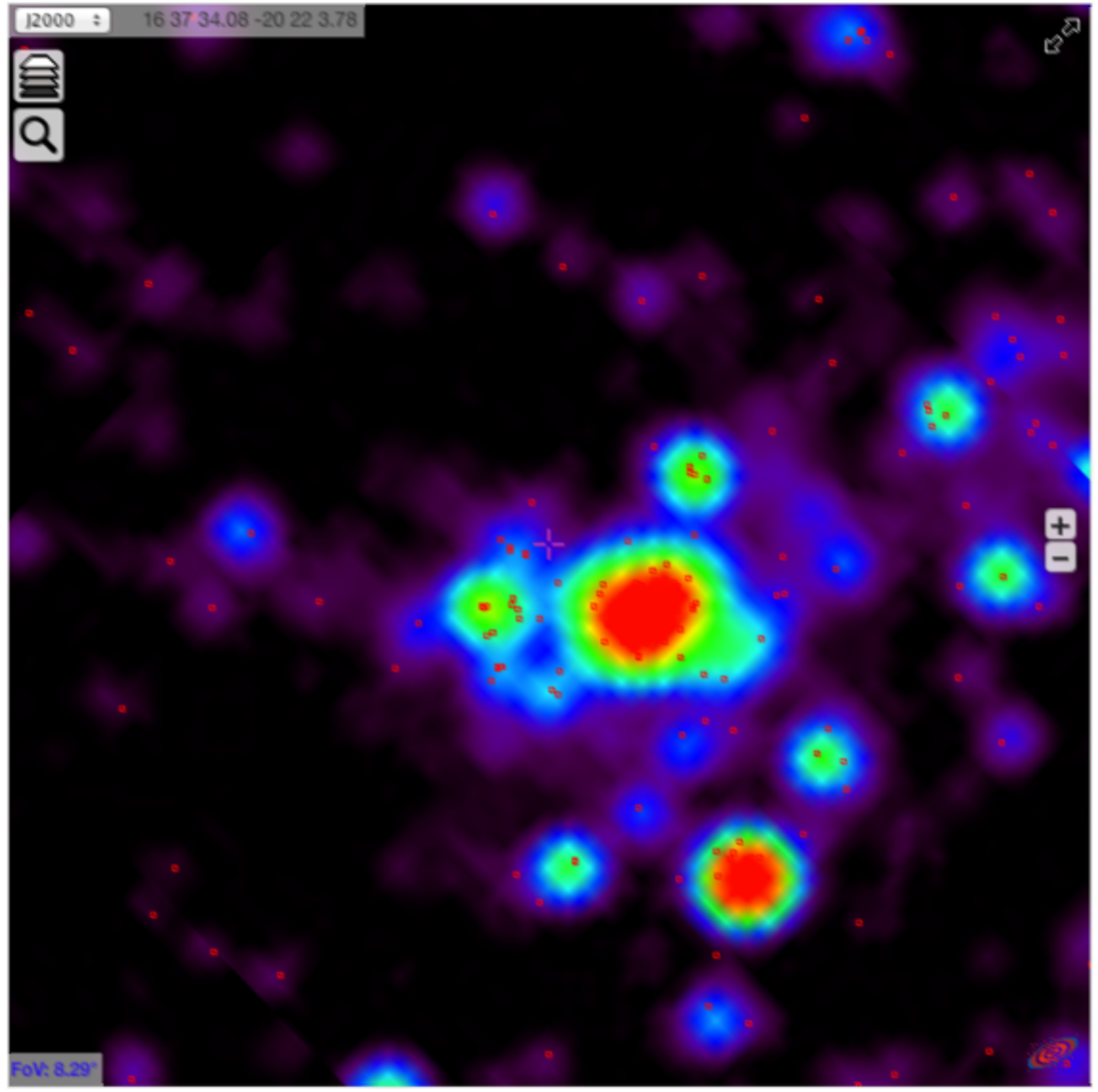
**Band**  
Radio Infrared Ultraviolet X-ray

**Custom**  
Harvard

**Year**

**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

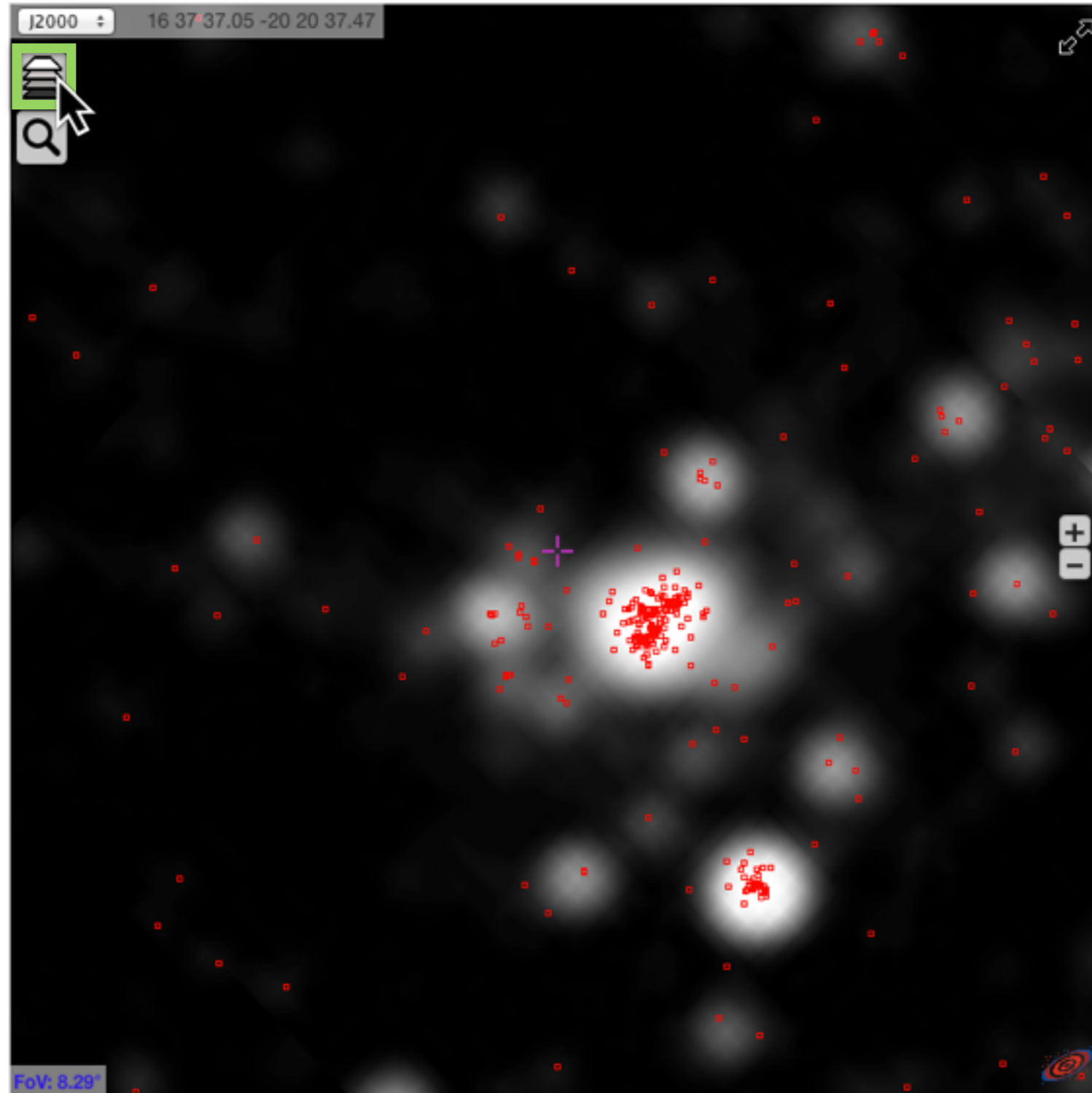
Year



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

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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

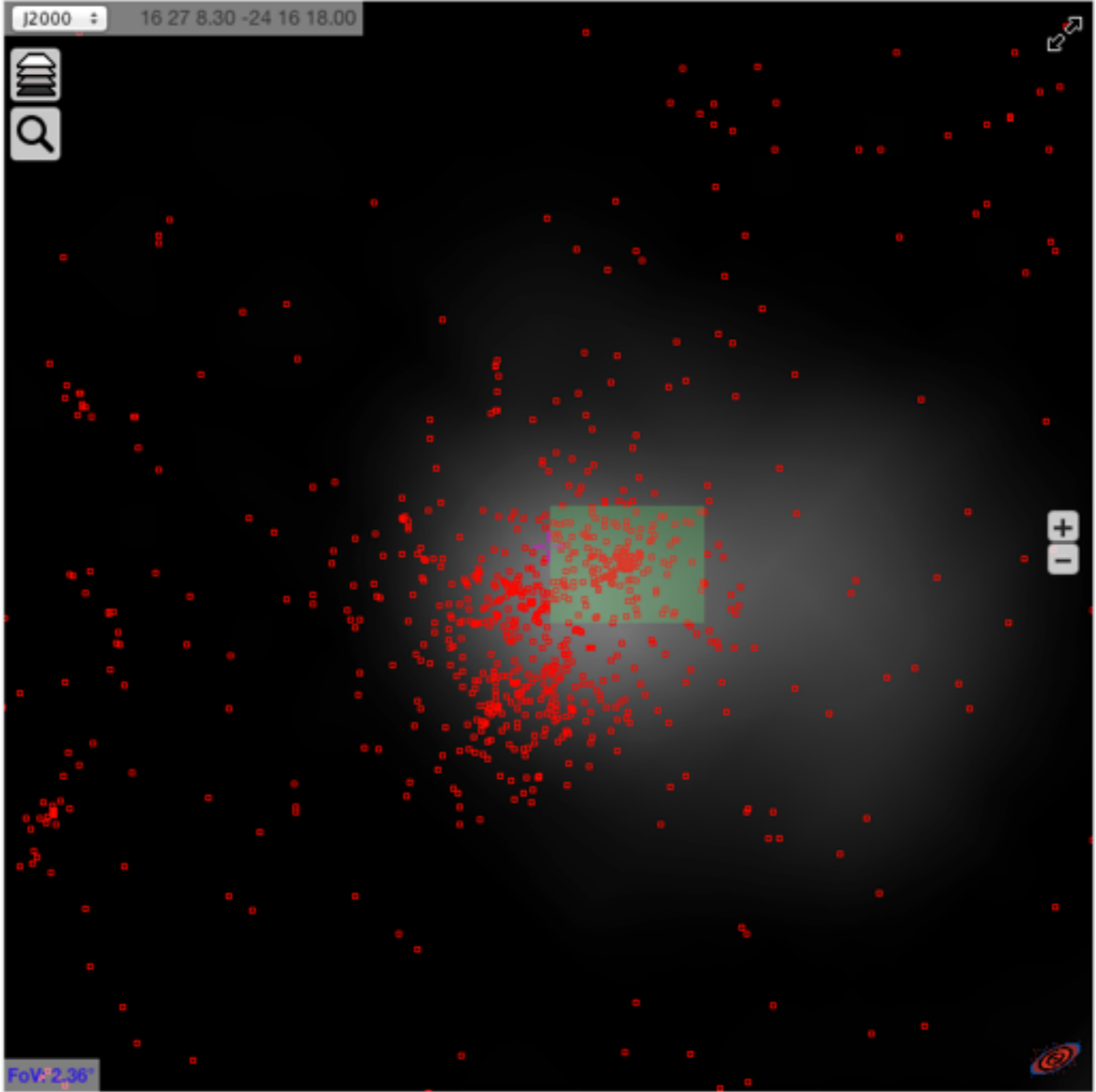
J2000 16 27 8.30 -24 16 18.00


  




FoV: 2.36°





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

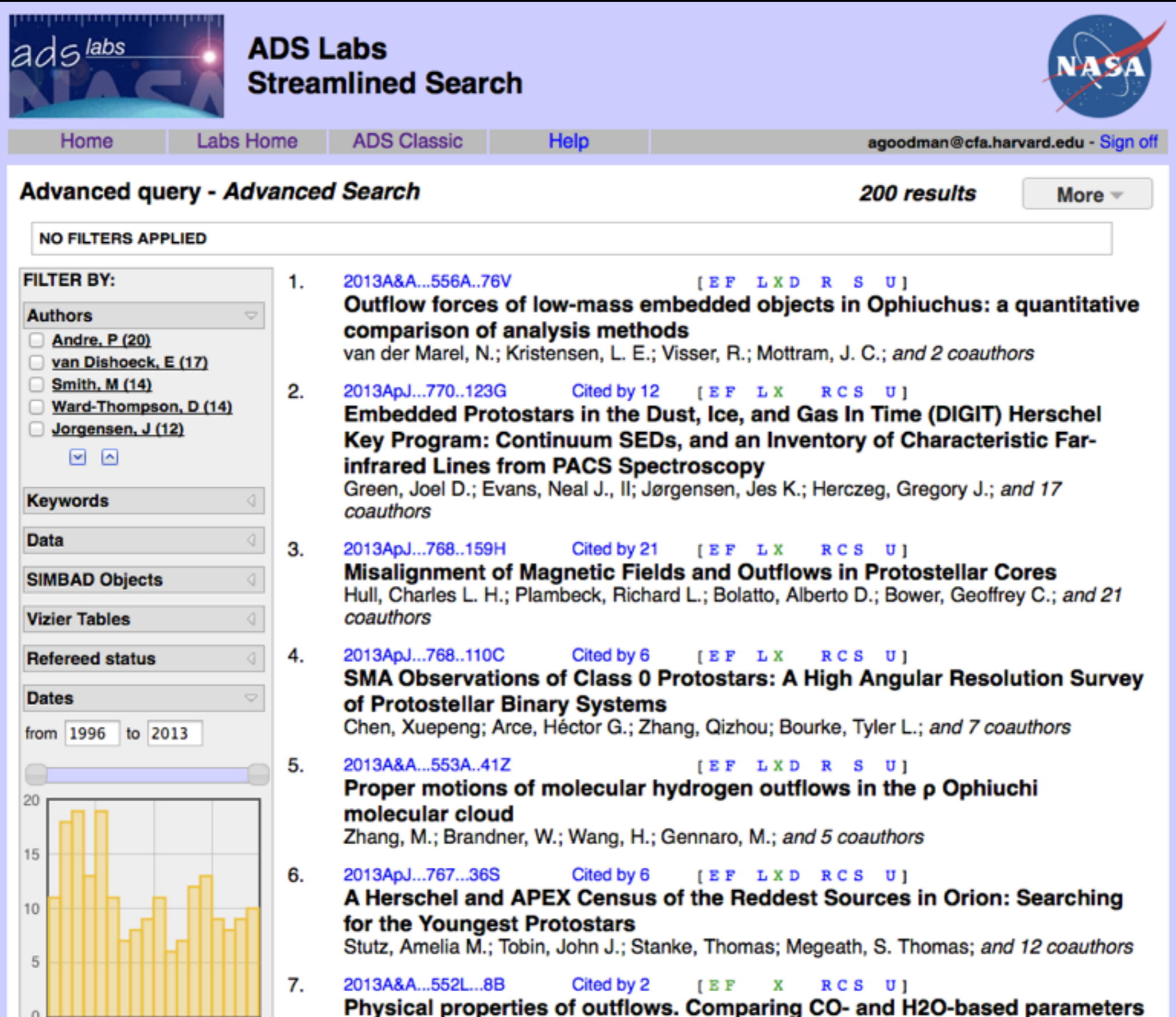
The screenshot shows the ALADiN web interface. On the left, there are filter panels for 'Object' (All Stars, Galaxies, HII regions, Nebulae, Other), 'Band' (Radio, Infrared, Ultraviolet, X-ray), 'Custom' (Harvard), and 'Year' (with a slider). Below these is a 'TOGGLE BASE LAYER' section with options like Optical, Mellinger, GALEX, AIS, DSS2, Red, IRIS, 2MASS, Halpha, and VTSS. A 'Select tool' button is at the bottom of the filters.

The main window displays a pop-up titled 'Selected papers/objects'. It has two buttons: 'Open papers in ADS' (highlighted with a purple box) and 'Open object list' (highlighted with an orange box). Below the buttons are two tabs: 'Papers' (selected) and 'Objects'. A note states: 'Note: List truncated to 200 most recent papers'. A list of 25 astronomical papers follows, each with author names, journal names, volume/issue, and year.

Navigation links at the top include 'The ADS All Sky Survey', 'About', 'Watch videos', 'Tour', and 'Open WWT version'. The top right says 'Astronomy articles. In the sky.' The bottom right features the ALADiN logo.

# 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 header with the ADS Labs logo, the text "ADS Labs Streamlined Search", and the NASA logo. Below the header is a navigation bar with links for "Home", "Labs Home", "ADS Classic", and "Help", along with the user's email "agoodman@cfa.harvard.edu" and a "Sign off" link. The main content area is titled "Advanced query - Advanced Search" and shows "200 results". A search bar contains the text "NO FILTERS APPLIED". On the left side, there is a "FILTER BY:" section with several filter categories: "Authors" (listing Andre, P (20), van Dishoeck, E (17), Smith, M (14), Ward-Thompson, D (14), and Jorgensen, J (12)), "Keywords", "Data", "SIMBAD Objects", "Vizier Tables", "Refereed status", and "Dates" (set from 1996 to 2013). Below the "Dates" filter is a histogram showing the distribution of papers over time. The main list of results consists of 7 entries, each with a citation number, a link to the paper, a list of keywords in brackets, a title, and the authors. The results are:

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

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](#)

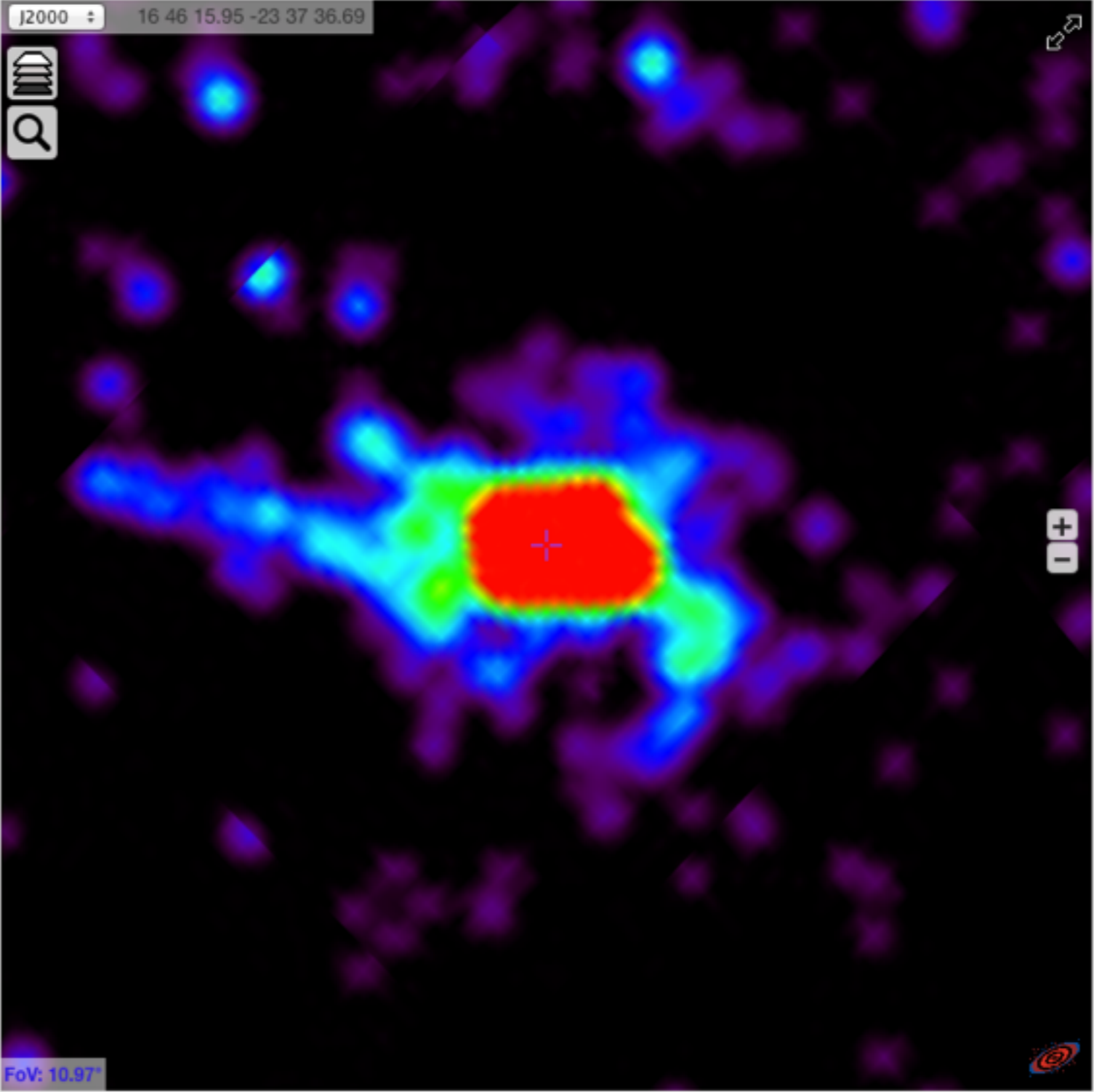
**Custom**  
[Harvard](#)

**Year**


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

Select tool

J2000 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...

$(\alpha, \delta) = 246.78^\circ, -24.55^\circ$  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**

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JENSEN E.L.N., et al. *Astrophys. J.*, 459, 212-226 (1996)

$(\alpha, \delta) = 246.72^\circ, -23.97^\circ$  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

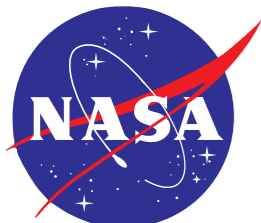
Christopher **Beaumont**, Harvard-CfA

Thomas **Boch**, CDS Strasbourg

Jonathan **Fay**, Microsoft Research

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

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



Stephen

all lines

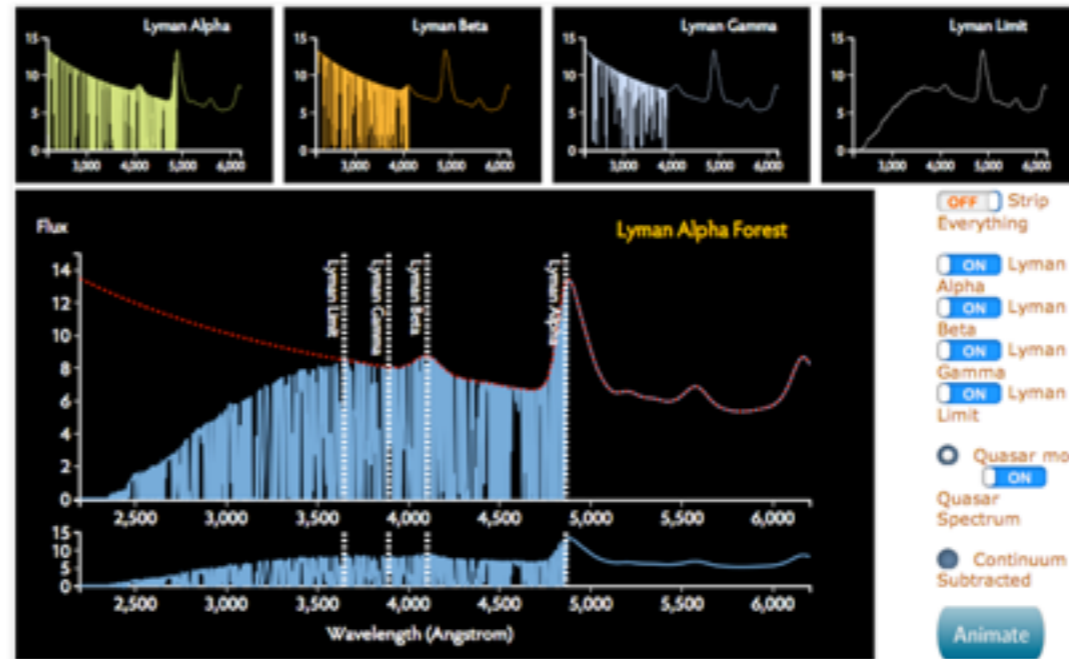
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He 6563 Å

