Figuring out why the Loch Ness Monster is Resting in the Milky Way, Online


The Astronomer, Vermeer


"Nessie", Spitzer Space Telescope

Alyssa A. Goodman

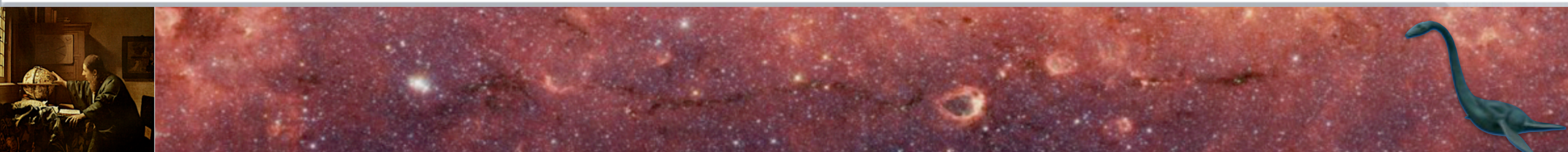
Harvard-Smithsonian Center for Astrophysics

WORKING DRAFT OPEN SCIENCE ARTICLE AUTHOREA.COM/249

The Bones of the Milky Way

Alyssa Goodman, Joao Alves, Chris Beaumont, Tom Dame, James Jackson, Jens Kauffmann, Thomas Robitaille, Alberto Pepe, Michelle Borkin, Andreas Burkert, Bob Benjamin + Add author Export article

Abstract. The very long, thin infared dark cloud ``Nessie'' is even longer than had been previously claimed, and an analysis of its Galactic location suggests that it lies directly in the Milky Way's mid-plane, tracing out a highly elongated bone-like feature within the prominent Scutum-Centaurus spiral arm. Re-analysis of mid-infrared imagery from the Spitzer Space Telescope shows that this IRDC is at least 2, and possibly as many as 8 times longer than had originally been claimed by Nessie's discoverers, Jackson et al. (2010); its aspect ratio is therefore at least 150:1, and possibly as large as 800:1. A careful accounting for both the Sun's offset from the Galactic plane (~ 25 pc) and the Galactic center's offset from the $(l^{II}, b^{II}) = (0, 0)$ position defined by the IAU in 1959 shows that the latitude of the true Galactic mid-plane at the 3.1 kpc distance to the Scutum-Centaurus Arm is not $b = 0$, but instead closer to $b = -0.5$, which is the latitude of Nessie to within a few pc. Apparently, Nessie lies *in* the Galactic mid-plane. An analysis of the radial velocities of low-density (CO) and high-density (NH_3) gas associated with the Nessie dust feature suggests that Nessie runs along the Scutum-Centaurus Arm in position-position-velocity space, which means it likely forms a dense 'spine' of the arm in real space as well. No galaxy-scale simulation to date has the spatial resolution to predict a Nessie-like feature, but extant simulations do suggest that highly elongated over-dense filaments should be associated with a galaxy's spiral arms. Nessie is situated in the closest major spiral arm to the Sun toward the inner Galaxy, and appears almost perpendicular to our line of sight, making it the easiest feature of its kind to detect from our location (a shadow of an Arm's bone, illuminated by the Galaxy beyond). Although the Sun's offset from the Galactic plane is not significant compared with the thickness of the plane as traced by Population I objects such as GMCs and HII regions, it may be significant compared with an extremely thin layer that might be traced out by Nessie-like objects. Future high-resolution extinction and molecular line data may therefore allow us to exploit the Sun's position above the plane to gain a small amount of perspective on the Galactic disk.



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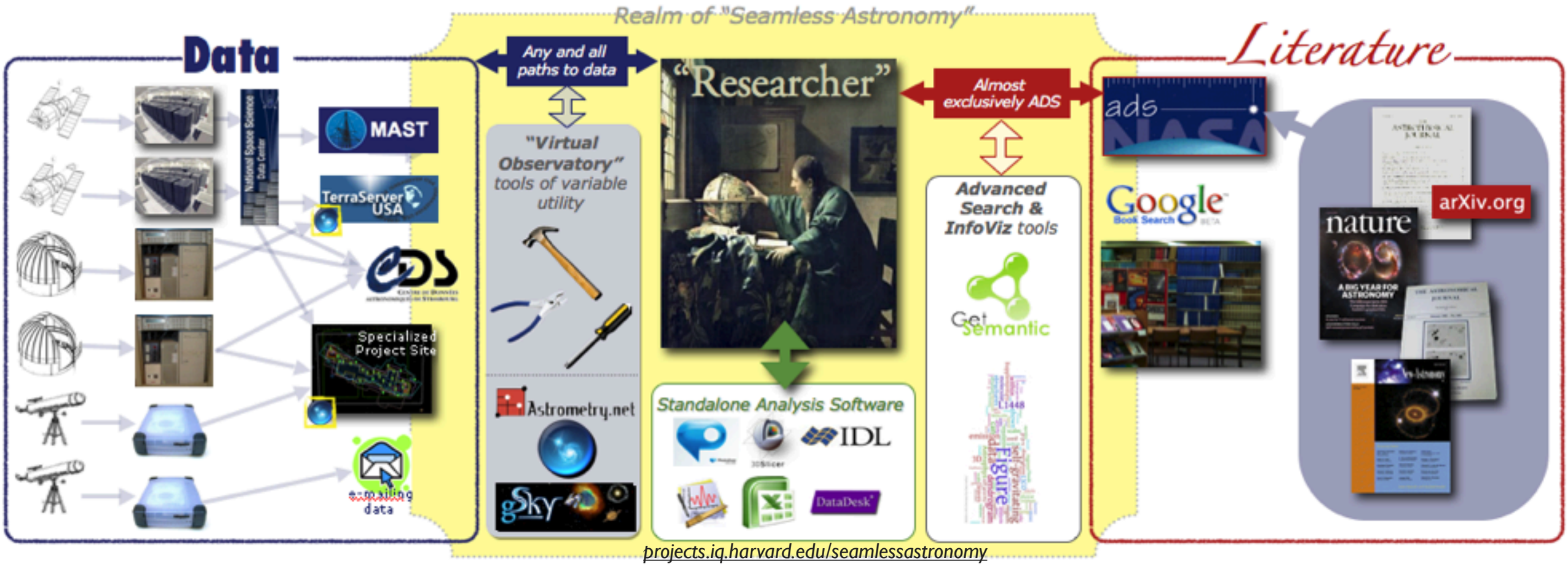

Alberto Accomazzi, Christopher Beaumont, Douglas Burke, Raffaele D'Abrusco, Rahul Davé, Christopher Erdmann, Pepi Fabbiano, Alyssa Goodman, Edwin Henneken, Jay Luker, Gus Muench, Michael Kurtz, Max Lu, Victoria Mittelbach, Alberto Pepe, Arnold Rots, Patricia Udomprasert (Harvard-Smithsonian CfA); Mercé Crosas (Harvard Institute for Quantitative Social Science); Christine Borgman (UCLA); Jonathan Fay & Curtis Wong (Microsoft Research); Alberto Conti (Space Telescope Science Institute)

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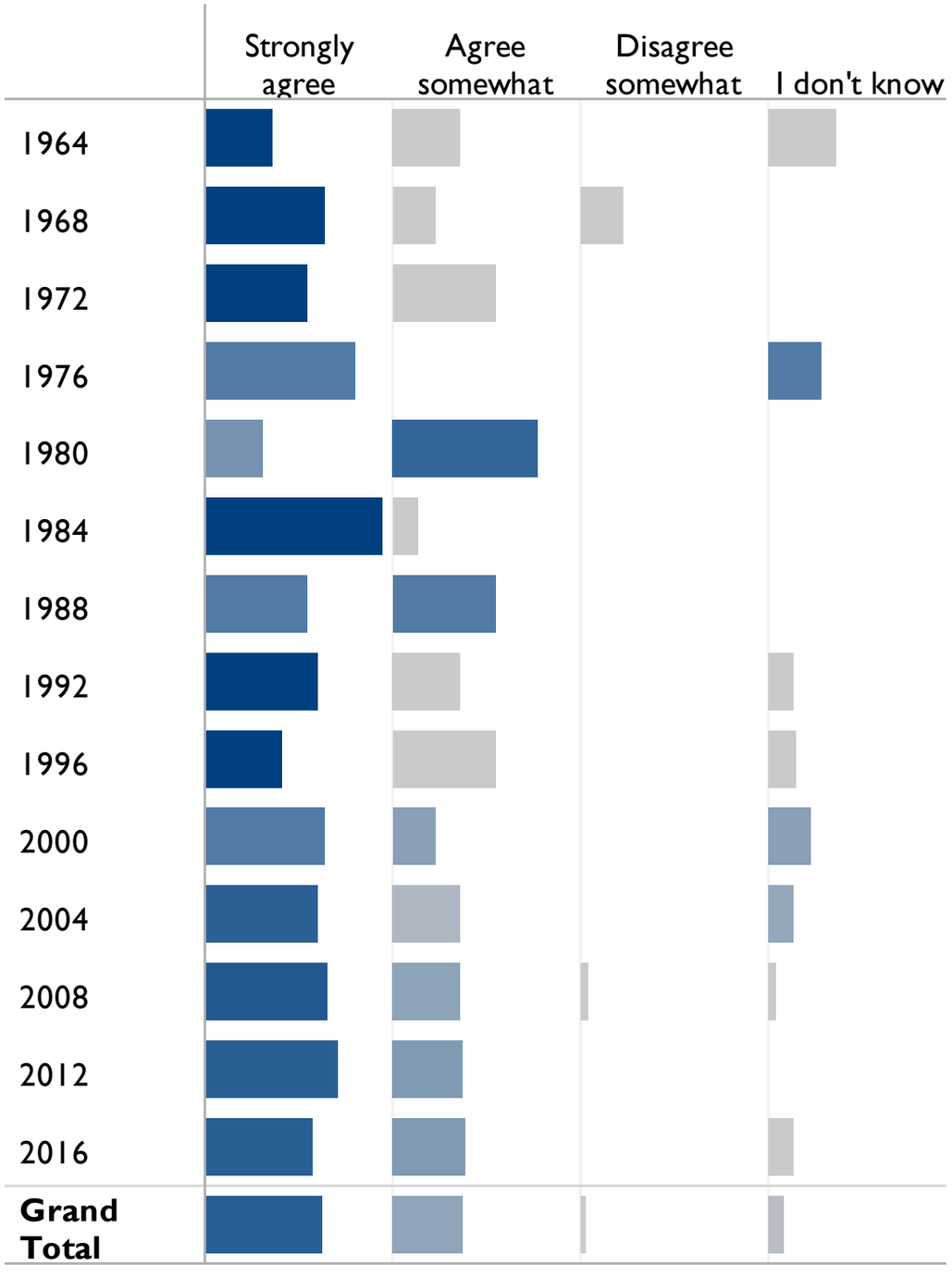
Opinions

of 170 PhD-level Scientists at the Harvard-Smithsonian Center for Astrophysics (gathered April 17-18, 2013)

Full results at: http://tinyurl.com/cfa-data-survey-results

"I think that the future of astrophysical research will rely more on sharing of code and data in the future than it has in the past."



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large file size	not shared my data due to large file sizes
don't know how	not shared my data because I don't know how.
too much effort	not shared my data because it takes too much effort.
think no one wants it	not shared my data because I don't think anyone will want it.
other	Other

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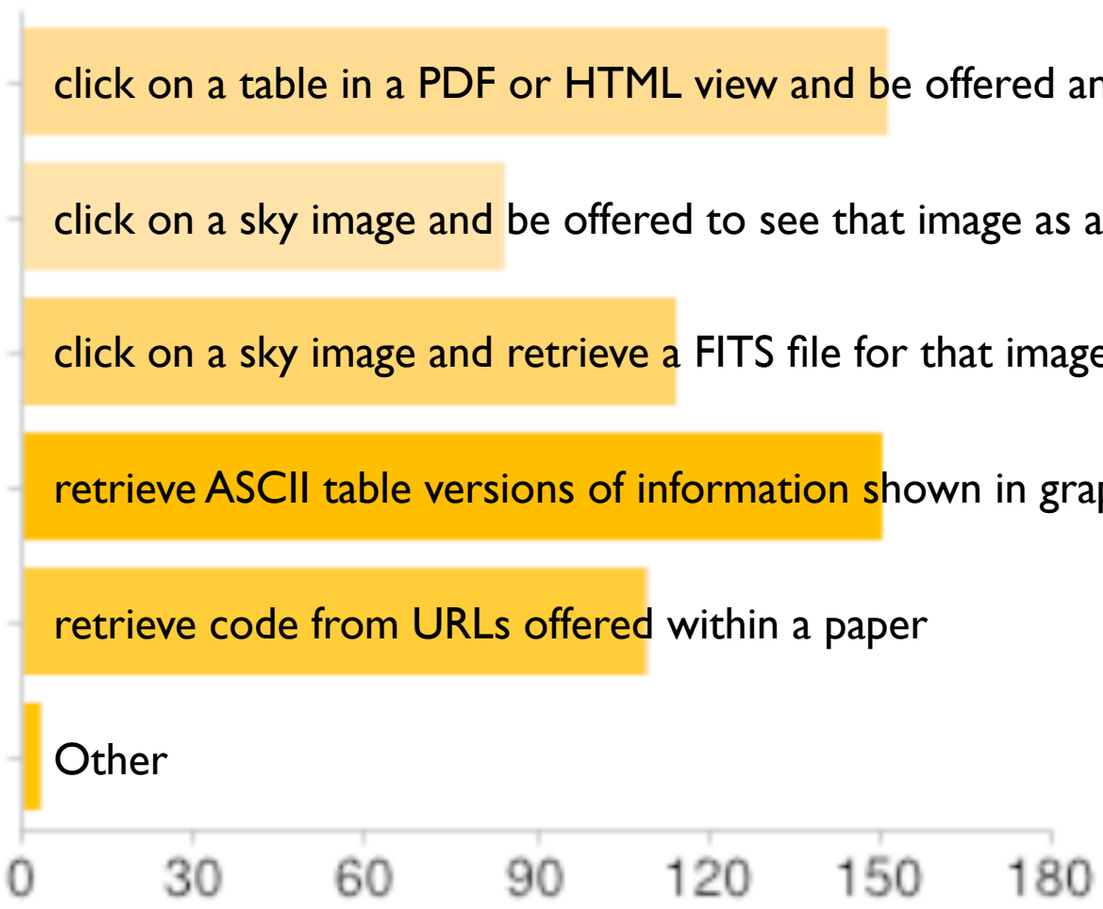

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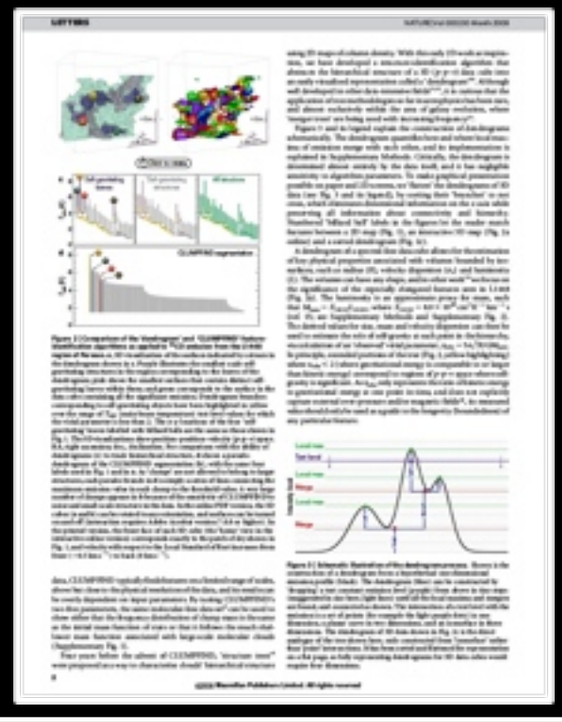
VOLUME I JANUARY 1895 NUMBER 1

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 Janssen and perfected by Hale and Deslandres, by means of which a photograph of the Sun's prominences may be obtained at any time as readily as it is during an eclipse. The essential features of this device are the simultaneous movements of the collimator-slit across the Sun's image, with that of a second slit (at 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 endeeble-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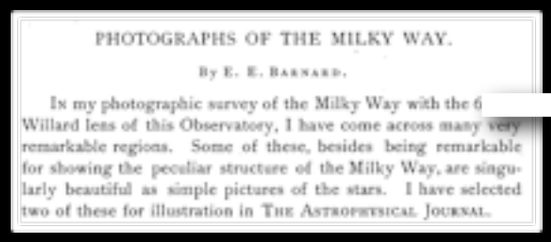
PHOTOGRAPHS OF THE MILKY WAY.

