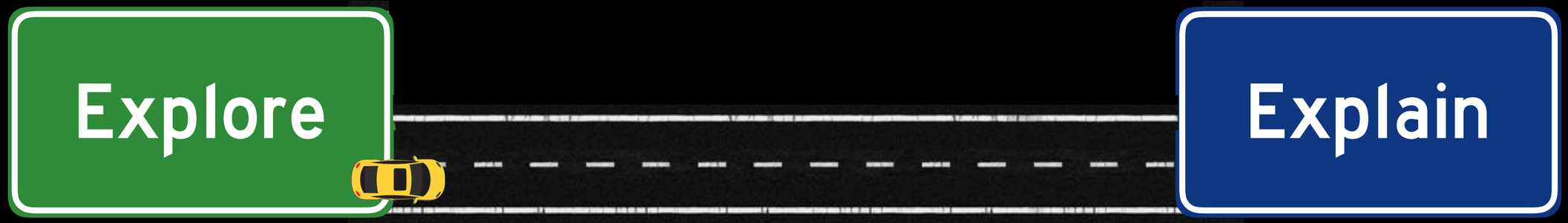
The Road from Exploration to Explanation, and Back

Alyssa A. Goodman
Harvard-Smithsonian Center for Astrophyscs + Radcliffe Insitute for Advanced Study
@AlyssaAGoodman

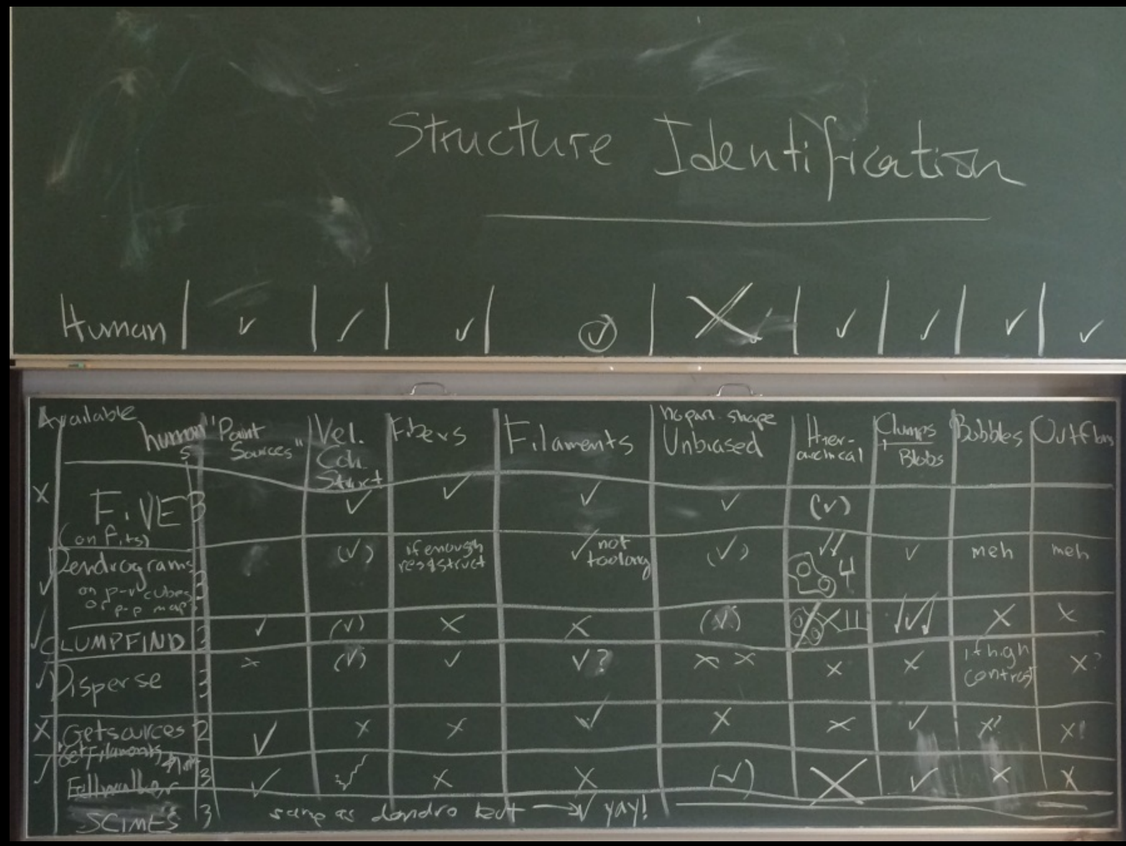
Traditionally, travel from exploration to explanation is called
"Scholarly Publishing" if its *dry*, and "Public Outreach," if it's *beautiful*.



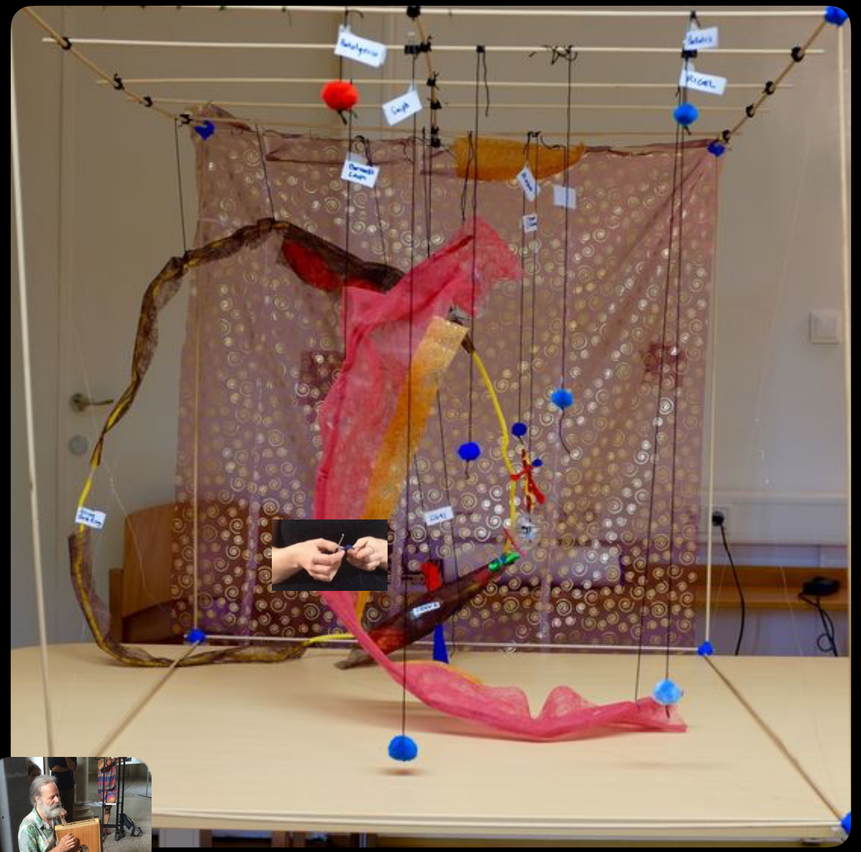
It’s much harder to go the other way.

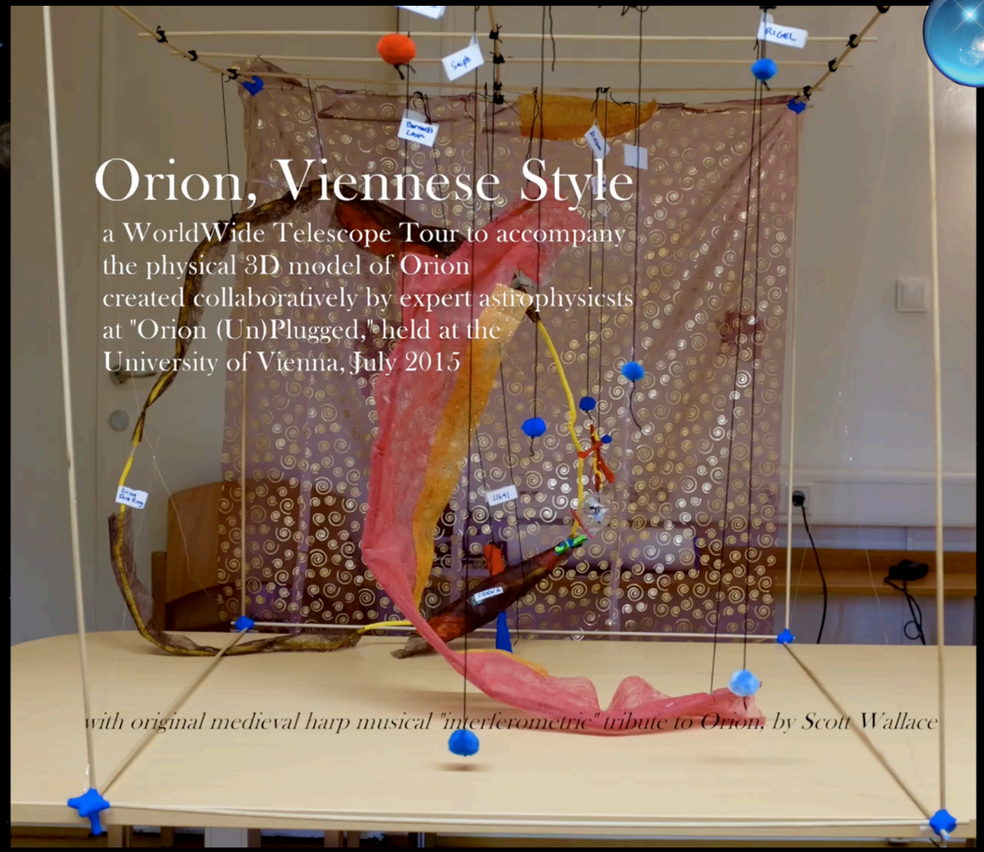
Explore
And, the *best* roads are two-way.
Explain

VIENNA


Structure Identification
Human
Available
FIVE
Dendrograms
CLUMPFIND
Disperse
Getsources
SCIMES
Filaments
Unbiased
Bubbles
meh
same as dendro test → yay!