OIII 5007 Å

Yuan-Sen  
Ting

Interstellar  
Absorption  
and the  
Lyman Alpha  
Forest



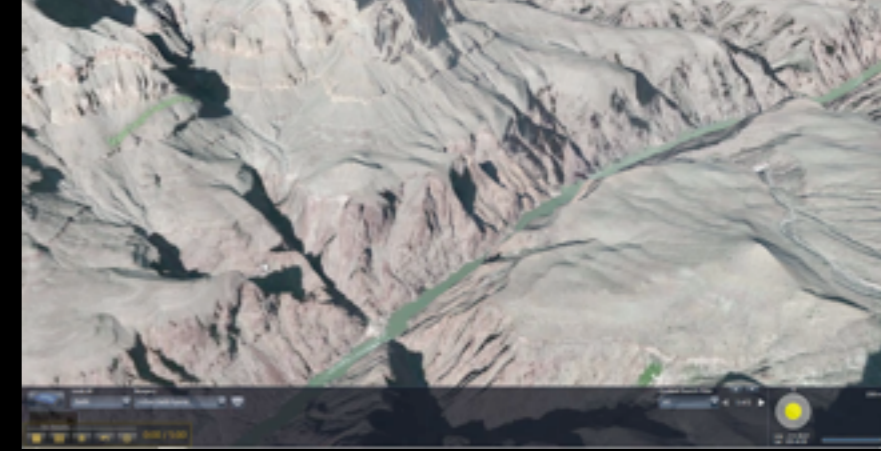
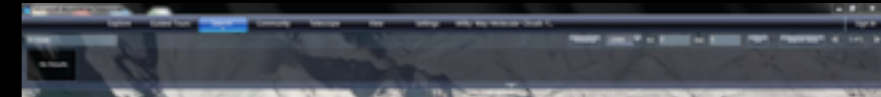
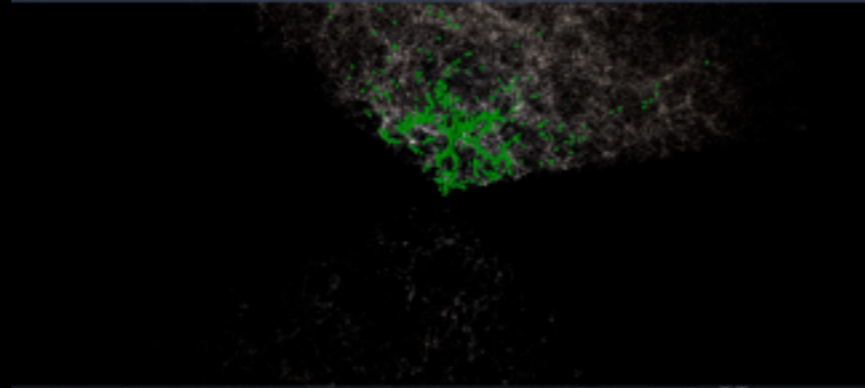
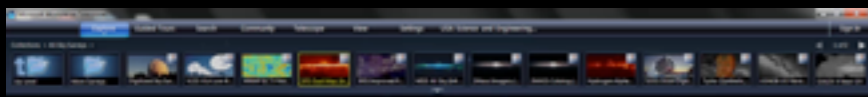
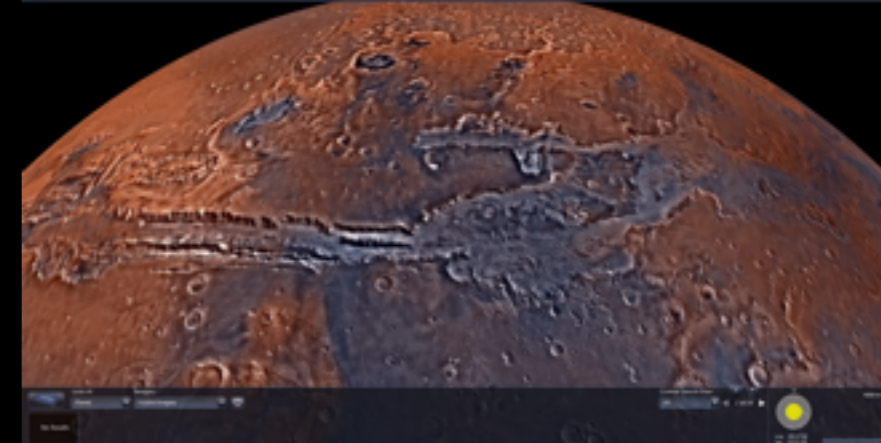
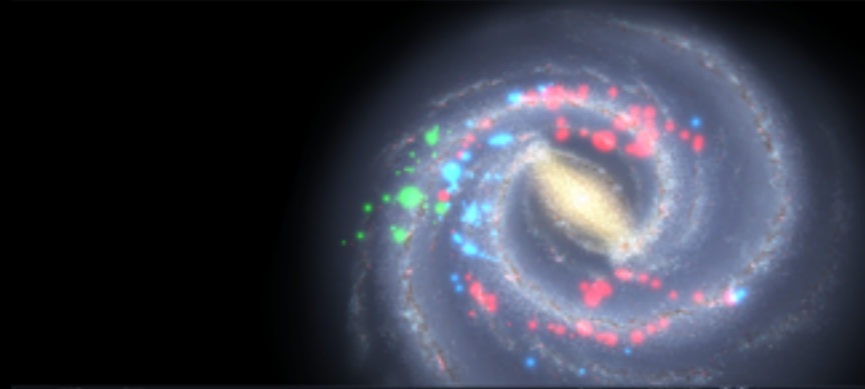
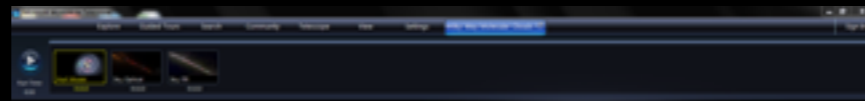
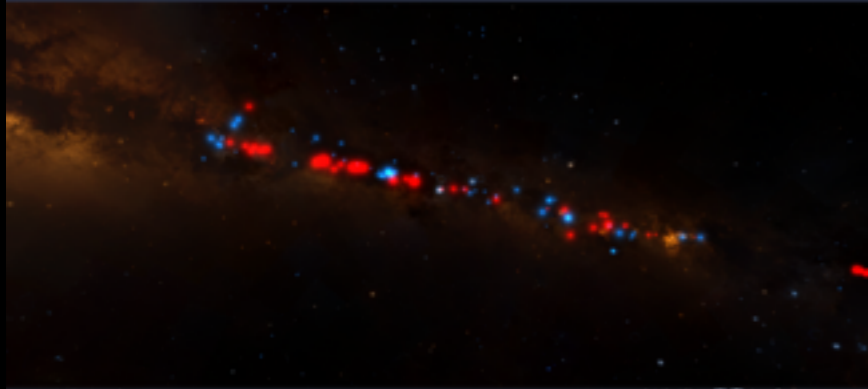
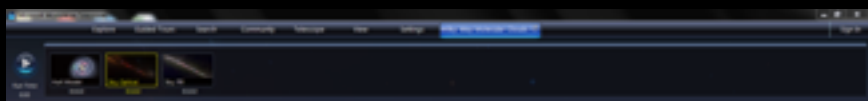
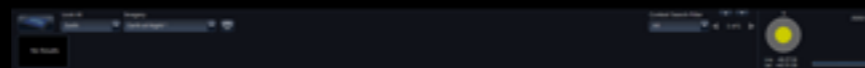
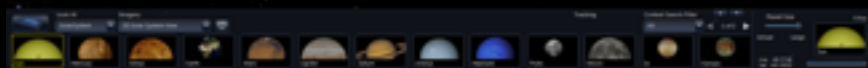
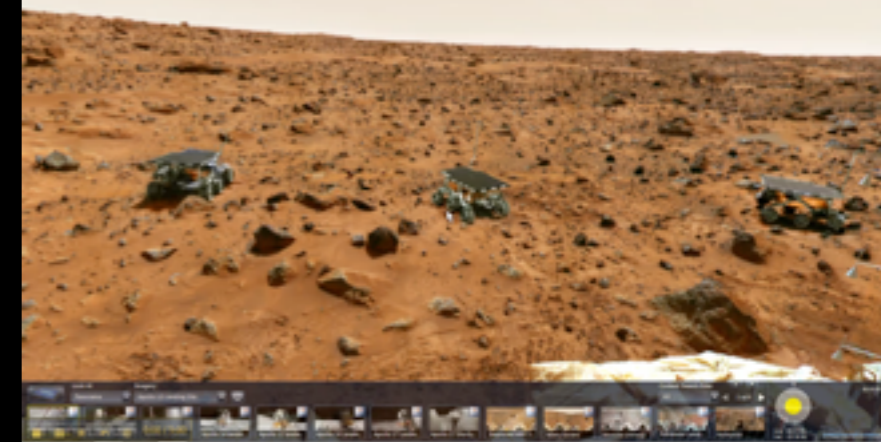
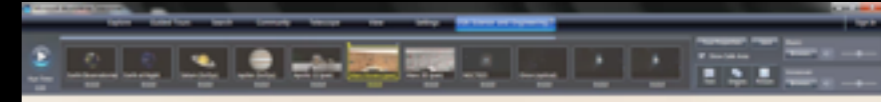
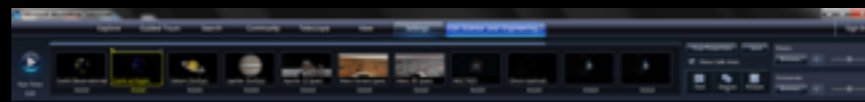
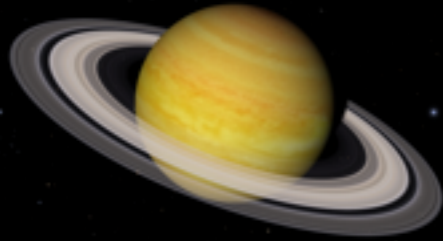
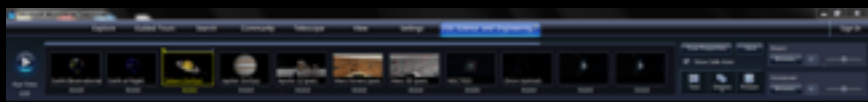
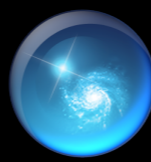
JavaScript

[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/>

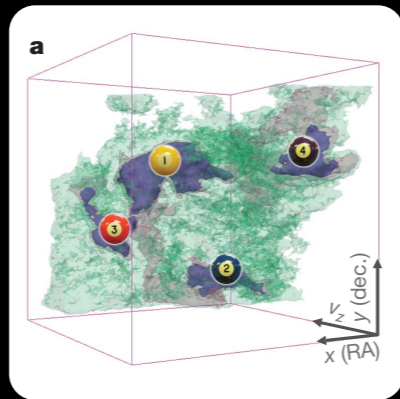
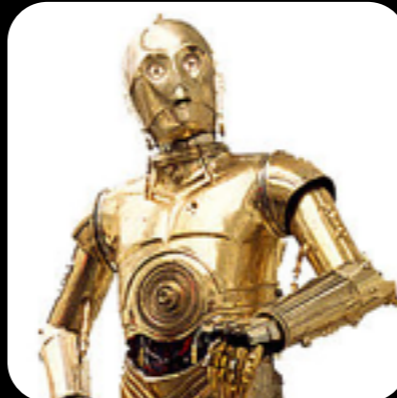
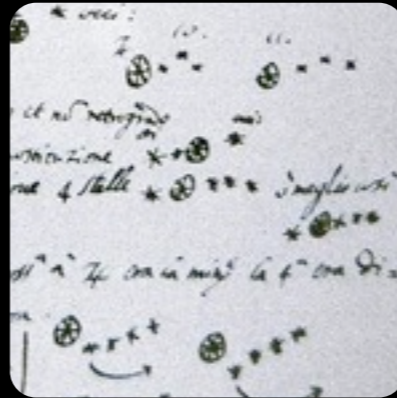


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# VISUALIZATION IN ASTRONOMY: FROM GALILEO TO THE ZOONIVERSE

ALYSSA A. GOODMAN  
HARVARD-SMITHSONIAN  
CENTER FOR ASTROPHYSICS  
@AAGIE





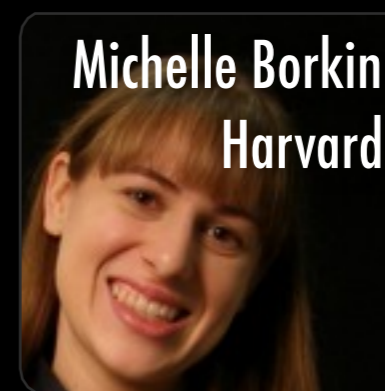
# COLLABORATORS



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Alberto Conti  
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David Hogg  
NYU



Chris Lintott  
Zooniverse, Oxford



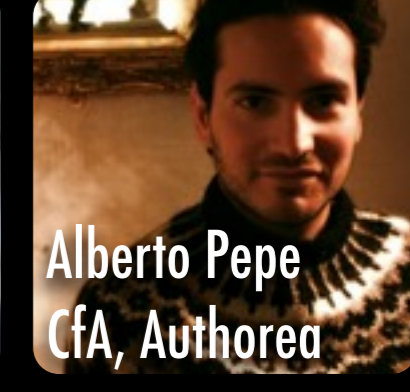
Elizabeth Newton  
CfA



August Munech  
CfA



Josh Peek  
Columbia



Alberto Pepe  
CfA, Authorea



Adrian Price-Whelan  
Columbia



Thomas Robitaille  
MPIA



Erik Rosolowsky  
U. Alberta



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



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Zooniverse, Oxford



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Microsoft Research

# RELATIVE STRENGTHS



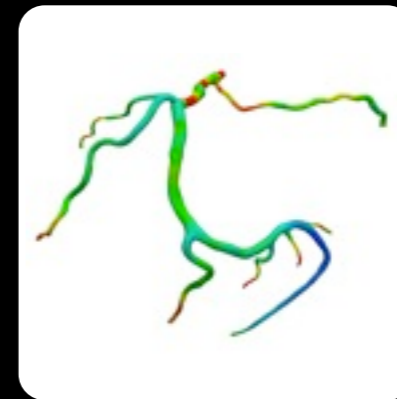
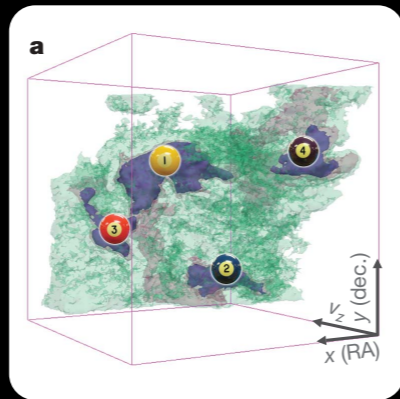
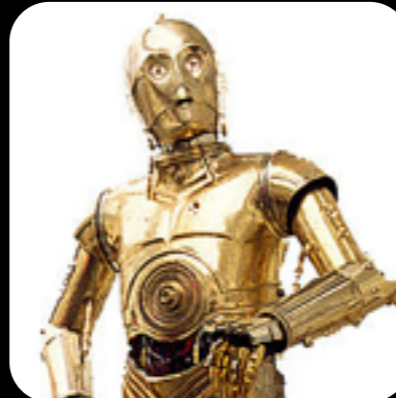
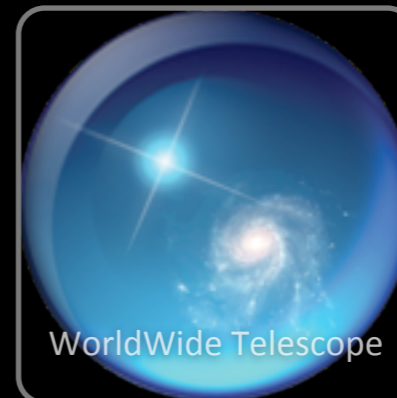
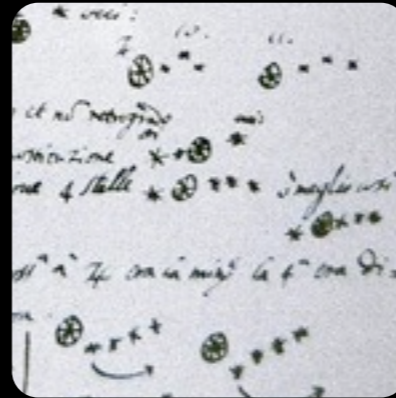
**Pattern Recognition**  
**Creativity**



**Calculations**



# LINKING VISUALIZATION & UNDERSTANDING IN ASTRONOMY







# GALILEO GALILEI (1564-1642)



*Sc. Principe.*  
 Galileo Galilei Familiari. Seruo della Ser. V. inuigilanti  
 do amittuano, et lo ogni spirito fa essere no solo satisfatto  
 alvario che non della stessa di Mathematico nelle sue  
 Dio di Padova,  
 Inuere diuere determinate di presentare al Sc. Principe  
 l'ordine et il governo di giuramento inestimabile di ogni  
 negozio et in ista marittima o terrestre stano di tenere per  
 sto nuovo artificio ne l'ingegno segreto et solano a disposizione  
 di l'ordine di Galileo sanato dalle piu re di te speculazioni di  
 proprietta in l'quantaggio di scoprire Logici et Tele dell' inuicis  
 di Val hore et pu di mero prima di ogni scupra noi et distinguendo  
 il numero et la qualita dei vasselli guidare le sue forze  
 ballastori alla caccia al combattimento o alla fuga, o pure aus  
 nella campagna aperta di uere et particolarmente distinguere ogni suo  
 into et propriamente.  
 Feb 7 di gennaio  
 Giove si uide a 11  
 Feb 8 udi  
 Feb 10 di uide in tale uisione  
 Feb 13 di uide in uisione a Giove 4 stelle  
 Feb 14 di uide  
 Feb 15 di uide in uisione a Giove 4 stelle  
 Feb 16 di uide in uisione a Giove 4 stelle  
 Feb 17 di uide in uisione a Giove 4 stelle

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

*SIDERIUS NUNCIVS*  
 On the third, at the seventh hour, the stars were arranged in this  
 quence. The eastern one was 1 minute, 30 seconds from Jupiter  
 : closest western one 2 minutes; and the other western one wa  
 East \* ○ \* \* West  
 0 minutes removed from this one. They were absolutely on the  
 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  
 listant 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  
 0 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  
 n 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



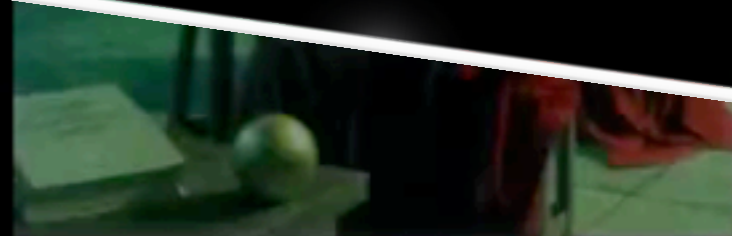


# GALILEO GALILEI



## GALILEO'S "NEW ORDER"

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



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

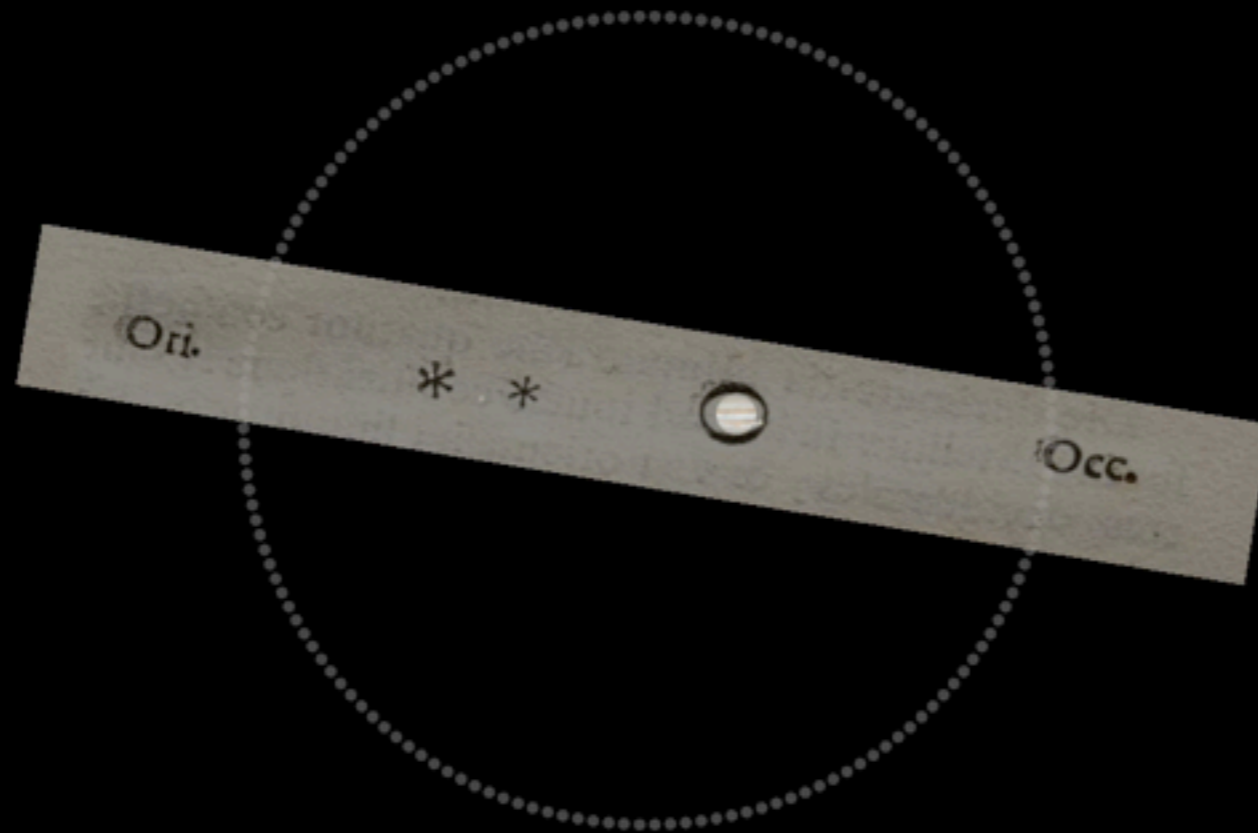




# GALILEO GALILEI



January 11, 1610



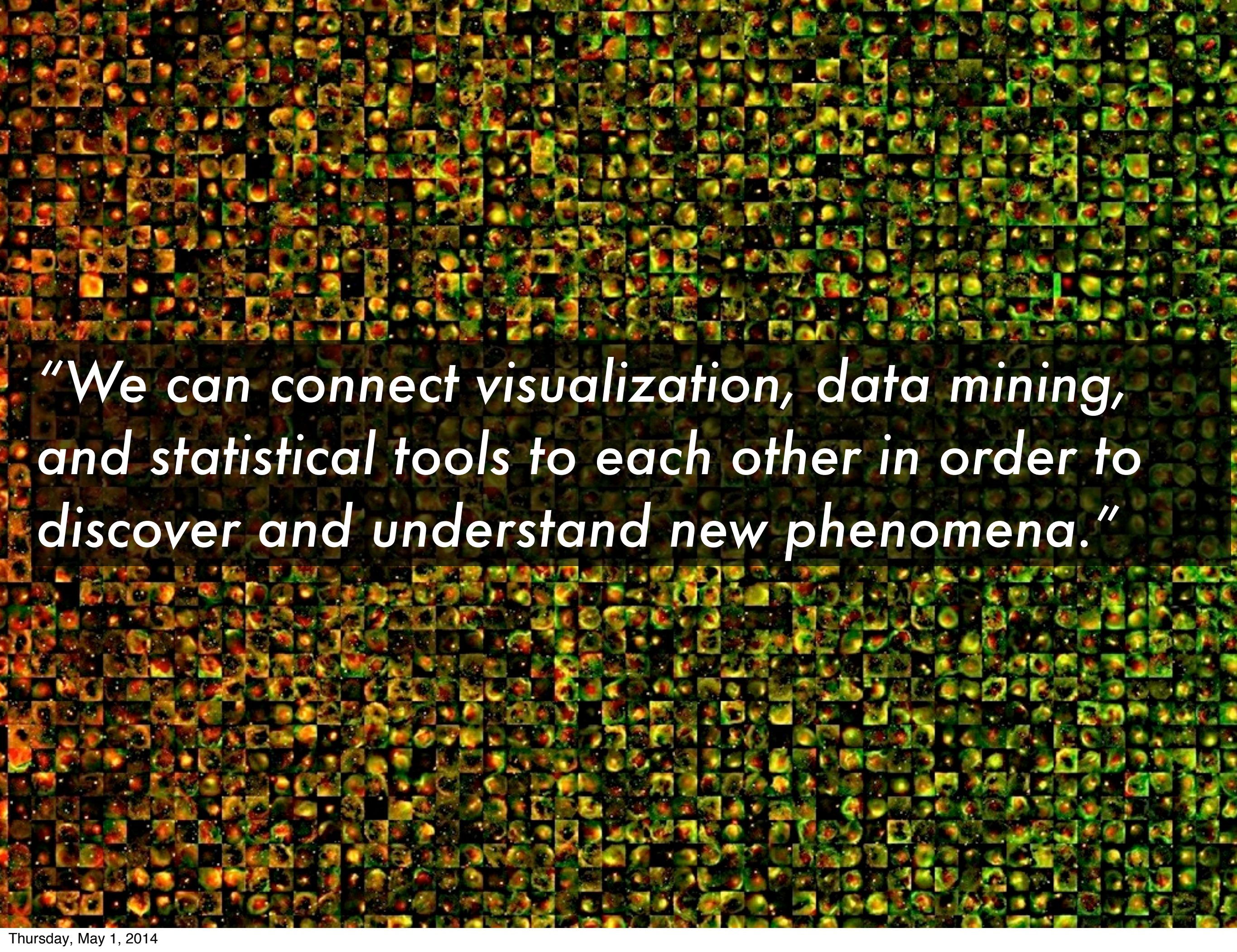
*Galileo's New Order, A WorldWide Telescope Tour by Goodman, Wong & Udomprasert 2010*

FROM GALILEO



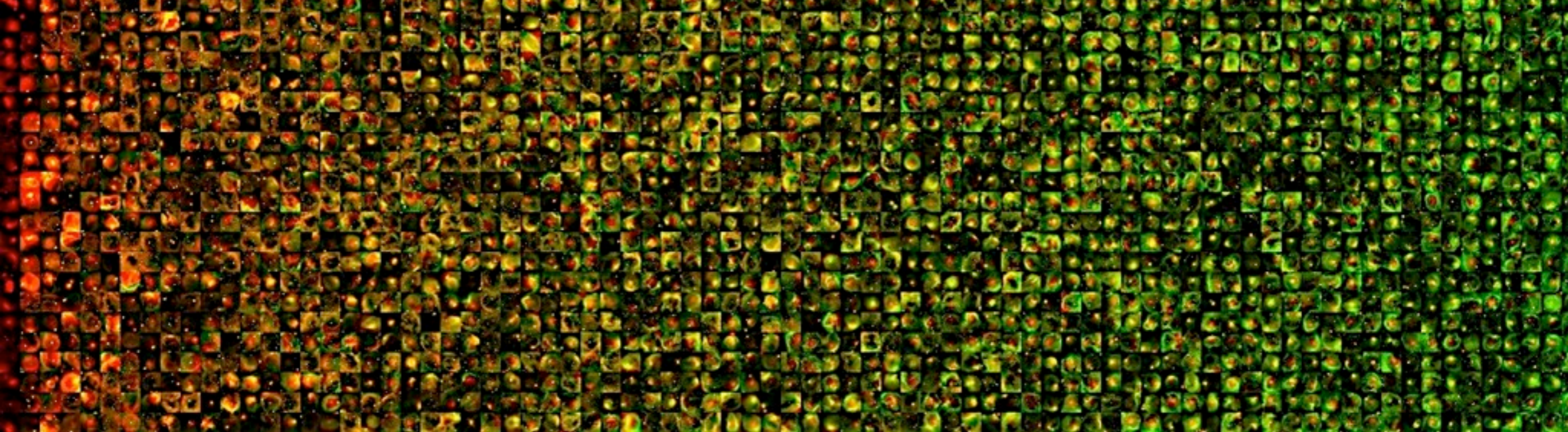
TO THE ZOONIVERSE



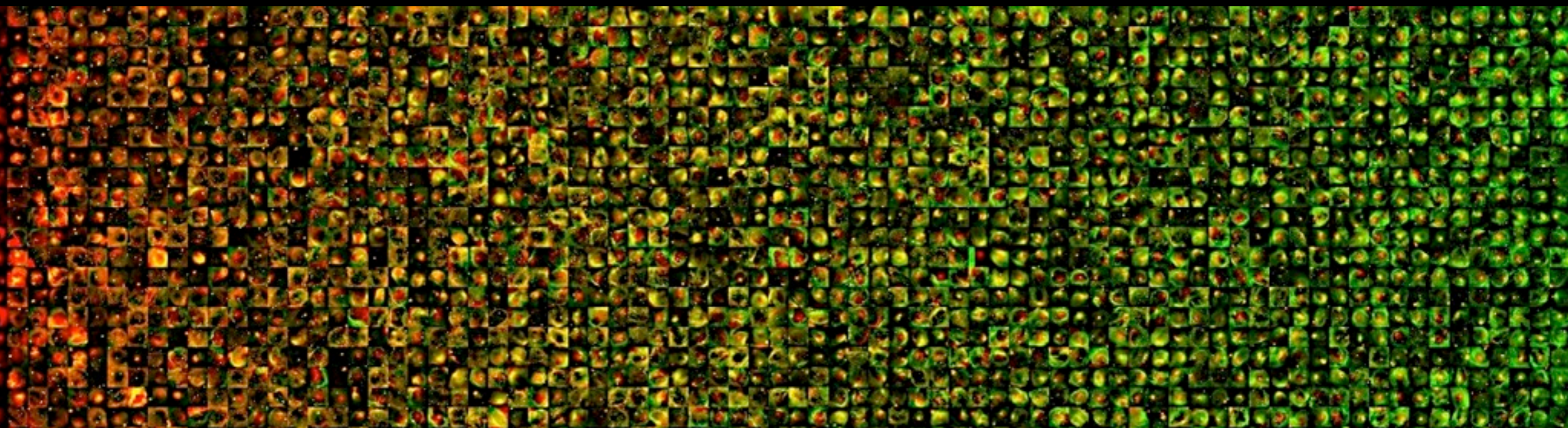


*“We can connect visualization, data mining, and statistical tools to each other in order to discover and understand new phenomena.”*





# BIG DATA, WIDE DATA





# 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!




# THE MILKY WAY PROJECT




What do you see in this image?