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In my photographic survey of the Milky Way with the 6 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.

[demo 3D PDF]

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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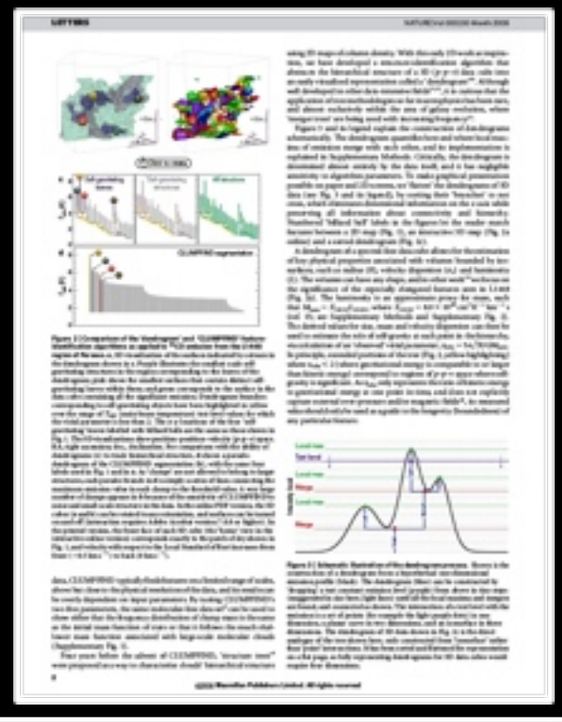
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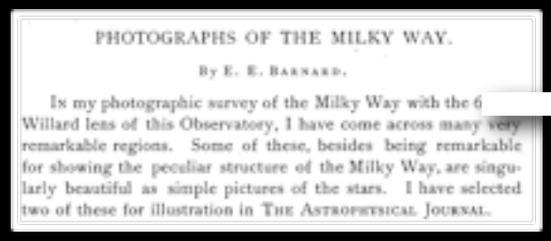
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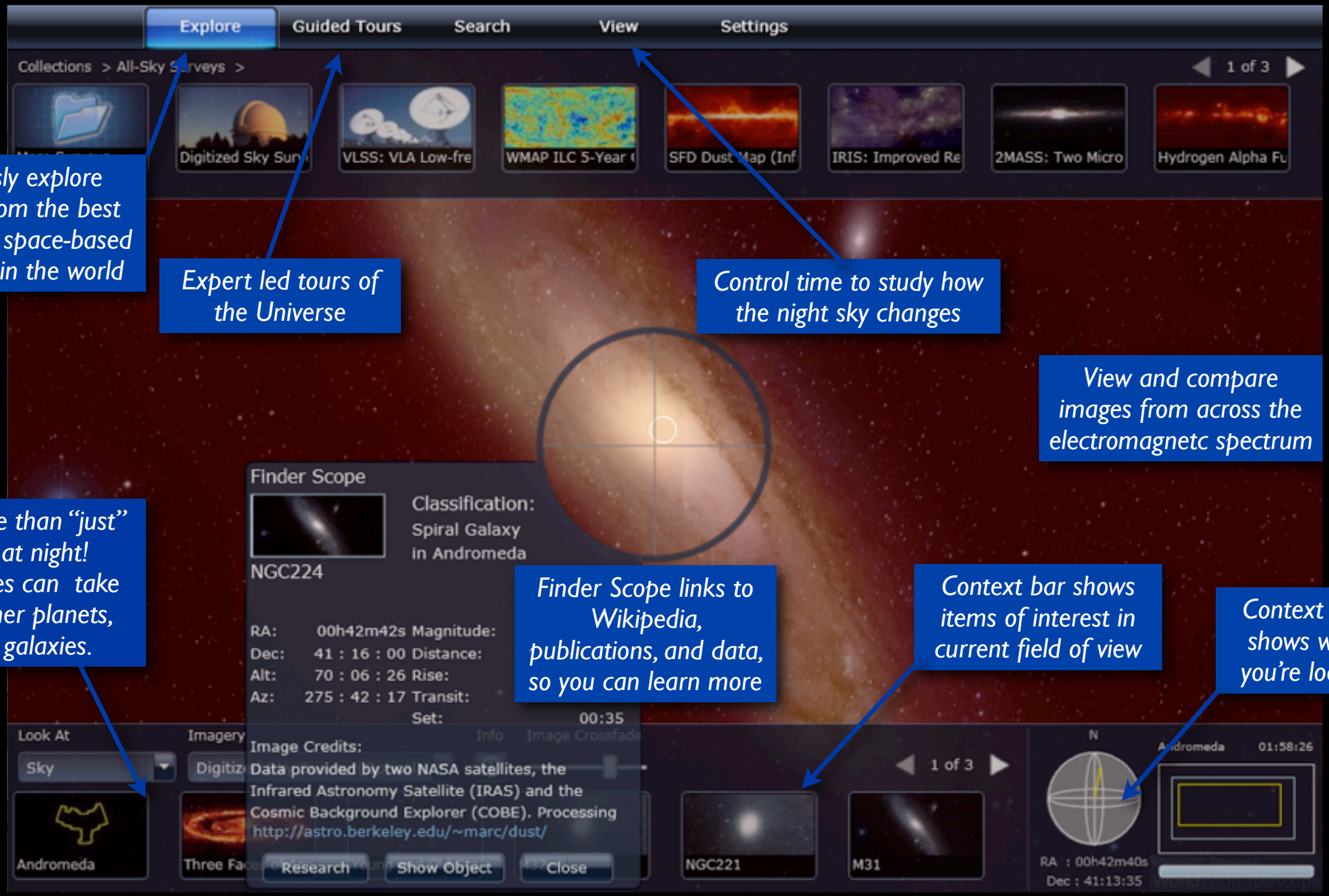

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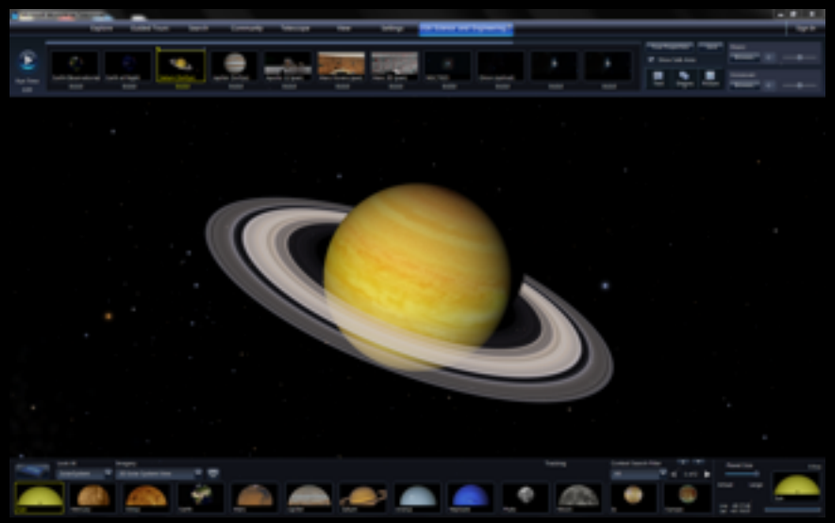