VIENNA



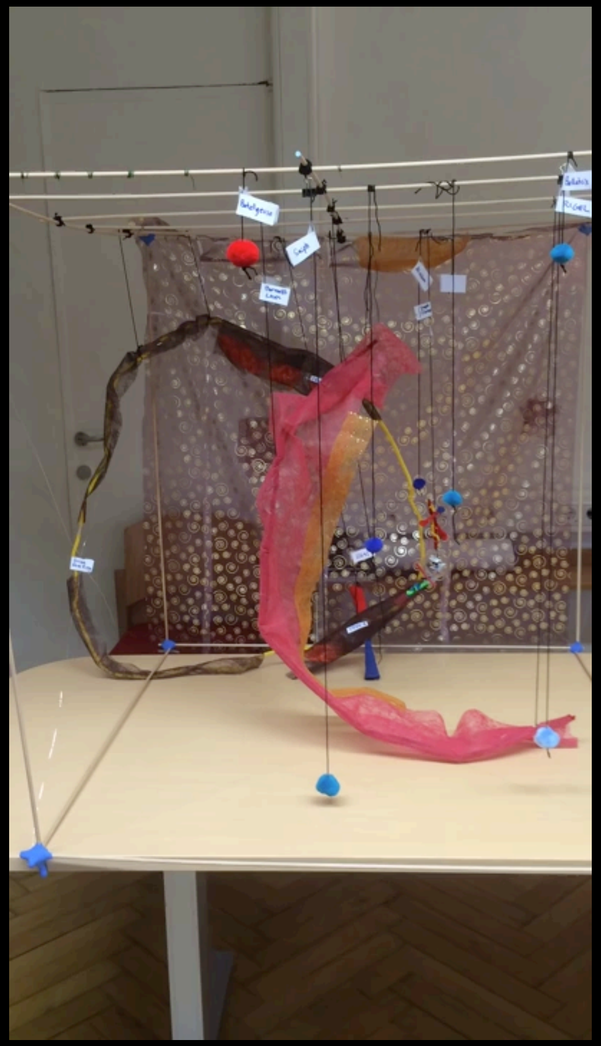


Orion, Viennese Style

a WorldWide Telescope Tour to accompany
the physical 3D model of Orion
created collaboratively by expert astrophysicsts
at "Orion (Un)Plugged," held at the
University of Vienna, July 2015

with original medieval harp musical "interferometric" tribute to Orion, by Scott Wallace

VIENNA



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DOI: 10.1051/0004-6361/201527160
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Astronomy & Astrophysics

VISION – Vienna survey in Orion

I. VISTA Orion A Survey⋆,⋆⋆

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[10] SIM/CENTRA, Faculdade de Ciencias de Universidade de Lisboa, Ed. C8, Campo Grande, 1749-016 Lisboa, Portugal
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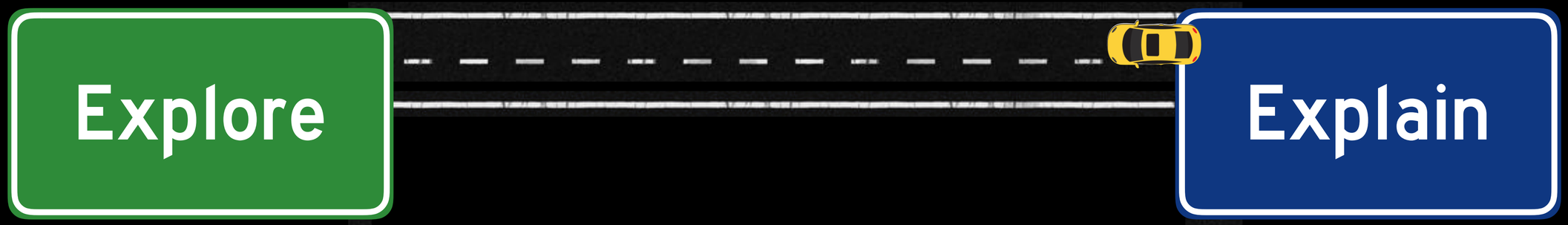
ABSTRACT

Context. Orion A hosts the nearest massive star factory, thus offering a unique opportunity to resolve the processes connected with the formation of both low- and high-mass stars. Here we present the most detailed and sensitive near-infrared (NIR) observations of the entire molecular cloud to date.
Aims. With the unique combination of high image quality, survey coverage, and sensitivity, our NIR survey of Orion A aims at establishing a solid empirical foundation for further studies of this important cloud. In this first paper we present the observations, data reduction, and source catalog generation. To demonstrate the data quality, we present a first application of our catalog to estimate the number of stars currently forming inside Orion A and to verify the existence of a more evolved young foreground population.
Methods. We used the European Southern Observatory's (ESO) Visible and Infrared Survey Telescope for Astronomy (VISTA) to survey the entire Orion A molecular cloud in the NIR J, H, and K_S bands, covering a total of ~18.3 deg^2. We implemented all data reduction recipes independently of the ESO pipeline. Estimates of the young populations toward Orion A are derived via the K_S-band luminosity function.
Results. Our catalog (799 995 sources) increases the source counts compared to the Two Micron All Sky Survey by about an order of magnitude. The 90% completeness limits are 20.4, 19.9, and 19.0 mag in J, H, and K_S, respectively. The reduced images have 20% better resolution on average compared to pipeline products. We find between 2300 and 3000 embedded objects in Orion A and confirm that there is an extended foreground population above the Galactic field, in agreement with previous work.

THE REAL WORLD

New Ideas
Discoveries

Public Outreach
Scholarly Publishing



“It’s much harder to go the other way.”

Astronomy Picture of the Day

Discover the cosmos! Each day a different image or photograph of our fascinating universe is featured, along with a brief explanation written by a professional astronomer.

2018 March 11

Duel Particle Beams in Herbig-Haro 24
Image Credit: NASA, ESA, Hubble Heritage (STScI/AURA)/Hubble-Europe Collaboration;
Acknowledgment: D. Padgett (NASA's GSFC), T. Megeath (U. Toledo), B. Reipurth (U. Hawaii)

Explanation: This might look like a double-bladed lightsaber, but these two cosmic jets actually beam outward from a newborn star in a galaxy near you. Constructed from Hubble Space Telescope image data, the stunning scene spans about half a light-year across Herbig-Haro 24 (HH 24), some 1,300 light-years away in the stellar nurseries of the Orion B molecular cloud complex. Hidden from direct view, HH 24's central protostar is surrounded by cold dust and gas flattened into a rotating accretion disk. As material from the disk falls toward the young stellar object it heats up. Opposing jets are blasted out along the system's rotation axis. Cutting through the region's interstellar matter, the narrow, energetic jets produce a series of glowing shock fronts along their path.

Public Outreach

March 11, 2018 Astronomy Picture of the Day

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March 11, 2018 Astronomy Picture of the Day

Explain

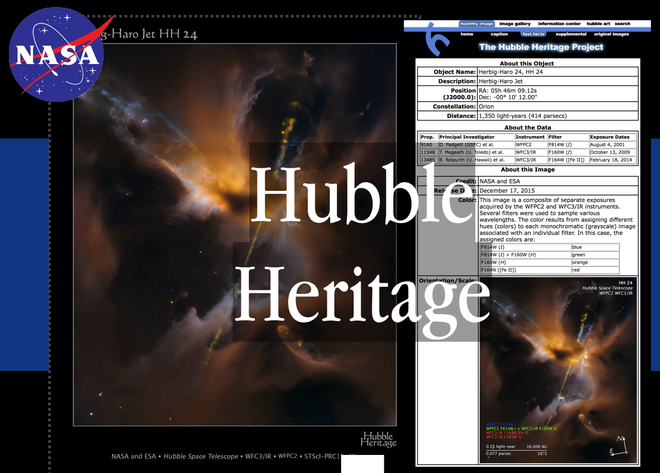
Herbig-Haro Jet HH 24

Hubble Heritage

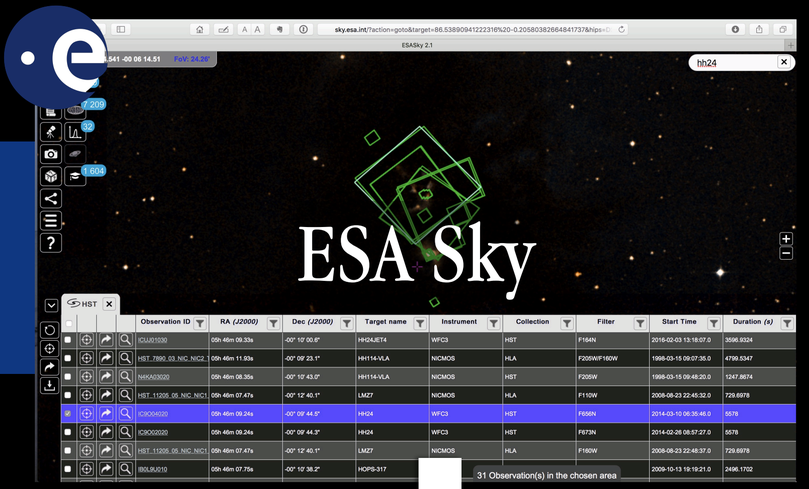
NASA and ESA • *Hubble Space Telescope* • WFC3/IR • WFPC2 • STScI-PRC15-42a