  
**Bubble**

  
**Star Cluster**

  
**EGO**

  
**Galaxy**

  
**Object**

**Nothing to mark**



# BIG DATA AND "HUMAN-AIDED COMPUTING"

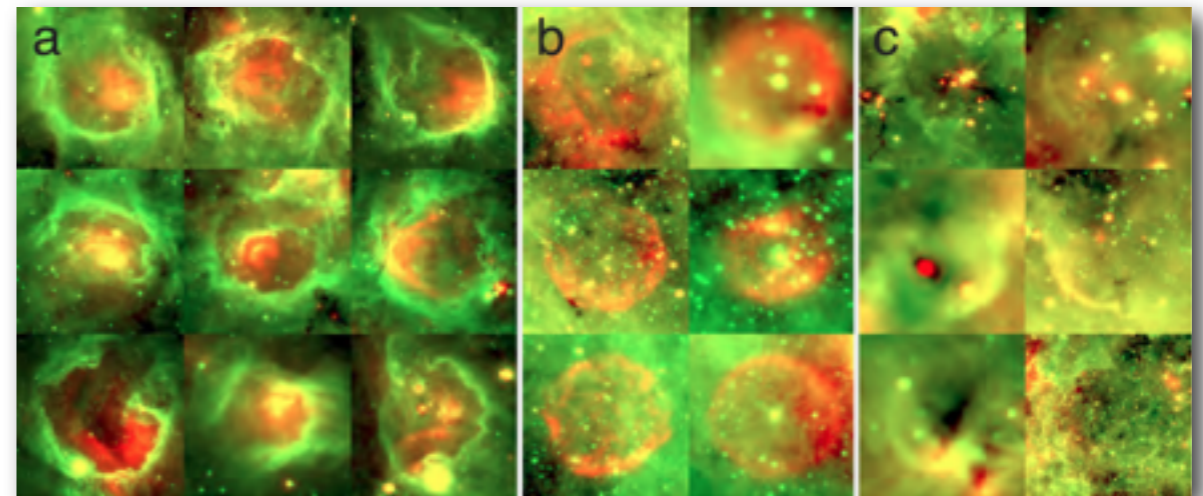
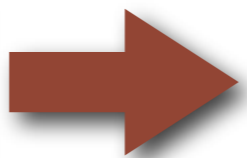


THE MILKY WAY PROJECT ZOONIVERSE REAL SCIENCE ONLINE

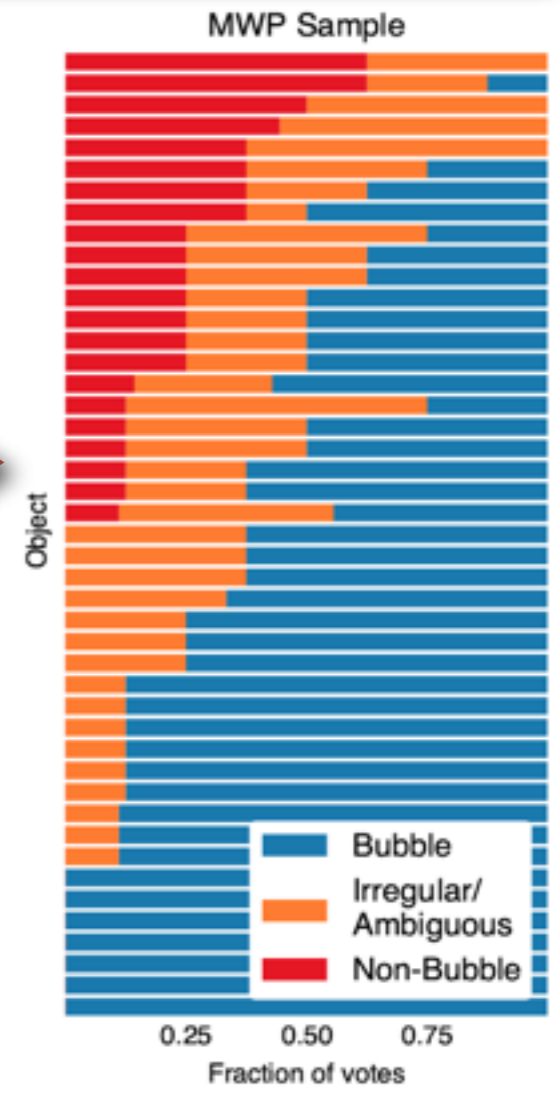
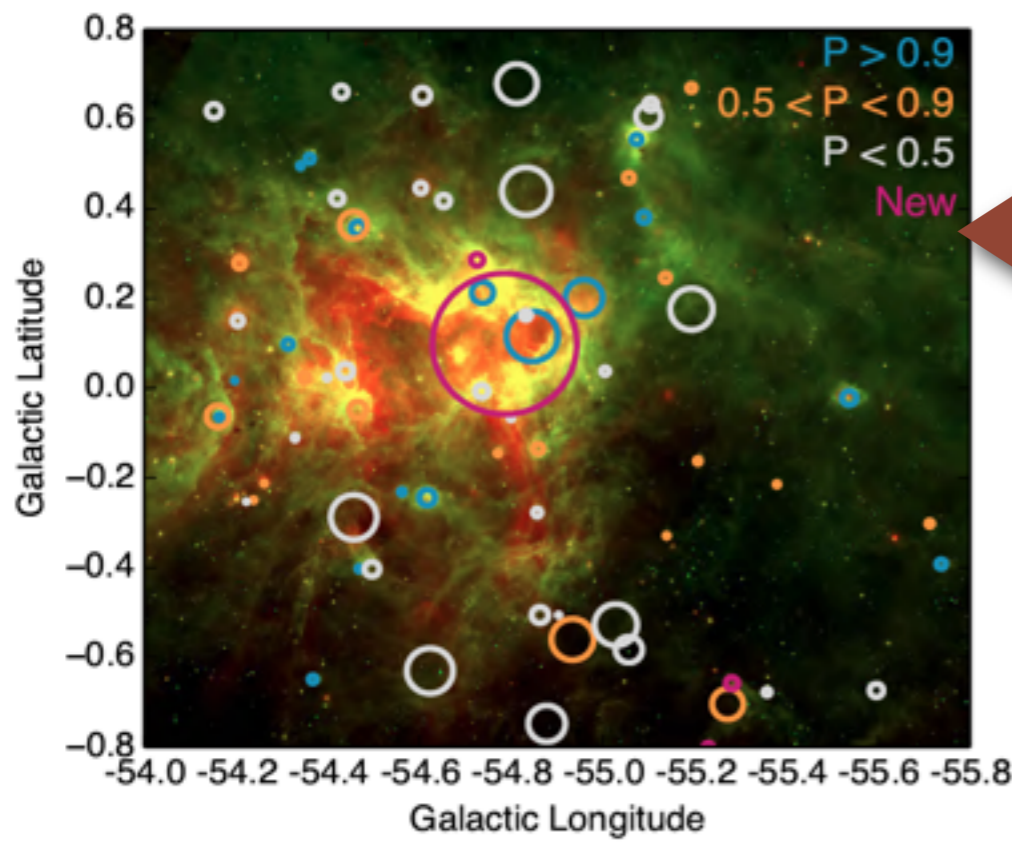
## mark bubbles

What do you see in this image?

Bubble Star Cluster EGO Galaxy Object I'm done!

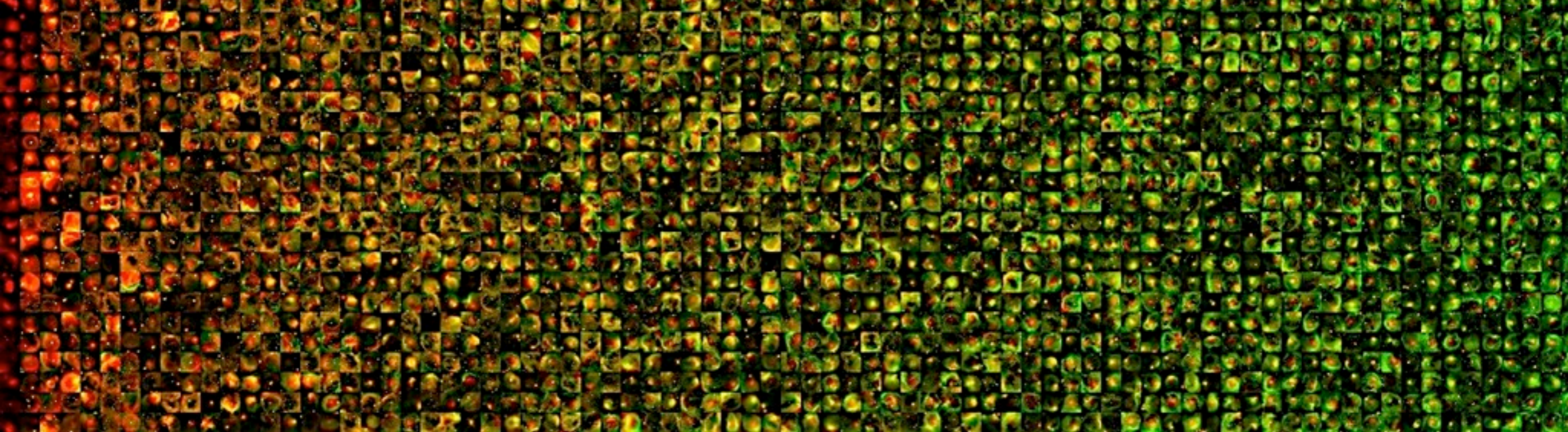


machine-learning algorithm (Brut)

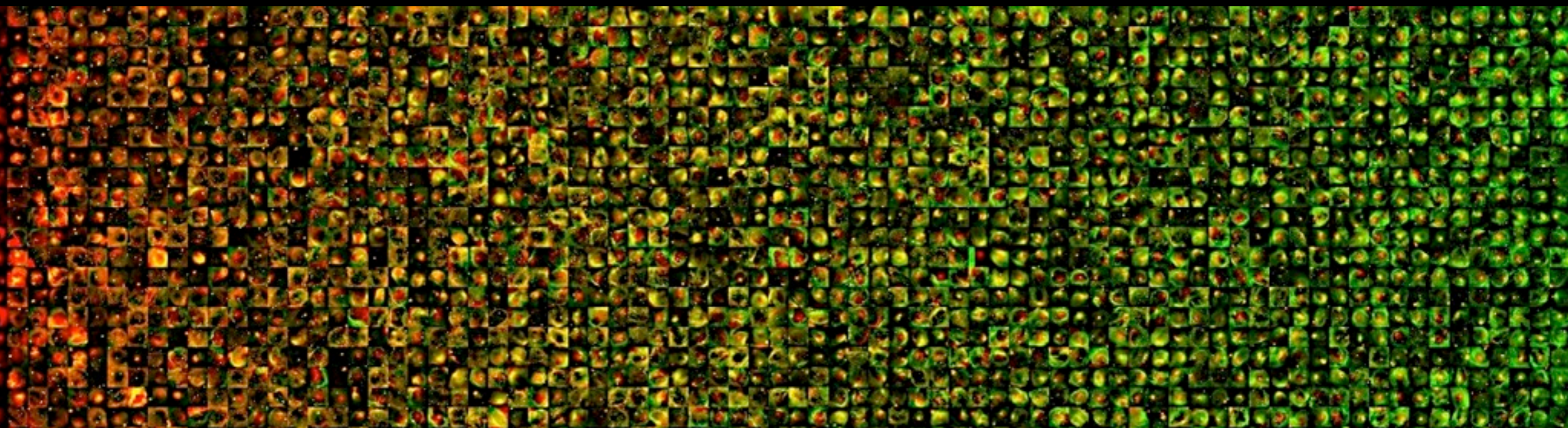


example here from: **Beaumont**, Goodman, Kendrew, Williams & Simpson 2014; based on **Milky Way Project** catalog (Simpson et al. 2013), which came from **Spitzer/GLIMPSE** (Churchwell et al. 2009, Benjamin et al. 2003), cf. Shenoy & Tan 2008 for discussion of HAC; **astroml.org** for machine learning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










# BIG DATA, WIDE DATA

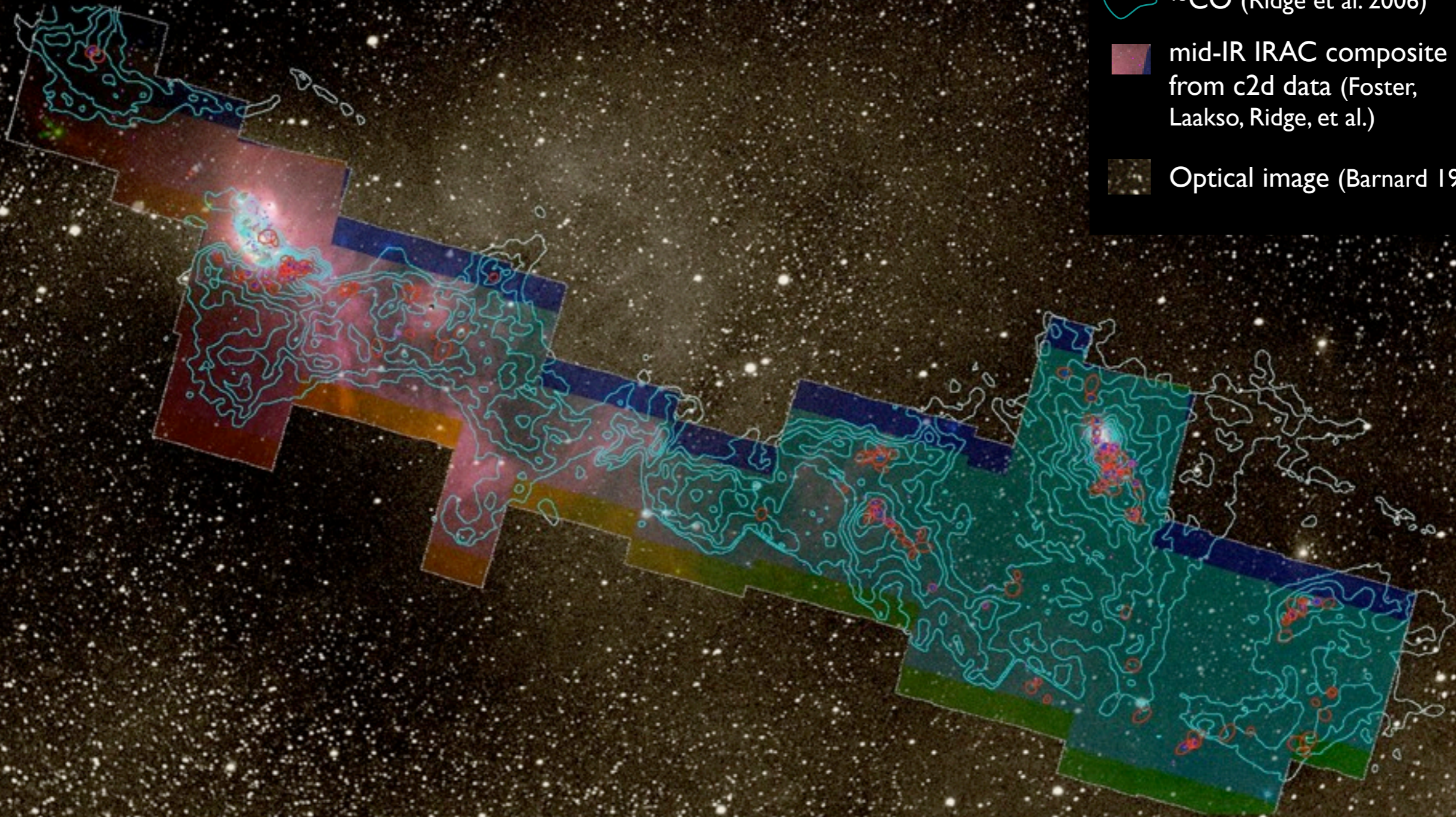




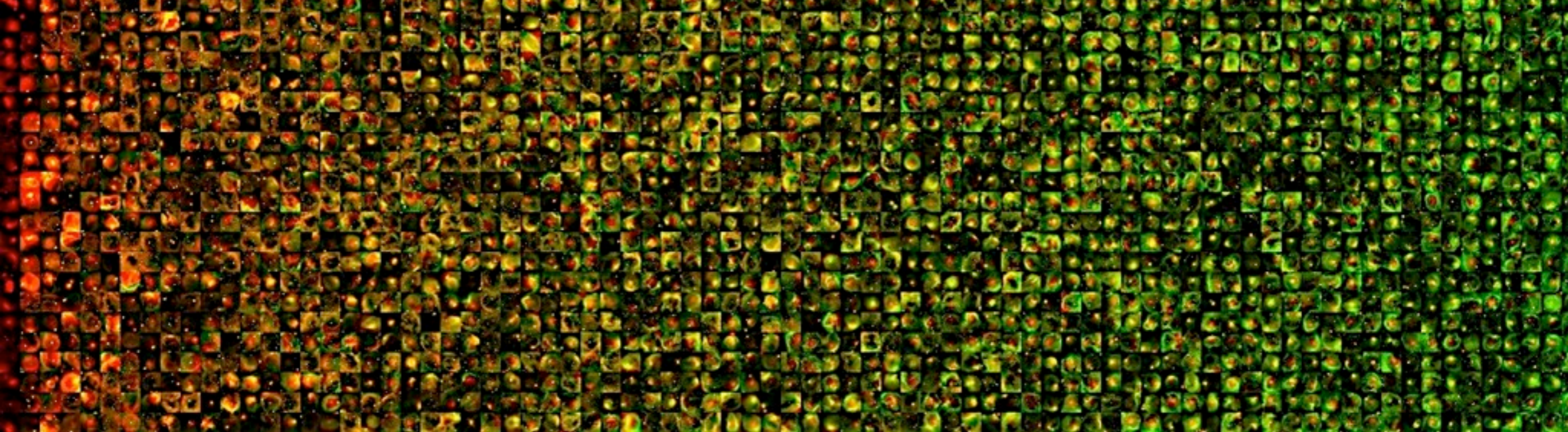
# WIDE DATA

COMPLETE

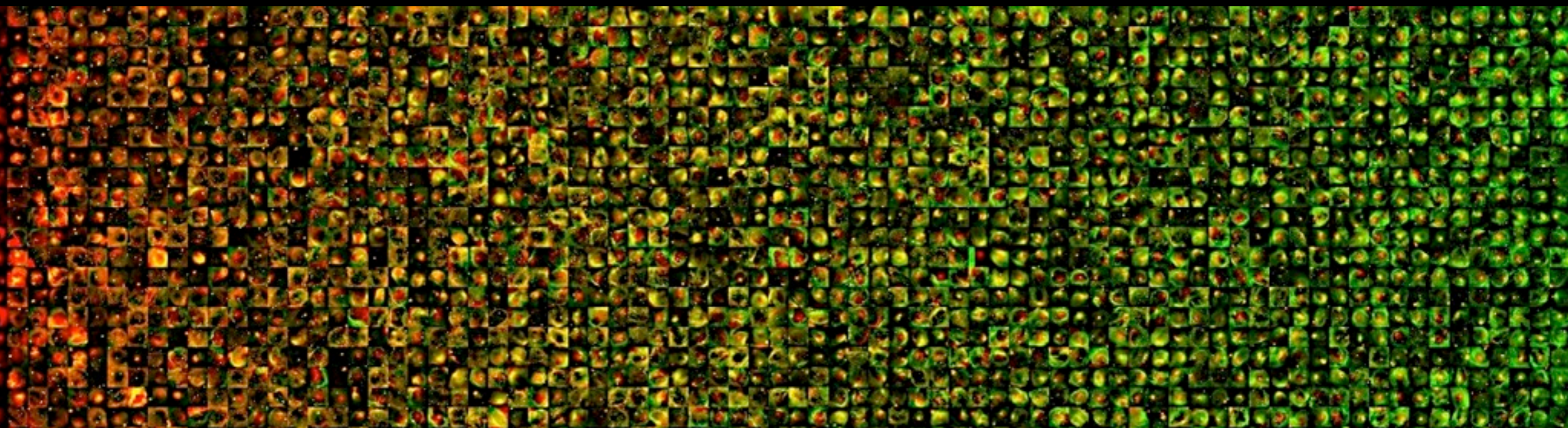
-  mm peak (Enoch et al. 2006)
-  sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)
-   $^{13}\text{CO}$  (Ridge et al. 2006)
-  mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al.)
-  Optical image (Barnard 1927)