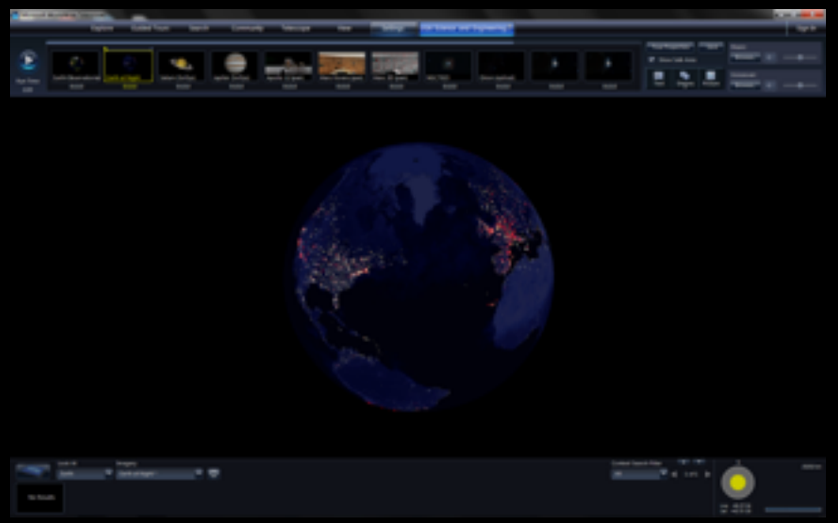

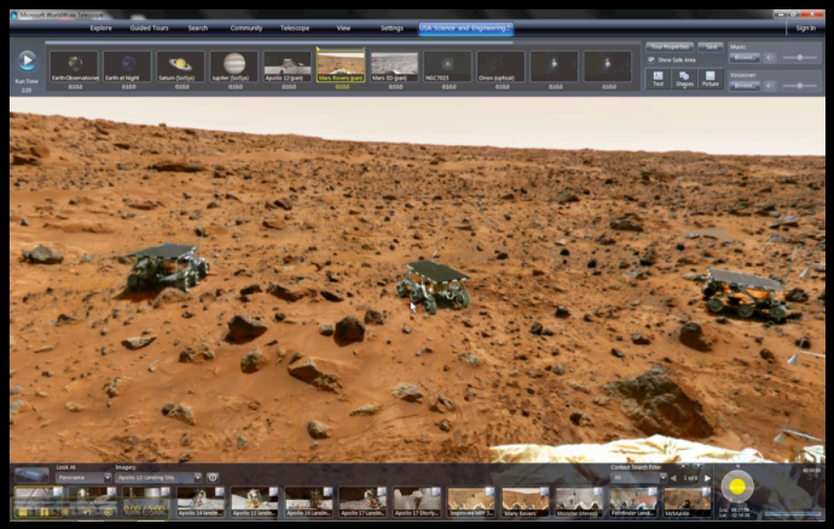

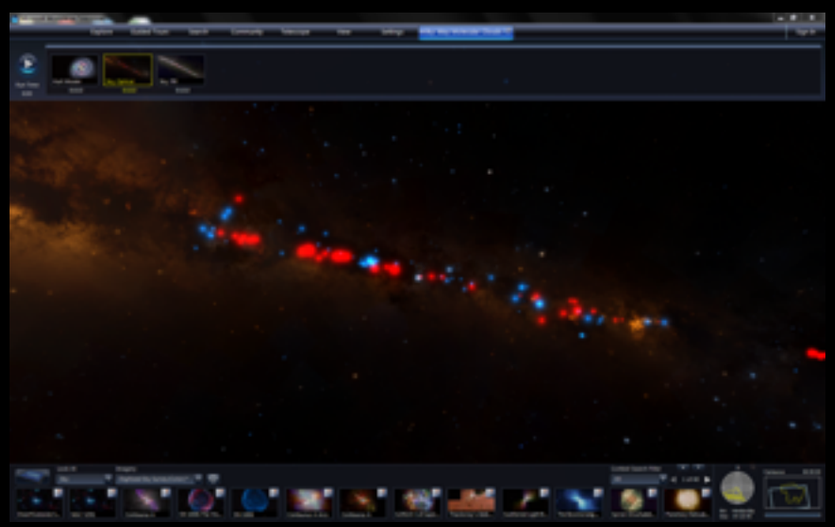

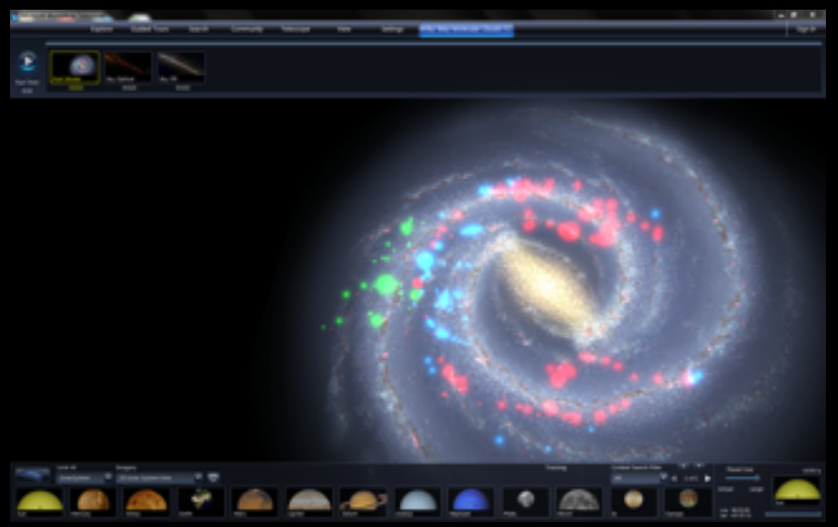

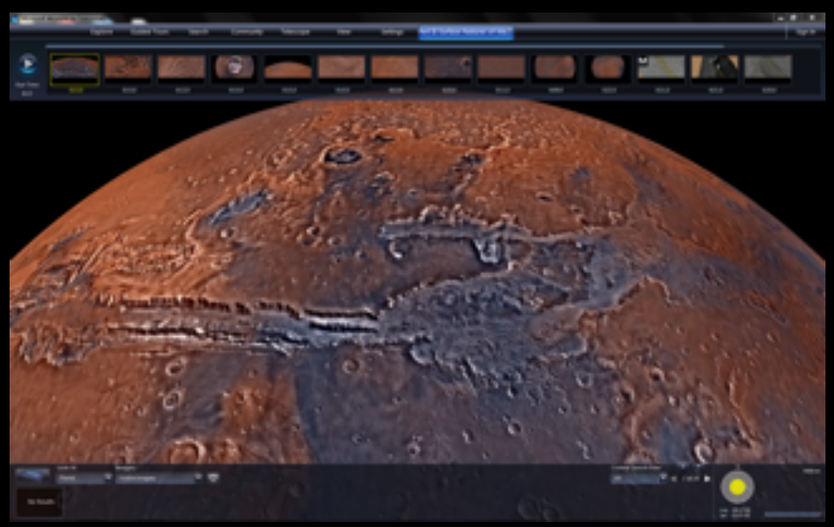

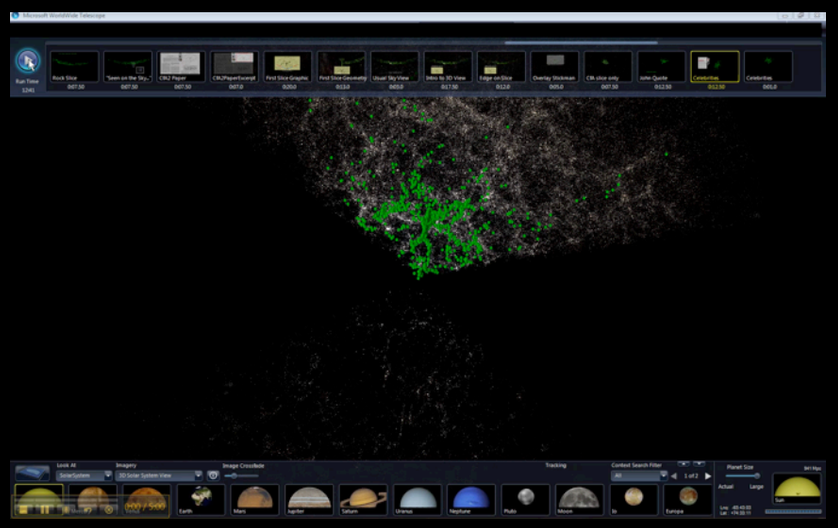

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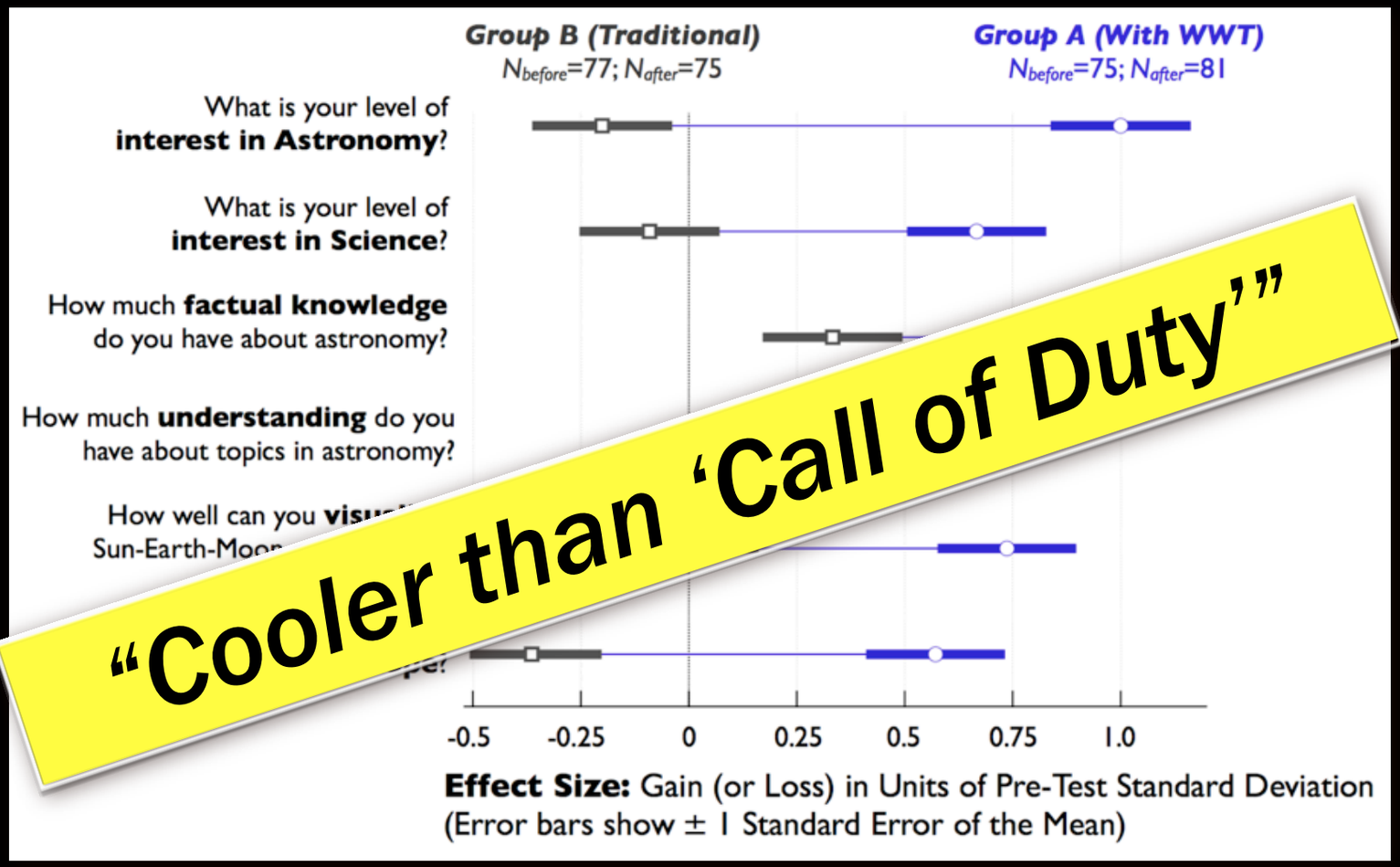

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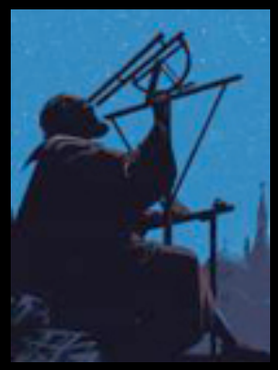

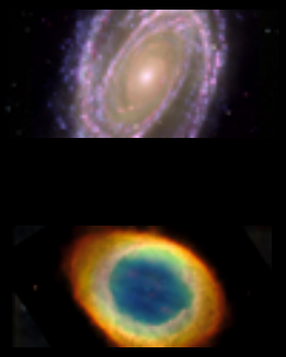

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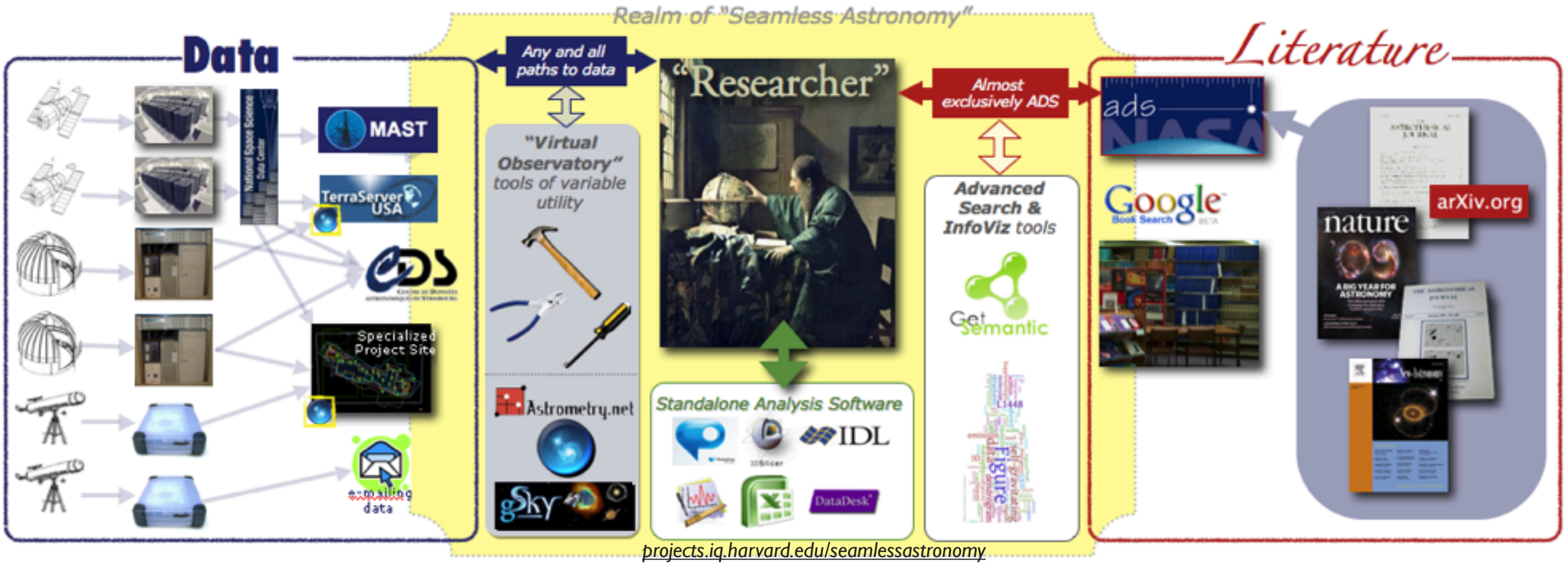

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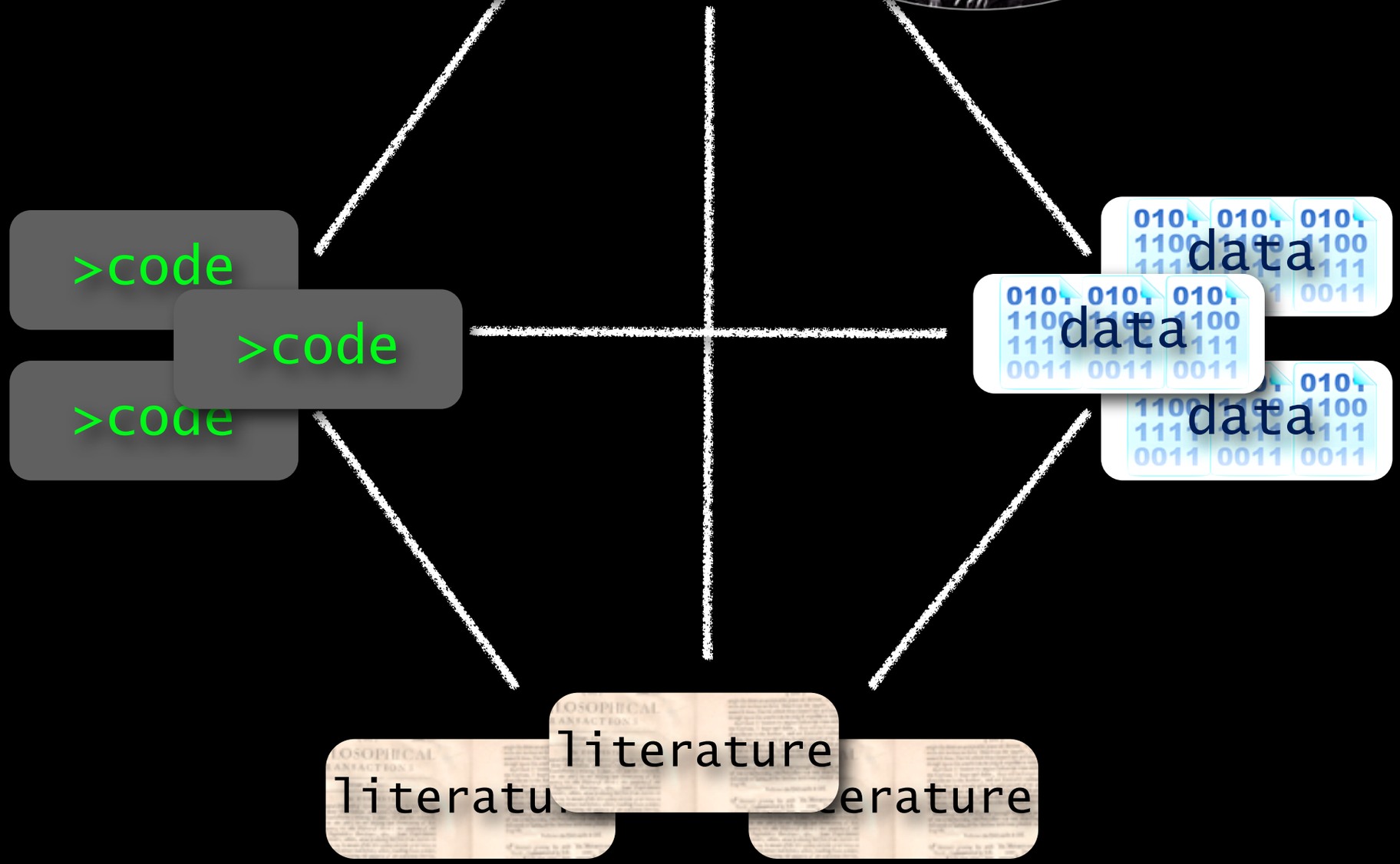

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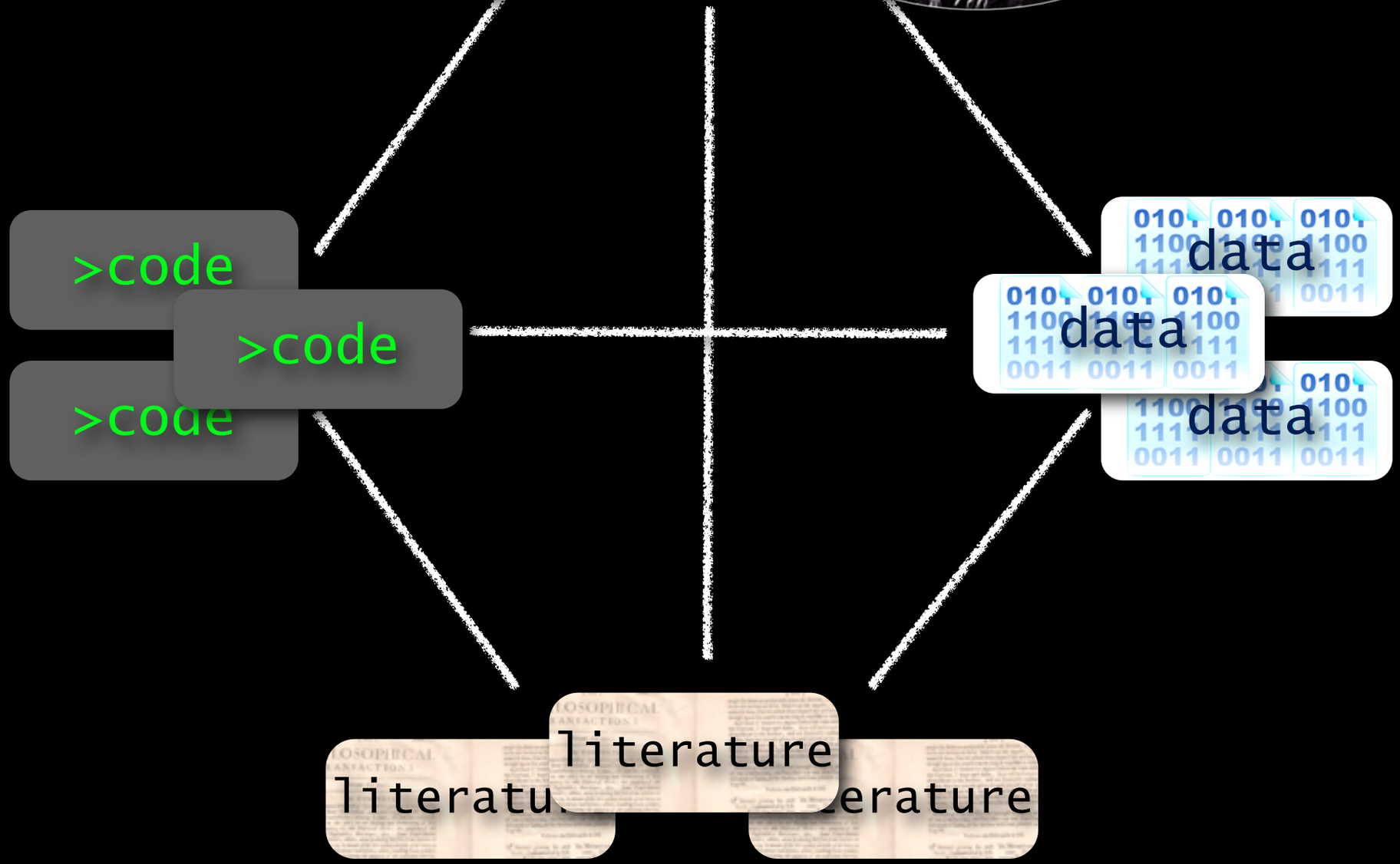

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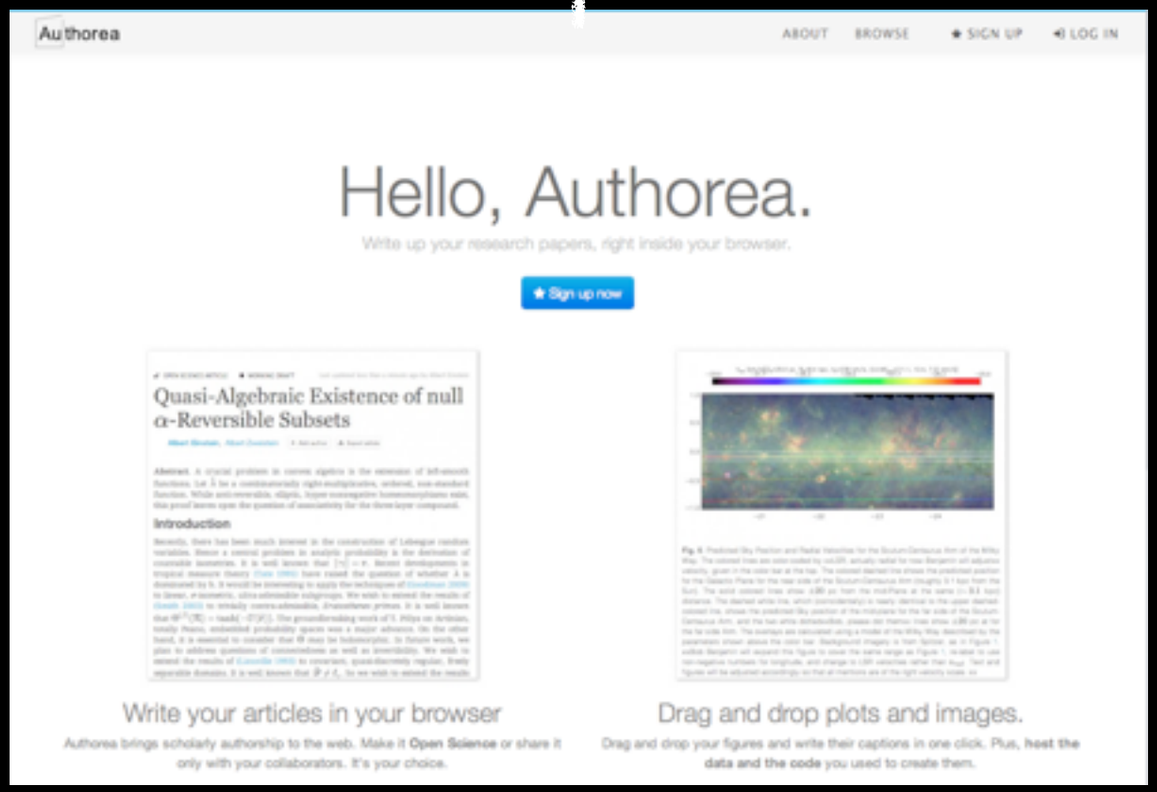