2015 Hubble Heritage Press Release

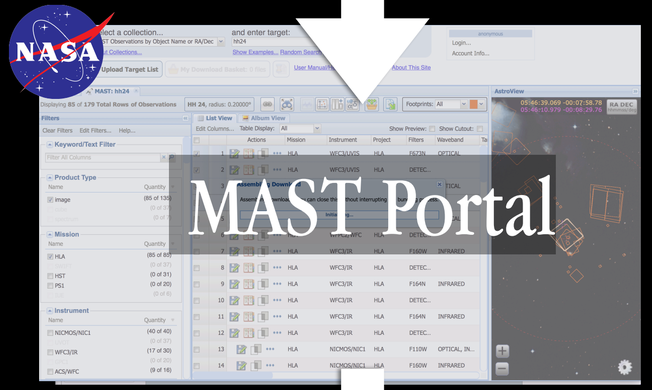
Explain



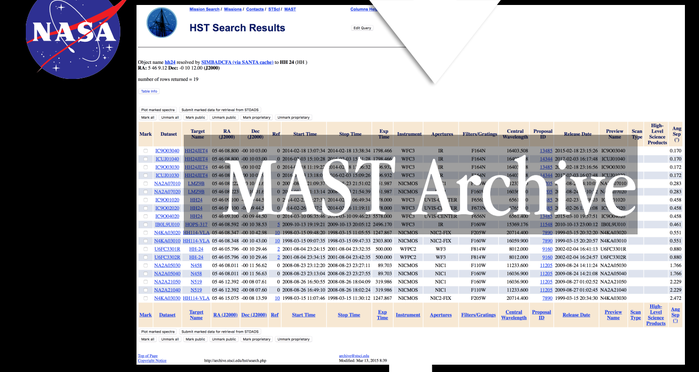
Hubble Heritage



ESA Sky

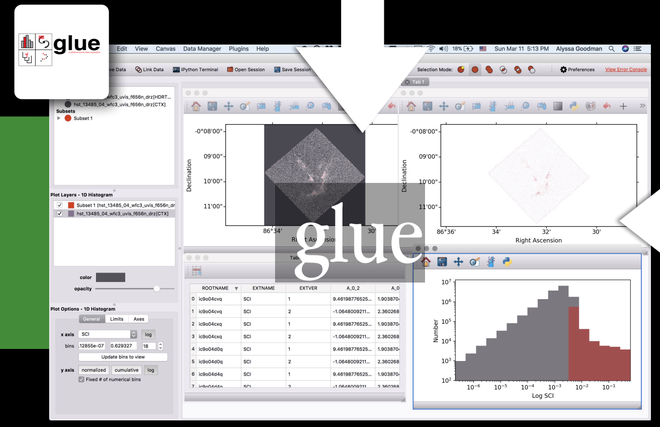


MAST Portal

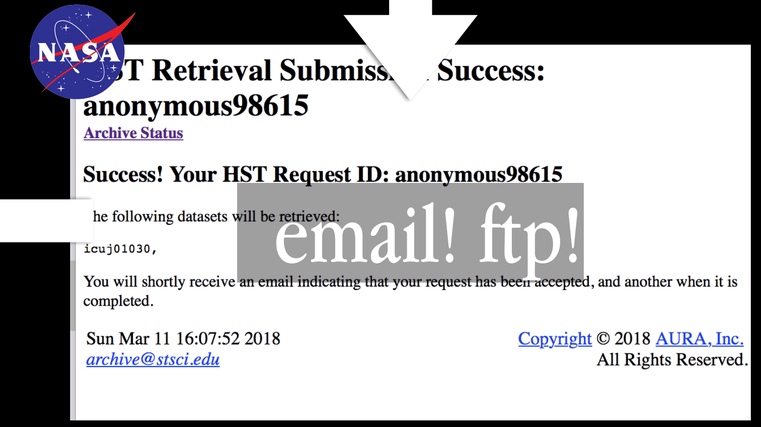


MAST Archive

Explore



glue

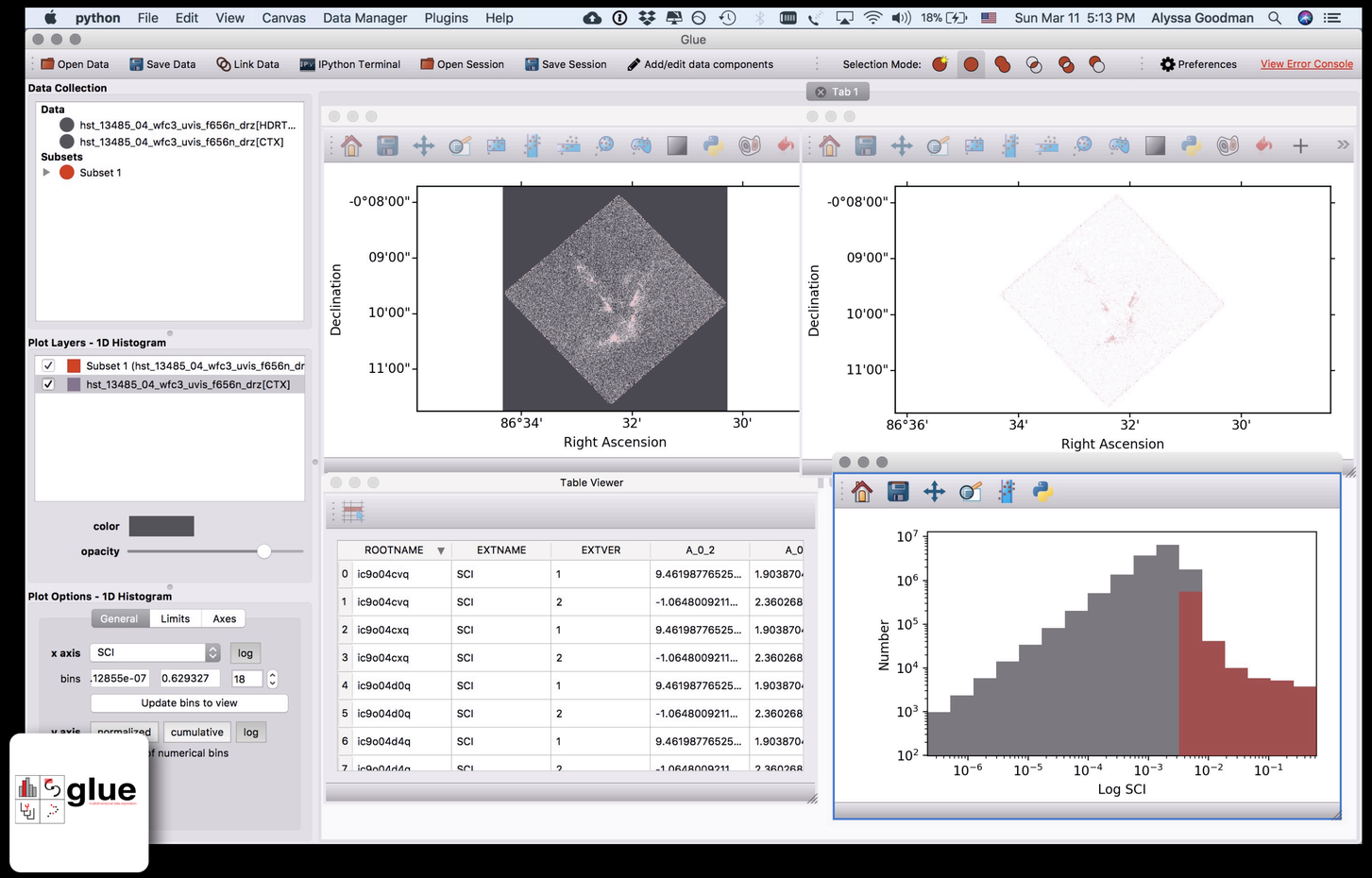


email! ftp!

Explore

A 5 minute journey, if you know the way.

Explain

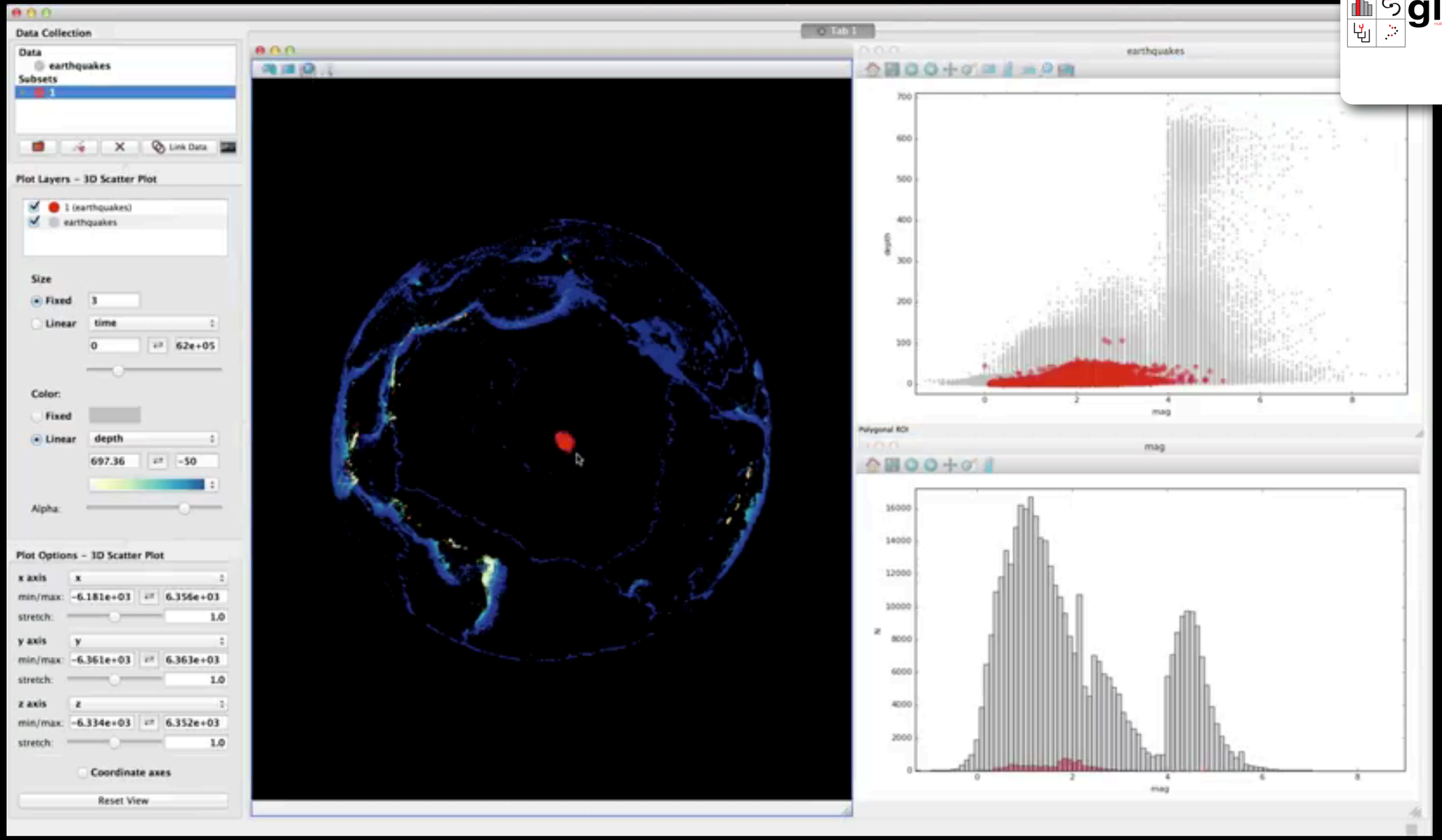


Herbig-Haro Jet HH 24

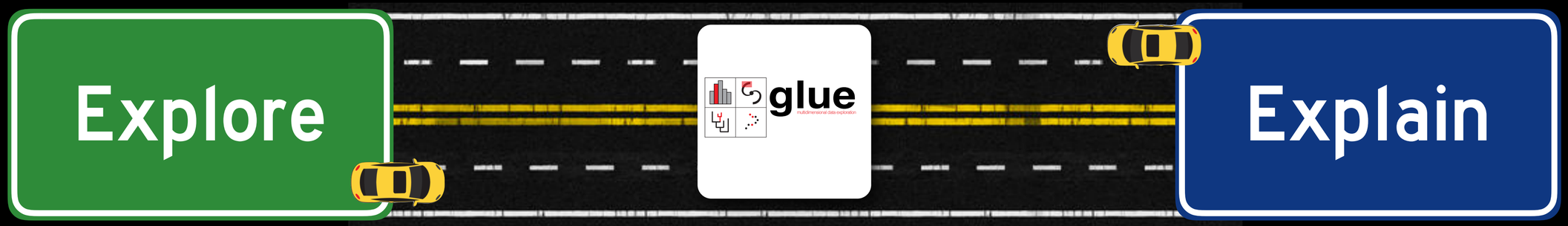
Hubble Heritage

NASA and ESA • *Hubble Space Telescope* • WFC3/IR • WFPC2 • STScI-PRC15-42a

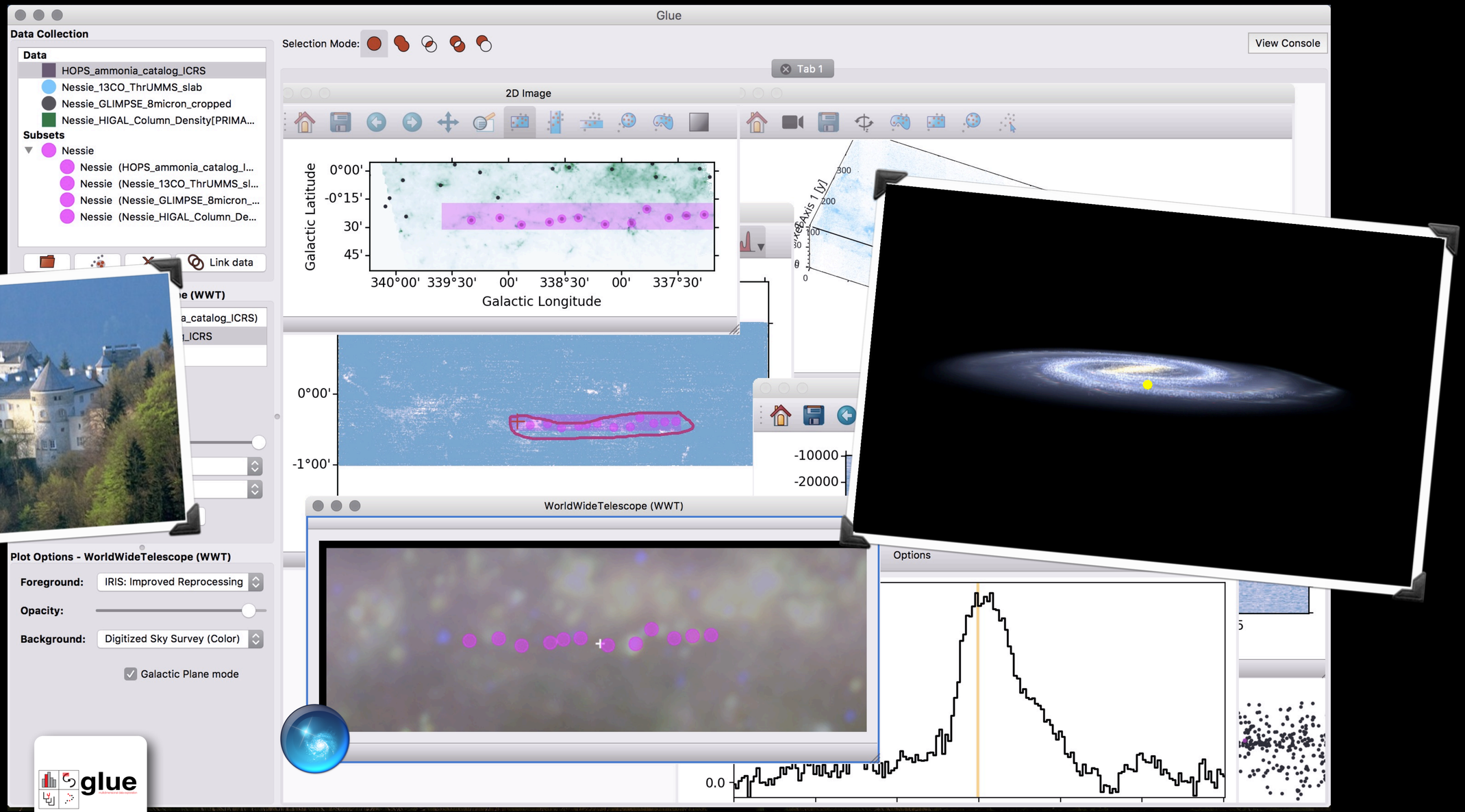
“Linked Views of High-dimensional Data” (in Python)