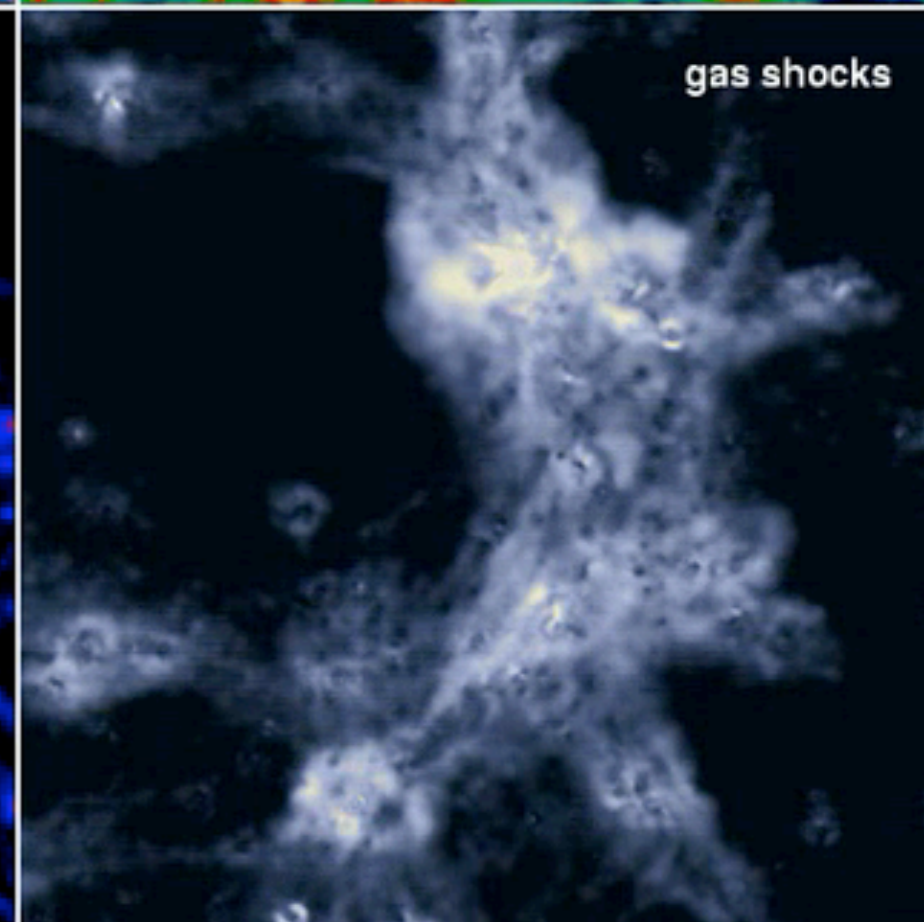
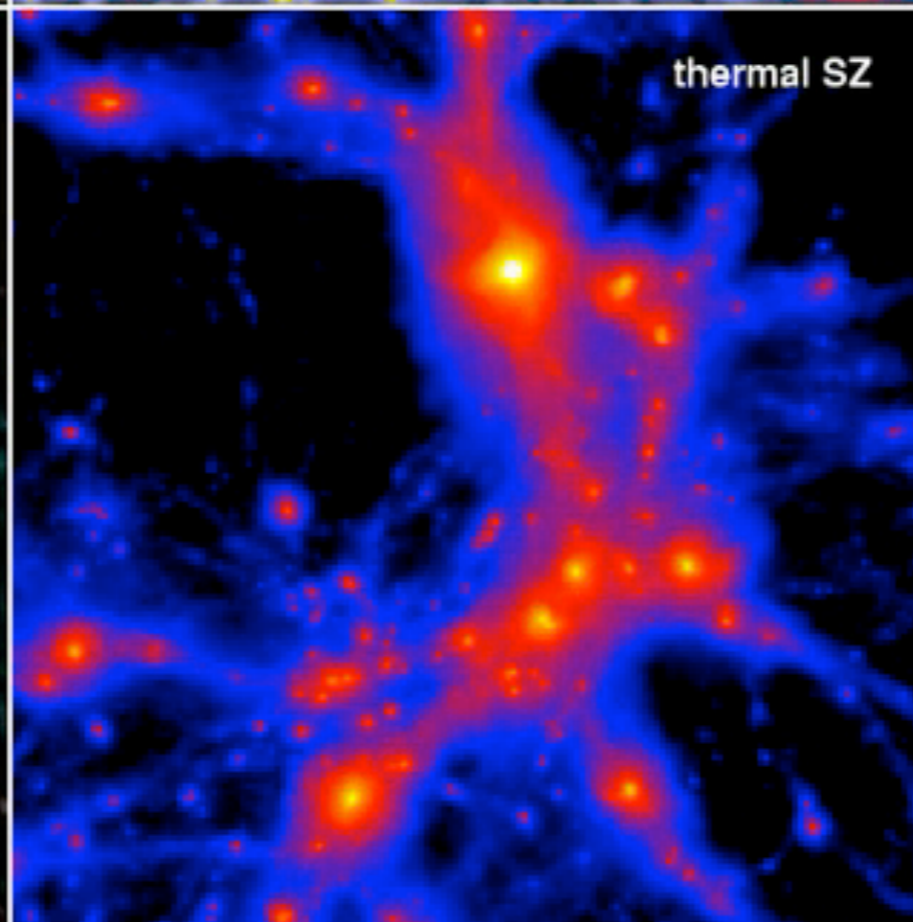
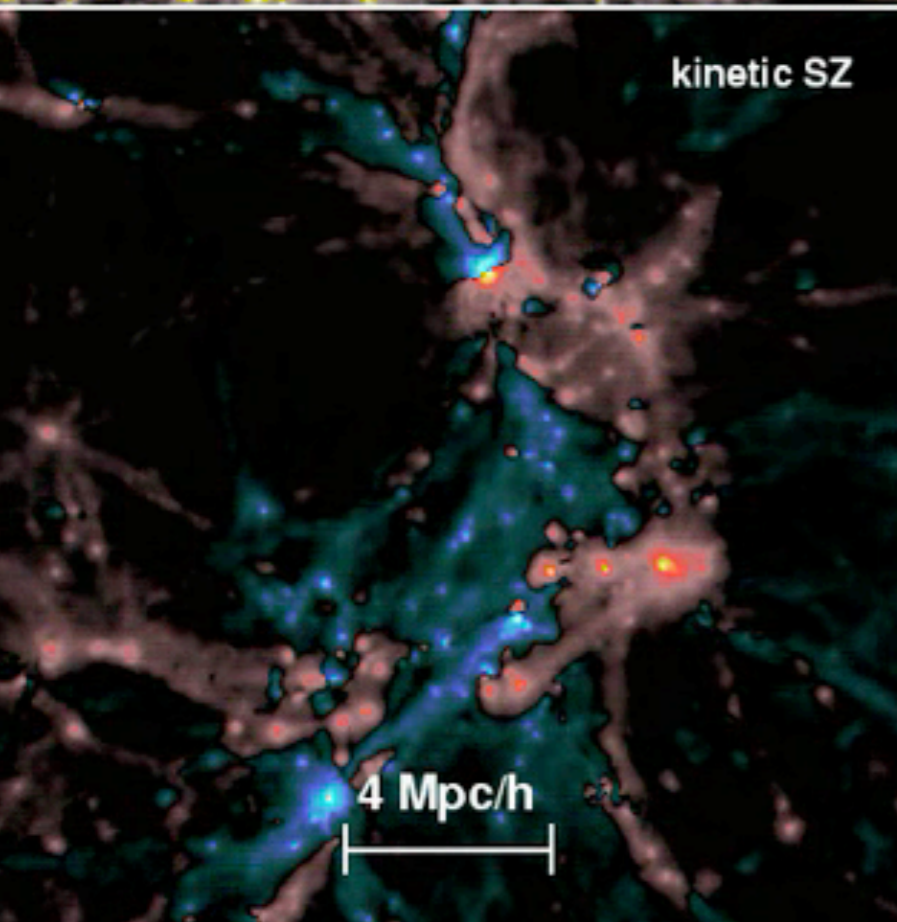
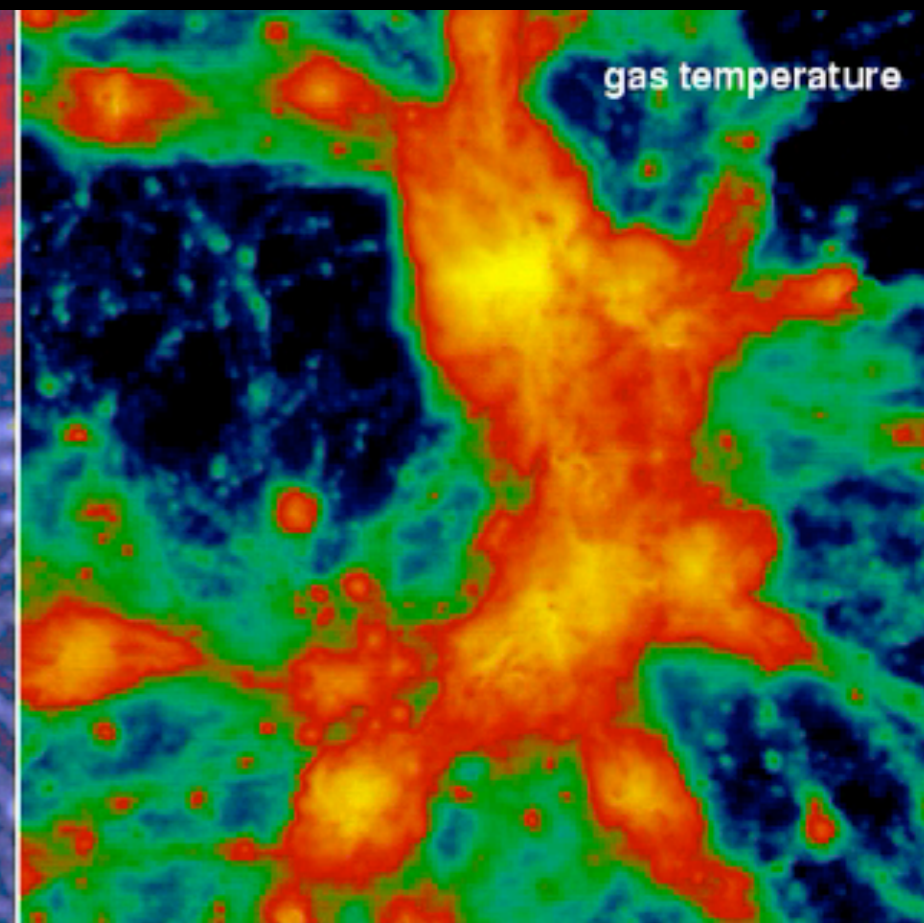
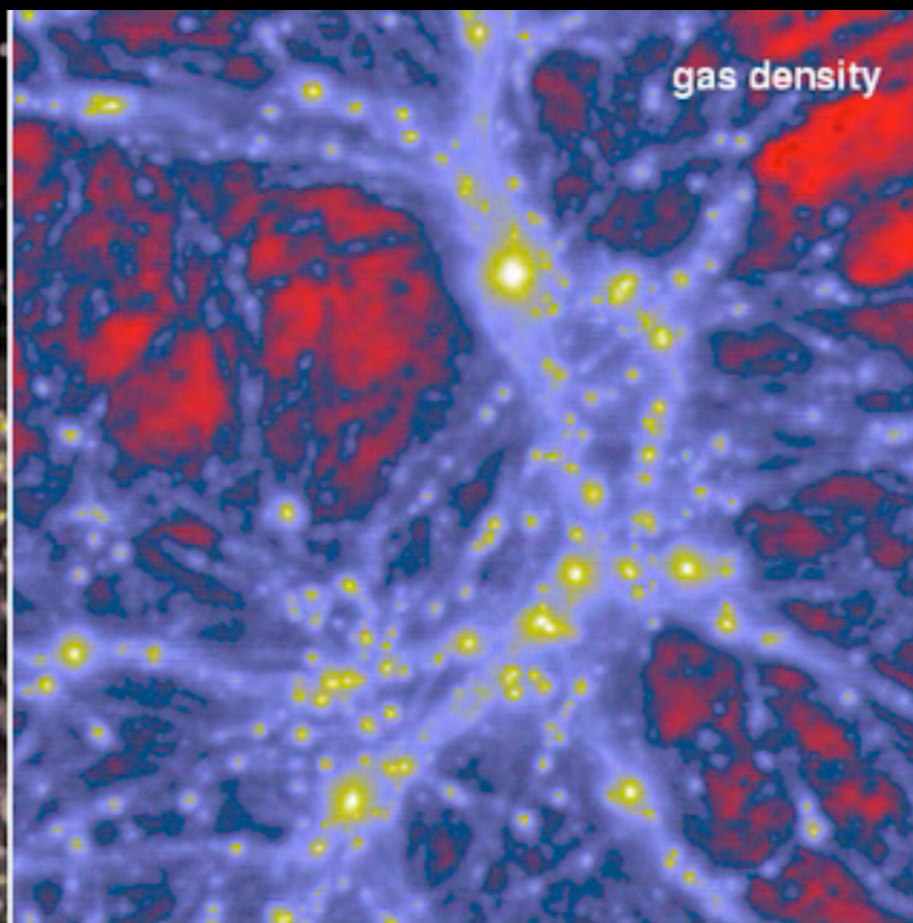
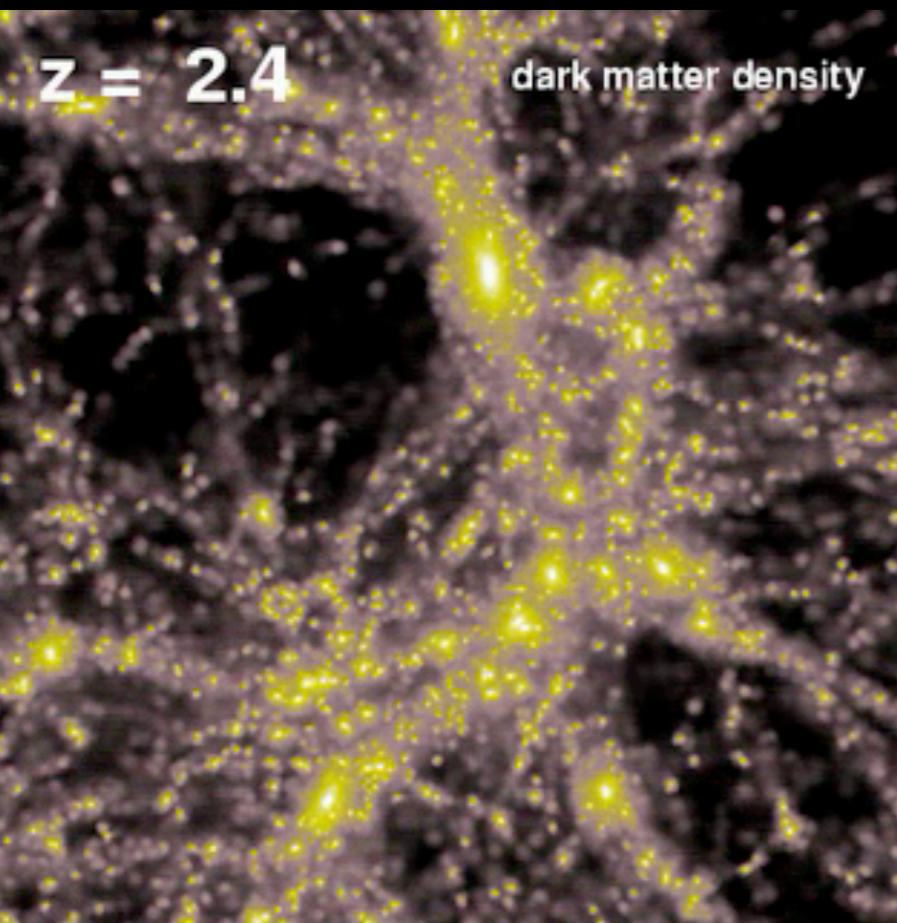




# BIG AND WIDE DATA

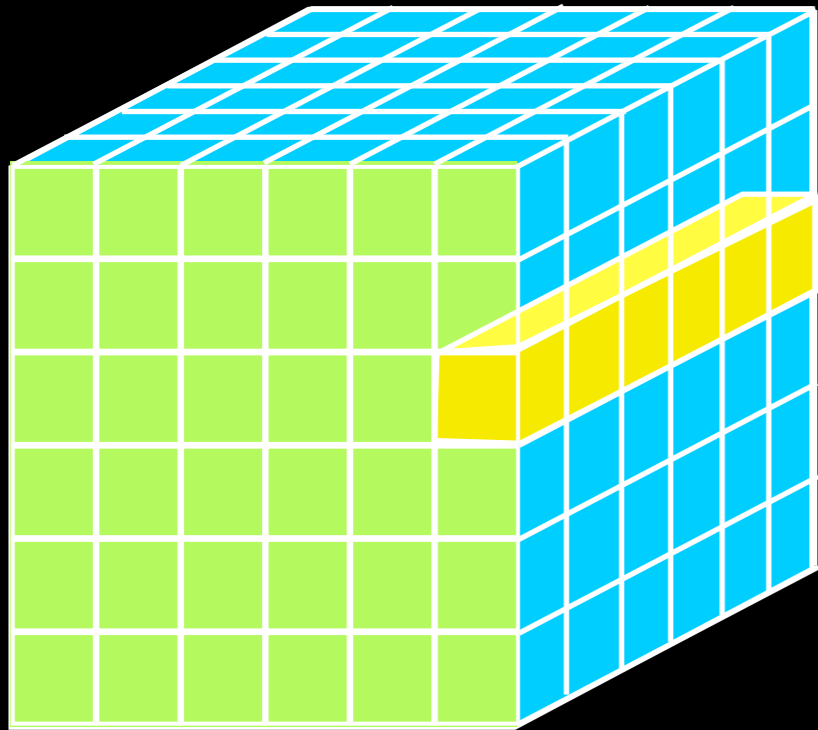






*Movie: Volker Springel, formation of a cluster of galaxies*










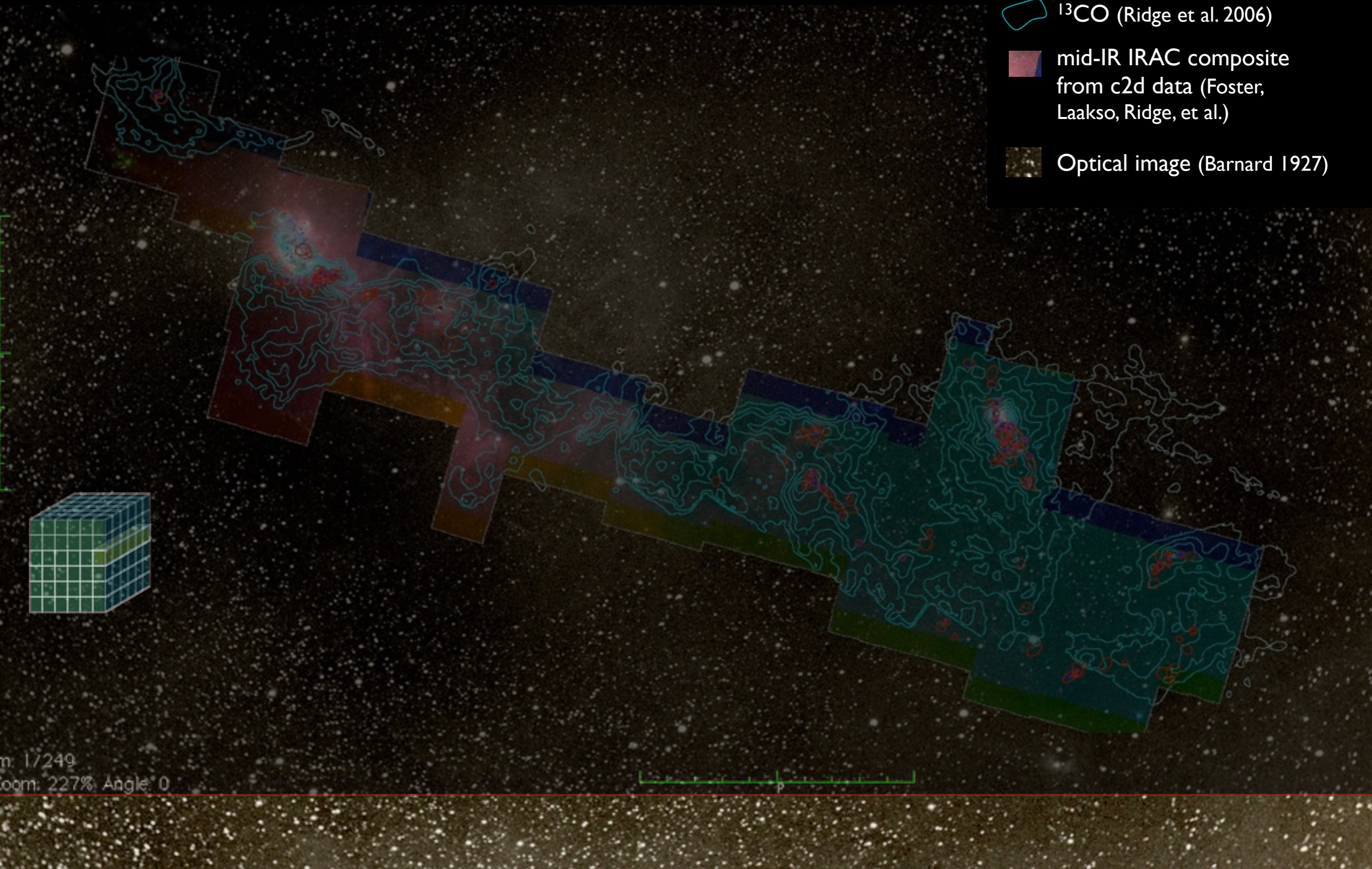
"DATA, DIMENSIONS, DISPLAY"

- 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"

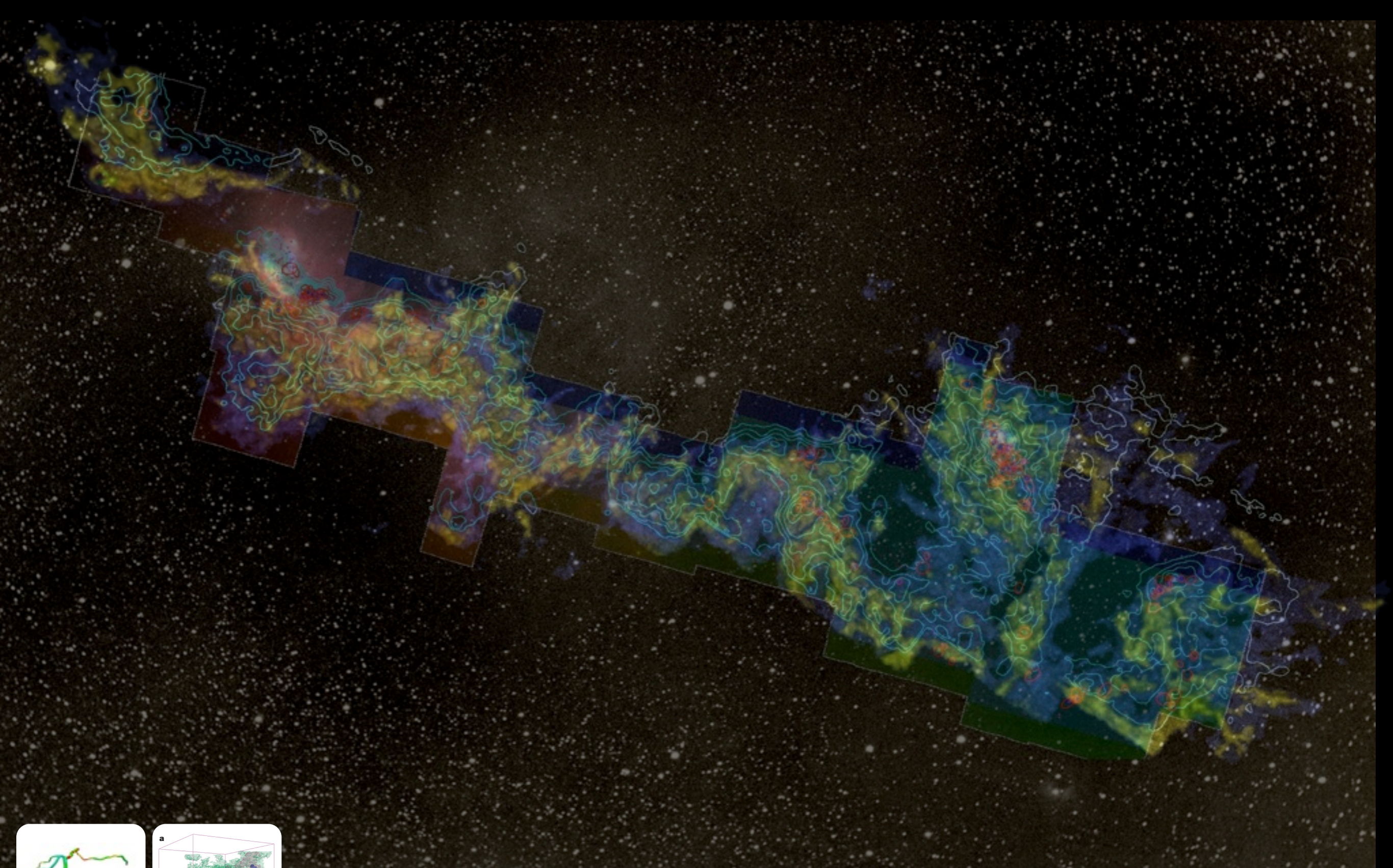


# WIDE DATA, "IN 3D"

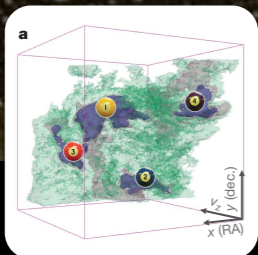
-  mm peak (Enoch et al. 2006)
-  sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)
-   $^{13}\text{CO}$  (Ridge et al. 2006)
-  mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al.)
-  Optical image (Barnard 1927)







3D Viz made with VolView



AstronomicalMedicine@iig

COMPLETE



1610



# WHAT DO WE PUBLISH?

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

30 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 less than the rest. But at the seventh hour the eastern one 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 and extended on the same straight line along the

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 1 minute from Jupiter. They were on the same straight line with Jupiter and equal in magnitude.

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

1665



1895

ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

VOLUME I JANUARY 1895 NUMBER 1

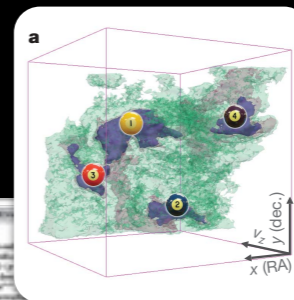
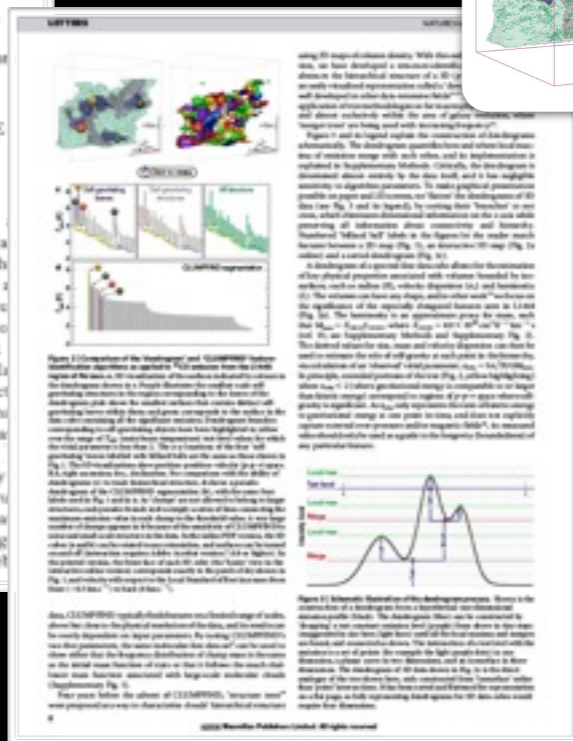
ON THE CONDITIONS WHICH AFFECT THE SPECTRO-PHOTOGRAPHY OF THE SUN.

By ALBERT A. MICHELSON.