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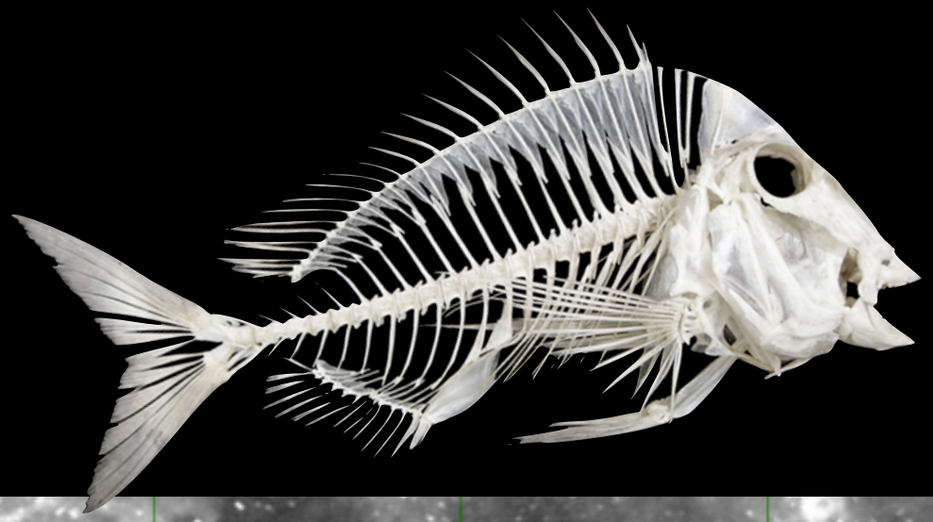

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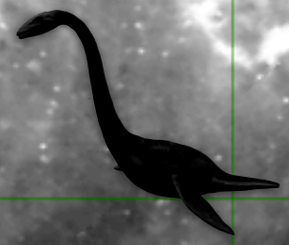


Alyssa A. Goodman (Harvard-Smithsonian Center for Astrophysics)

with collaborators at (alphabetically by insitution):

Boston University: James Jackson

Caltech: Jens Kauffmann

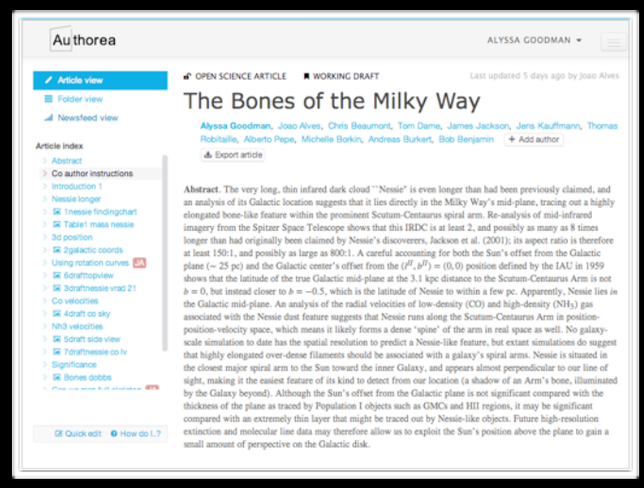
Harvard - Smithsonian: Christopher Beaumont, Michelle A. Borkin, Thomas M. Dame

Max Planck Insitute for Astronomy: Thomas Robitaille

U. Munich: Andreas Burkert

U. Vienna: Joao F. Alves

U. Wisconsin: Robert A. Benjamin



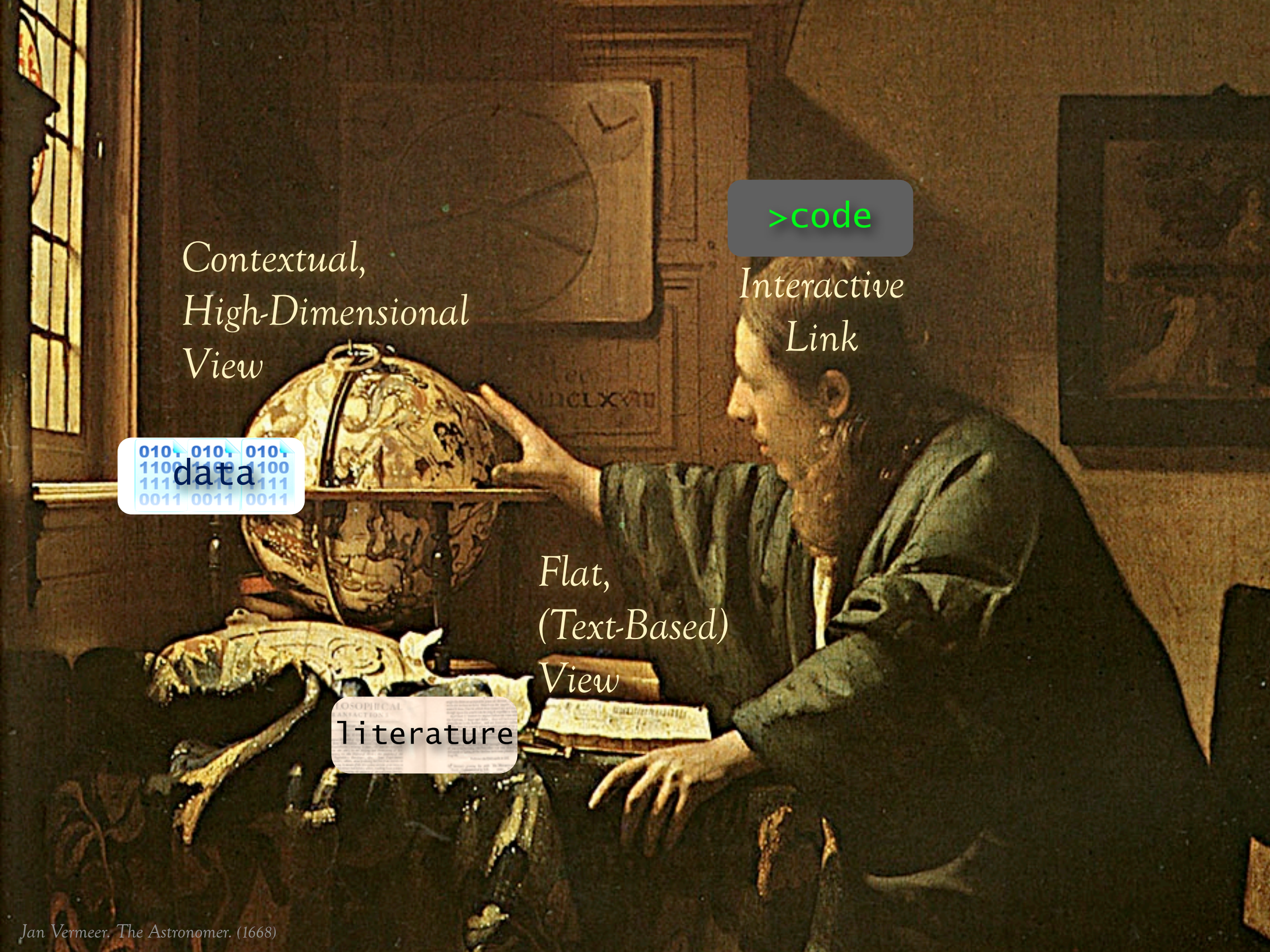
Alyssa Goodman, m:617-230-7080; url: milkywaybones.org

Ringberg Castle, Bavaria
“Early Phases of Star Formation”
July 2012

Question *Andi Burkert*: Is Nessie “parallel to the Galactic Plane”?

Answer *no one* immediately knew the answer!

AG decides to look into this and...



Jan Vermeer. The Astronomer. (1668)

"Is Nessie Parallel to the Galactic Plane?"

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The Astrophysical Journal Letters, 719:L185–L189, 2010 August 20 doi:10.1088/2041-8205/719/2/L185

THE "NESSIE" NEBULA: CLUSTER FORMATION IN A FILAMENTARY INFRARED DARK CLOUD

James M. Jackson[1], Susanna C. Finn[1], Edward T. Chambers[2], Jill M. Rathborne[3], and Robert Simon[4]
[1] Institute for Astrophysical Research, Boston University, Boston, MA 02215, USA; jackson@bu.edu, sfinn@bu.edu
[2] Department of Physics and Astronomy, Northwestern University, Evanston, IL 60208, USA; e-chambers@northwestern.edu
[3] Australia Telescope National Facility and Universidad de Chile, Santiago, Chile; rathborn@das.uchile.cl
[4] I. Physikalisches Institut, Universität zu Köln, 50937 Köln, Germany; simonr@ph1.uni-koeln.de
Received 2010 April 13; accepted 2010 July 21; published 2010 August 3

ABSTRACT

The "Nessie" Nebula is a filamentary infrared dark cloud (IRDC) with a large aspect ratio of over 150:1 (1.°5 × 0.°01 or 80 pc × 0.5 pc at a kinematic distance of 3.1 kpc). Maps of HNC (1–0) emission, a tracer of dense molecular gas, made with the Australia Telescope National Facility Mopra telescope, show an excellent morphological match to the mid-IR extinction. Moreover, because the molecular line emission from the entire nebula has the same radial velocity to within ±3.4 km s^{-1}, the nebula is a single, coherent cloud and not the chance alignment of multiple unrelated clouds along the line of sight. The Nessie Nebula contains a number of compact, dense molecular cores which have a characteristic projected spacing of ~4.5 pc along the filament. The theory of gravitationally bound gaseous cylinders predicts the existence of such cores, which, due to the "sausage" or "varicose" fluid instability, fragment from the cylinder at a characteristic length scale. If turbulent pressure dominates over thermal pressure in Nessie, then the observed core spacing matches theoretical predictions. We speculate that the formation of high-mass stars and massive star clusters arises from the fragmentation of filamentary IRDCs caused by the "sausage" fluid instability that leads to the formation of massive, dense molecular cores. The filamentary molecular gas clouds often found near high-mass star-forming regions (e.g., Orion, NGC 6334, etc.) may represent a later stage of IRDC evolution.

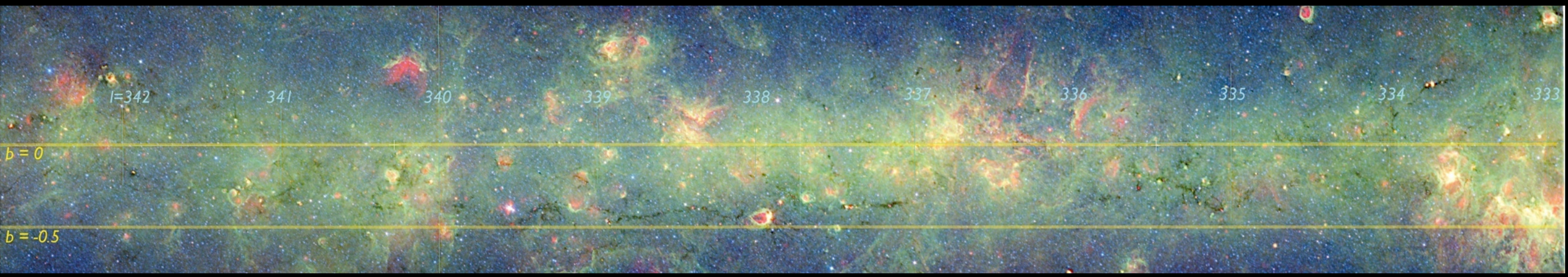
Key words: ISM: clouds – stars: formation

Jackson et al. 2010

Monster to Bone

There could be ~1000 more of these to find...a full skeleton perhaps?

milkywaybones.org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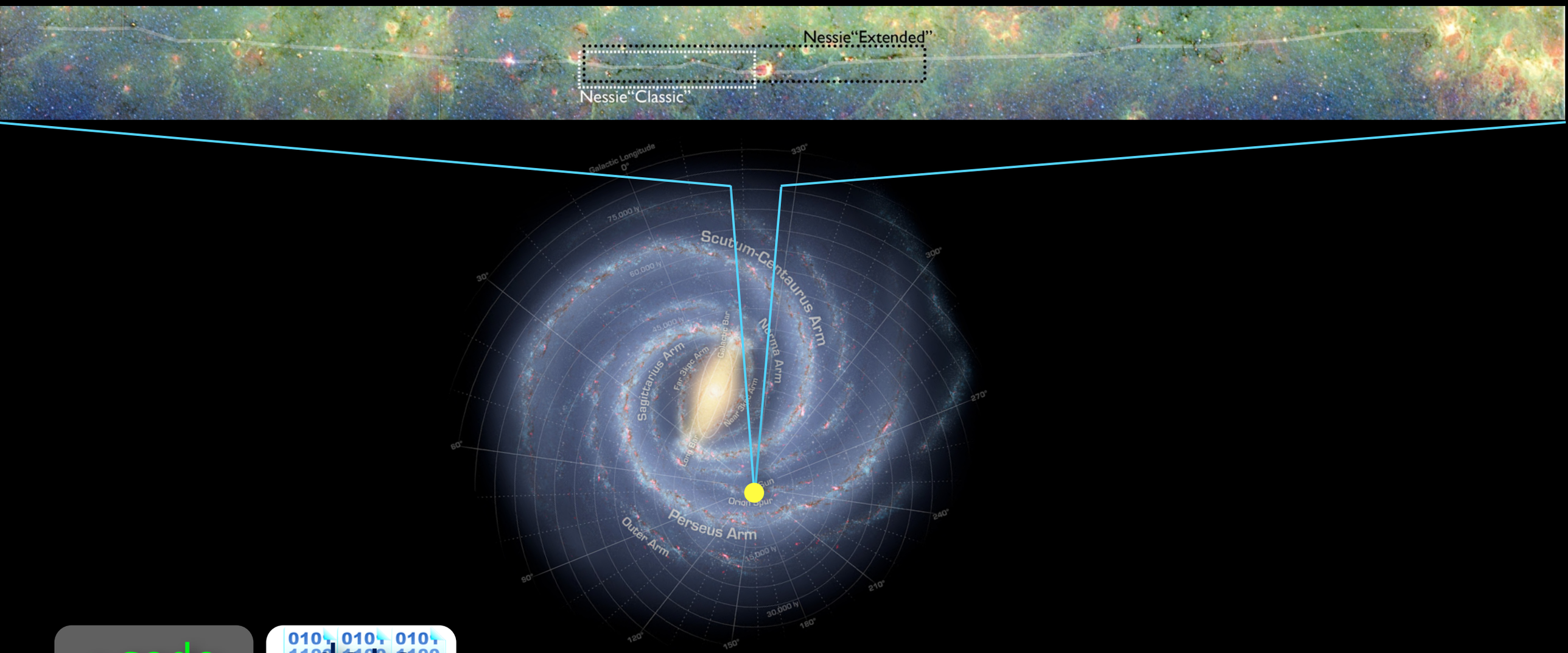
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Nessie "Classic"
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300°
270°
240°
210°
180°
150°
120°
90°
60°
30°
75,000 ly
60,000 ly
45,000 ly
30,000 ly
15,000 ly
Scutum-Centaurus Arm
Norma Arm
Sagittarius Arm
Far 3kpc Arm
Near 3kpc Arm
Galactic Bar
Long Bar
Sun
Orion Spur
Perseus Arm
Outer Arm