video by Tom Robitaille, lead glue developer glue created by: C. Beaumont, M. Borkin, M. Breddels, P. Qian, T. Robitaille, and A. Goodman, PI


Explore
glue
multidimensional data exploration
Explain

glueing together the Milky Way



Citizen Science

Glue

Open Data | Save Data | Link Data | IPython Terminal | Open Session | Add/edit data components | Selection Mode: | Preferences | View Error Console

Data Collection

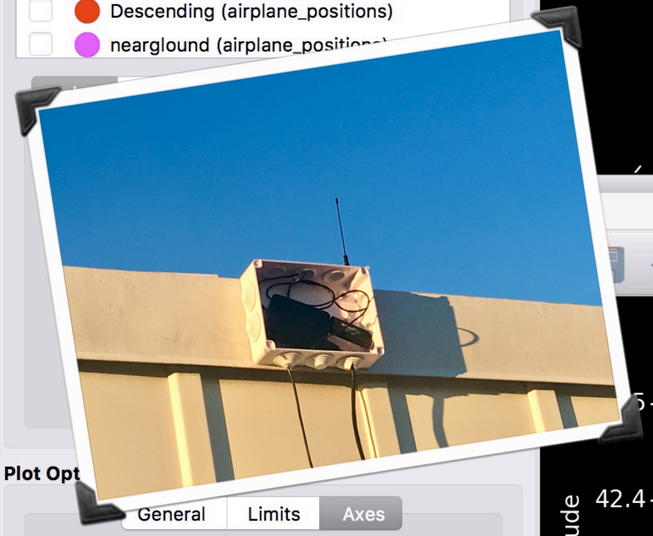
satelliteimages

Subsets

- fastplanes
- nearglound
- Descending
- Climbing
- Landing
- A Day in the Life of Logan

Plot Layers - 2D Scatter

- A Day in the Life of Logan (airplane_positions
- Landing (airplane_positions)
- Climbing (airplane_positions)
- Descending (airplane_positions)
- nearglound (airplane_positions)



Plot Opt

General | Limits | Axes

x label: Heading (degrees)