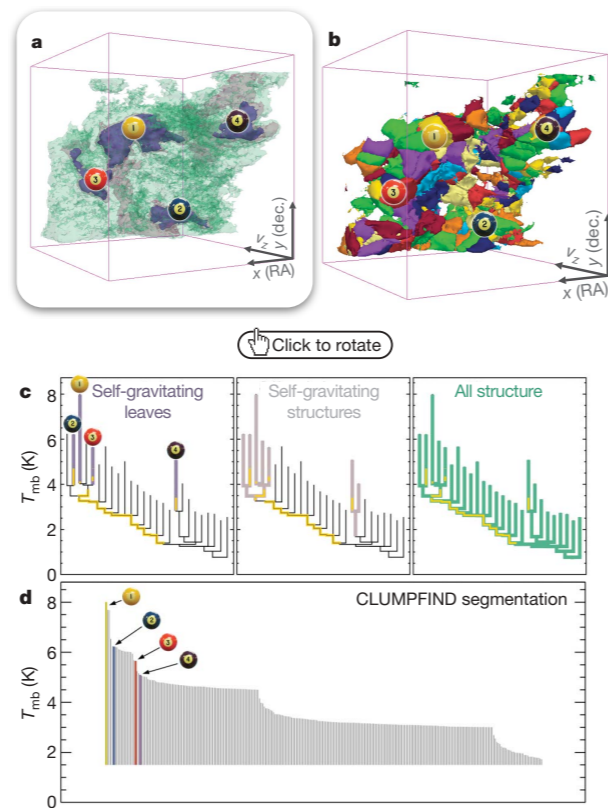
The recent developments in solar spectro-photography are in great measure due to the device originally suggested by Jansen and perfected by Hale and Deslandres, by means of which a photograph of the Sun's prominences may be obtained at a time as readily as it is during an eclipse. The essential features of this device are the simultaneous movements of the camera-slit across the Sun's image, with that of a second slit (the focus of the photographic lens) over a photographic plate. If these relative motions are so adjusted that the same spectral line 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 effect

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

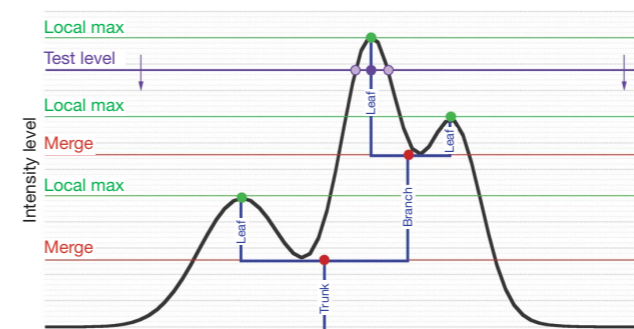
data, CLUMPFIND typically finds features on a limited range of scales, above but close to the physical resolution of the data, and its results can be overly dependent on input parameters. By tuning CLUMPFIND's two free parameters, the same molecular-line data set<sup>8</sup> can be used to show either 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 help of 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 'dendrogram'. This algorithm, well developed in other data-intensive applications such as image segmentation and almost exclusively within the astronomical community, are being used with increasing frequency.

Figure 3 and its legend explain the dendrogram process schematically. The dendrogram quantifies the hierarchical structure of a volume of emission merge with each other, as explained in Supplementary Methods and Supplementary Fig. 2. The dendrogram is sensitive to algorithm parameters, but the results are 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 (see Fig. 3).

A dendrogram of a spectral line emission cube, such as surfaces, such as radius ( $r$ ), luminosity ( $L$ ), and velocity dispersion ( $\sigma_v$ ). The volumes can have any shape, and the significance of the especially elongated features (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.

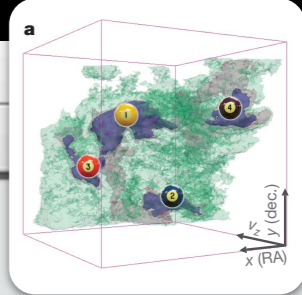
Goodman et al. 2009, Nature, cf. Fluke et al. 2009

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-

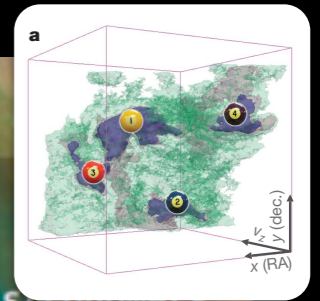
overlapping features as an option, significant emission found between prominent clumps is typically either appended to the nearest clump or turned into a small, usually 'pathological', feature needed to encompass all the emission being modelled. When applied to molecular-line





# AstroBetter

Tips and Tricks for Professional Astronomers



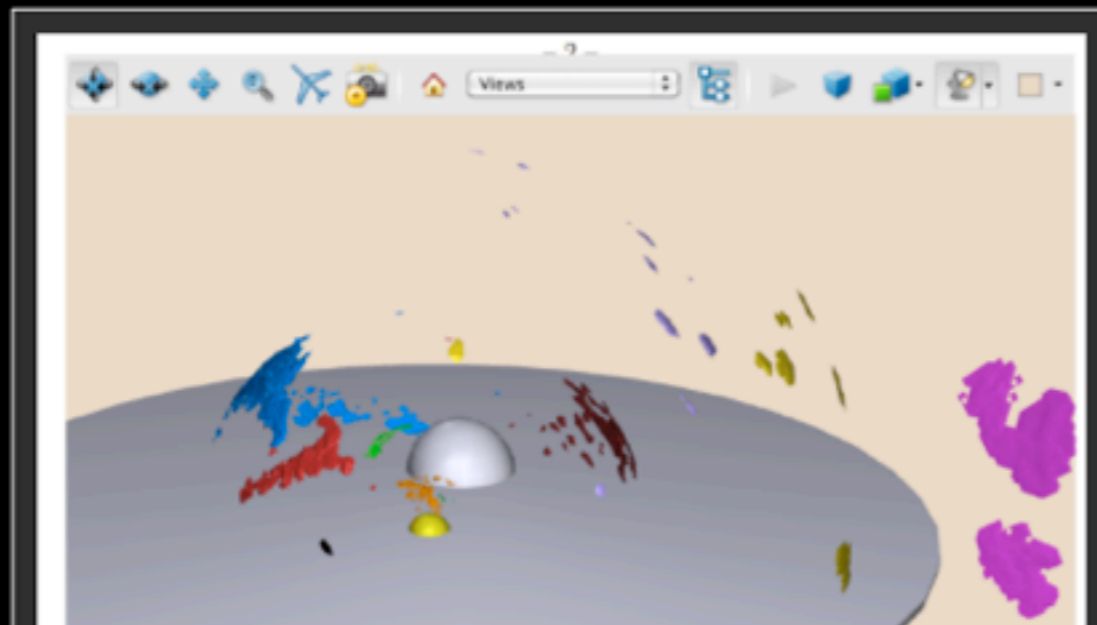
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## Tutorial for embedding 3D interactive graphics into PDF

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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- [Planck](#) (8)
- [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

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

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

East \* ○ \* West

on a straight line, as in the adjoining figure. The easternmost was distant 3 minutes from the next one, while this one was 40 seconds from Jupiter, Jupiter was 4 minutes from the nearest western one, and this one 6 minutes from the westernmost one. Their magnitudes were nearly equal; the one closest to Jupiter appeared than the rest. But at the seventh hour the eastern 30 seconds apart. Jupiter was 1 minute from the

East \*\* ○ \*\*

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

On the fifth, the sky was cloudy.

On the sixth, only two stars appeared flanking Ju

East \* ○ \*

in the adjoining figure. The eastern one was 2 m western one 1 minute from Jupiter. They were on th line with Jupiter and equal in magnitude.

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

1665



1895

**ASTROPHYSICAL JOURNAL**

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

VOLUME I JANUARY 1895

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

**PHOTOGRAPHS OF THE MILKY WAY.**

By E. E. BARNARD.

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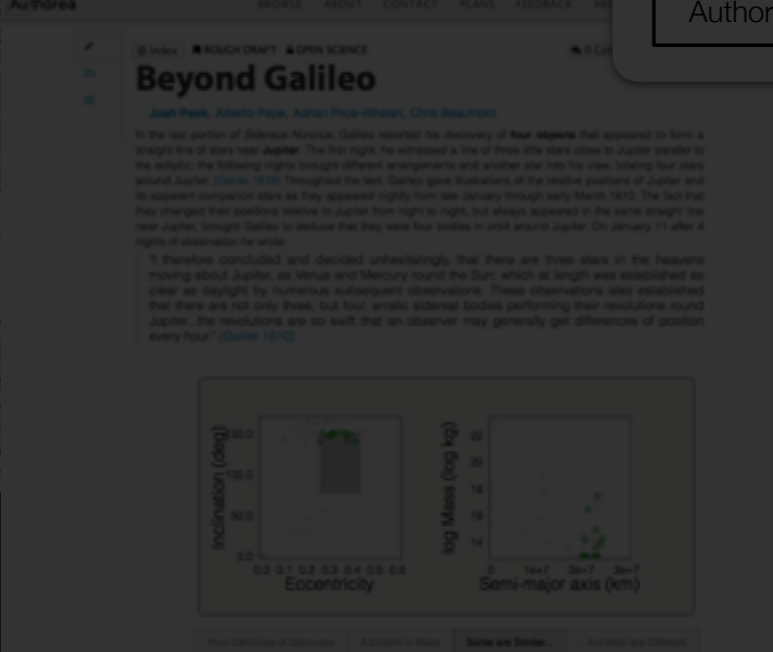
... always tails on the second side, then a photographic im of the Sun will be reproduced by light of this particular wavelength.

Evidently the process is not limited to the photography 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

2009



2014





1610



SIDEREUS NUNCIUS

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VOLUME I JANUARY 1895 NUMBER 1

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

.....HOW TO "UN"PUBLISH GRAPHICAL DATA



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$\alpha(1875) 3^h 30^m 30s, \delta(1875) +31^{\circ} 25'$   
 $\alpha(2000) +31^{\circ} 00'$

Area  
In Perseus and Taurus

Galactic Coordinates  
 $127^{\circ}, -18^{\circ}$

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

Chart Table Plate & Chart Text

enlarge [+] printable PDF



ADS ALL SKY SURVEY

Bar-p01-p003\_sm  
Barnard's Image of Perseus, from www.library.gatech.edu/tpdi/tpdi.php

December 17, 2003

astrometry.net

Hello, this is the blind astrometry solver. Your results are: (RA, Dec) center: (54.3096782484, 31.43266374) degrees Orientation: 5.2134585754 deg E of N Pixel scale: 18.56371997 arcseconds Your field contains: NGC 1465 IC 1985 (Per / Ark 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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ADS ALL SKY SURVEY

WorldWide Telescope

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Open Collections > Bar-p01-p003\_sm > Barnard's Image of Perseus

ADS ALL SKY SURVEY

WorldWide Telescope



# AND, SOON...HUMANS WILL SEE THE INVISIBLE!



+



ADS All-Sky Survey  
**oldAstronomy**

No. 1, 1998

ORIGIN AND EVOLUTION OF THE CEPHEUS BUBBLE

243

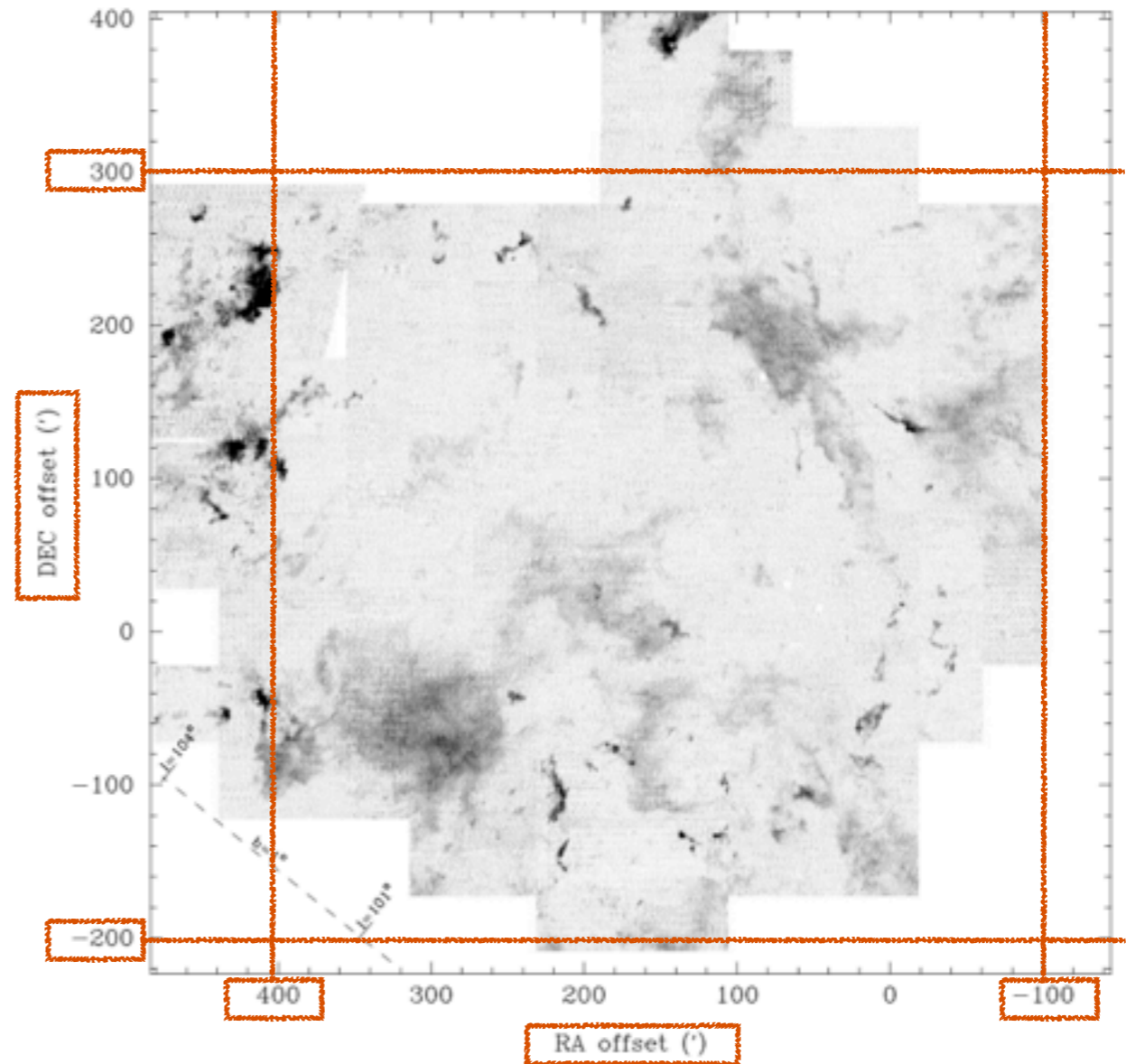
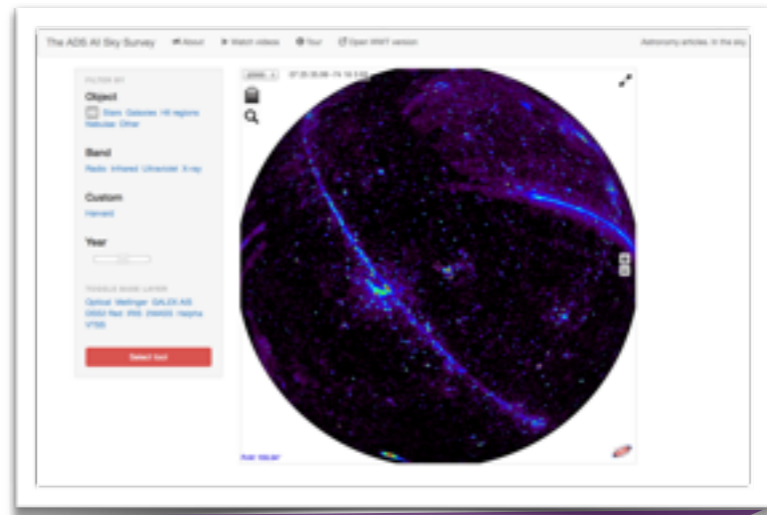



FIG. 1.—Peak intensity of CO 1–0 emission. The gray scale represents antenna temperature values scaled linearly between 0 and 3.5 K. The strongest emission occurs at the S140 region and globule A of IC 1396, where the peak antenna temperature is about 10 K. The position offsets are measured from  $\alpha(1950)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

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

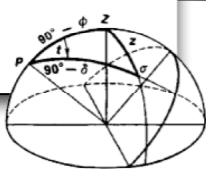




Object Data




CENTRE DE DONNÉES ASTRONOMIQUES DE STRASBOURG



ADDITIONAL DATABASE

Literature



PRIMARY DATABASE

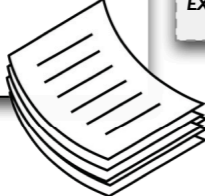
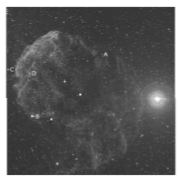
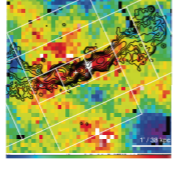


IMAGE EXTRACTION

Optical images



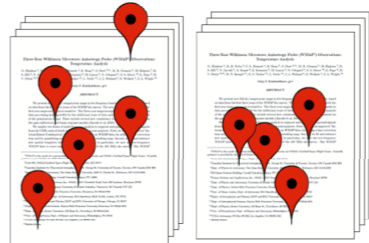
Non Optical images



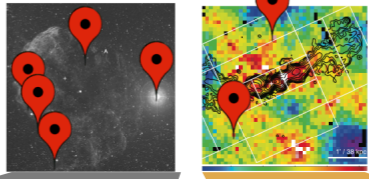
ARTICLE-OBJECT MATCHING

ASTROMETRIC MEASUREMENT

Astrotagged literature

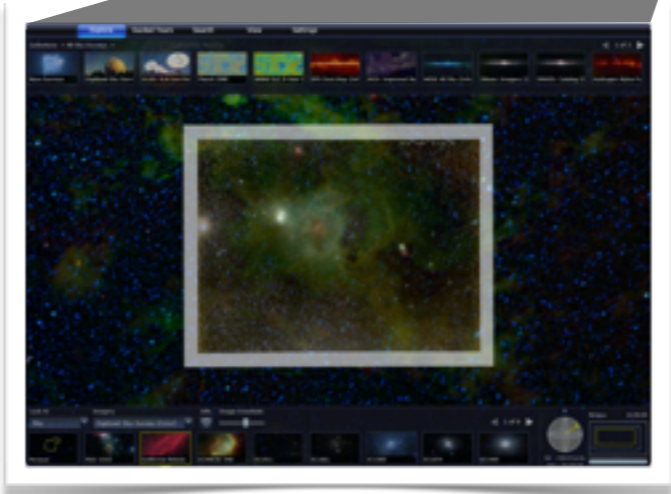


Astro-referenced images



DATA VIEWERS

- HISTORICAL DATA LAYER
- ALL-SKY LITERATURE HEATMAP
- NASA ARCHIVES

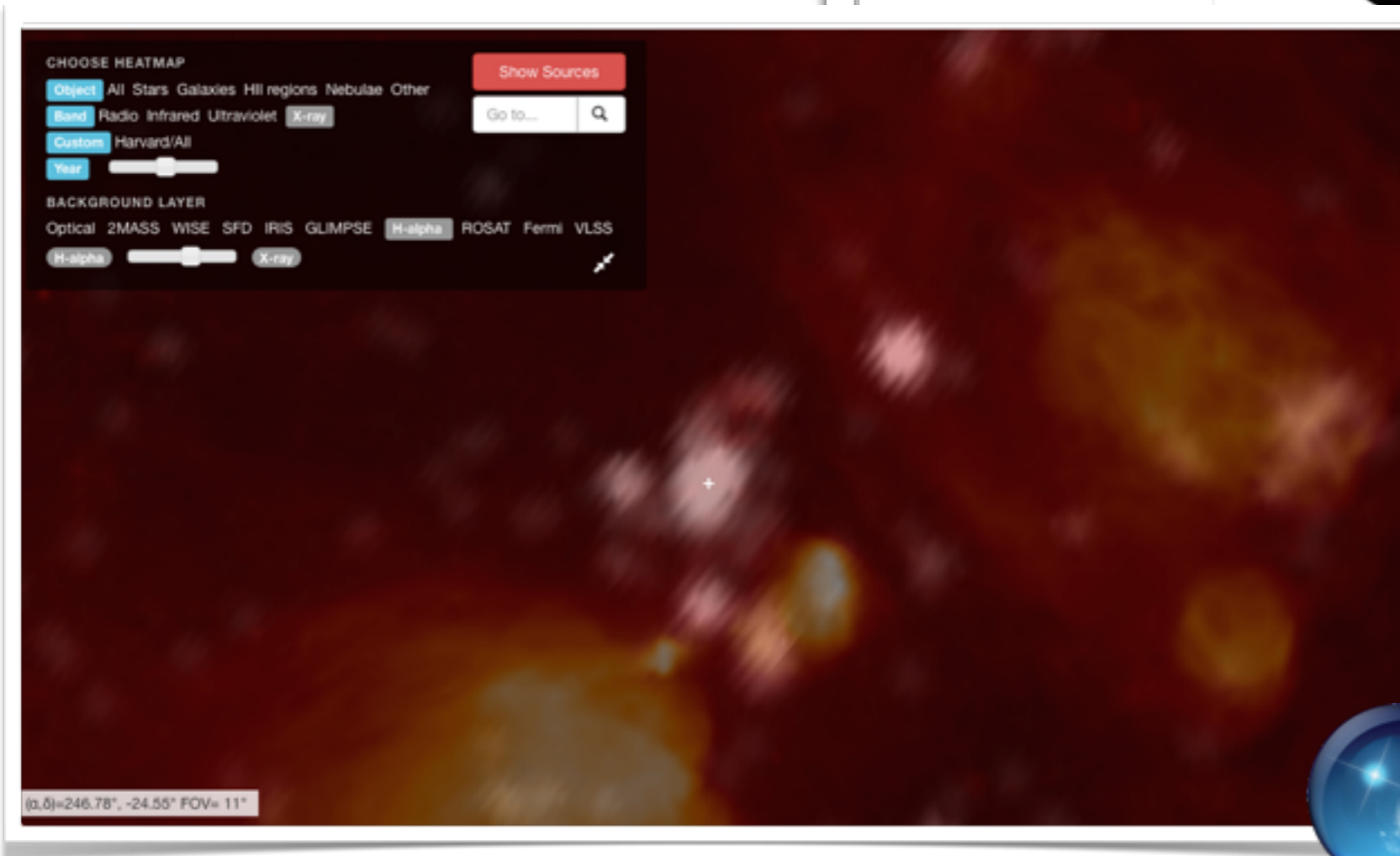
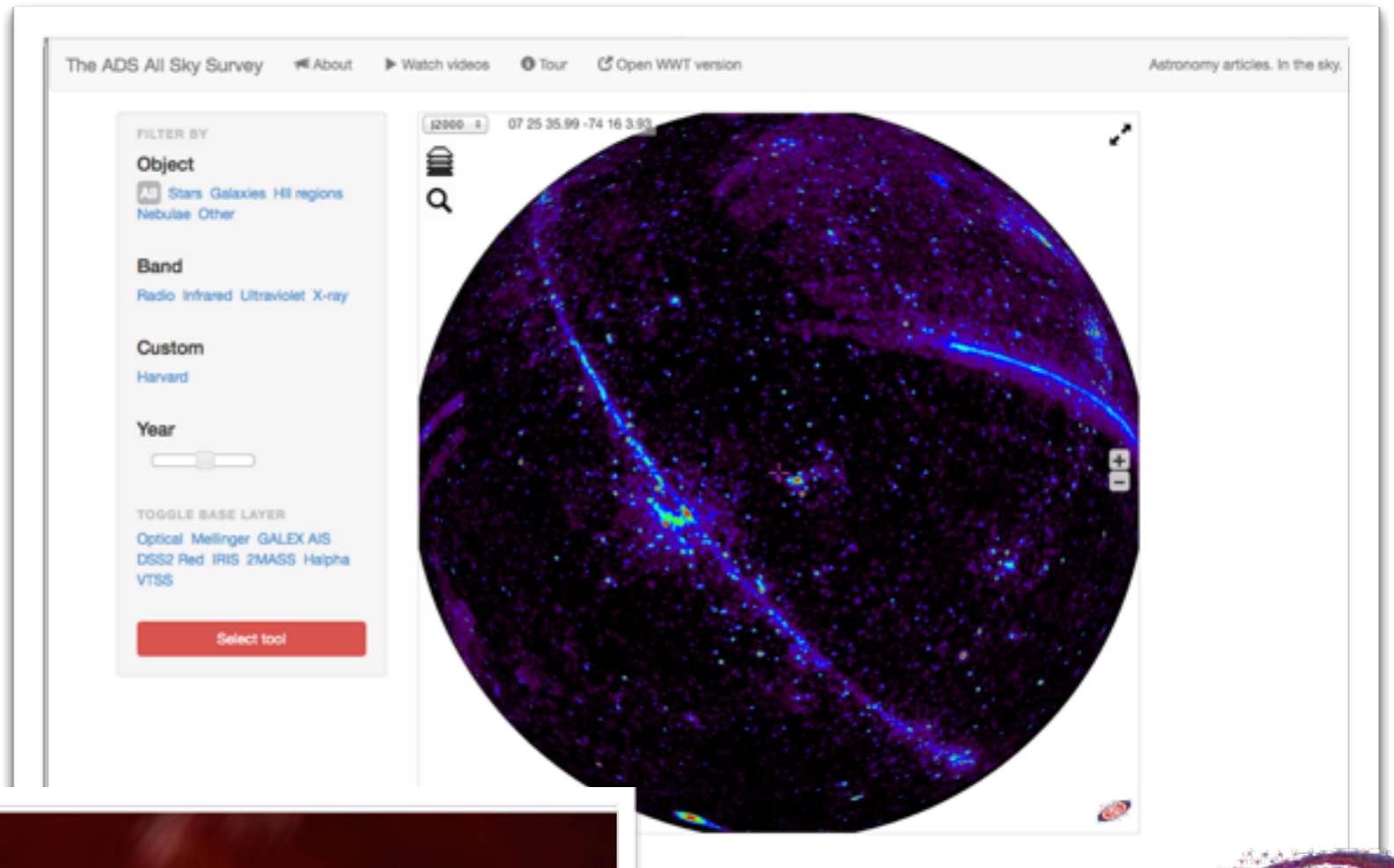


slide courtesy of Alberto Pepe





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No plugins required, use any  
browser, any platform*



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[Nebulae](#) [Other](#)

Band

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

Custom

[Harvard](#)