>code

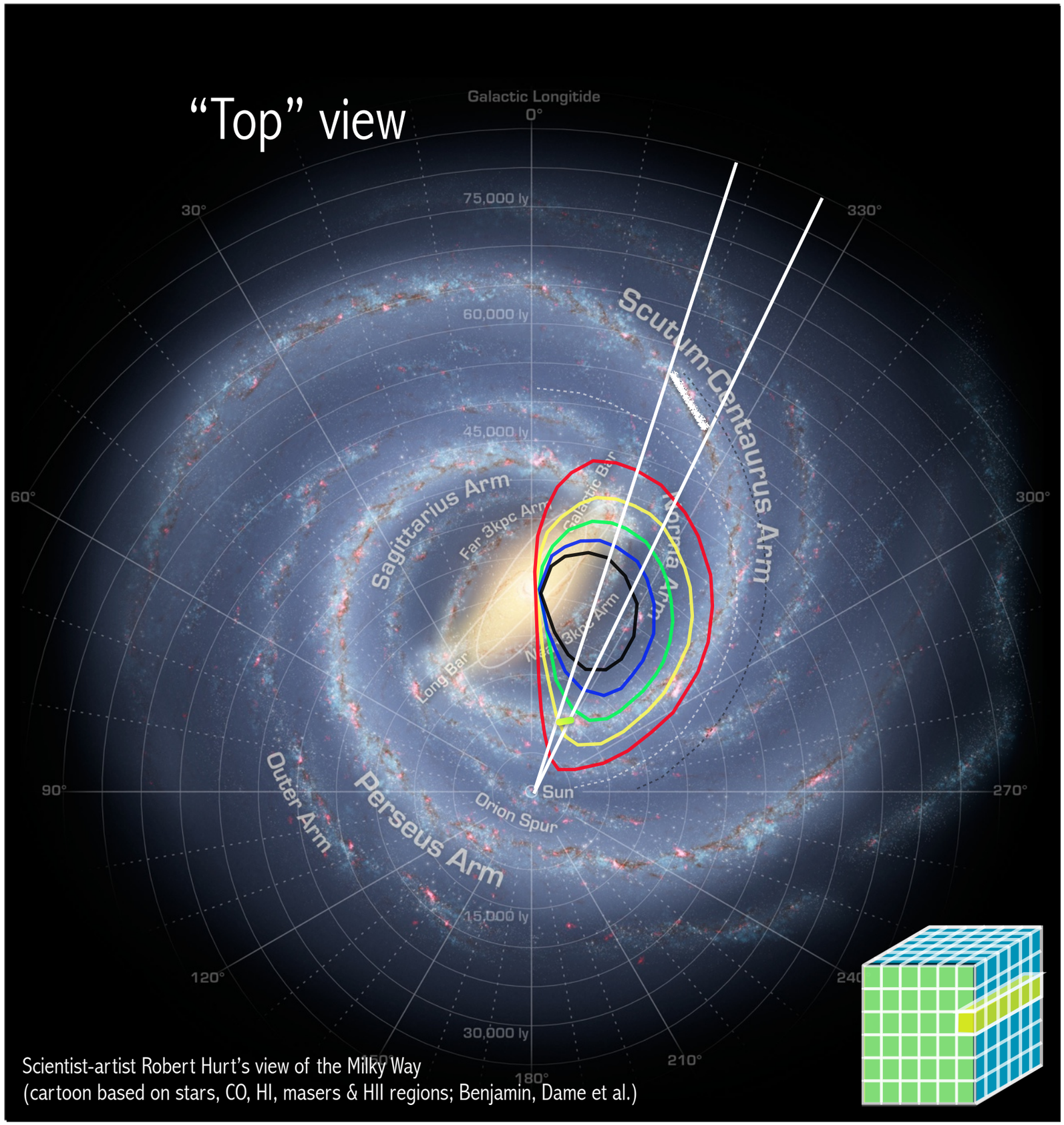
data

The Milky Way

The Milky Way
(Artist's Conception)

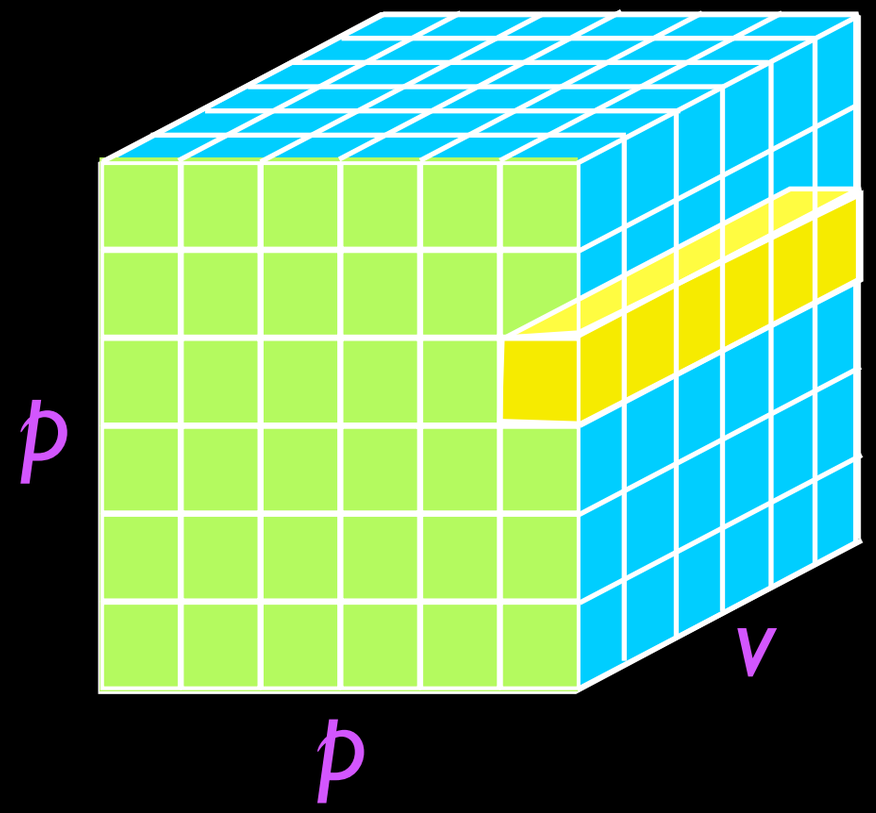
>code

Using Velocity Constraints



Scientist-artist Robert Hurt's view of the Milky Way
(cartoon based on stars, CO, HI, masers & HII regions; Benjamin, Dame et al.)

-20
-40
-60
-80
-100



GENERALLY

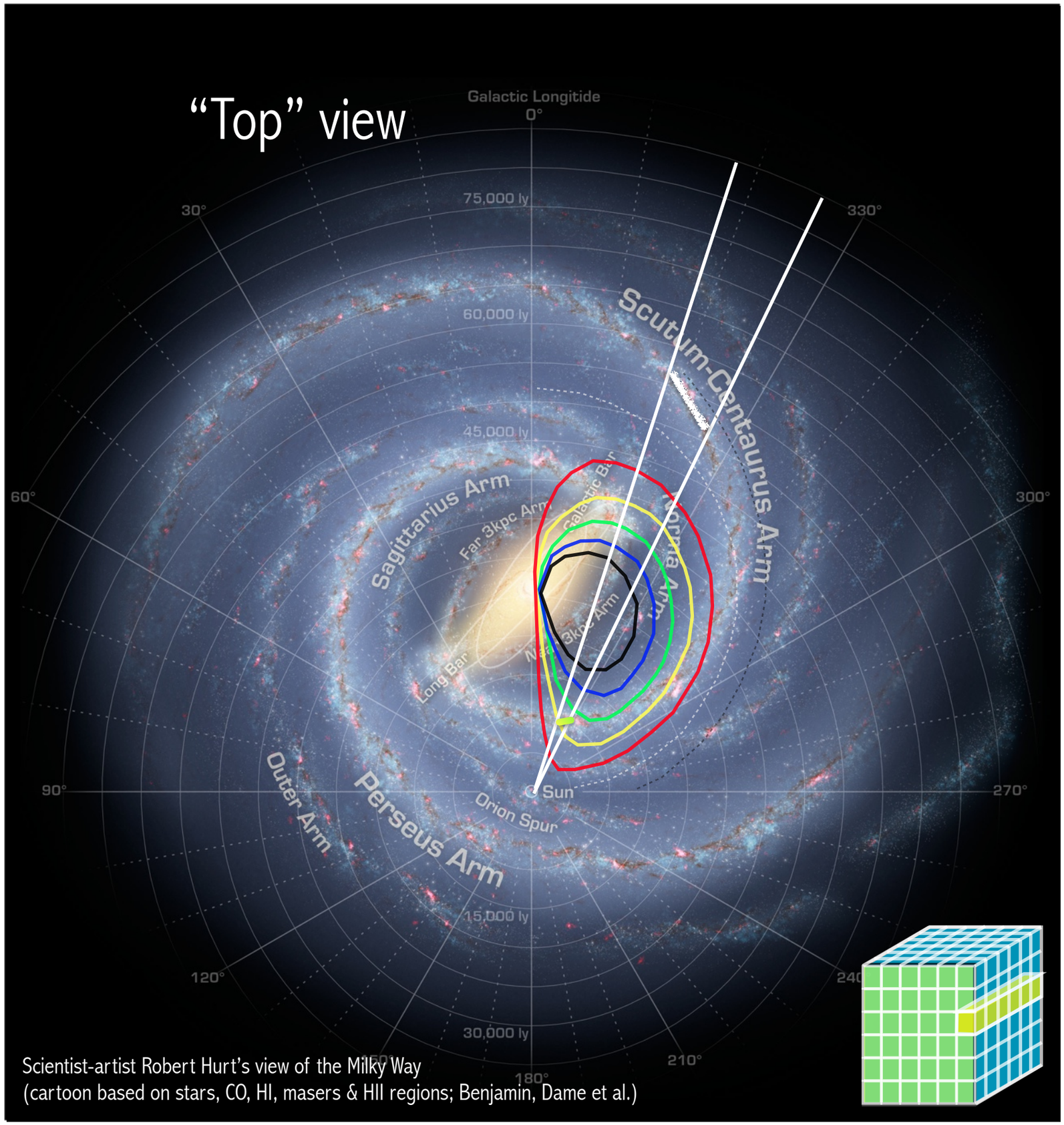
1D: Columns = "Spectra", "SEDs" or "Time Series"

2D: Faces or Slices = "Images"

3D: Volumes (e.g. *p-p-v*) = "3D Renderings", "2D Movies"

4D: Time Series of Volumes = "3D Movies"

Using Velocity Constraints

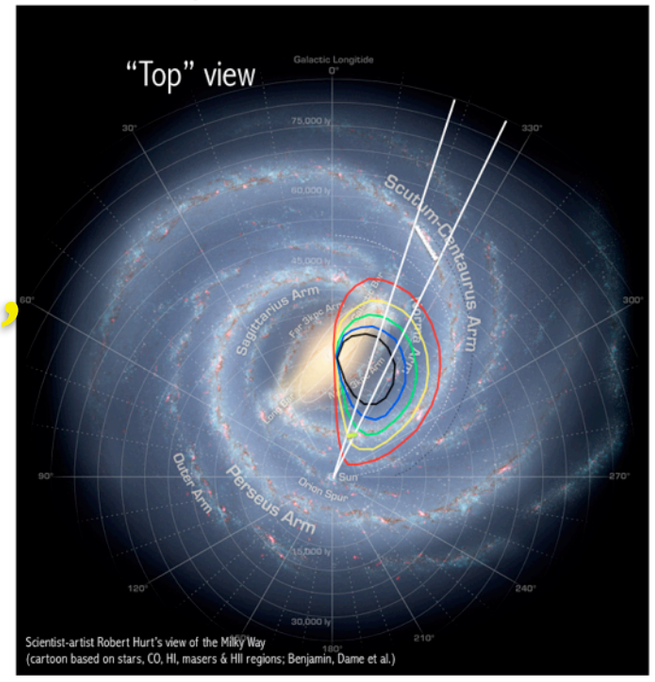


Scientist-artist Robert Hurt's view of the Milky Way
(cartoon based on stars, CO, HI, masers & HII regions; Benjamin, Dame et al.)

-20
-40
-60
-80
-100

Using Velocity Constraints

"x"



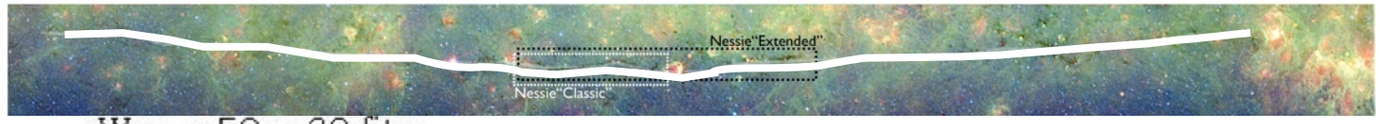
"z"