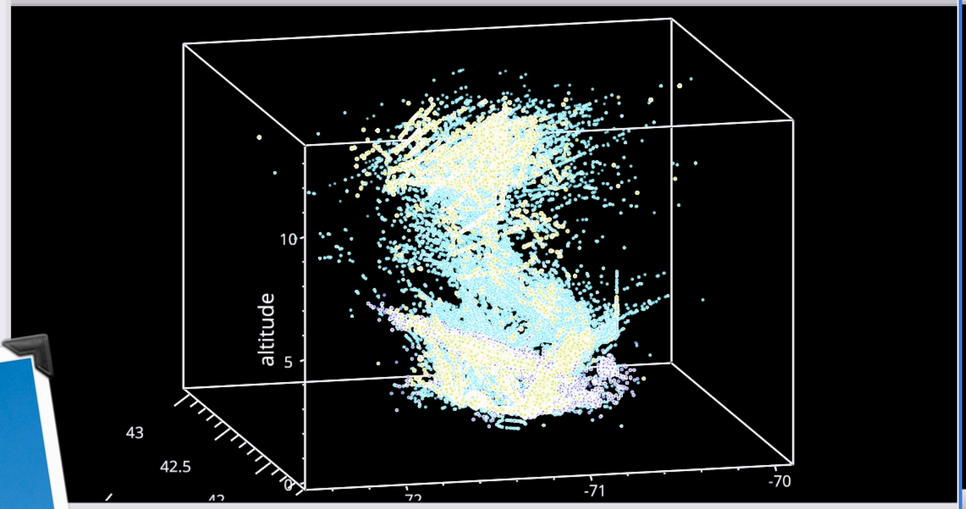
y label: Ground Speed

	x	y
axis label size	10	
axis label weight	medium	
tick label size	10	

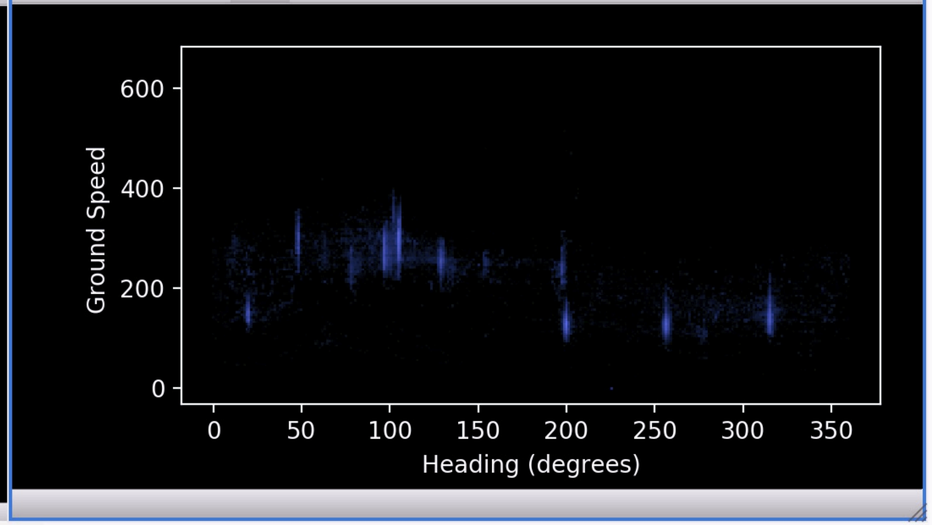
Apply to all plots

glue

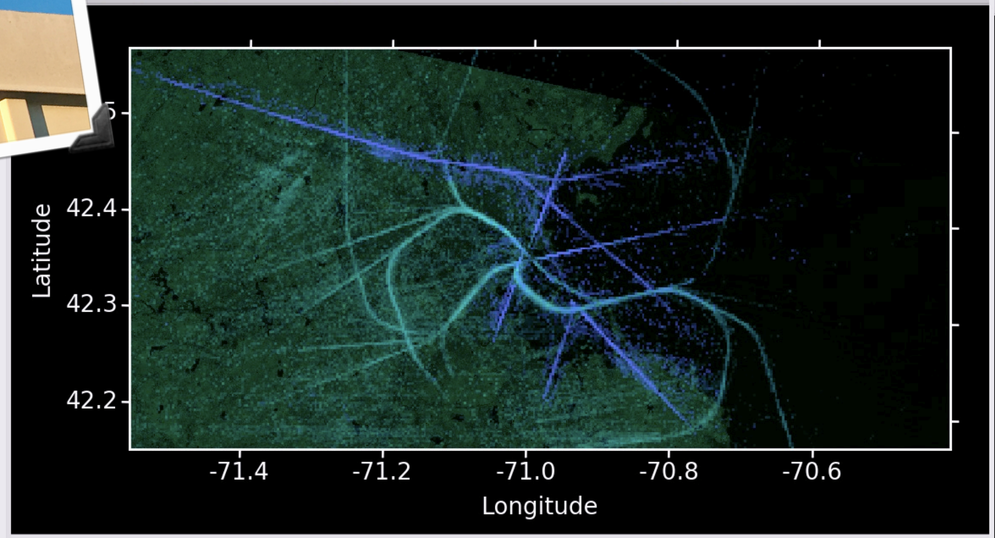
3D Scatter



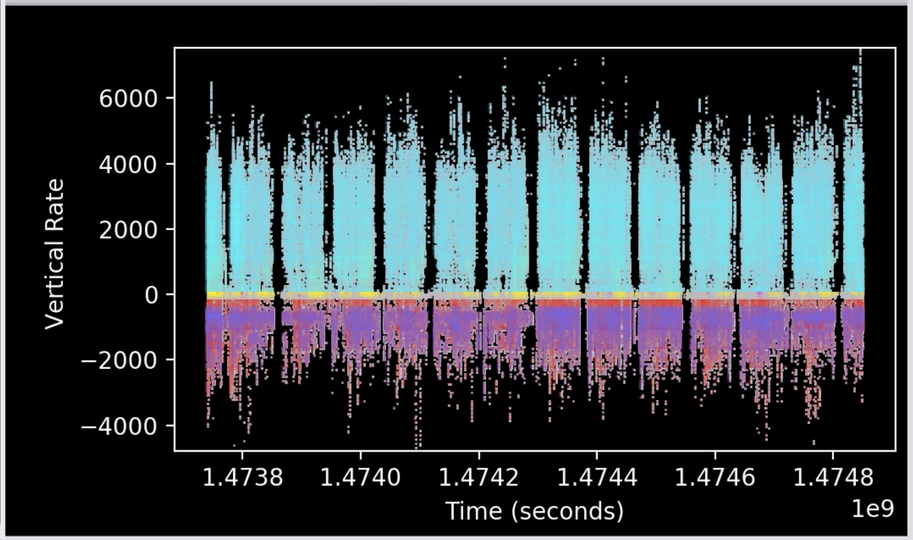
2D Scatter



2D Image

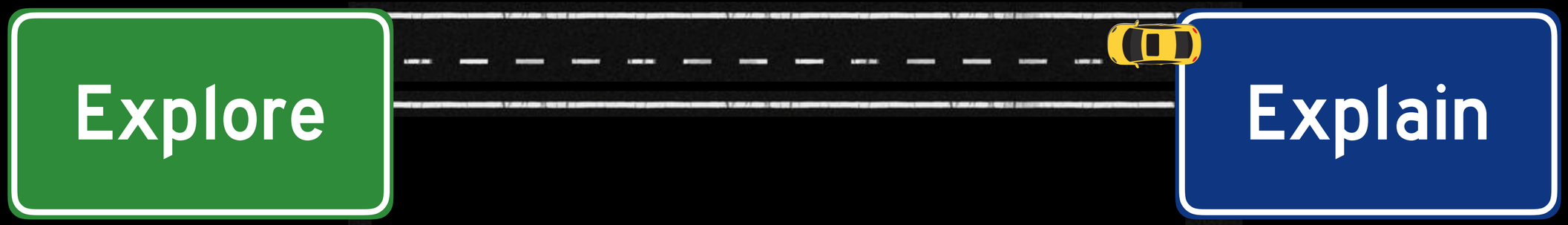


2D Scatter



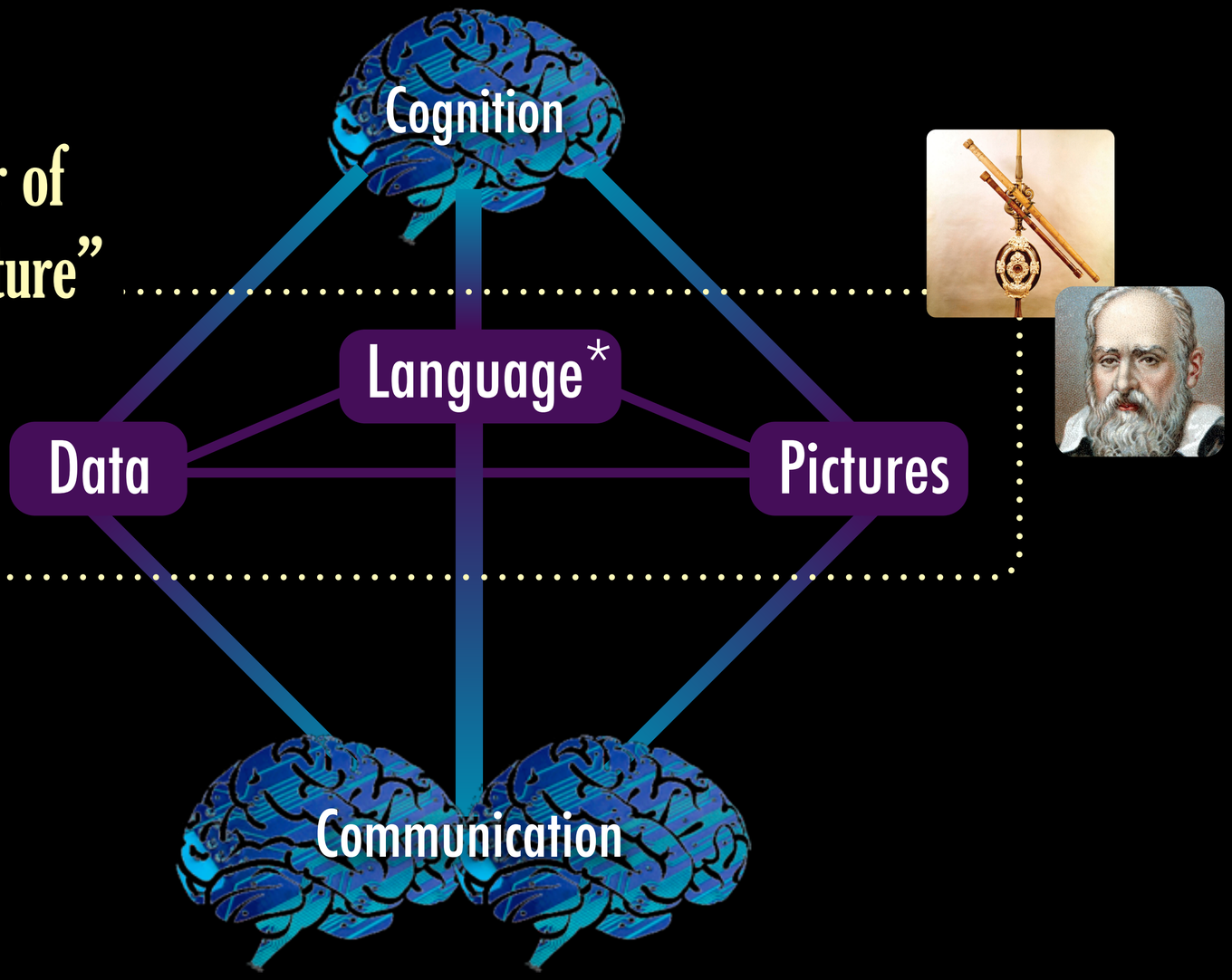
New Ideas
Discoveries

Public Outreach
Scholarly Publishing



“It’s much harder to go the other way.”

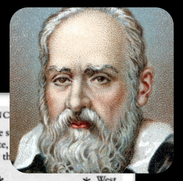
“Paper of the Future”



*“Language” includes words & math

4 Centuries from Galileo to Galileo

1610



SIDEREUS NUNC

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

East * ○ * * West

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

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

East * * ○ * * West

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

East ** ○ * *

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

On the fifth, the sky was cloudy.

On the sixth, only two stars appeared flanking Ju

East * ○ *

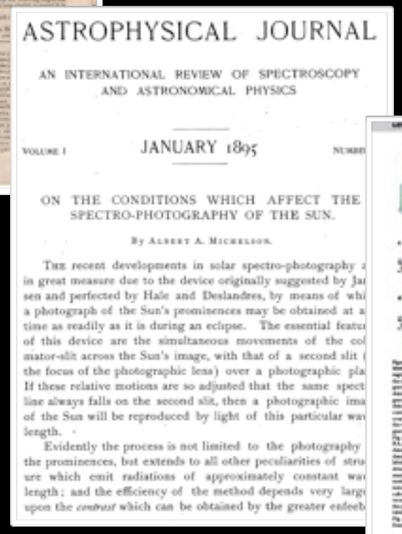
in the adjoining figure. The eastern one was 2 mi
western one 3 minutes from Jupiter. They were on th
line with Jupiter and equal in magnitude.

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

1665

PHILOSOPHICAL TRANSACTIONS

1895



ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

VOLUME I JANUARY 1895 NUMBE

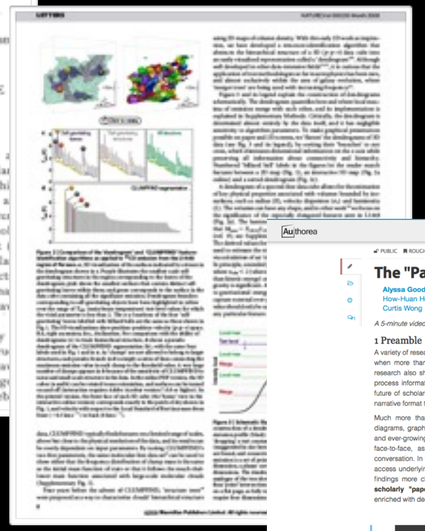
ON THE CONDITIONS WHICH AFFECT THE SPECTRO-PHOTOGRAPHY OF THE SUN.

By Albert A. Michelson.

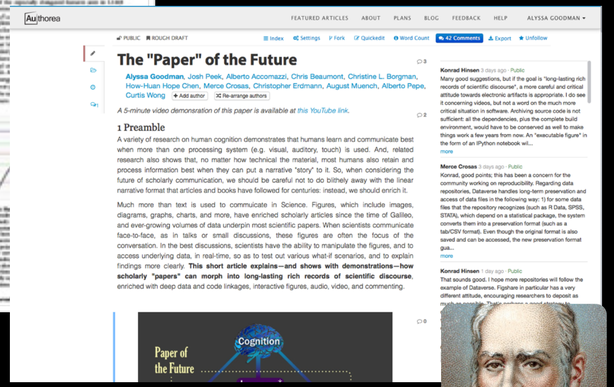
The recent developments in solar spectro-photography
in great measure due to the device originally suggested by Ja
sen and perfected by Hale and Deslandres, by means of whi
a photograph of the Sun's prominences may be obtained at a
time as readily as it is during an eclipse. The essential featu
of this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

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

2009



2015



Authorea

FEATURED ARTICLES ABOUT PLANS BLOG FEEDBACK HELP ALYSSA GOODMAN

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

The "Paper" of the Future

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

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

1 Preamble

A variety of research on human cognition demonstrates that humans learn and communicate best when more than one processing system (e.g. visual, auditory, touch) is used. And, related research also shows that, no matter how technical the material, most humans also retain and process information best when they can put a narrative "story" to it. So, when considering the future of scholarly communication, we should be careful not to do blithely away with the linear narrative format that articles and books have followed for centuries: instead, we should enrich it.

Much more than text is used to communicate in Science. Figures, which include images, diagrams, graphs, charts, and more, have enriched scholarly articles since the time of Galileo, and ever-growing volumes of data underpin most scientific papers. When scientists communicate face-to-face, as in talks or small discussions, these figures are often the focus of the conversation. In the best discussions, scientists have the ability to manipulate the figures, and to access underlying data, in real-time, so as to test out various what-if scenarios, and to explain findings more clearly. **This short article explains—and shows with demonstrations—how scholarly "papers" can morph into long-lasting rich records of scientific discourse**, enriched with deep data and code linkages, interactive figures, audio, video, and commenting.

Paper of the Future

Cognition

Konrad Hinsen 3 days ago · Public

Many good suggestions, but if the goal is "long-lasting rich records of scientific discourse", a more careful and critical attitude towards electronic artifacts is appropriate. I do see it concerning videos, but not a word on the much more critical situation in software. Archiving source code is not sufficient: all the dependencies, plus the complete build environment, would have to be conserved as well to make things work a few years from now. An "executable figure" in the form of an IPython notebook wil...

more

Merce Crosas 3 days ago · Public

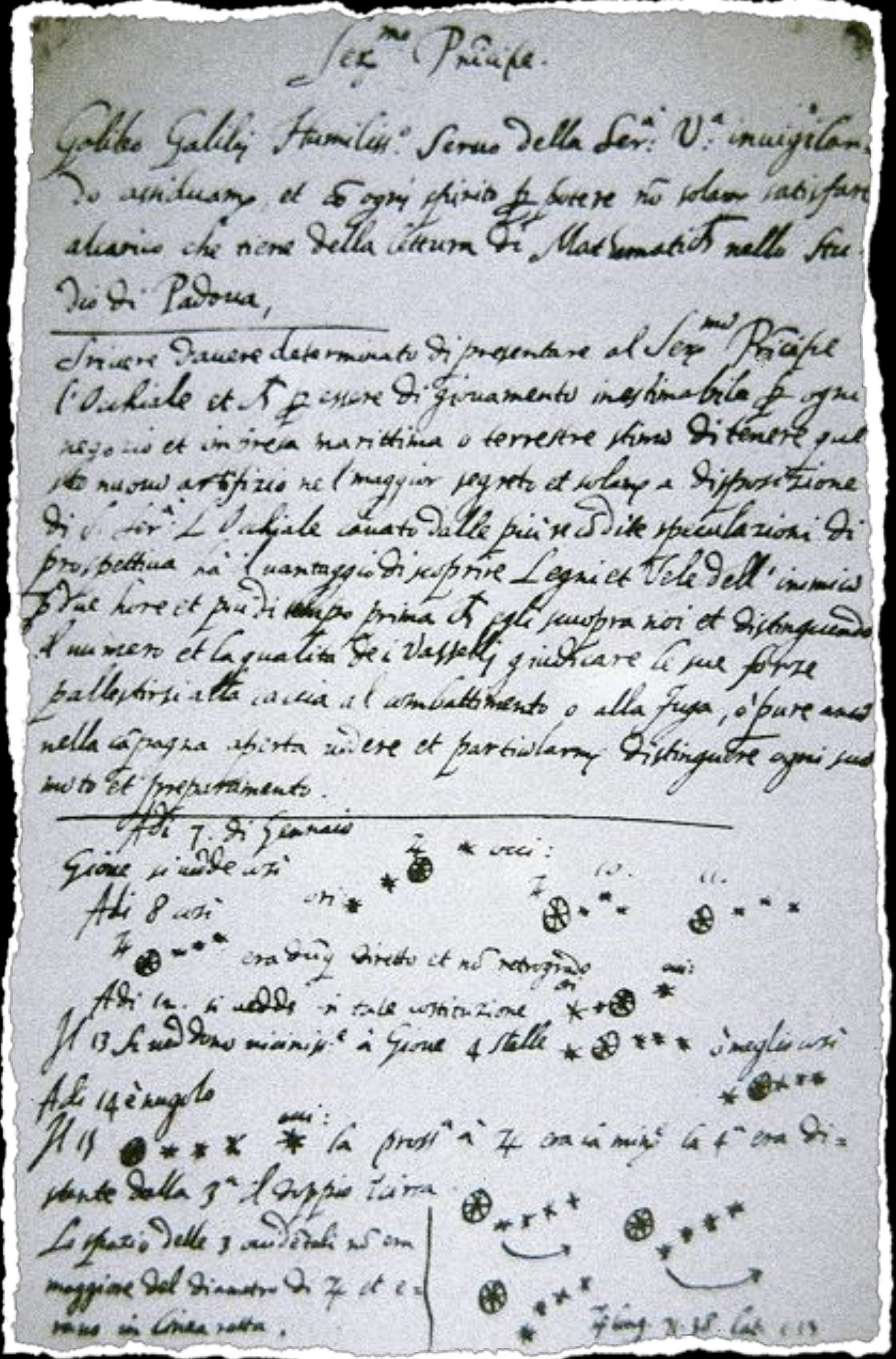
Konrad, good points; this has been a concern for the community working on reproducibility. Regarding data repositories, Dataverse handles long-term preservation and access of data files in the following way: 1) for some data files that the repository recognizes (such as R Data, SPSS, STATA), which depend on a statistical package, the system converts them into a preservation format (such as a tab/CSV format). Even though the original format is also saved and can be accessed, the new preservation format gua...