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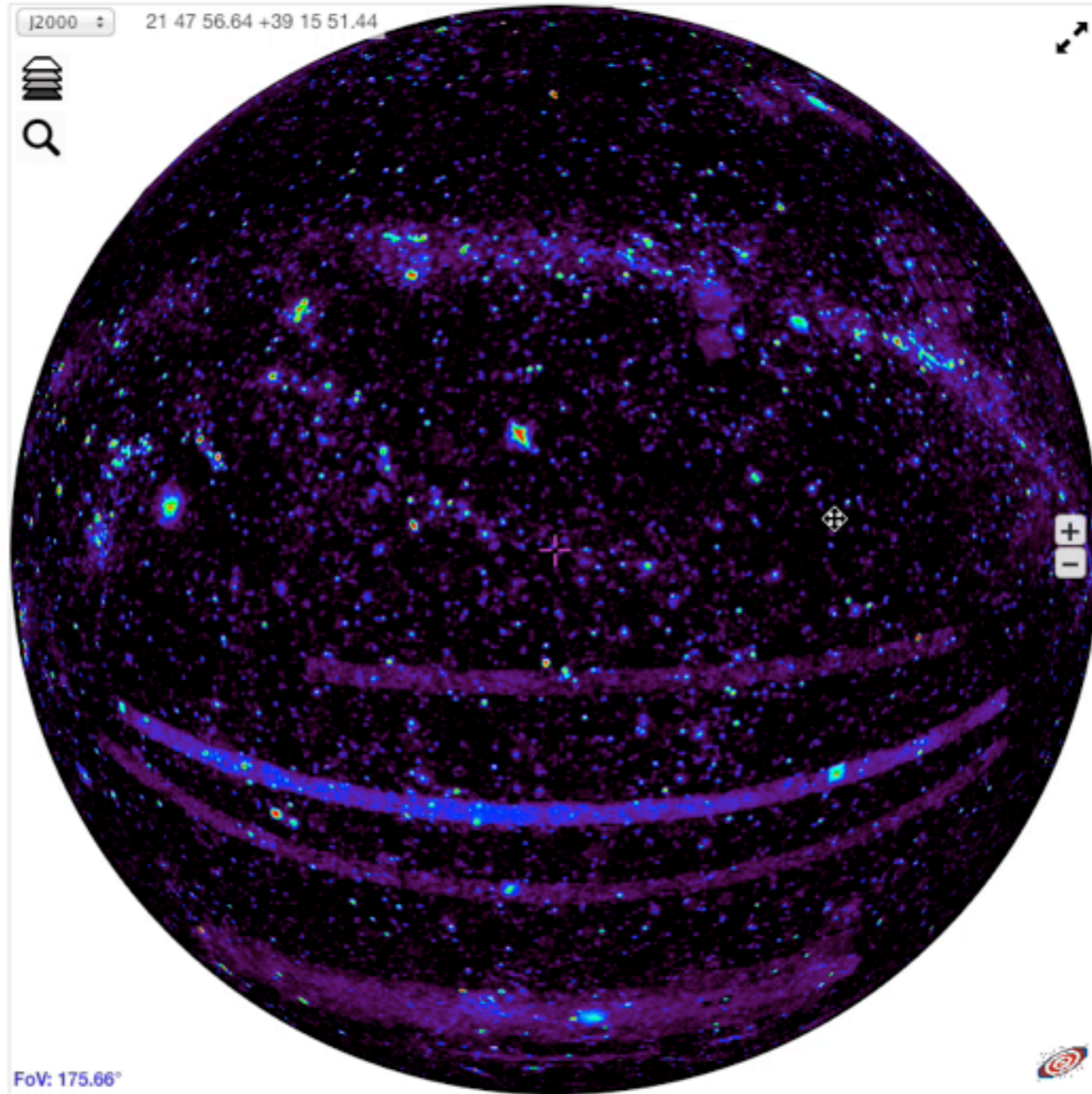


TOGGLE BASE LAYER

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[DSS2 Red](#) [IRIS](#) [2MASS](#) [Halpha](#)  
[VTSS](#)

Select tool

J2000 : 21 47 56.64 +39 15 51.44



FoV: 175.66°





1610



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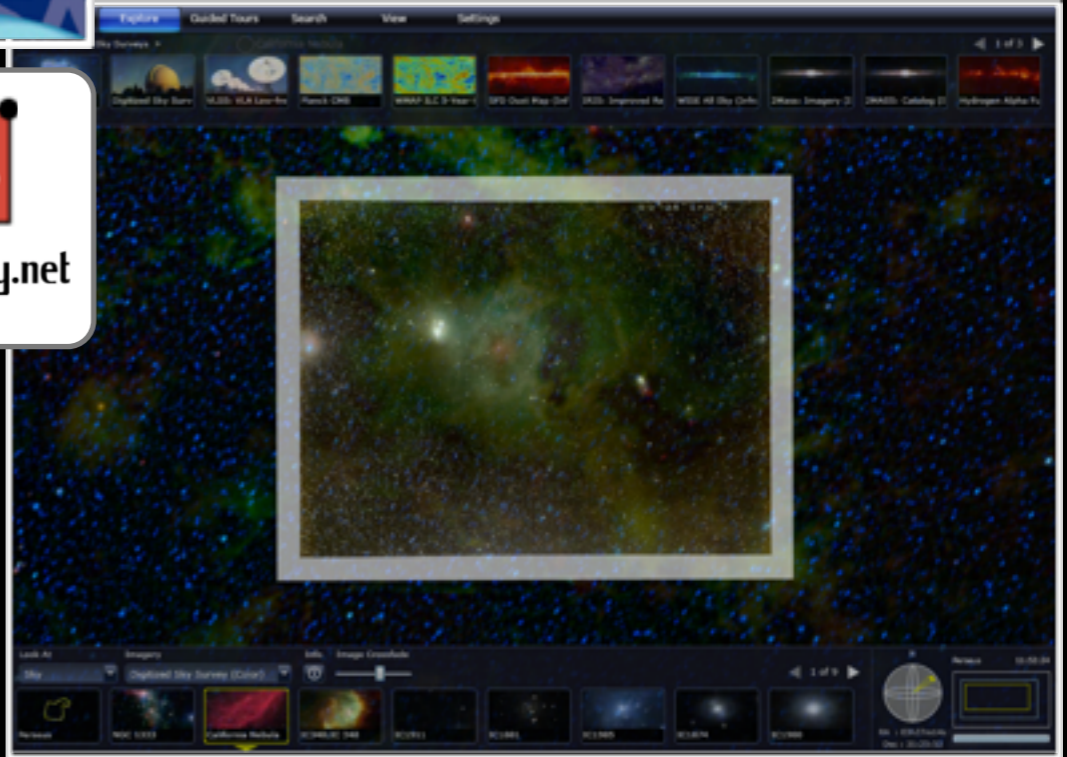
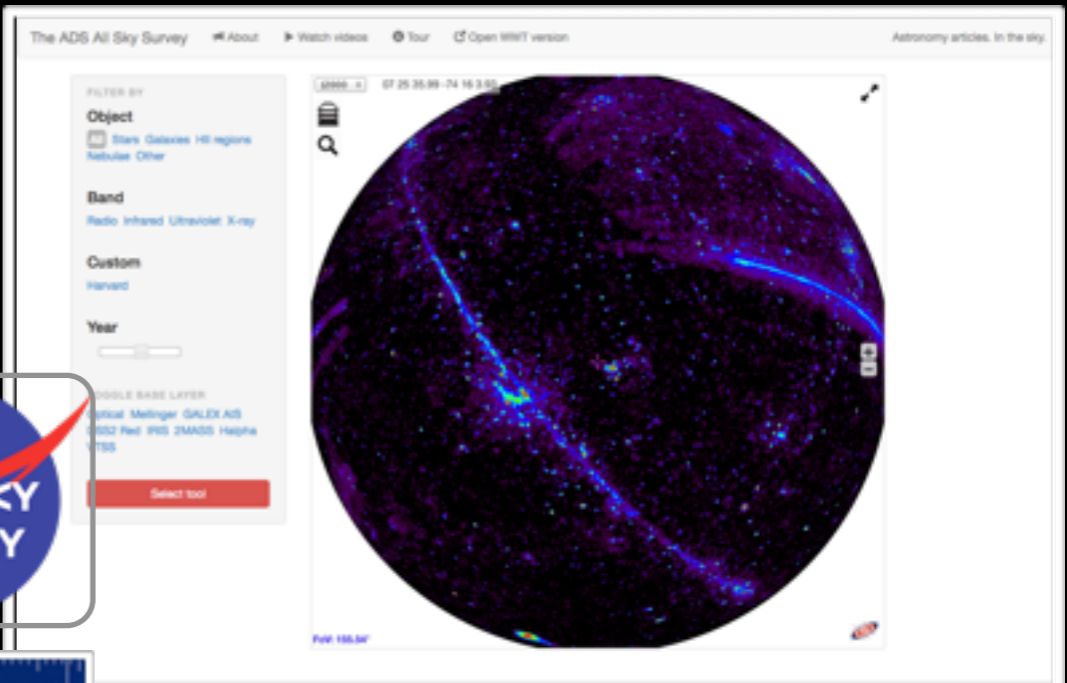
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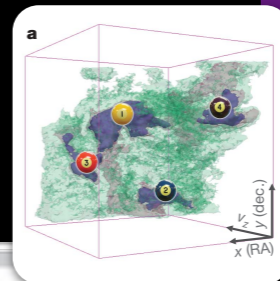
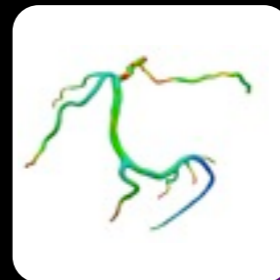
Evidently the process is not limited to the photography of the prominences, but extends to all other peculiarities of structure which emit radiations of approximately constant wavelength; and the efficiency of the method depends very largely upon the contrast which can be obtained by the greater exte-





# THE RIVETING SEQUEL

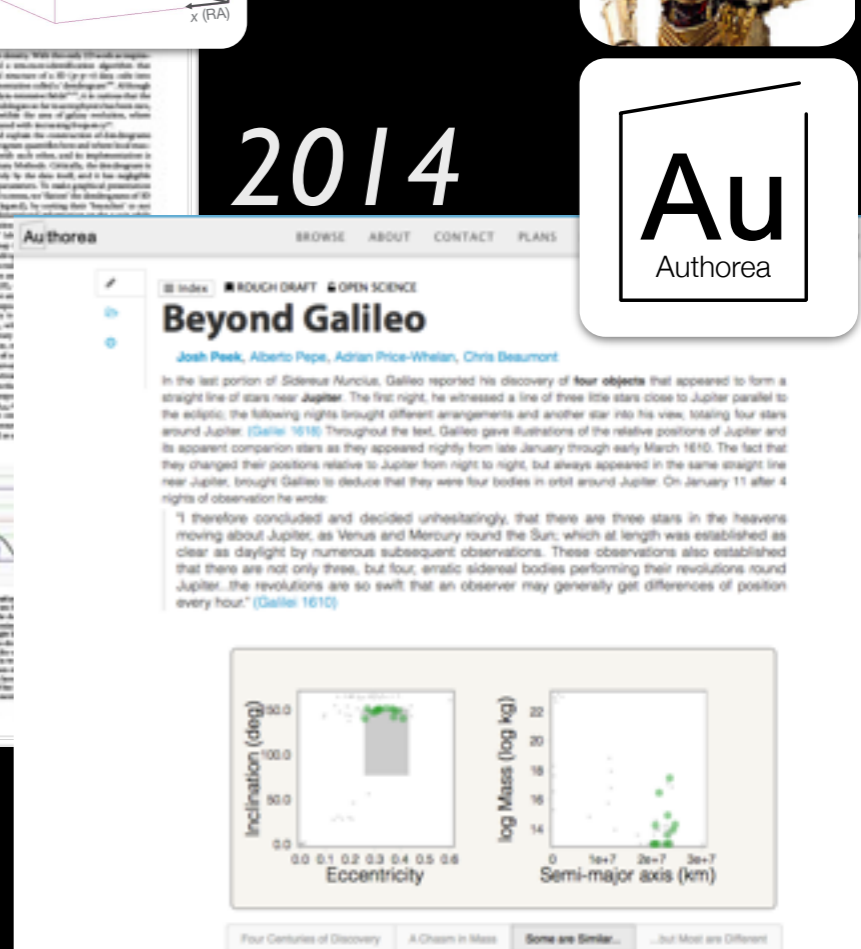
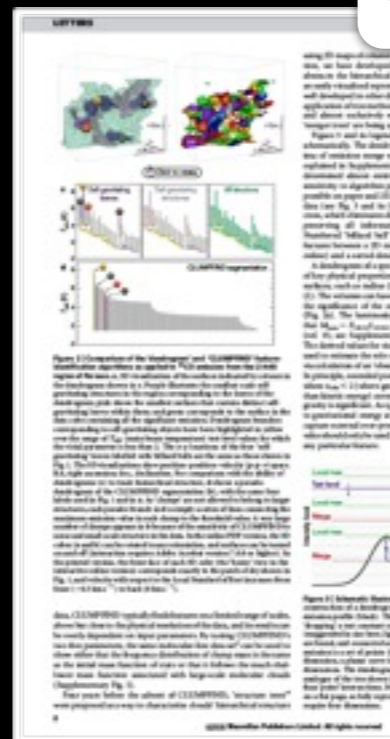
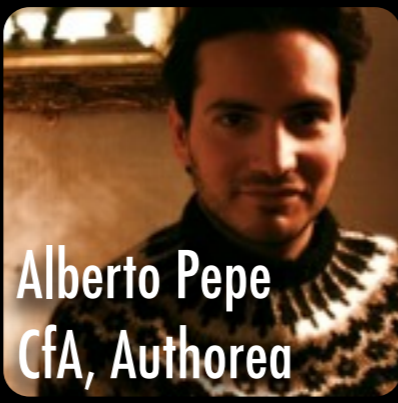
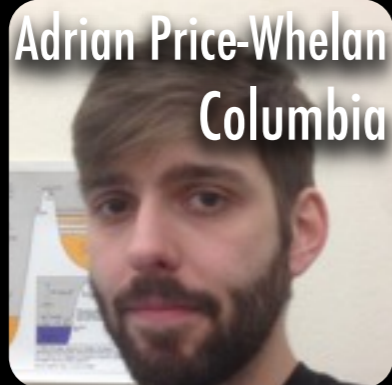
2009



.astronomy

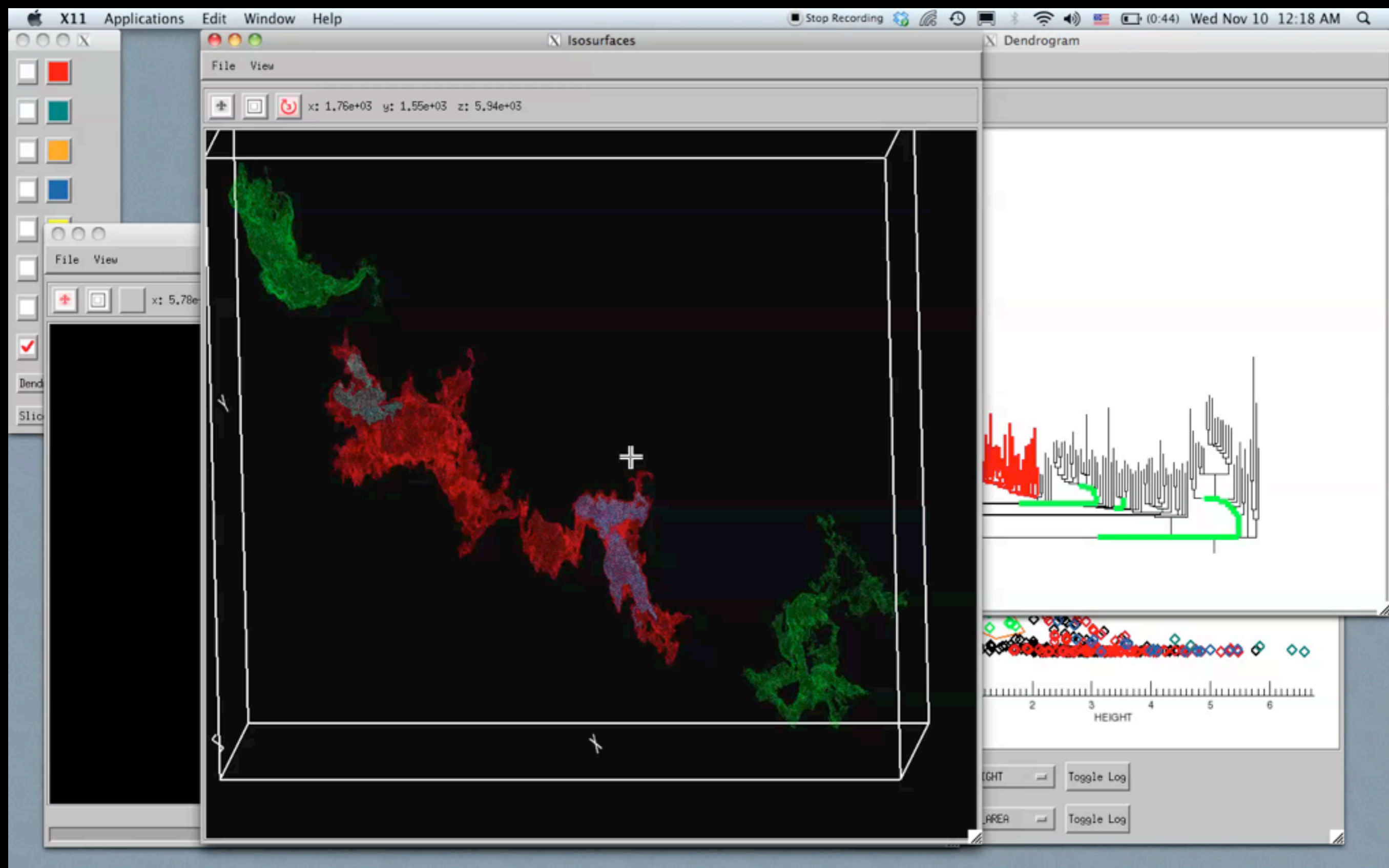


2014





# LINKED VIEWS OF HIGH-DIMENSIONAL DATA



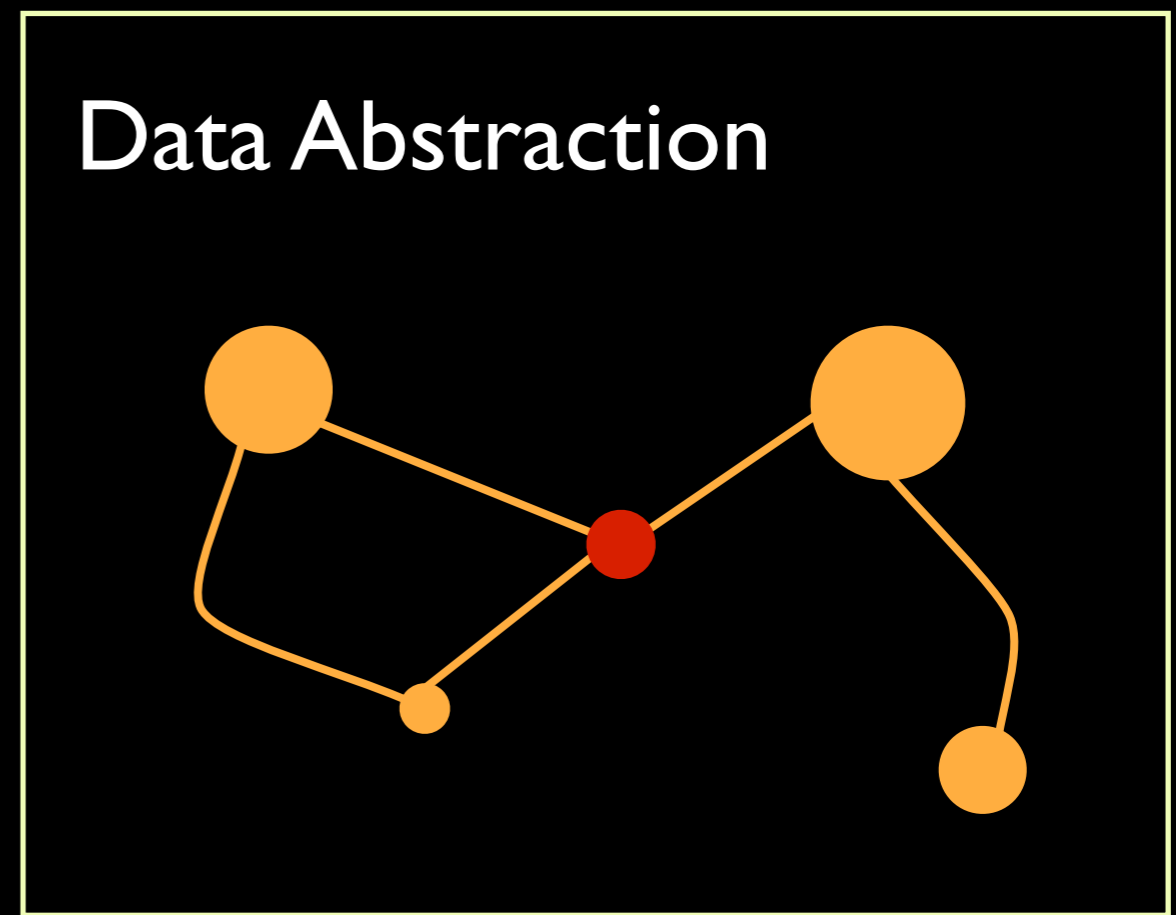
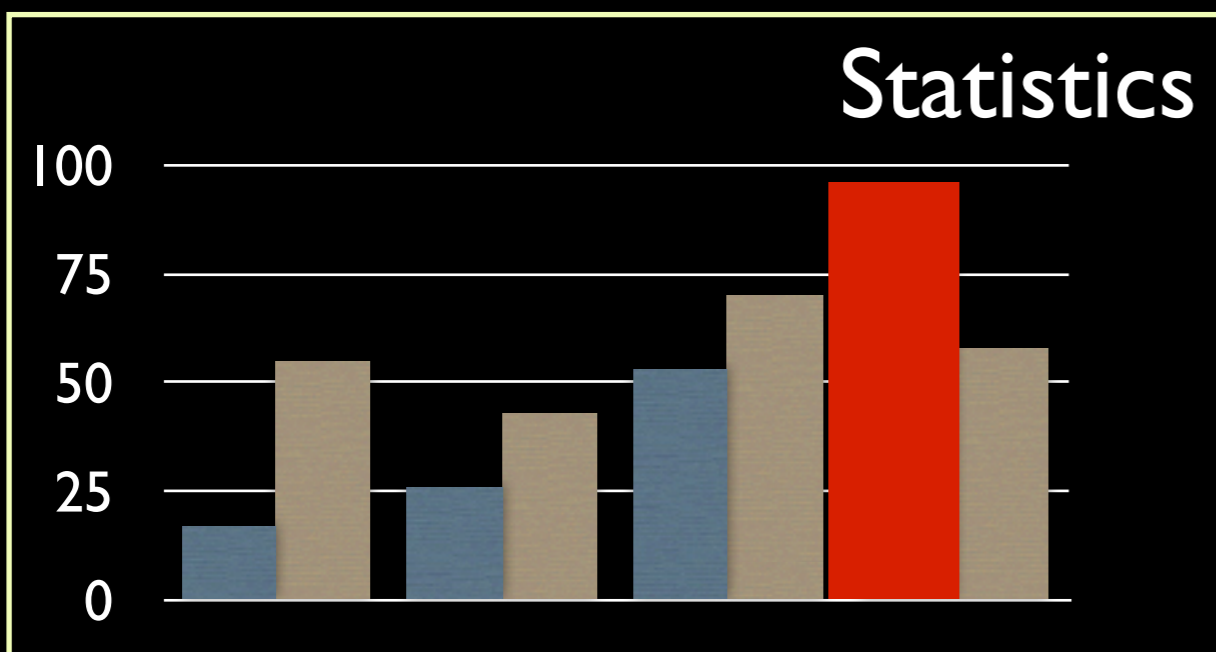
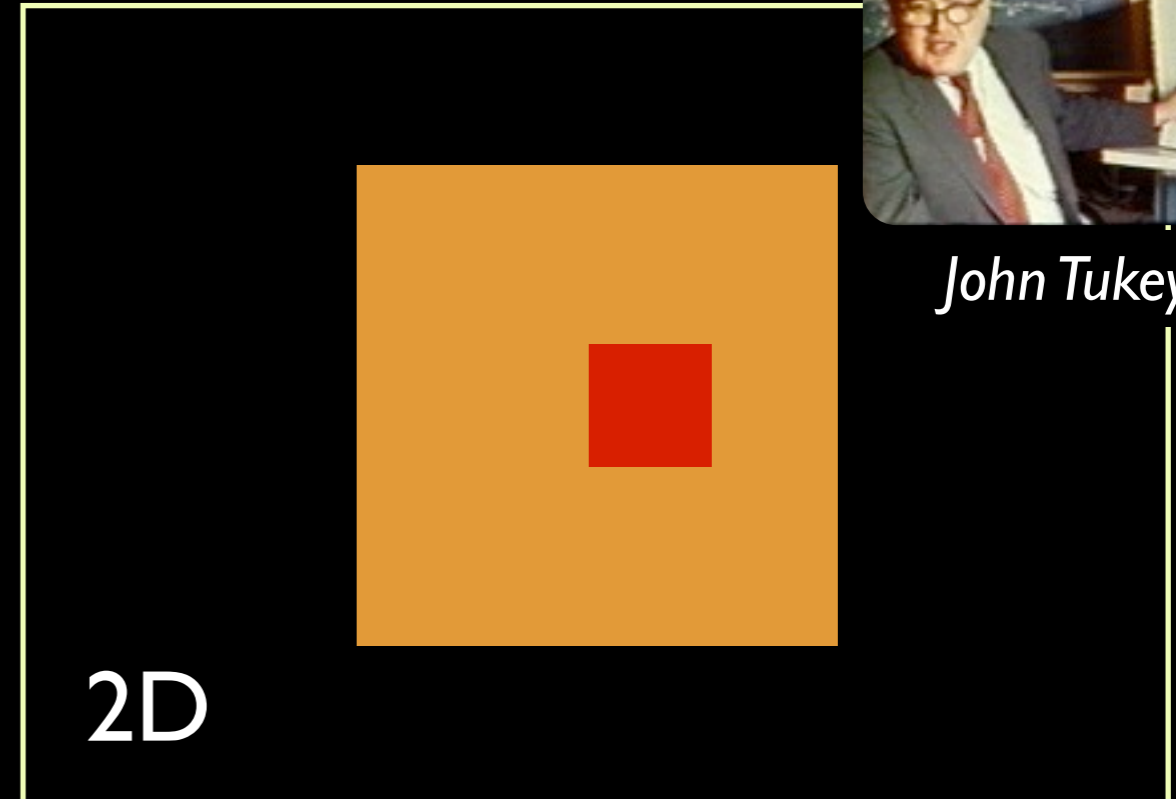
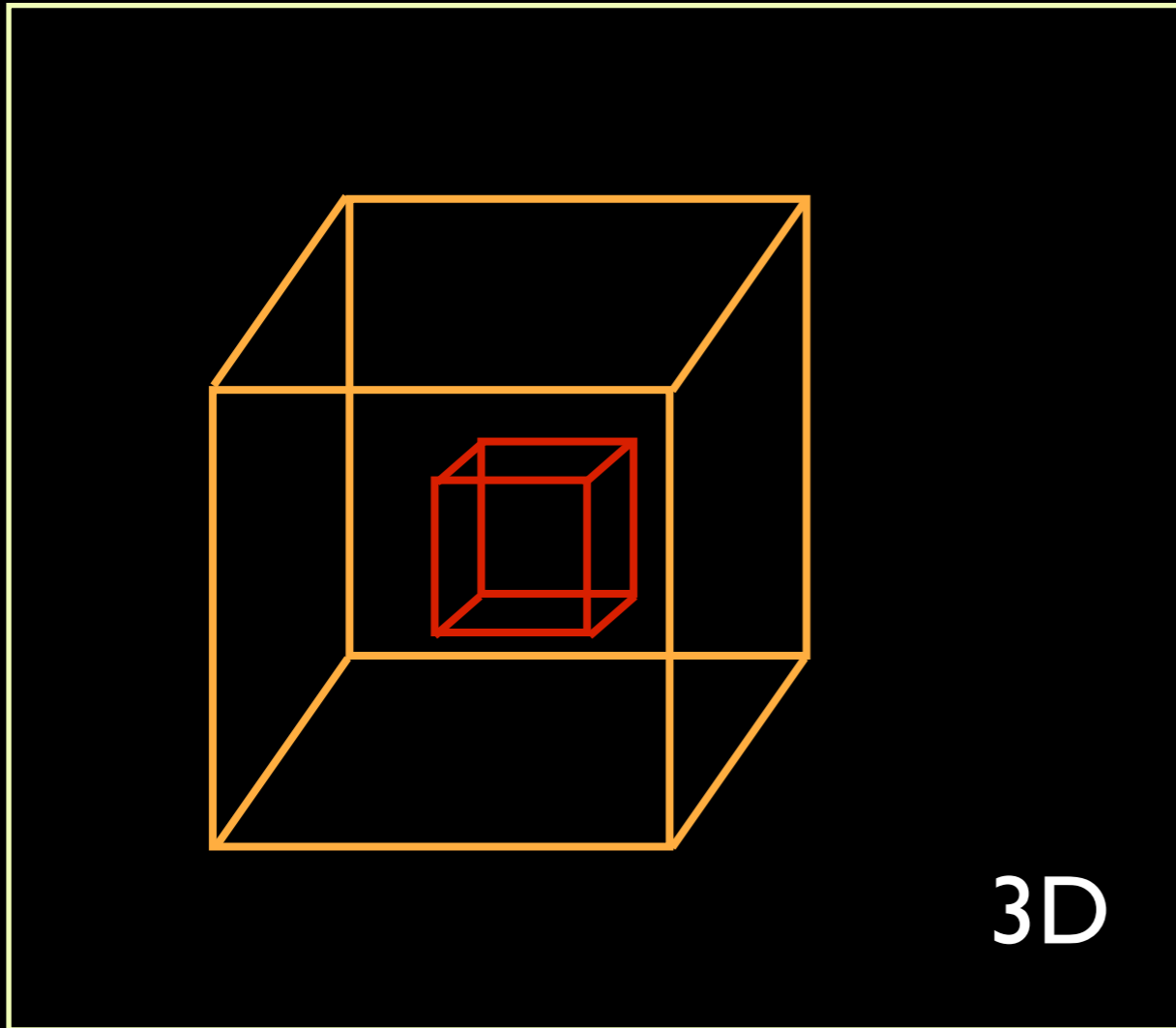
Video & implementation: **Christopher Beaumont**, CfA;  
inspired by AstroMed work of Douglas Alan, Michelle Borkin, AG, Michael Halle, Erik Rosolowsky