-20
-40
-60
-80
-100

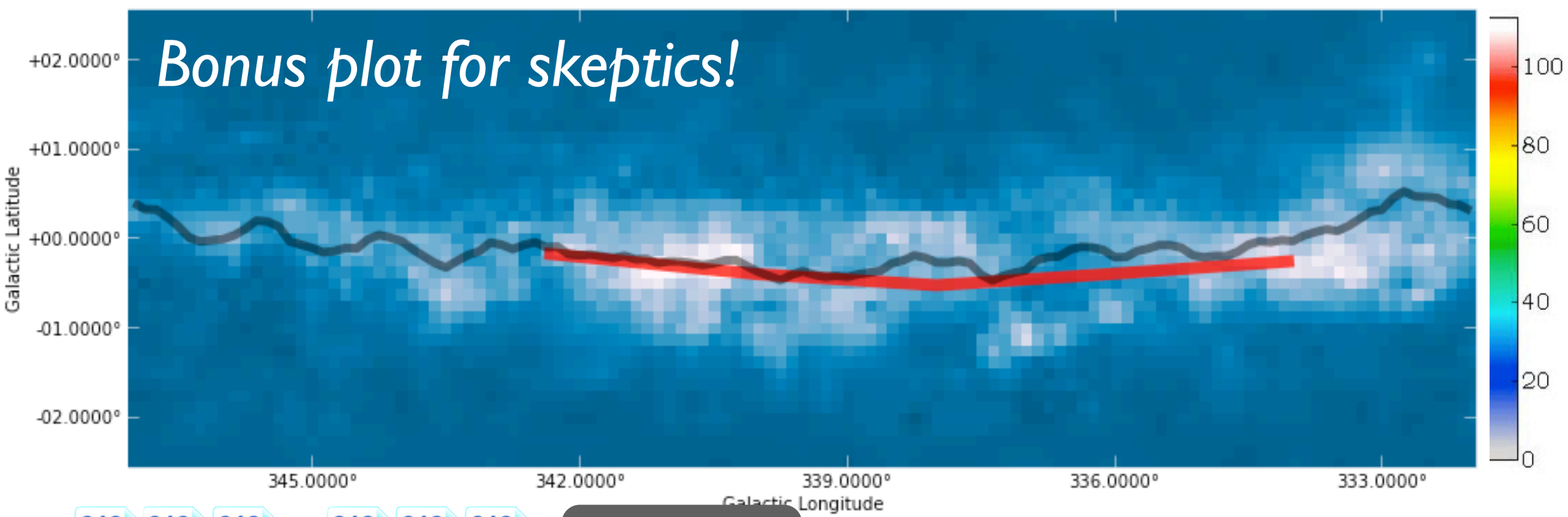
x

y

1 degree ~ 60 pc at 3.5 kpc



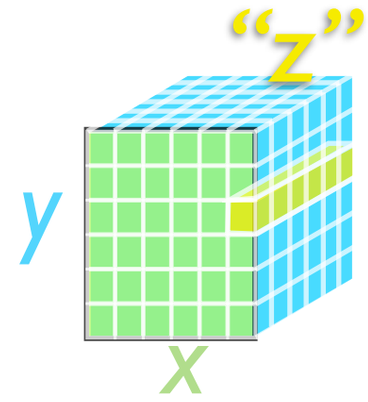
Wco m50 m30.fits



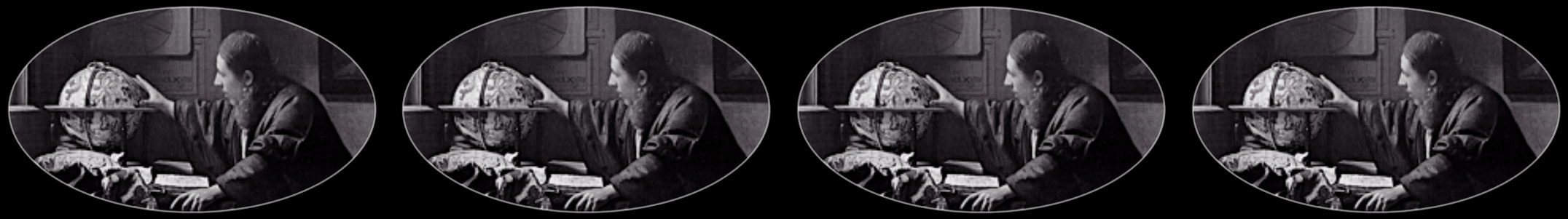
data

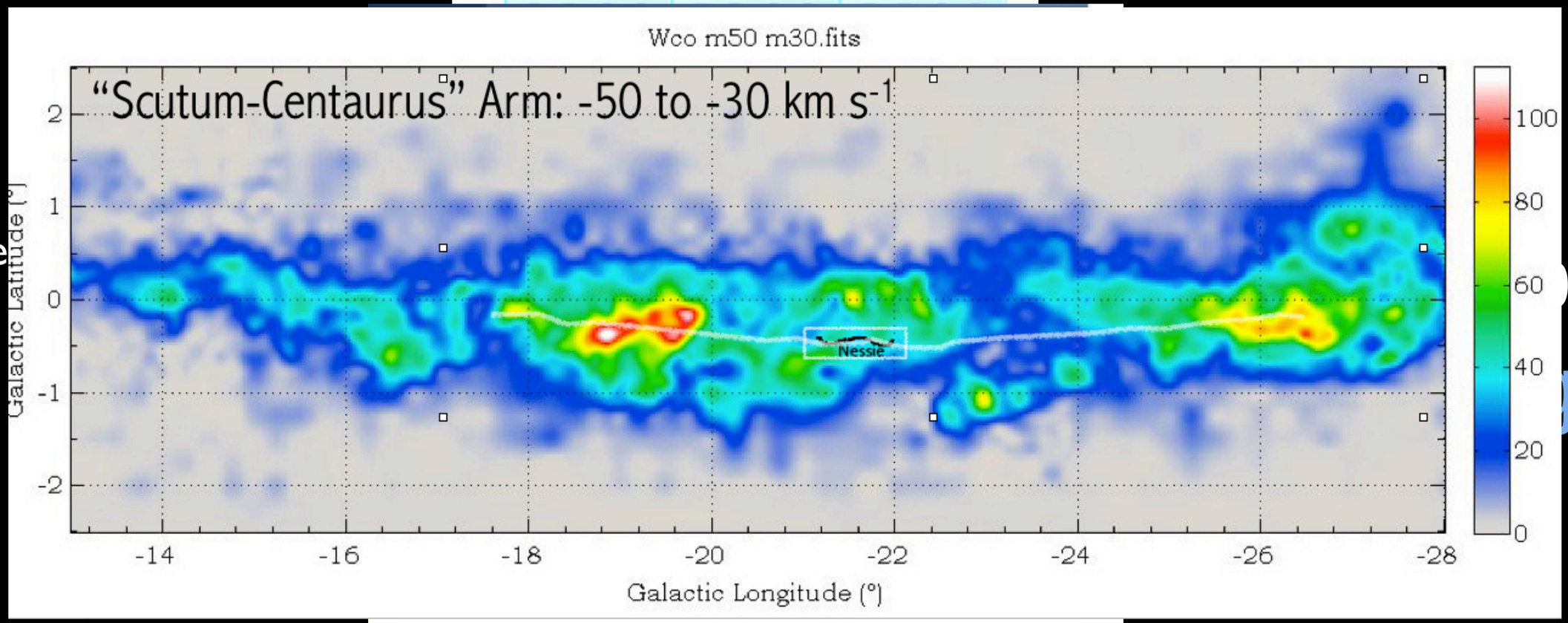
data

>code



Seamless Astronomy





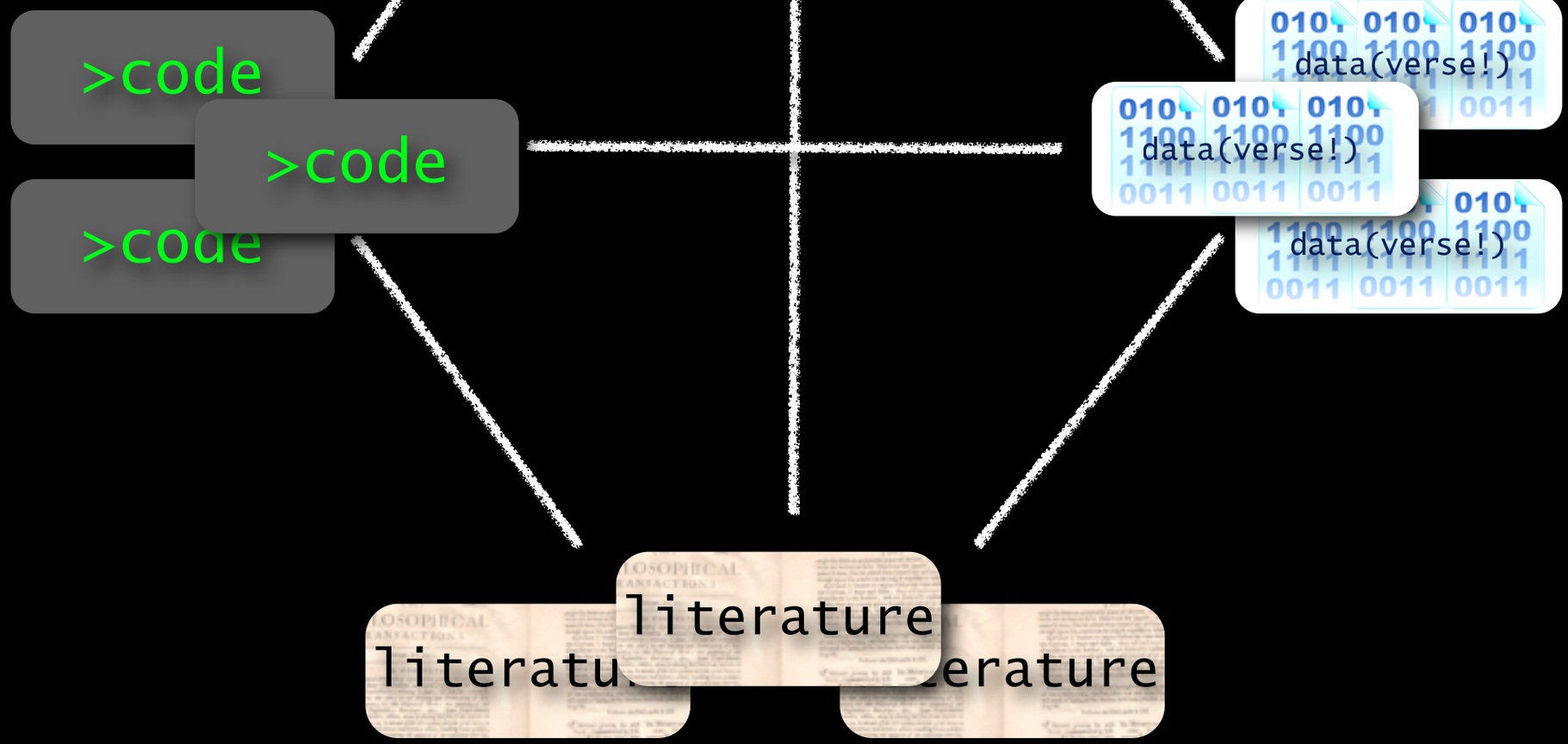
Seamless Astronomy

>code

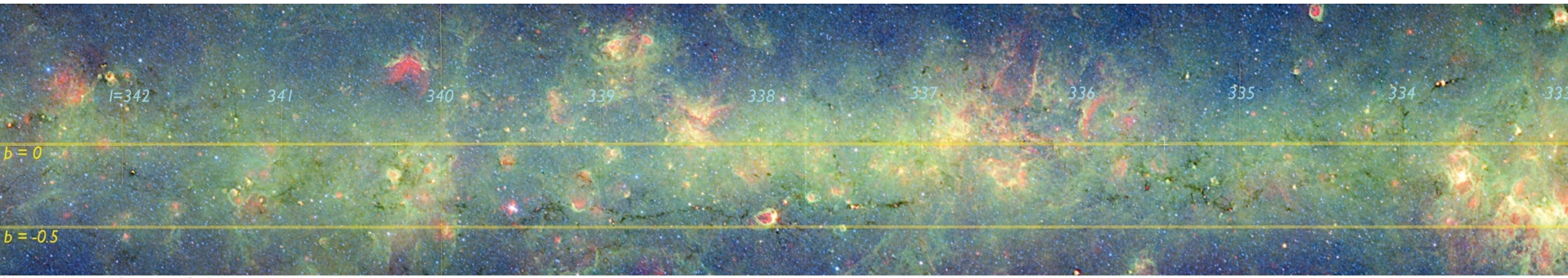
data(verse!)

literature

Seamless Astronomy



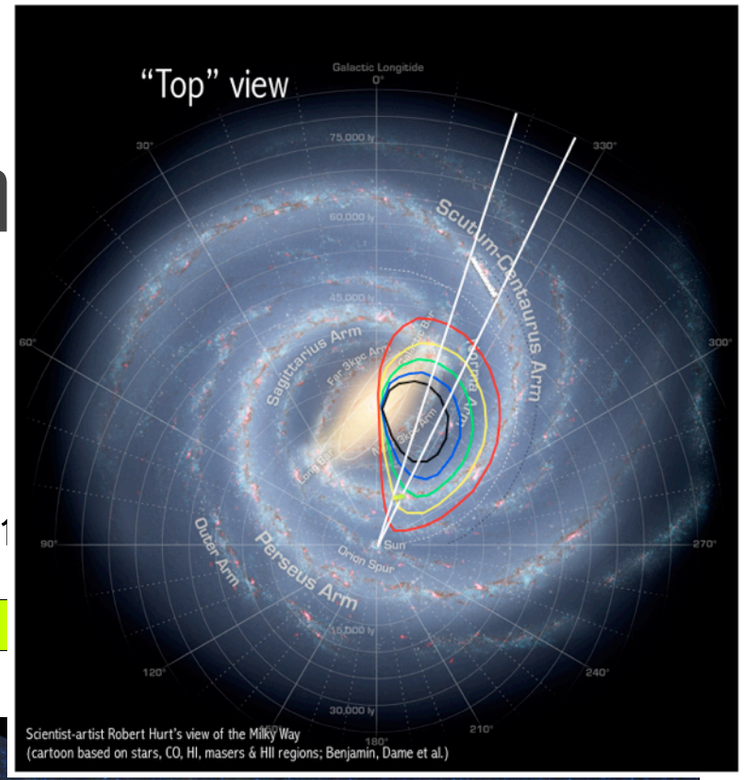
Why b<0?!
Galactic Geometry: 1959 and Now



The equatorial plane of the new co-ordinate system must of necessity pass through the sun. It is a fortunate circumstance that, within the observational uncertainty, both the sun and Sagittarius A lie in the mean plane of the Galaxy as determined from the hydrogen observations. If the sun had not been so placed, points in the mean plane would not lie on the galactic equator.

[Blaauw et al. 1959]

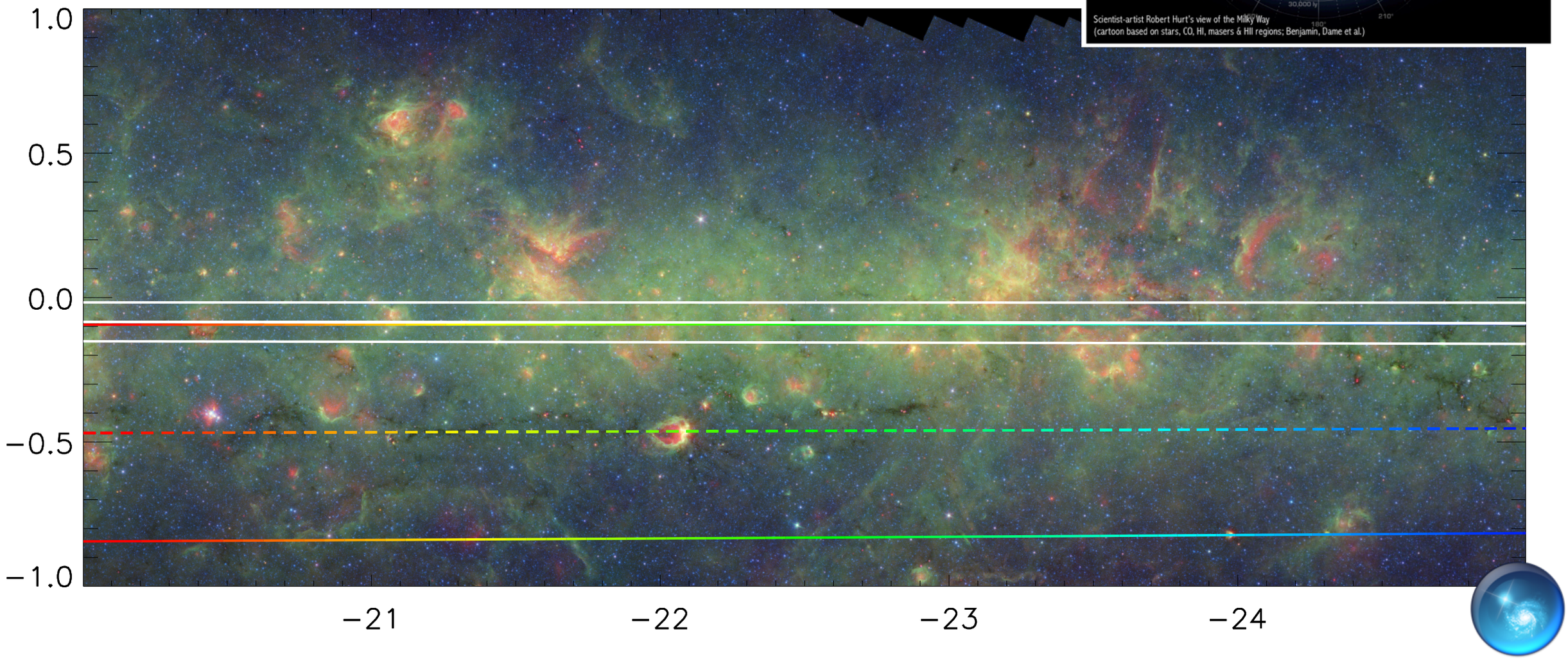
Predicted Near & Far Scutum-Centaurus Arm