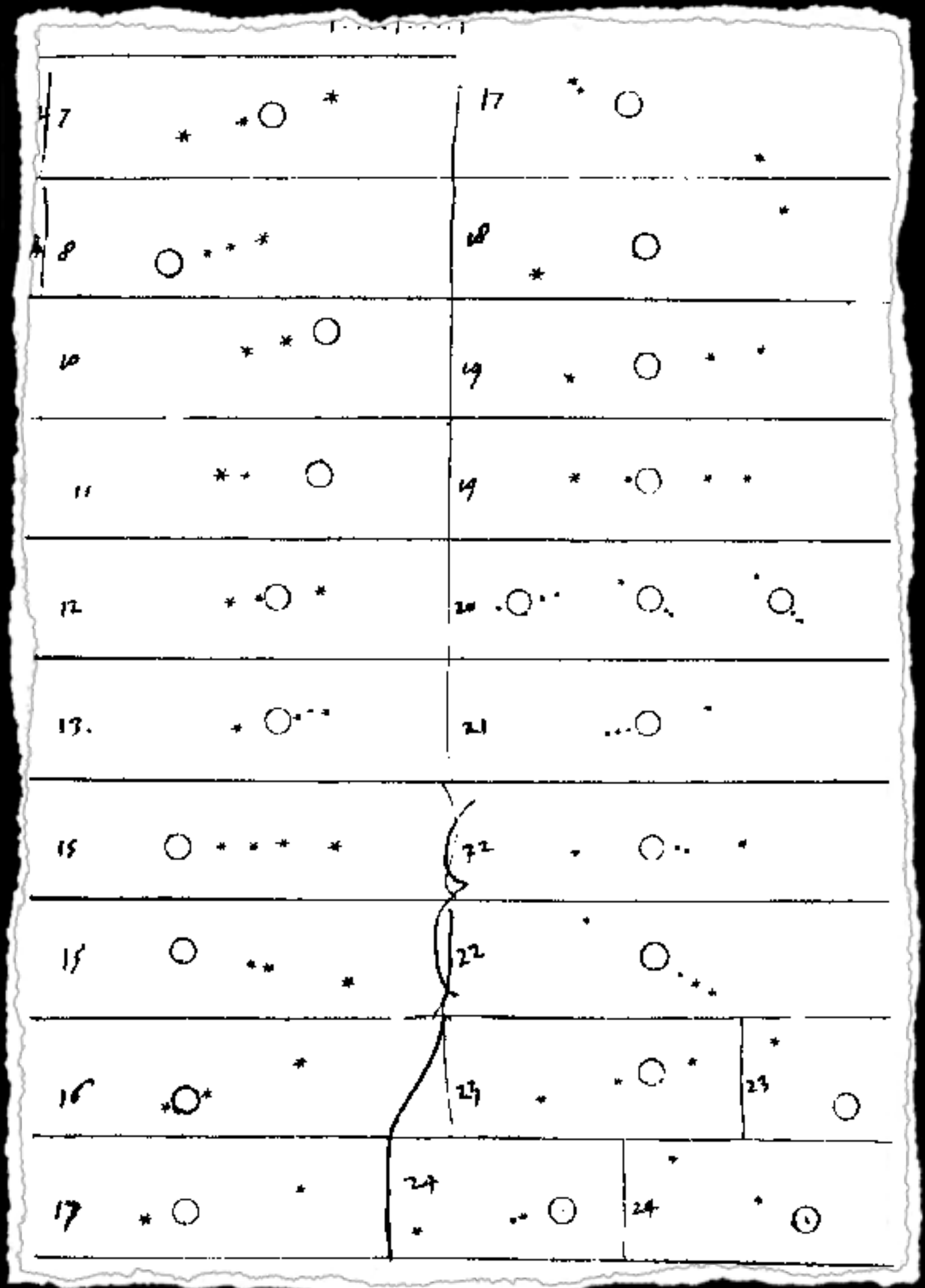
more

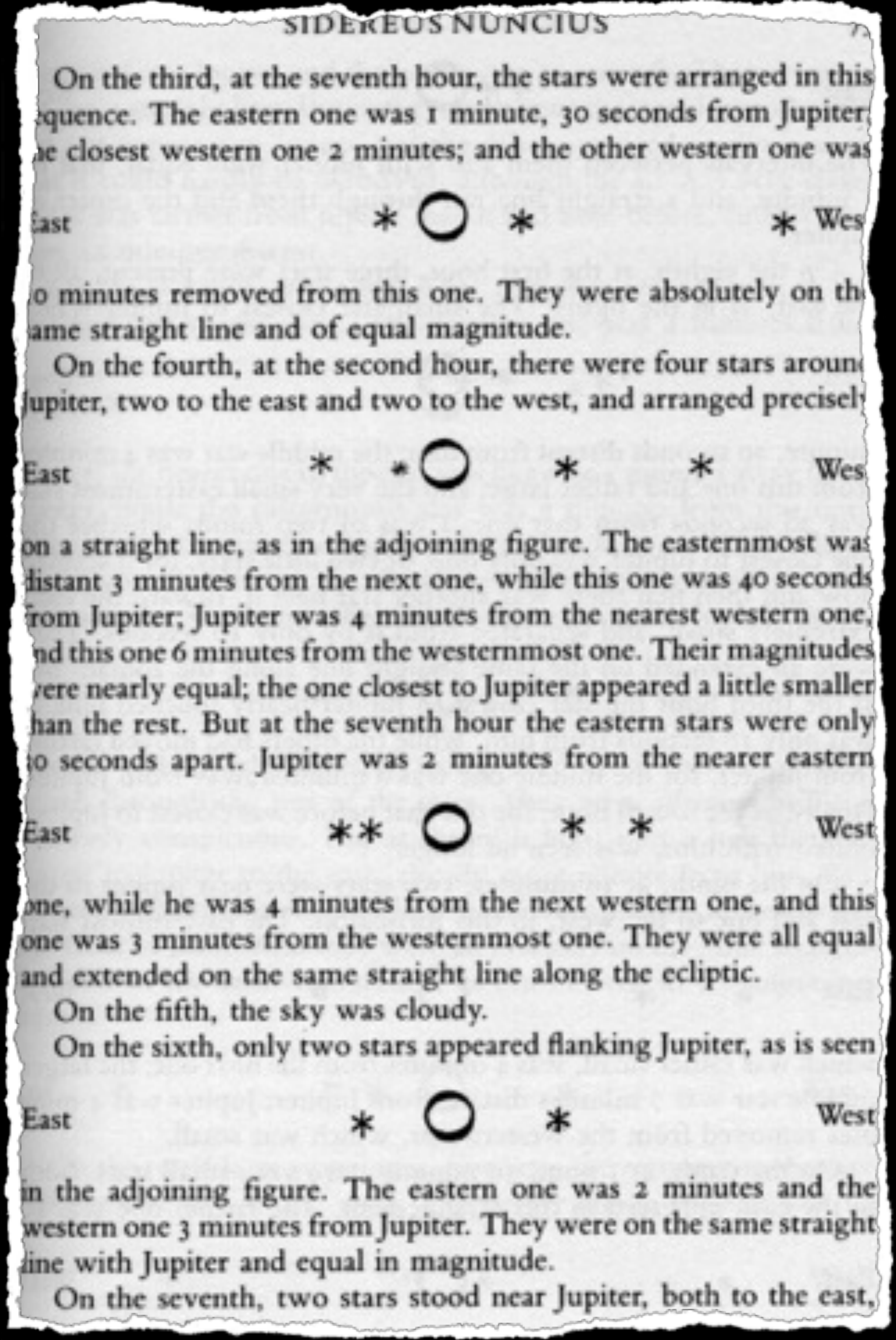
Konrad Hinsen 1 day ago · Public

That sounds good. I hope more repositories will follow the example of Dataverse. Figshare in particular has a very different attitude, encouraging researchers to deposit as

Galileo Discovers Jupiter's Moons, 1610







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e closest western one 2 minutes; and the other western one was

ast * O * * Wes

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

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

East * *O * * Wes

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, nd this one 6 minutes from the westernmost one. Their magnitudes vere nearly equal; the one closest to Jupiter appeared a little smaller han the rest. But at the seventh hour the eastern stars were only o seconds apart. Jupiter was 2 minutes from the nearer eastern

East ** O * * 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 * O * West

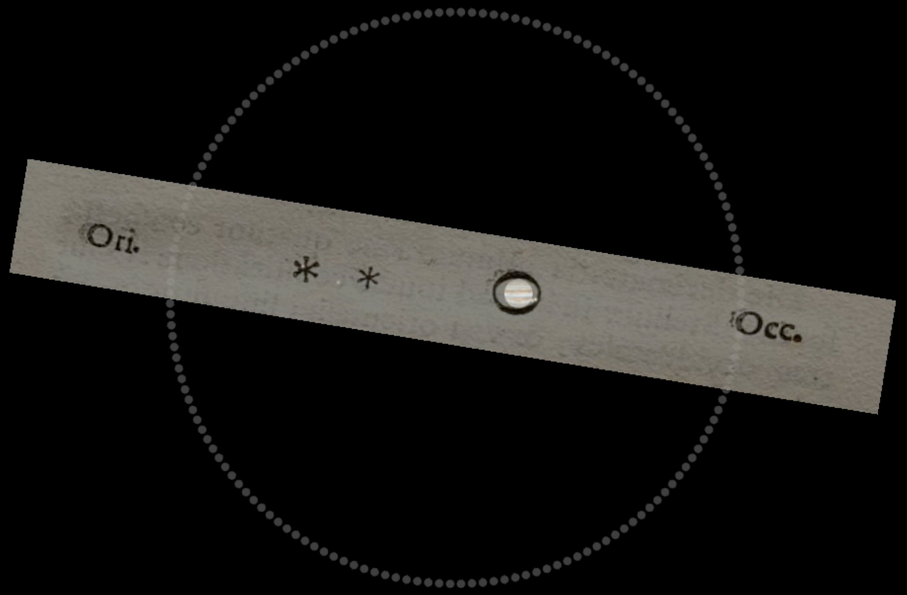
in the adjoining figure. The eastern one was 2 minutes and the western one 3 minutes from Jupiter. They were on the same straight line with Jupiter and equal in magnitude.