# LINKED VIEWS OF HIGH-DIMENSIONAL DATA



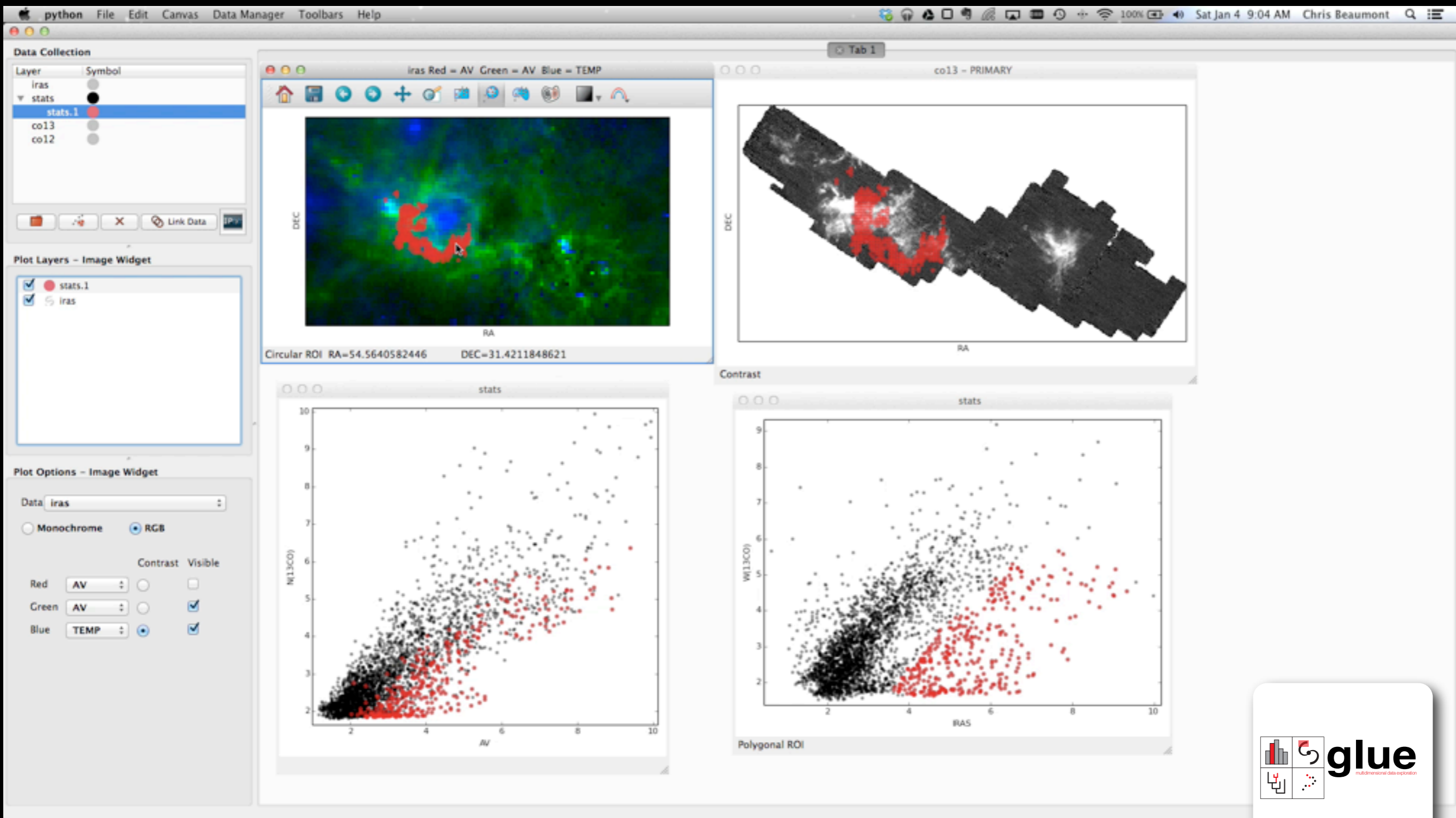
John Tukey



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



# LINKED VIEWS OF HIGH-DIMENSIONAL DATA GLUE



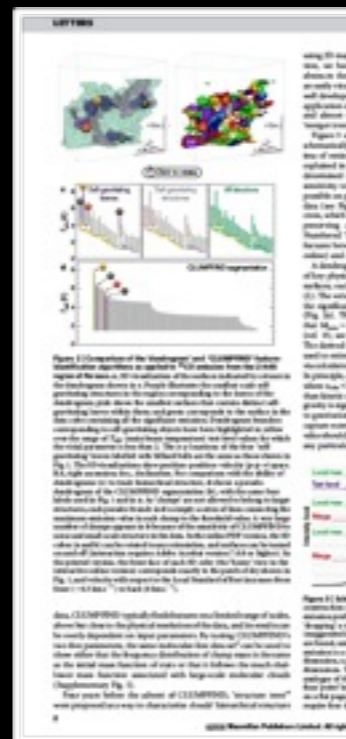
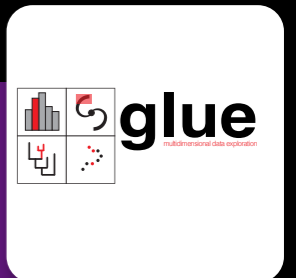
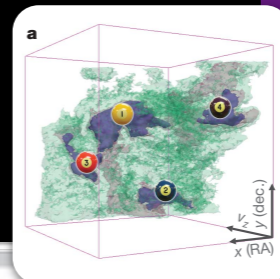
Beaumont, w/Goodman, Robitaille & Borkin

Thursday, May 1, 2014



# THE RIVETING SEQUEL

2009

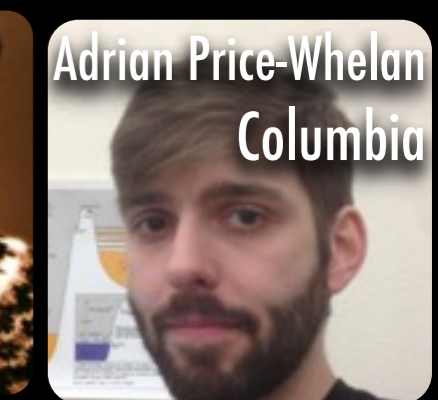
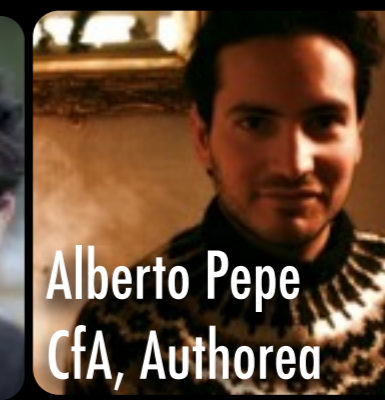
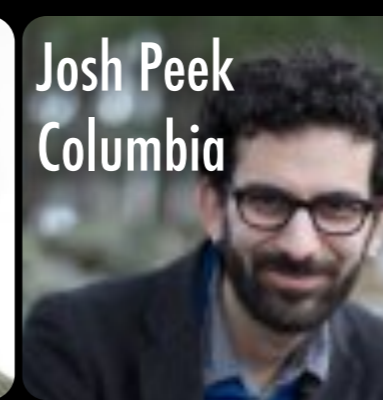


2014





# "THE STORY & THE SANDBOX" (GLUE:D3PO:AUTHOREA)



The screenshot shows a web browser displaying an article on the Authorea platform. The URL in the address bar is [https://www.authorea.com/users/2786/articles/4039/\\_show\\_article](https://www.authorea.com/users/2786/articles/4039/_show_article). The Authorea logo is in the top left, and navigation links (BROWSE, ABOUT, CONTACT, PLANS, FEEDBACK, HELP) and the user name (JOSH PEEK) are in the top right. The article title is "Beyond Galileo" by Josh Peek and Alberto Pepe. The article text discusses Galileo's discovery of four objects near Jupiter in 1610. At the bottom of the page, there are logos for glue, D3PO, and Authorea.

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## Beyond Galileo

Josh Peek, Alberto Pepe + Add author

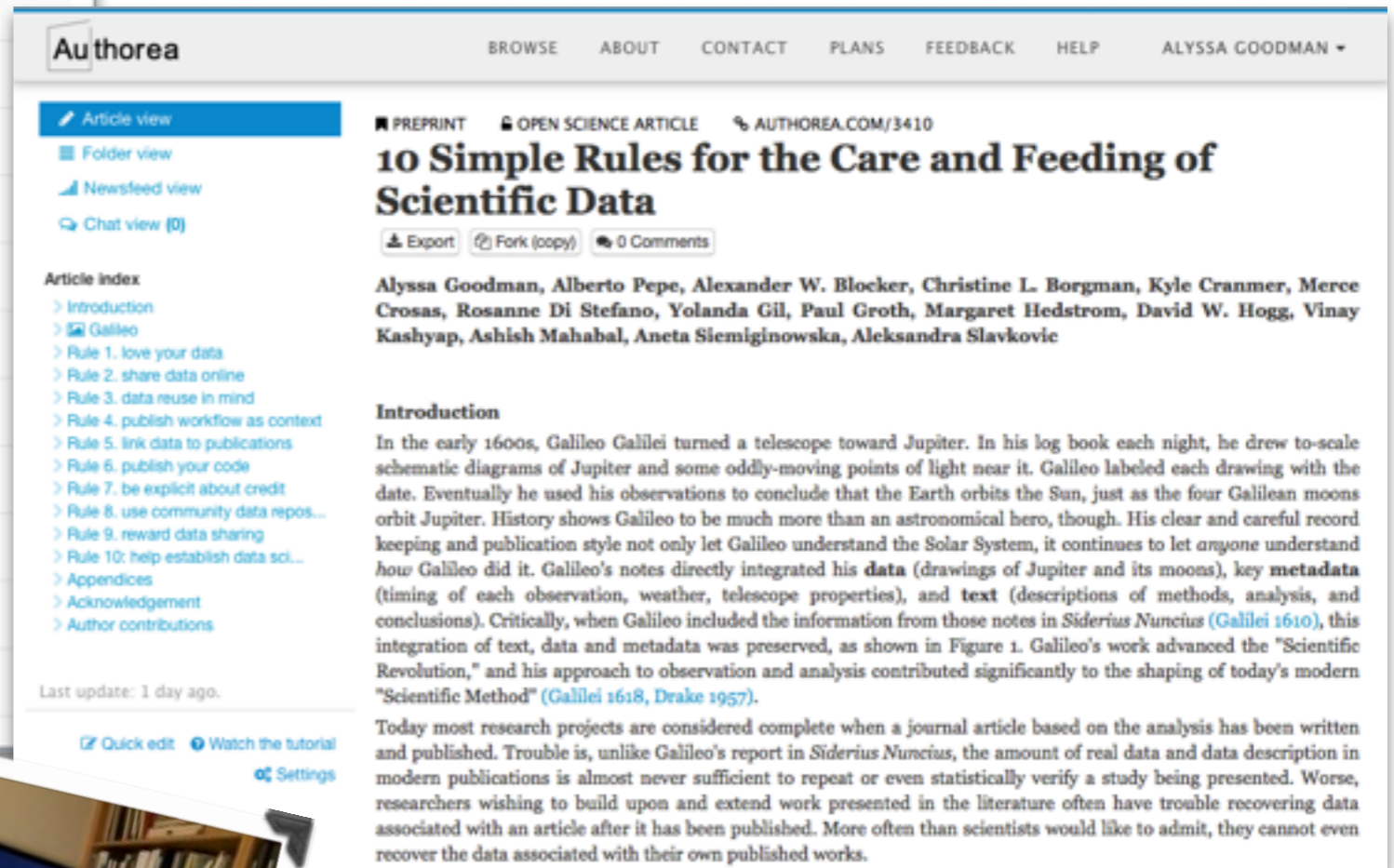
In the last portion of *Sidereus Nuncius*, Galileo reported his discovery of **four objects** that appeared to form a straight line of stars near **Jupiter**. The first night, he witnessed a line of three little stars close to Jupiter parallel to the ecliptic; the following nights brought different arrangements 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:

"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)

glue D3PO Au Authorea



# THE FUTURE IS IN ONLINE



BUT WE DO  
NEED TO  
FIGURE OUT  
HOW NOT  
TO LOSE IT.



[tinyurl.com/acidfreedigital](http://tinyurl.com/acidfreedigital)

WHAT'S AN  
"ACID-FREE"  
DIGITAL RECORD?



# THE FUTURE IS IN 3D

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

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**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

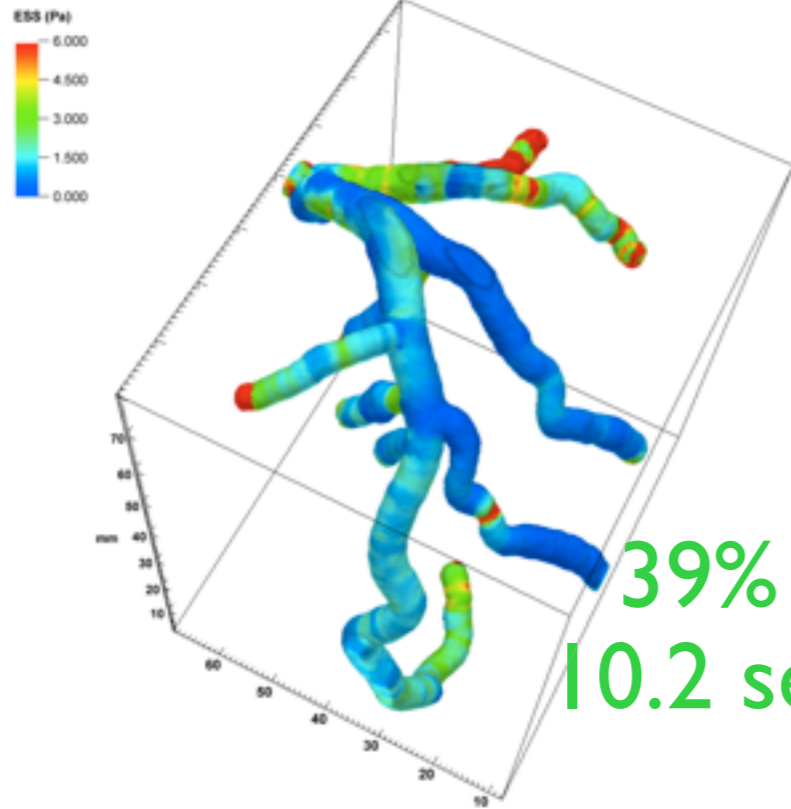
SPACE TELESCOPE SCIENCE INSTITUTE

yt viz from ALMA data  
(Turk, Rosolowsky)

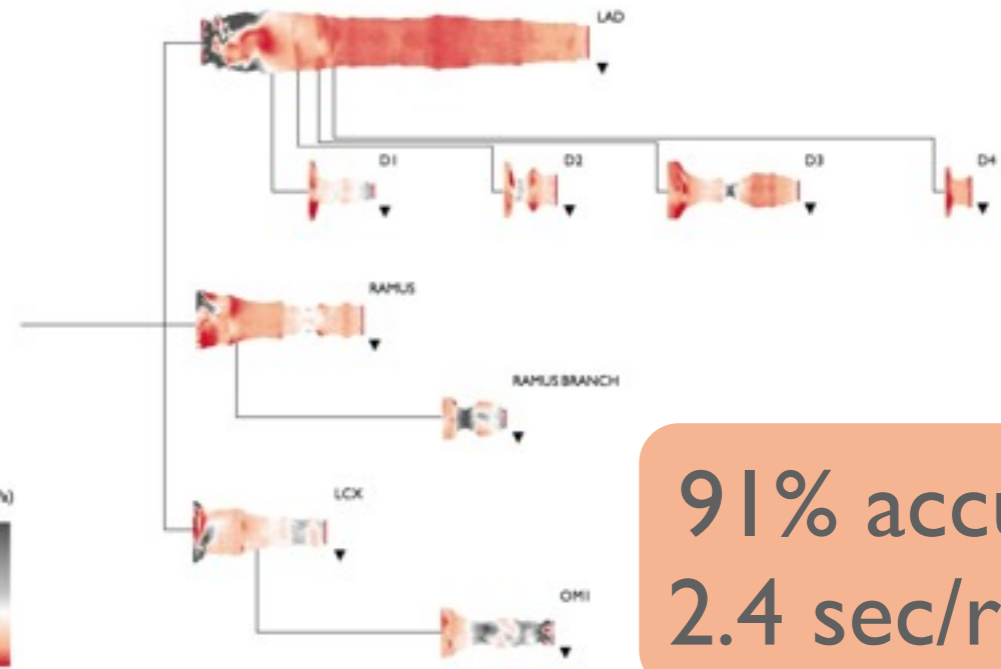
Glue "for" JWST  
(Beaumont et al., NASA)



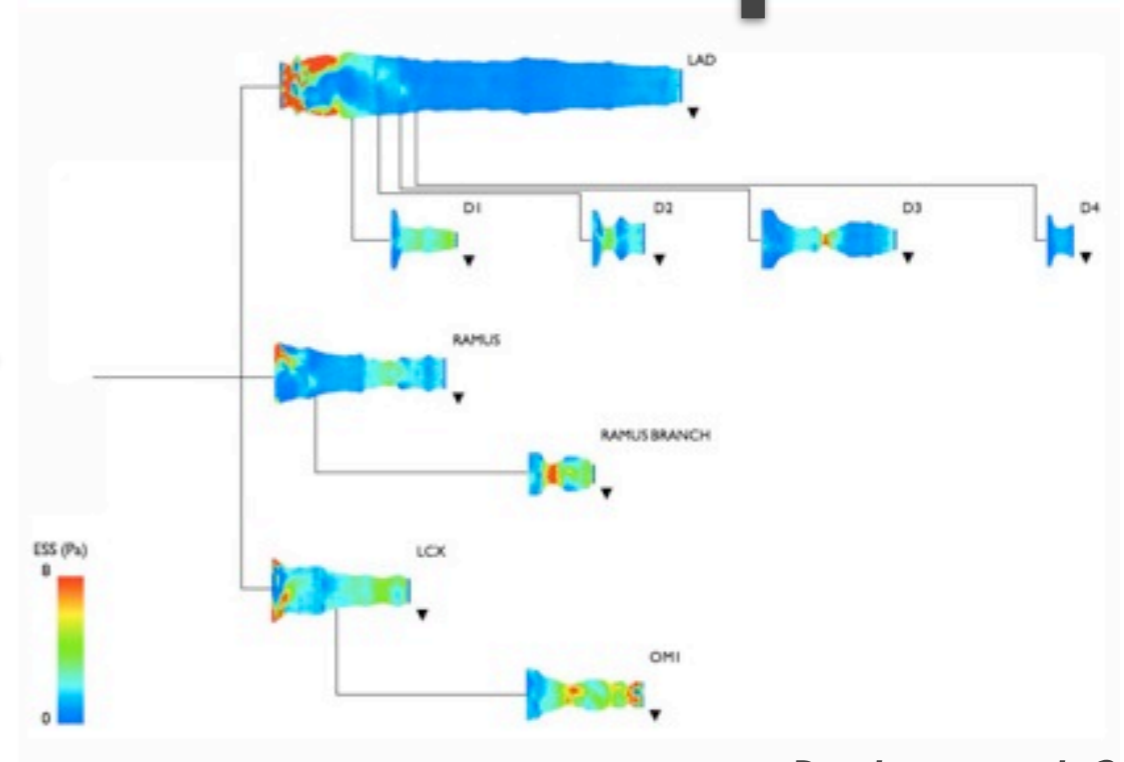
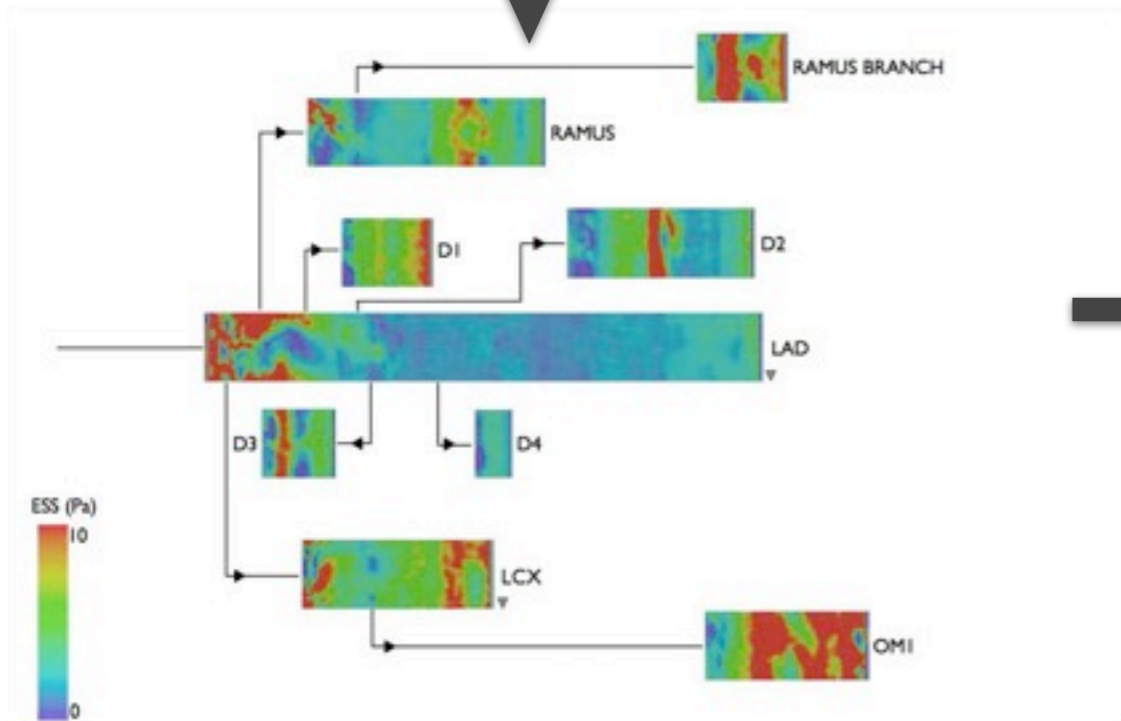
# DIMENSIONALITY & COLOR + "ASTRONOMICAL MEDICINE"



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10.2 sec/region



91% accurate  
2.4 sec/region



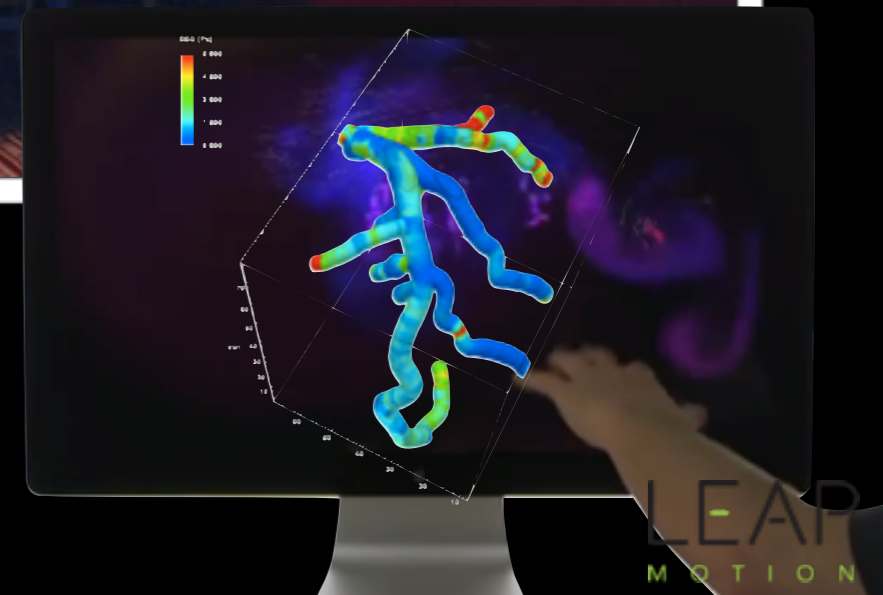
Borkin et al. 2011  
cf. [colorbrewer2.org](http://colorbrewer2.org)



# THE FUTURE IS MODULAR, OPEN-SOURCE, AND NOT (JUST) ON THE DESKTOP



**HACK**   
**TO THE FUTURE**





# THE FUTURE OFFERS NEW WAYS TO LEARN

## WorldWide Telescope Ambassadors



## Higher Ed

*the 2013 experiment*

HARVARD UNIVERSITY  
ASTRONOMY 201B  
DEMOFEST

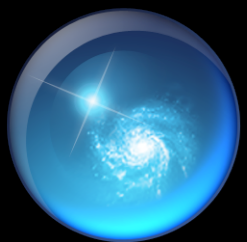


LOCATION  
Perkin Lobby and Wolbach Library, 60 Garden Street

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'. A central circular field of view shows a detailed view of the Andromeda galaxy (M31) with a crosshair. A 'Finder Scope' window is open, displaying 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 menu set to 'Sky', an 'Imagery' section with 'Digitized Sky Survey' and 'Three Faces of Andromeda' thumbnails, a 'Context bar' showing 'NGC221' and 'M31' thumbnails, a 'Context globe' showing the current field of view, and a 'Research' window with 'Show Object' and 'Close' buttons.