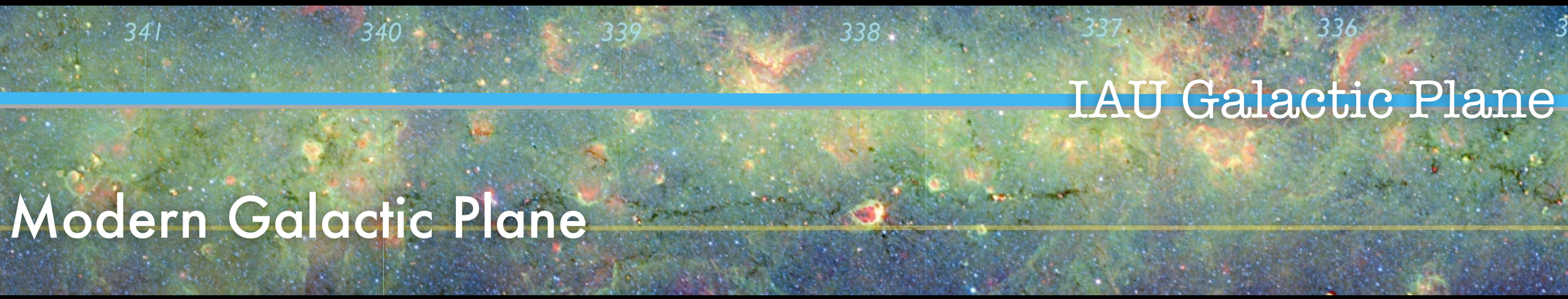


-20
-40
-60
-80
-100

V_{rad} (km/s) [Z_0=25.0 pc, R_0=8.4 kpc, V_0=239 km/s, $(U,V,W)_{sun}$=(11

−33.0 −31.7 −30.3 −29.0 −27.7

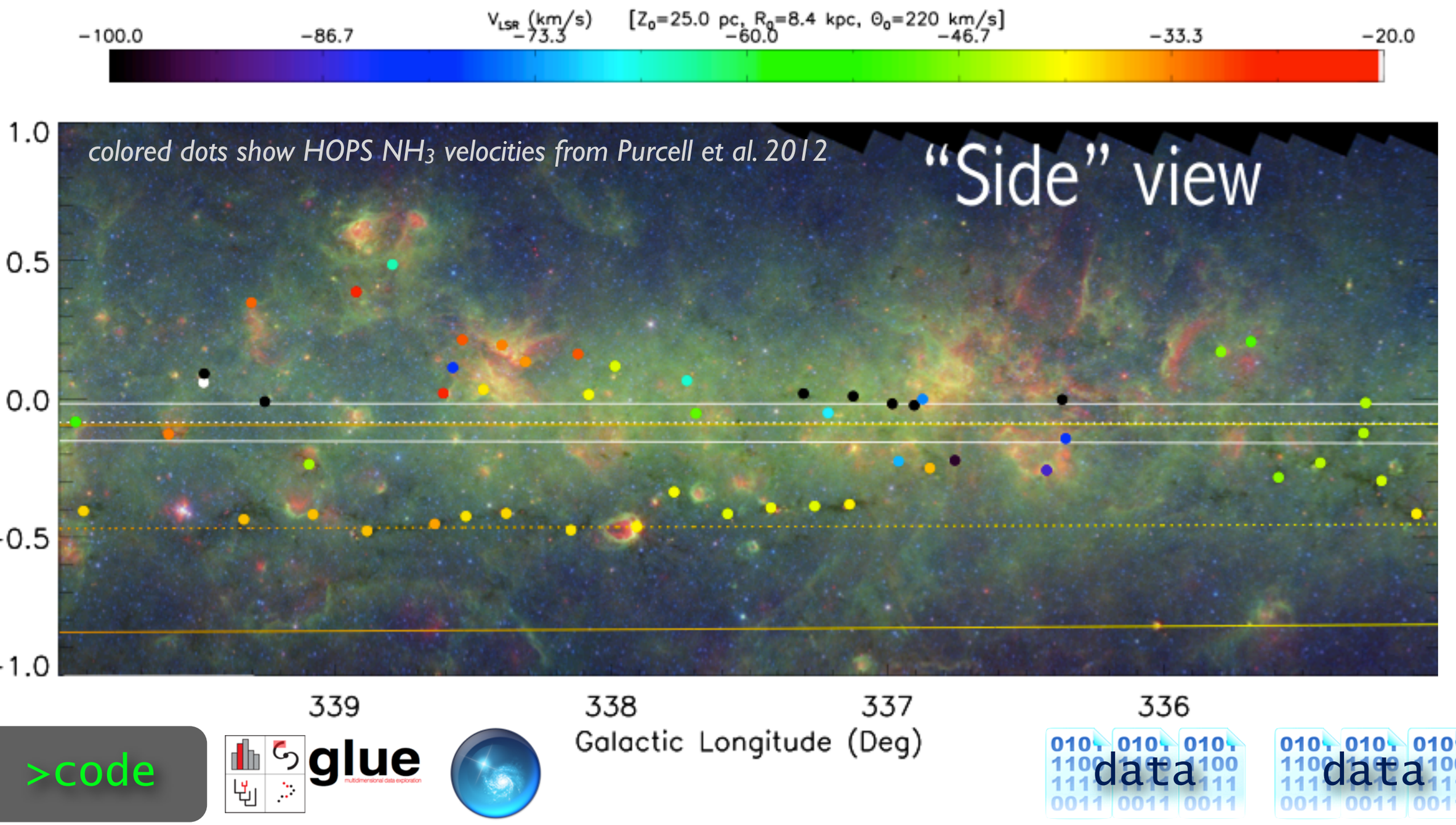




Yes, Nessie is EXACTLY in the Galactic Plane!

What about its distance?

Predicted Velocities match NH_3 Cores in Nessie Perfectly



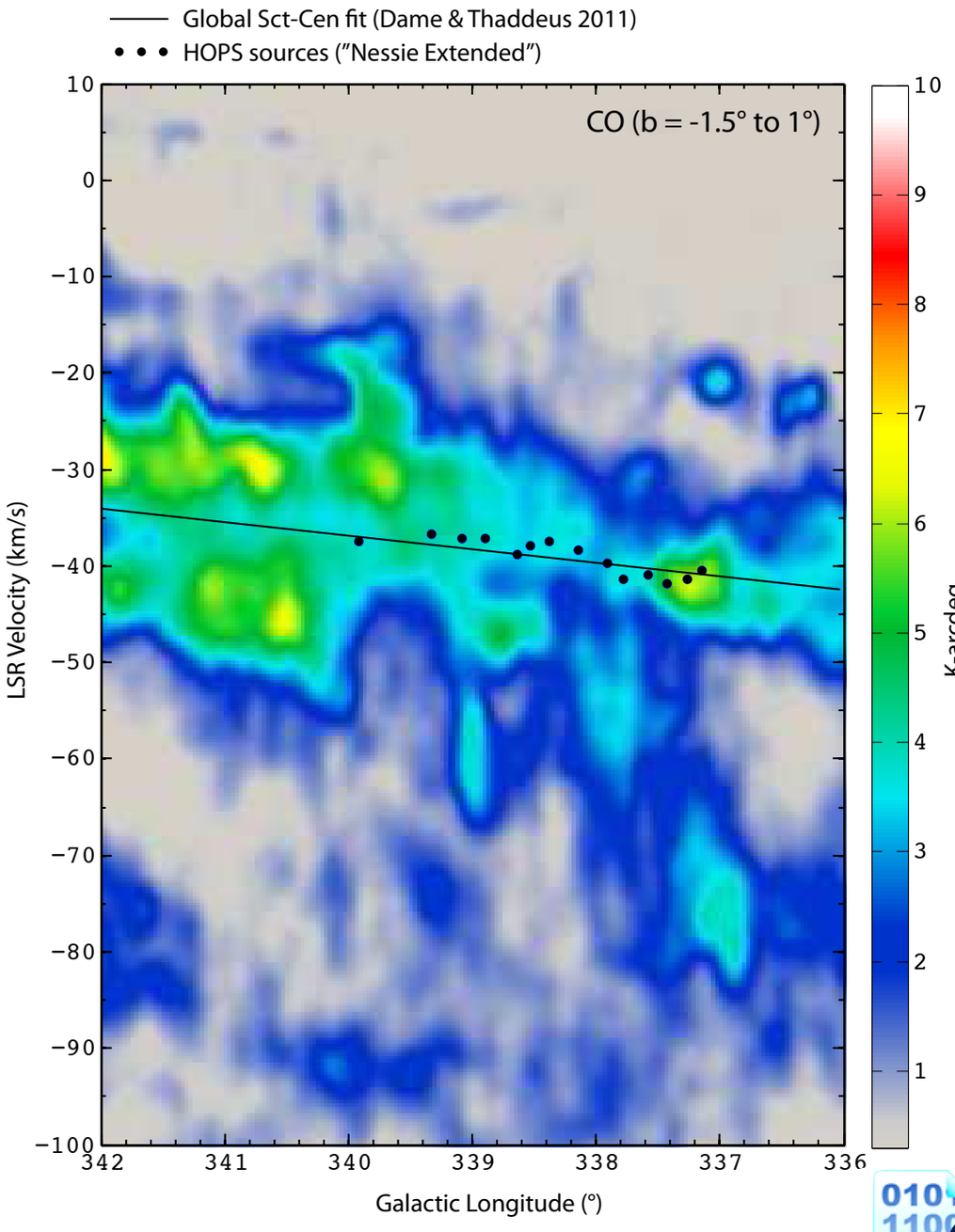
>code

glue
multidimensional data exploration

data

data

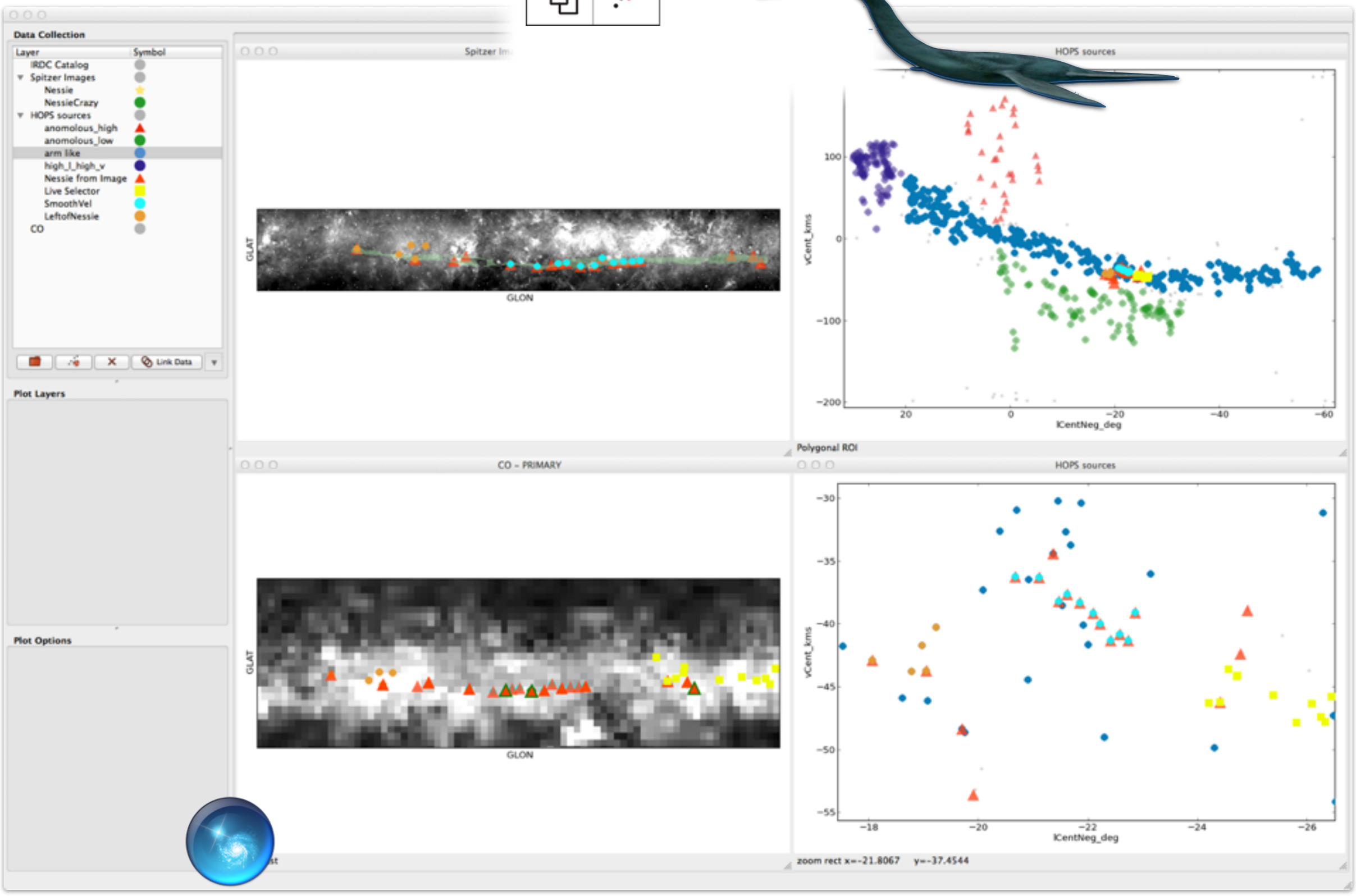
Predicted Velocities match NH_3 Cores in Nessie Perfectly



black dots show HOPS NH_3 velocities from Purcell et al. 2012; color is CO; line is log-spiral fit to full Scut-Cen Arm

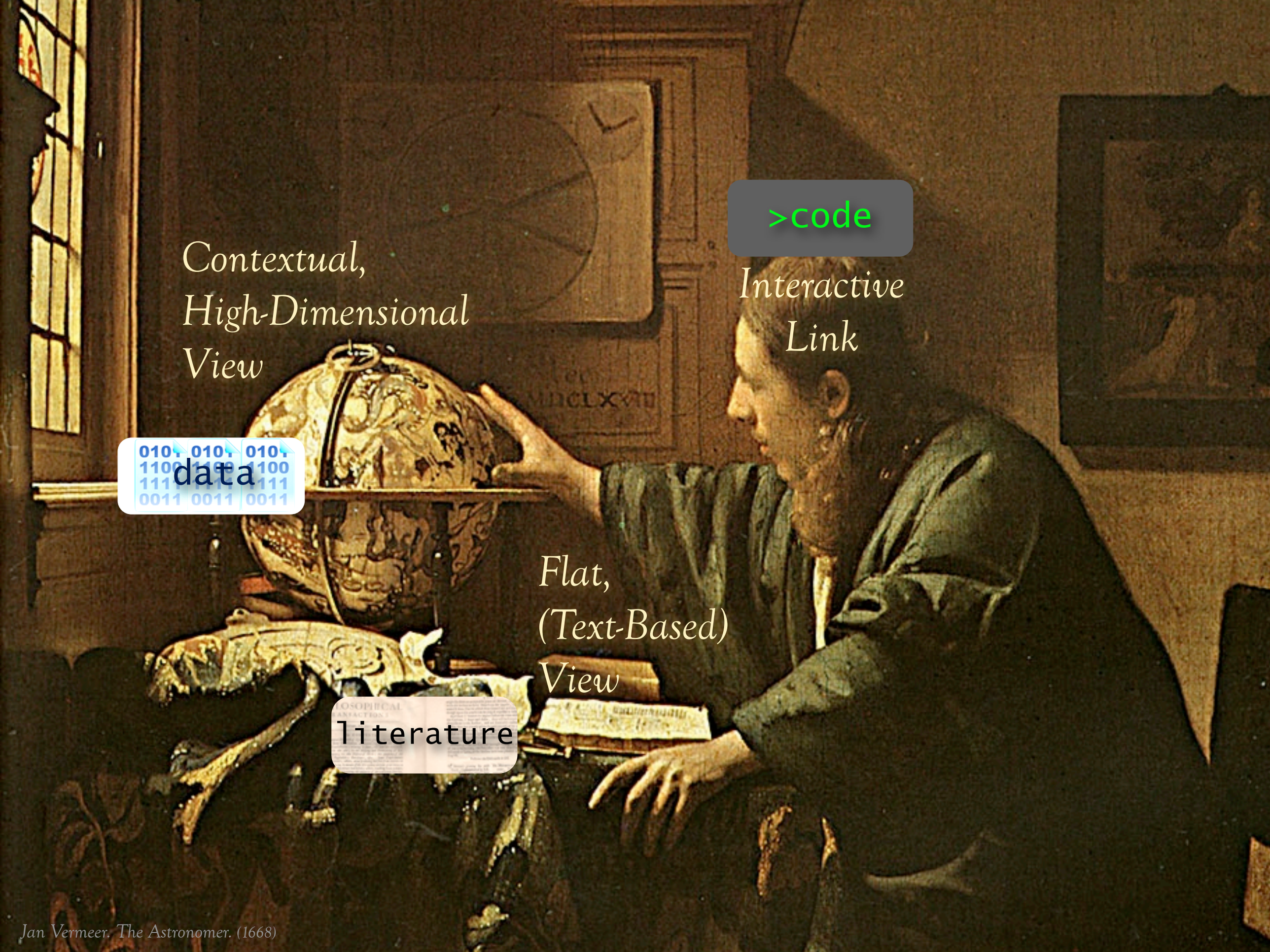
glue

multidimensional data exploration



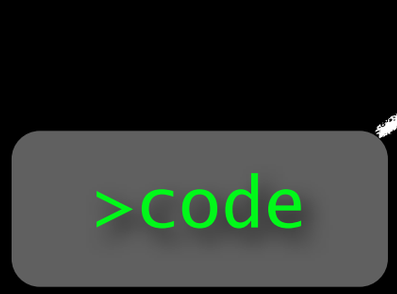
http://www.glueviz.org/en/latest/

Glue collaboration: ***Beaumont****, Borkin, Goodman, Pfister, Robitaille*



Jan Vermeer. The Astronomer. (1668)