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

Notes for & re-productions of Siderius Nuncius

January 11, 1610

1610



Galileo's New Order, A WorldWide Telescope Tour by Goodman, Wong & Udomprasert 2010
WWT Software Wong (inventor, MS Research), Fay (architect, MS Reseearch), et al., now open source, hosted by AAS, Phil Rosenfield, Director
see wwtambassadors.org for more on WWT Outreach

2015

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The "Paper" of the Future

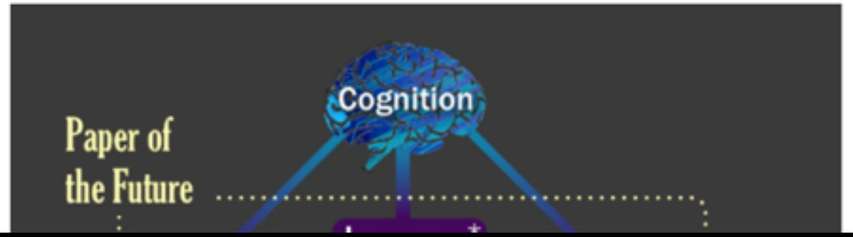
Alyssa Goodman, Josh Peek, Alberto Accomazzi, Chris Beaumont, Christine L. Borgman, How-Huan Hope Chen, Merce Crosas, Christopher Erdmann, August Muench, Alberto Pepe, Curtis Wong + Add author Re-arrange authors

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

1 Preamble

A variety of research on human cognition demonstrates that humans learn and communicate best when more than one processing system (e.g. visual, auditory, touch) is used. And, related research also shows that, no matter how technical the material, most humans also retain and process information best when they can put a narrative "story" to it. So, when considering the future of scholarly communication, we should be careful not to do blithely away with the linear narrative format that articles and books have followed for centuries: instead, we should enrich it.

Much more than text is used to commuicate in Science. Figures, which include images, diagrams, graphs, charts, and more, have enriched scholarly articles since the time of Galileo, and ever-growing volumes of data underpin most scientific papers. When scientists communicate face-to-face, as in talks or small discussions, these figures are often the focus of the conversation. In the best discussions, scientists have the ability to manipulate the figures, and to access underlying data, in real-time, so as to test out various what-if scenarios, and to explain findings more clearly. **This short article explains—and shows with demonstrations—how scholarly "papers" can morph into long-lasting rich records of scientific discourse**, enriched with deep data and code linkages, interactive figures, audio, video, and commenting.



Konrad Hinsen 3 days ago · Public
Many good suggestions, but if the goal is "long-lasting rich records of scientific discourse", a more careful and critical attitude towards electronic artifacts is appropriate. I do see it concerning videos, but not a word on the much more critical situation in software. Archiving source code is not sufficient: all the dependencies, plus the complete build environment, would have to be conserved as well to make things work a few years from now. An "executable figure" in the form of an IPython notebook wil...
more

Merce Crosas 3 days ago · Public
Konrad, good points; this has been a concern for the community working on reproducibility. Regarding data repositories, Dataverse handles long-term preservation and access of data files in the following way: 1) for some data files that the repository recognizes (such as R Data, SPSS, STATA), which depend on a statistical package, the system converts them into a preservation format (such as a tab/CSV format). Even though the original format is also saved and can be accessed, the new preservation format gua...
more

Konrad Hinsen 1 day ago · Public
That sounds good. I hope more repositories will follow the example of Dataverse. Figshare in particular has a very different attitude, encouraging researchers to deposit as much as possible. That's perhaps a good strategy to change habits, but in the long run it could well backfire when people find out in a few years that 90% of those deposits have become useless.

Christine L. Borgman 4 months ago · Private
"publications"

[demo]

d3po/Authorea: Peek, Price-Whelan, Pepe, Beaumont, Borkin, Newton; PoF: Goodman, Peek; WWT: Wong, Fay et al.; Astrometry.net: Hogg, Lang, Roweis et al.

2009

3D PDF
interactivity in a "Paper"

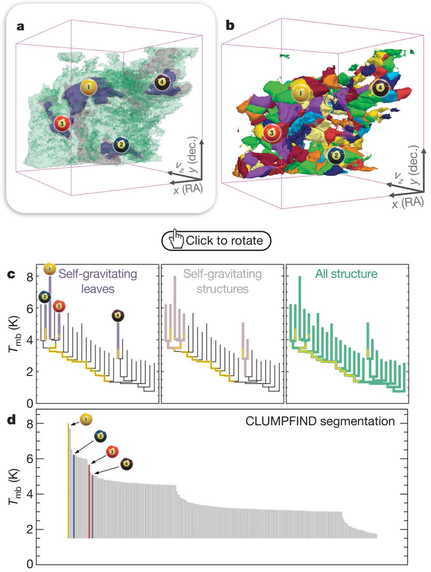


Figure 2 | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. a, 3D visualization of the surfaces indicated by colours in the dendrogram shown in **c**. Purple illustrates the smallest scale self-gravitating structures in the region corresponding to the leaves of the dendrogram; pink shows the smallest surfaces that contain distinct self-gravitating leaves within them; and green corresponds to the surface in the data cube containing all the significant emission. Dendrogram branches corresponding to self-gravitating objects have been highlighted in yellow over the range of T_{mb} (main-beam temperature) test-level values for which the virial parameter is less than 2. The x–y locations of the four 'self-gravitating' leaves labelled with billiard balls are the same as those shown in Fig. 1. The 3D visualizations show position–position–velocity (p–p–v) space. RA, right ascension; dec., declination. For comparison with the ability of dendrograms (**c**) to track hierarchical structure, **d** shows a pseudo-dendrogram of the CLUMPFIND segmentation (**b**), with the same four labels used in Fig. 1 and in **a**. As 'clumps' are not allowed to belong to larger structures, each pseudo-branch in **d** is simply a series of lines connecting the maximum emission value in each clump to the threshold value. A very large number of clumps appears in **b** because of the sensitivity of CLUMPFIND to noise and small-scale structure in the data. In the online PDF version, the 3D cubes (**a** and **b**) can be rotated to any orientation, and surfaces can be turned on and off (interaction requires Adobe Acrobat version 7.0.8 or higher). In the printed version, the front face of each 3D cube (the 'home' view in the interactive online version) corresponds exactly to the patch of sky shown in Fig. 1, and velocity with respect to the Local Standard of Rest increases from front (-0.5 km s^{-1}) to back (8 km s^{-1}).

data, CLUMPFIND typically finds features on a limited range of scales, above but close to the physical resolution of the data, and its results can be overly dependent on input parameters. By tuning CLUMPFIND's two free parameters, the same molecular-line data set[8] can be used to show either that the frequency distribution of clump mass is the same as the initial mass function of stars or that it follows the much shallower mass function associated with large-scale molecular clouds (Supplementary Fig. 1).

Four years before the advent of CLUMPFIND, 'structure trees'[9] were proposed as a way to characterize clouds' hierarchical structure using 2D maps of column density. With th…rly 2D work as inspiration, we have developed a structure-id…rithm that abstracts the hierarchical structure of a… an easily visualized representation calle… well developed in other data-intensive… application of tree methodologies so fa… and almost exclusively within the a… 'merger trees' are being used with in…

Figure 3 and its legend explain t… schematically. The dendrogram qua… ima of emission merge with each… explained in Supplementary Meth… determined almost entirely by t… sensitivity to algorithm paramet… possible on paper and 2D screen… data (see Fig. 3 and its legend… cross, which eliminates dimen… preserving all information… Numbered 'billiard ball' lab… features between a 2D map… online) and a sorted dendr…

A dendrogram of a spectr… of key physical properties… surfaces, such as radius (R), … (L). The volumes can have any shape, and… the significance of the especially elongated features… (Fig. 2a). The luminosity is an approximate proxy for mass, su… that $M_{lum} = X_{13CO} L_{13CO}$, where $X_{13CO} = 8.0 \times 10^{20}$ cm^2 K^{-1} km^{-1} s (ref. 15; see Supplementary Methods and Supplementary Fig. 2). The derived values for size, mass and velocity dispersion can then be used to estimate the role of self-gravity at each point in the hierarchy, via calculation of an 'observed' virial parameter, $\alpha_{obs} = 5\sigma_v^2 R/GM_{lum}$. In principle, extended portions of the tree (Fig. 2, yellow highlighting) where $\alpha_{obs} < 2$ (where gravitational energy is comparable to or larger than kinetic energy) correspond to regions of p–p–v space where self-gravity is significant. As α_{obs} only represents the ratio of kinetic energy to gravitational energy at one point in time, and does not explicitly capture external over-pressure and/or magnetic fields[16], its measured value should only be used as a guide to the longevity (boundedness) of any particular feature.

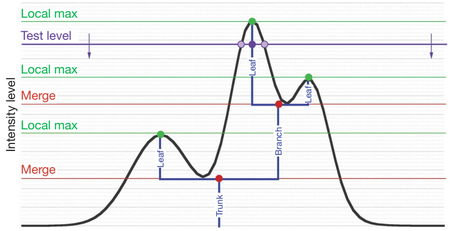


Figure 3 | Schematic illustration of the dendrogram process. Shown is the construction of a dendrogram from a hypothetical one-dimensional emission profile (black). The dendrogram (blue) can be constructed by 'dropping' a test constant emission level (purple) from above in tiny steps (exaggerated in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

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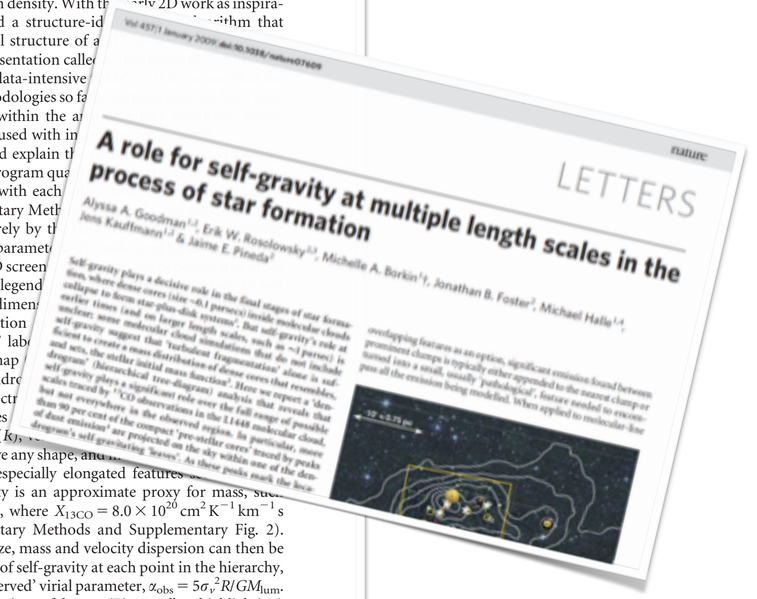