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

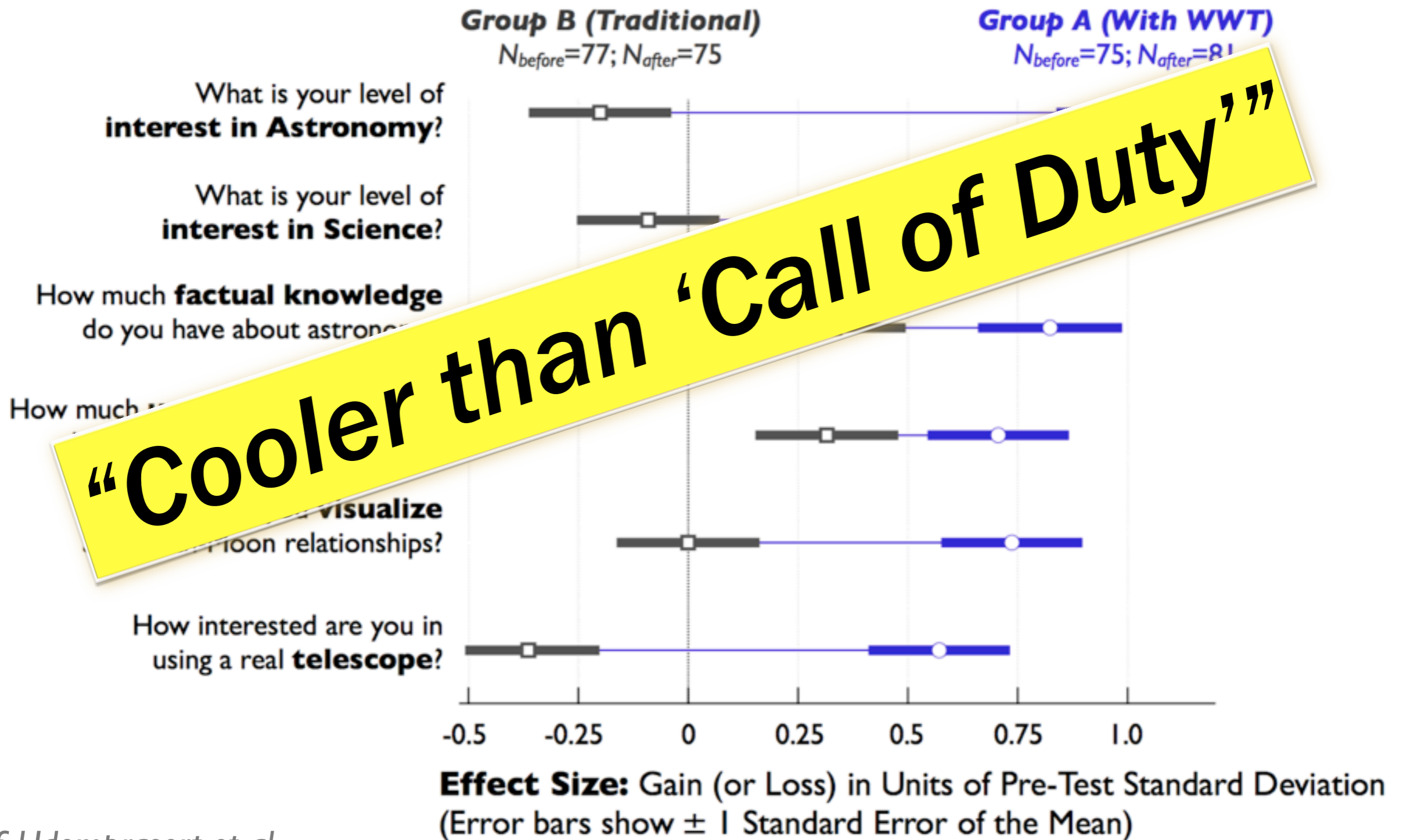
Context globe shows where you're looking.

WWT created by Curtis Wong & Jonathan Fay



# GAINS IN STUDENT INTEREST AND UNDERSTANDING

(“Traditional Way” vs “WWT Way”)

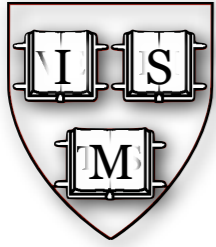


cf. Udomprasert et al.



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>



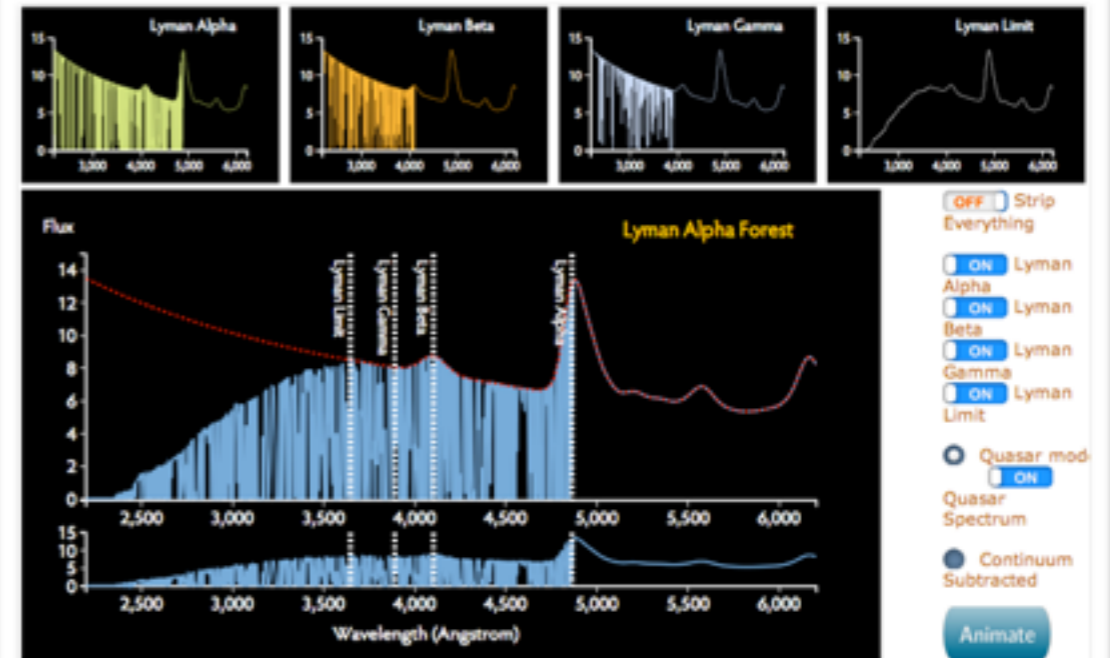
# VIZ IN HIGHER-ED

Stephen

all lines **SII 6716/6731 A** **He 6583 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)

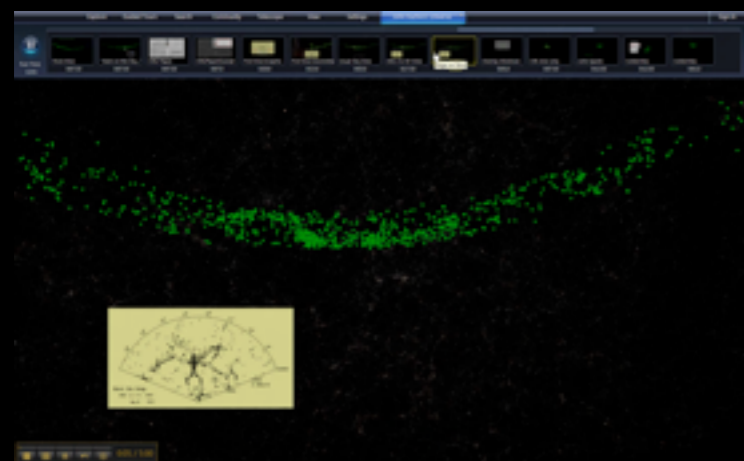
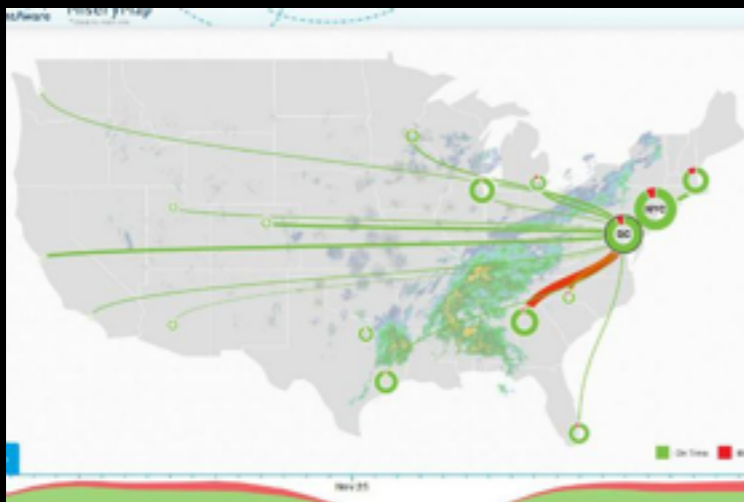
 JavaScript

<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"?

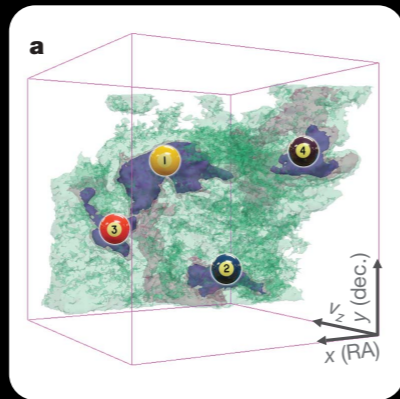
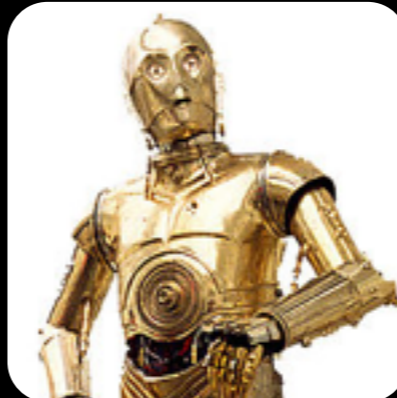
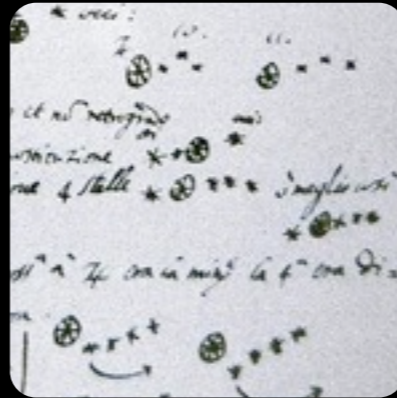
How do we value visualization specialists?

How much customization?

Will tools be preserved?

How much organization (orchestration) is too much?

# VISUALIZATION IN ASTRONOMY: FROM GALILEO TO THE ZOONIVERSE







extra slides (not shown)



# LINKING VISUALIZATION & UNDERSTANDING IN ASTRONOMY

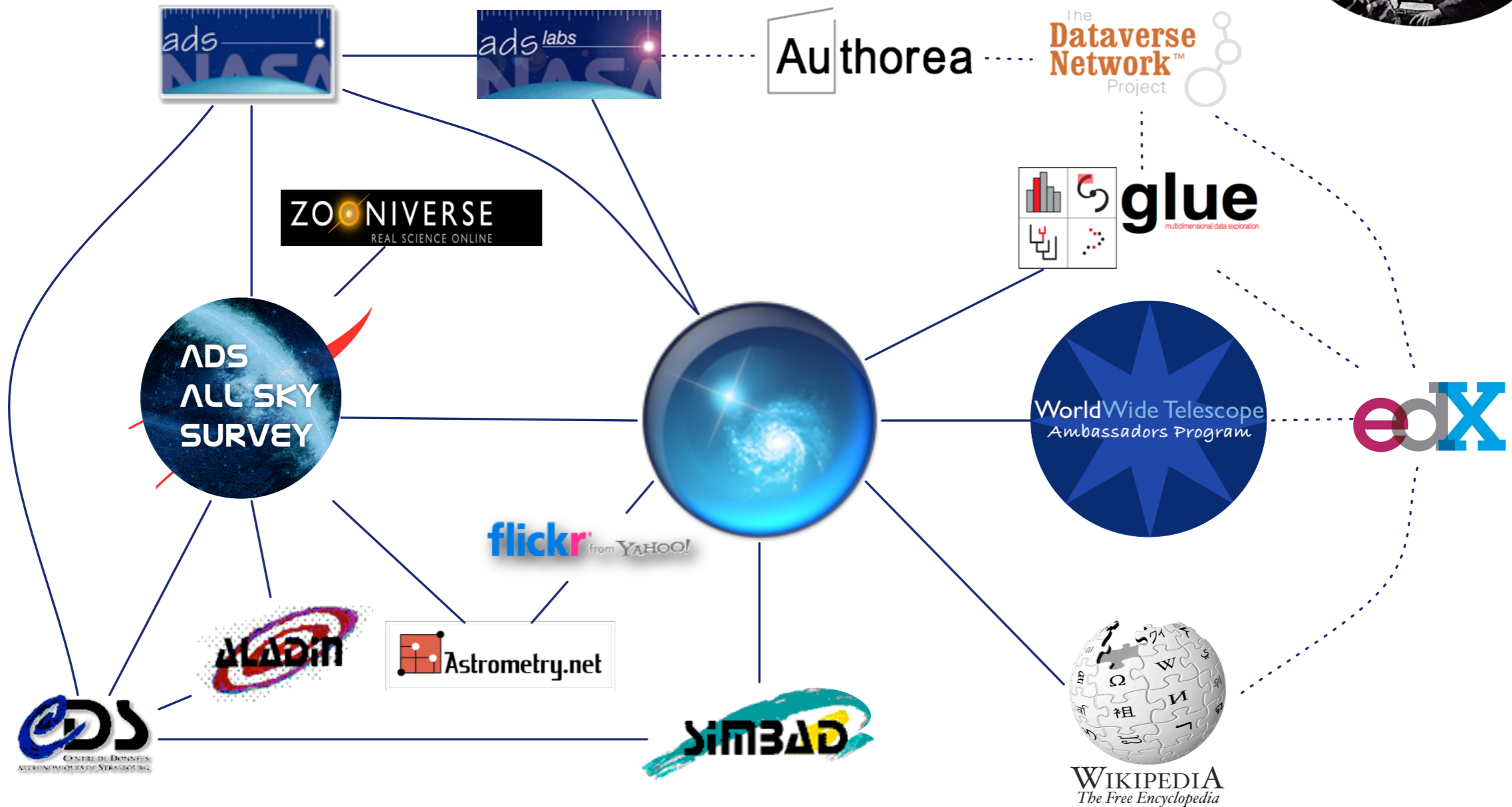
ALYSSA A. GOODMAN  
HARVARD-SMITHSONIAN  
CENTER FOR ASTROPHYSICS





# SEAMLESS ASTRONOMY

Linking scientific data, publications, and communities



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



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

30 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 less than the rest. But at the seventh hour the eastern one was 30 seconds apart. Jupiter was 1 minute from the

East \* \* \* \* \* West

one, while he was 4 minutes from the next western one, while this one was 1 minute from the westernmost one. They and extended on the same straight line along the

On the fifth, the sky was cloudy.

On the sixth, only two stars appeared flanking Jupiter

East \* \* \* \* \* West

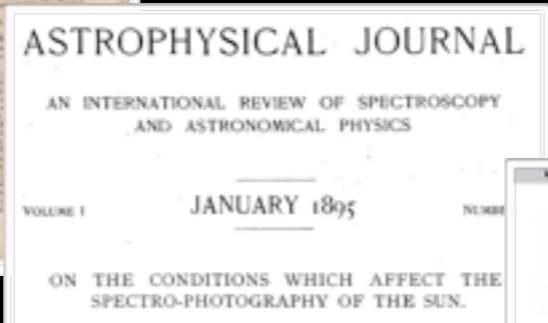
in the adjoining figure. The eastern one was 2 minutes from the next western one; the western one 1 minute from the westernmost one. They were on the same straight line with Jupiter and equal in magnitude.

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

1665



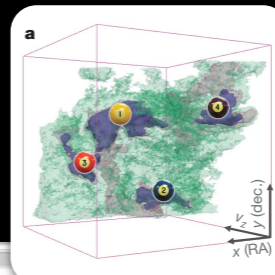
1895



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.

...ography by Jan...  
...ined at...  
...tial feat...  
...f the coo...  
...nd slit...  
...aphic pla...  
...me spec...  
...se alway...  
...s tails o...  
...n the sec...  
...nd, then...  
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...will be r...  
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...cular wa...  
...length.

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 colour which can be obtained by the greater effect

Authoria

BROWSE ABOUT CONTACT PLANS

ROUGH DRAFT OPEN SCIENCE

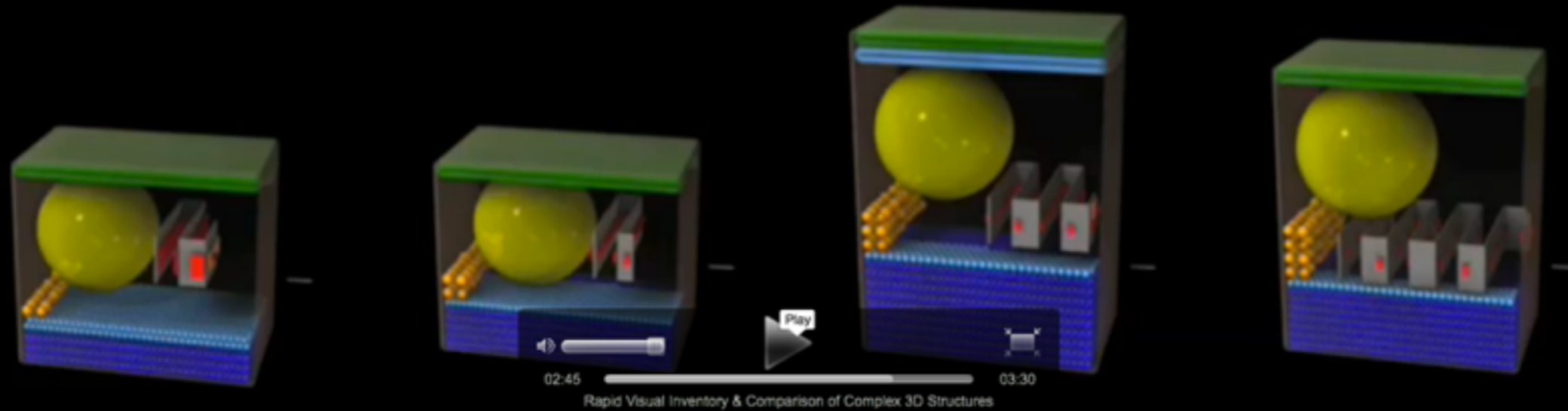
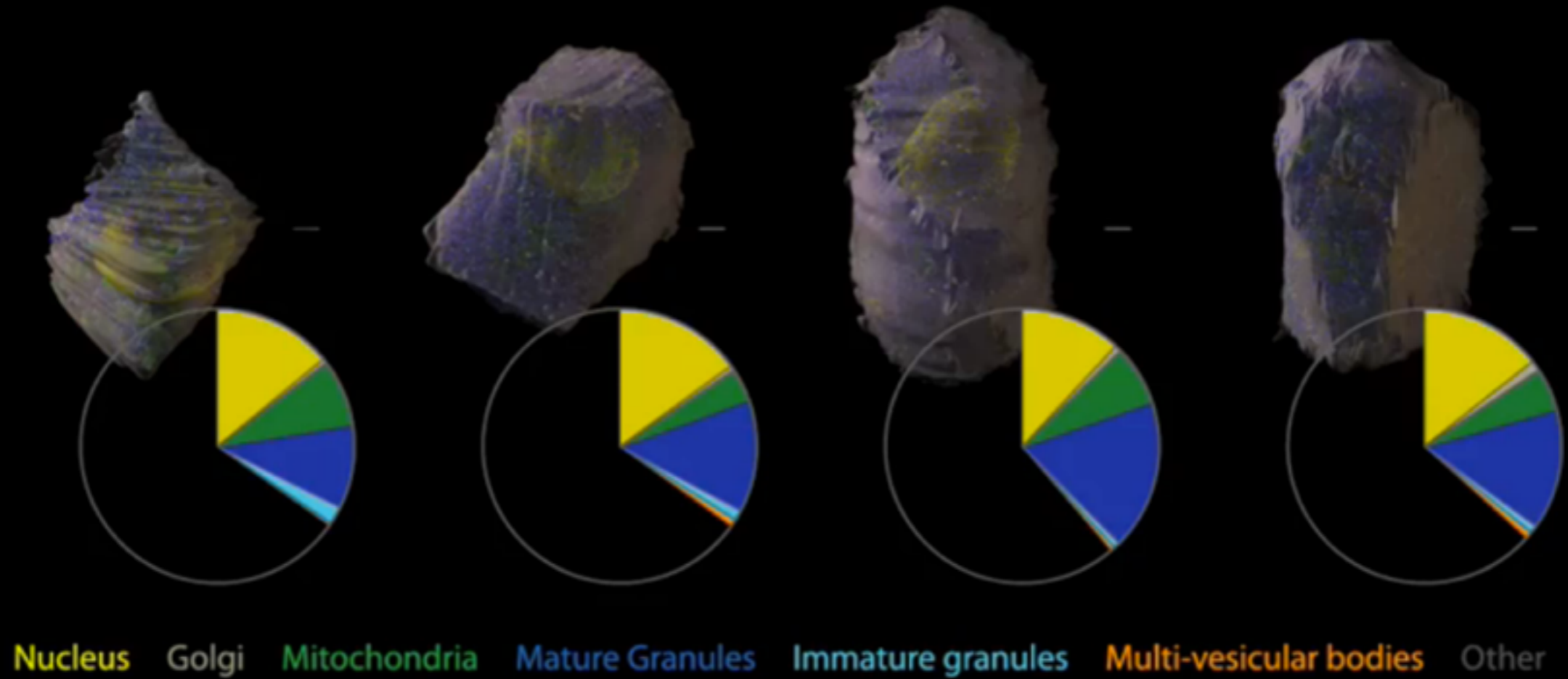
### Four centuries of discoveries

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.



[http://www.worldwidetelescope.org/webclient/default.aspx?wtm=http%3a%2f%2fwww.worldwidetelescope.org%2fwwtweb%2fshowimage.aspx%3freverseparity%3dTrue%26scale%3d13.4575%26name%3d1906ApJ...23%2b\(Page%3a%2b2%3b%2bImage%3a%2b1\)%26imageurl%3dhttp%3a%2f%2fwww.adsass.org%2foldastro%2fdata%2f1906ApJ...23..144B-002-001.png%26credits%3dADS%2bAll%2bSky%2bSurvey%26creditsUrl%3dhttp%2fadsass.org%2bra%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%2fwwtweb%2fshowimage.aspx%3freverseparity%3dTrue%26scale%3d13.4575%26name%3d1906ApJ...23%2b(Page%3a%2b2%3b%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%2bra%3d239%26y%3d948%26x%3d756%26rotation%3d179.892%26dec%3d-25.06%26thumb%3d%26wtm%3dtrue)