Goodman et al. 2009, Nature,
cf: Fluke et al. 2009

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

nature

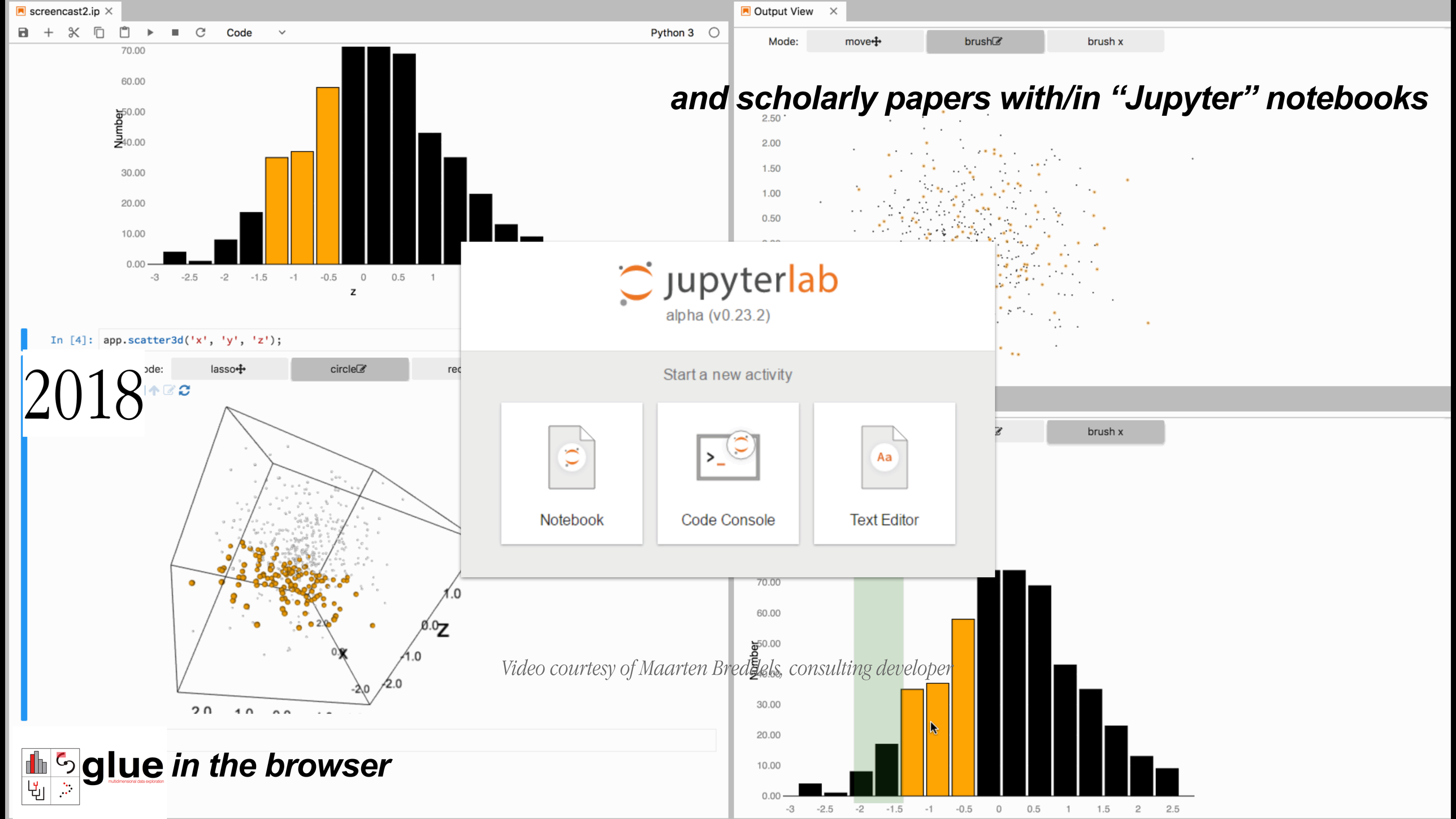
LETTERS

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

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

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

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



and scholarly papers with/in "Jupyter" notebooks

2018

Video courtesy of Maarten Breddels, consulting developer

glue *in the browser*

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Graph these comma-separated phrases: creativity,collaboration case-insensitive

between 1860 and 2008 from the corpus English with smoothing of 2 . Search lots of books

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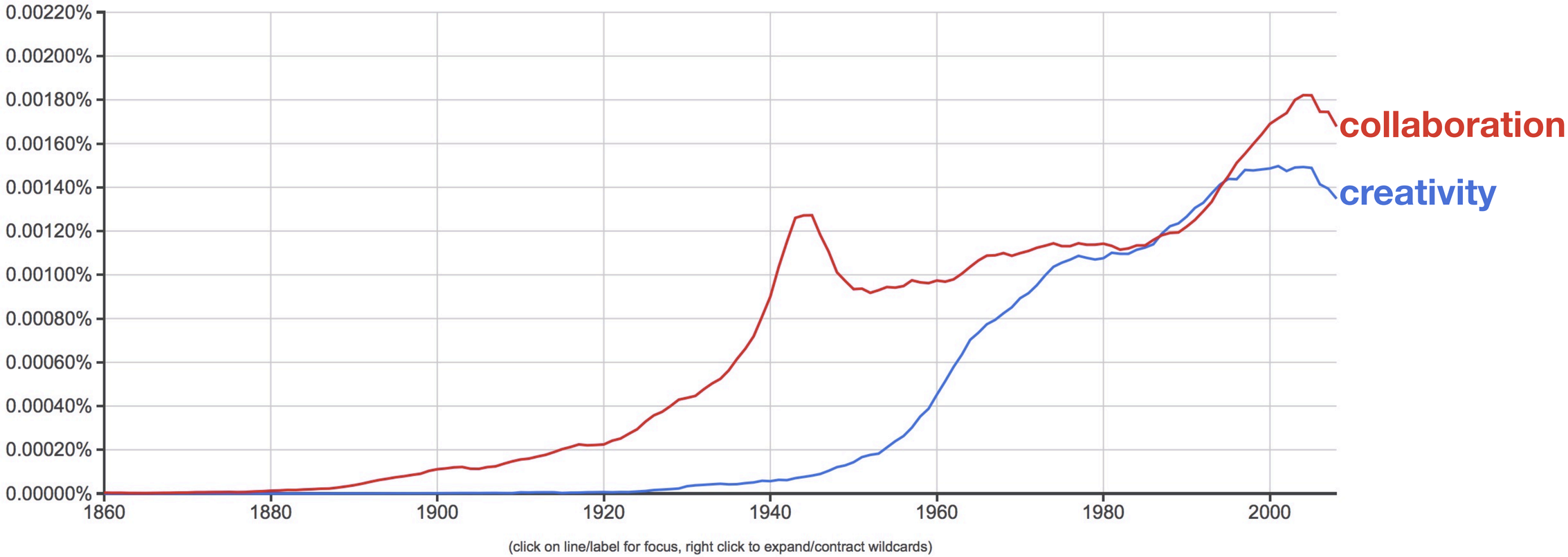
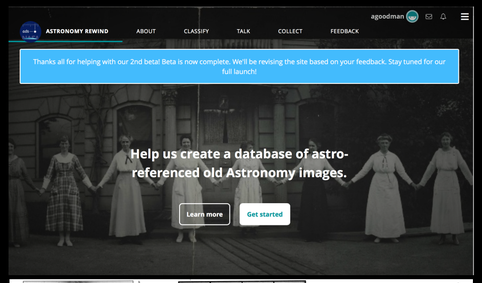
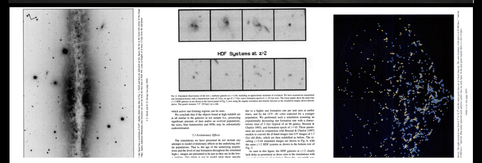


(click on line/label for focus, right click to expand/contract wildcards)

collaboration





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WORDS FROM THE RESEARCHER

"Your contributions unlock the information from old astronomy journals. Thank you and enjoy the images!"

ABOUT ASTRONOMY REWIND

This project is part of an ongoing NASA-funded effort aimed at turning the SAO/NASA Astrophysics Data System (ADS) into a data resource. The result will be a database of astro-referenced images, i.e., images of the sky for which coordinates, orientation, and pixel scale will be publicly available through NASA data archives, **the Astronomy Image Explorer**, and **World Wide Telescope**, thanks to your help!

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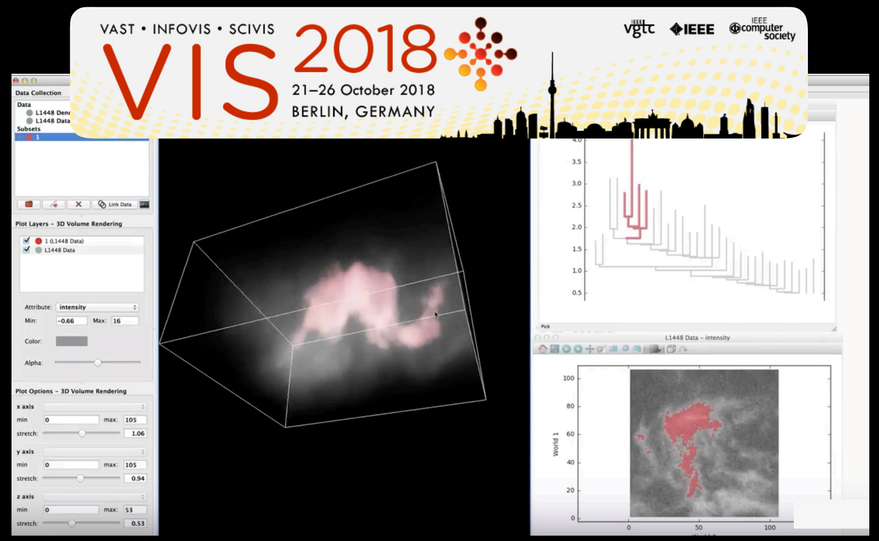

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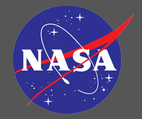

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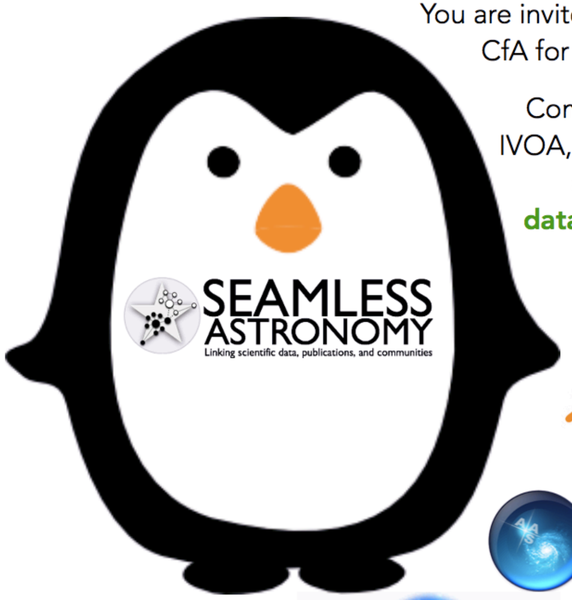
DEMO-FEST 2018 [A PARTY!]



You are invited to join the Seamless Astronomy group of the CfA for 1:1 software demos, snacks & green beverages.

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