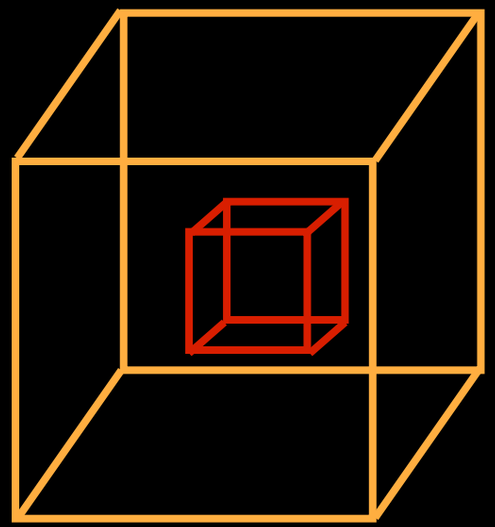
Seamless Astronomy: Data Visualization



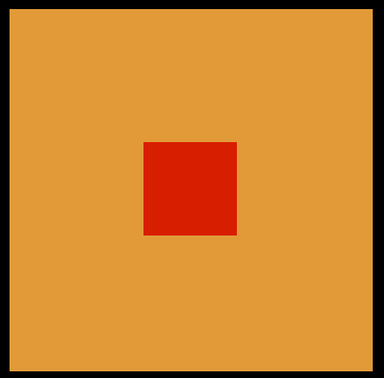
Glue collaboration (see *glueviz.org*): Chris **Beaumont**, lead & Alyssa **Goodman** (Harvard-CfA);
Michelle **Borkin** & Hanspeter **Pfister** (Harvard-SEAS/CS) and Thomas **Robitaille** (MPIA Heidelberg)

"Linked Views" = glue

multidimensional data exploration

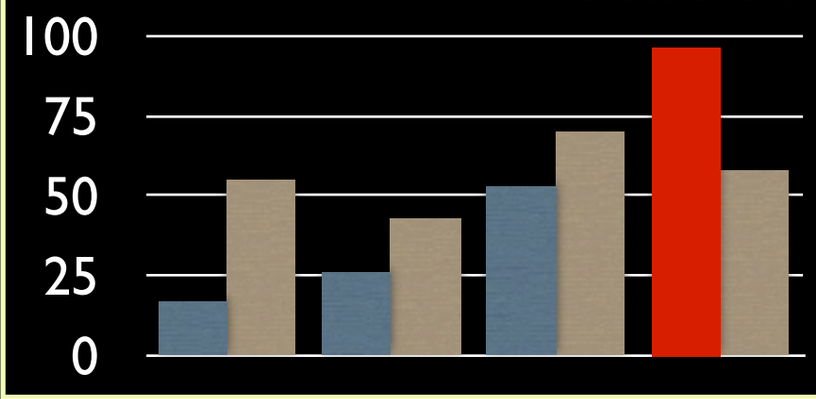


3D

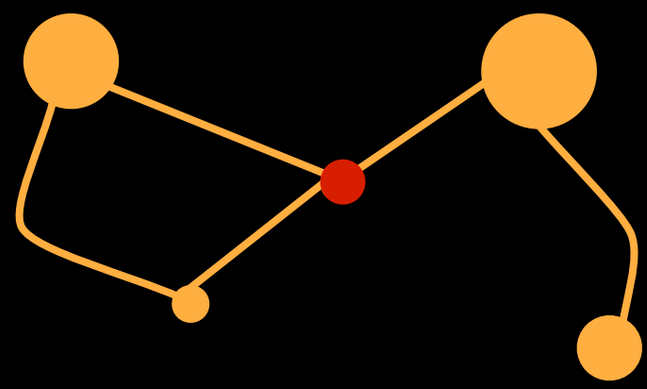


2D

Statistics



Data Abstraction



Glue

and the future of data exploration in astronomy

Chris Beaumont

Data are growing... up

big data

http://www.flickr.com/photos/redbeardmathpirate/3240091245/sizes/o/in/photostream/

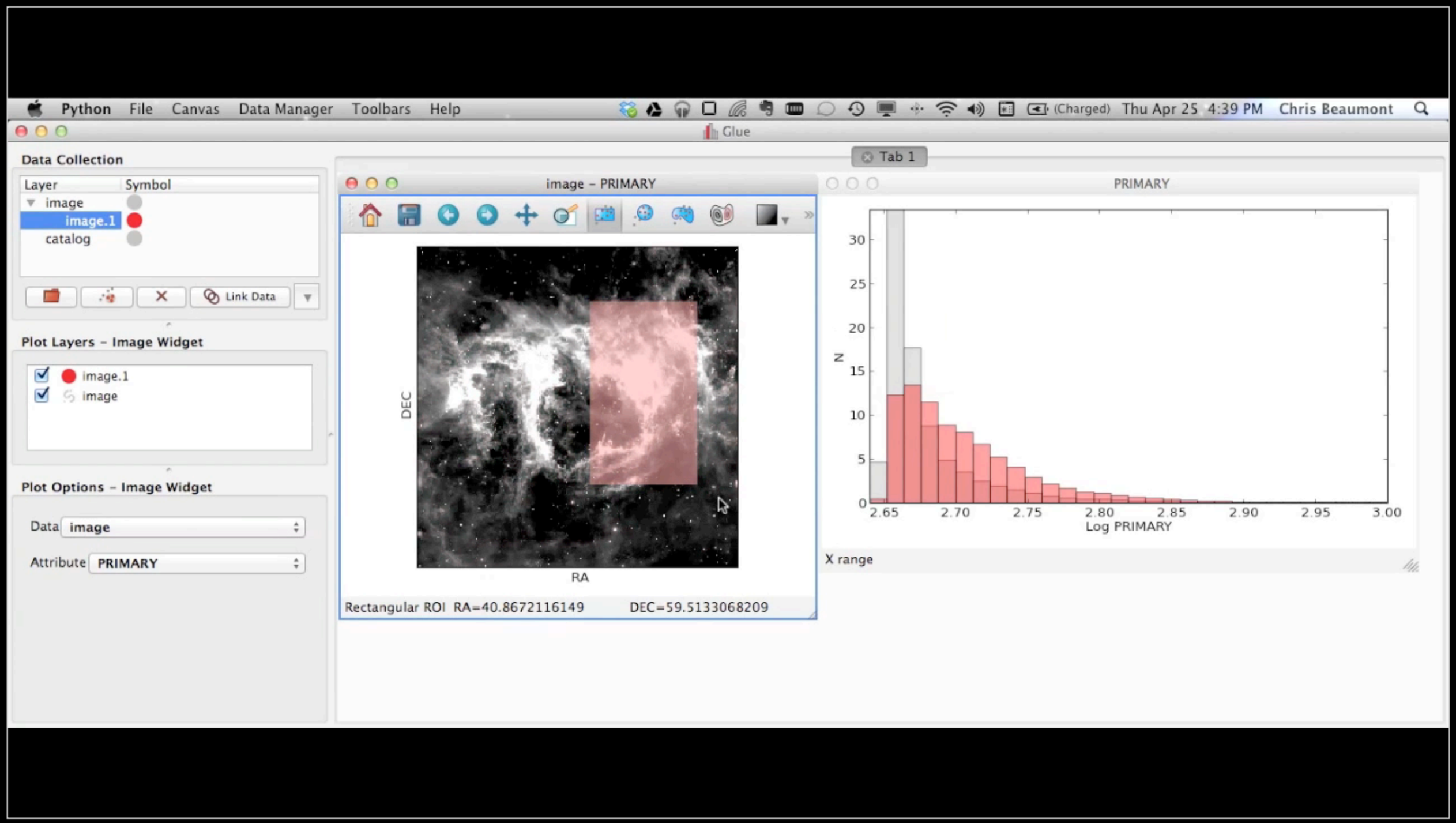
Data are growing... out

wide data

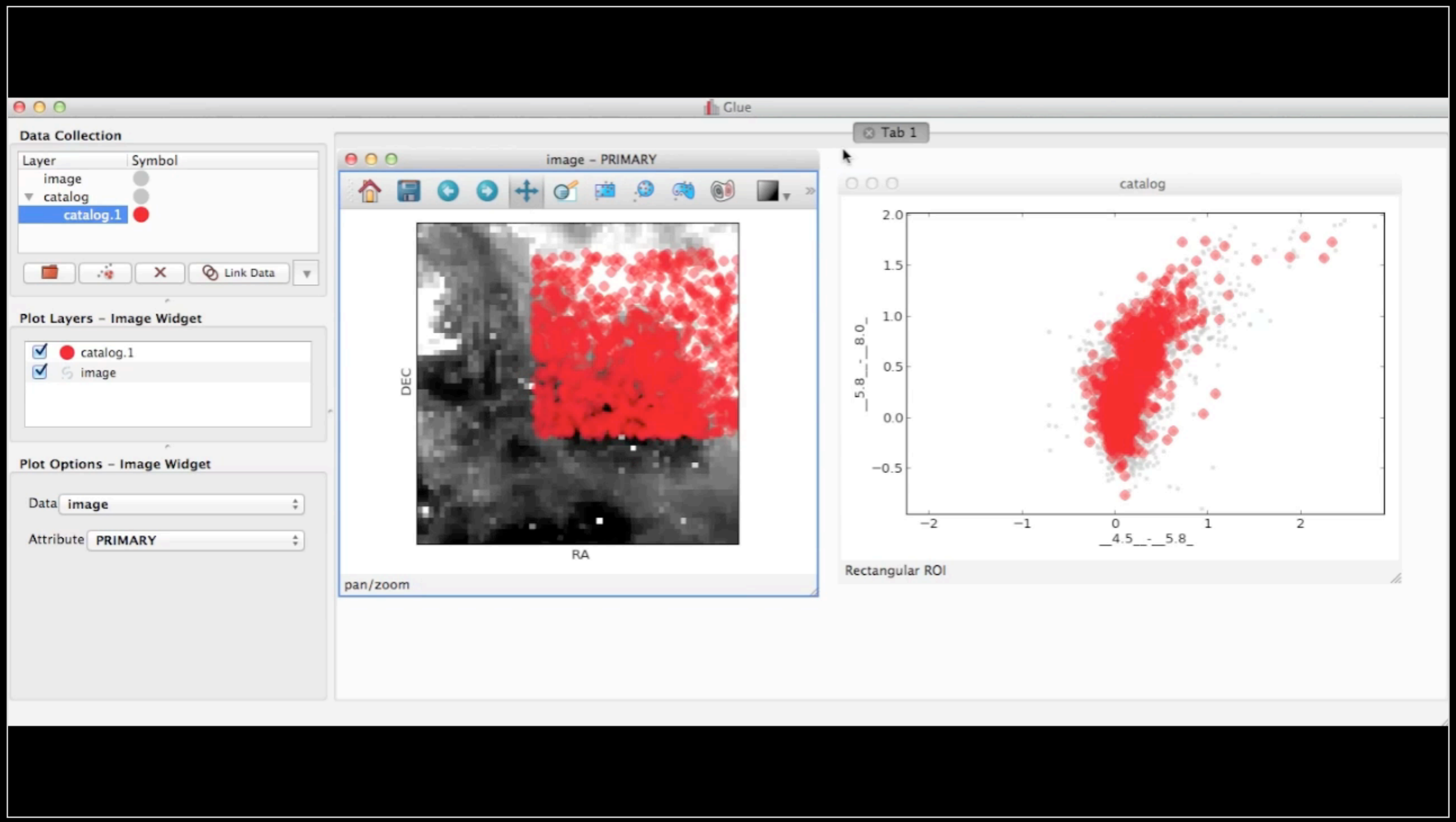
http://farm3.staticflickr.com/2600/3765042195_ae73e5831a_b.jpg

Tackling "wide data" with glue

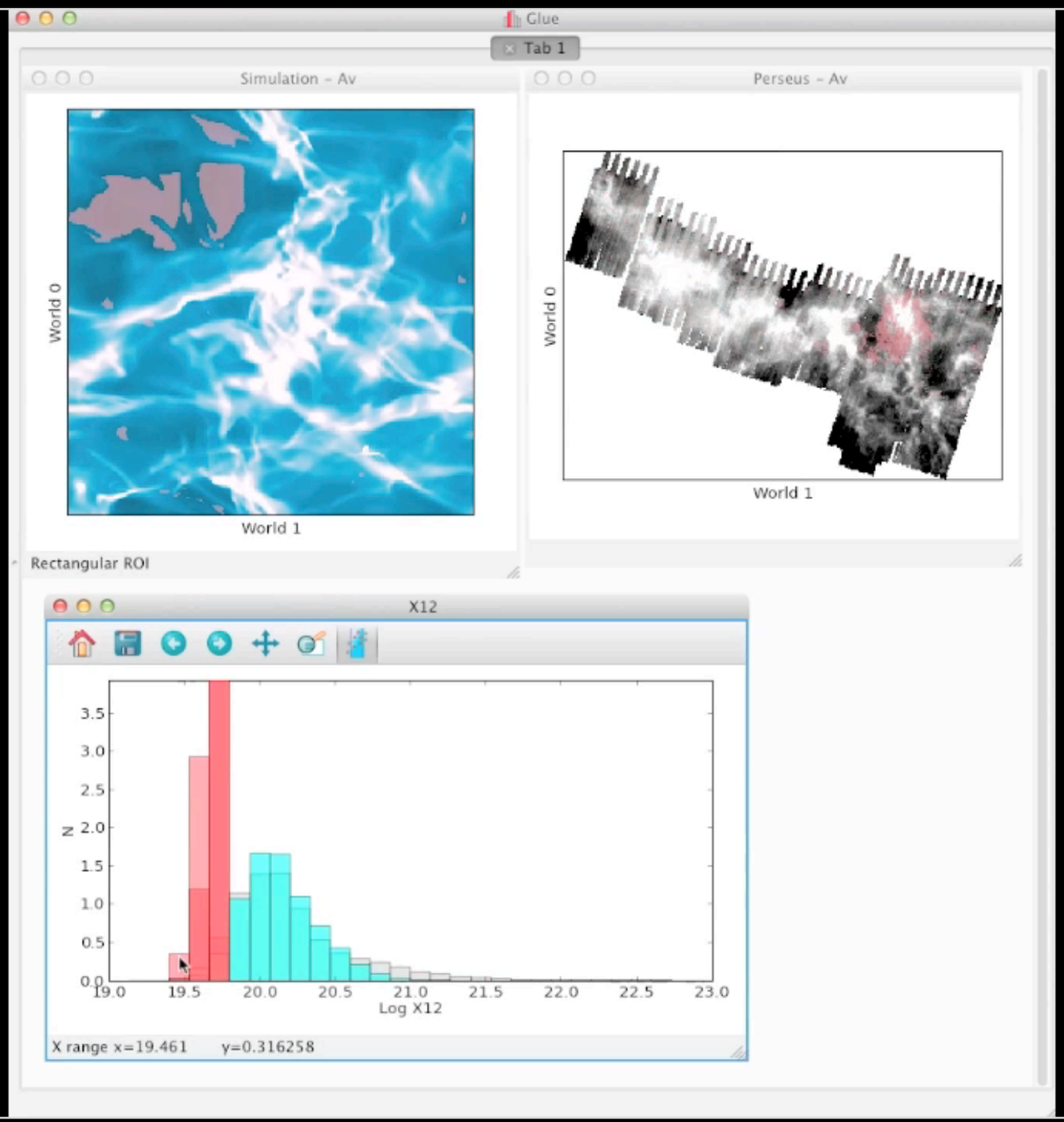
Tackling "wide data" with glue



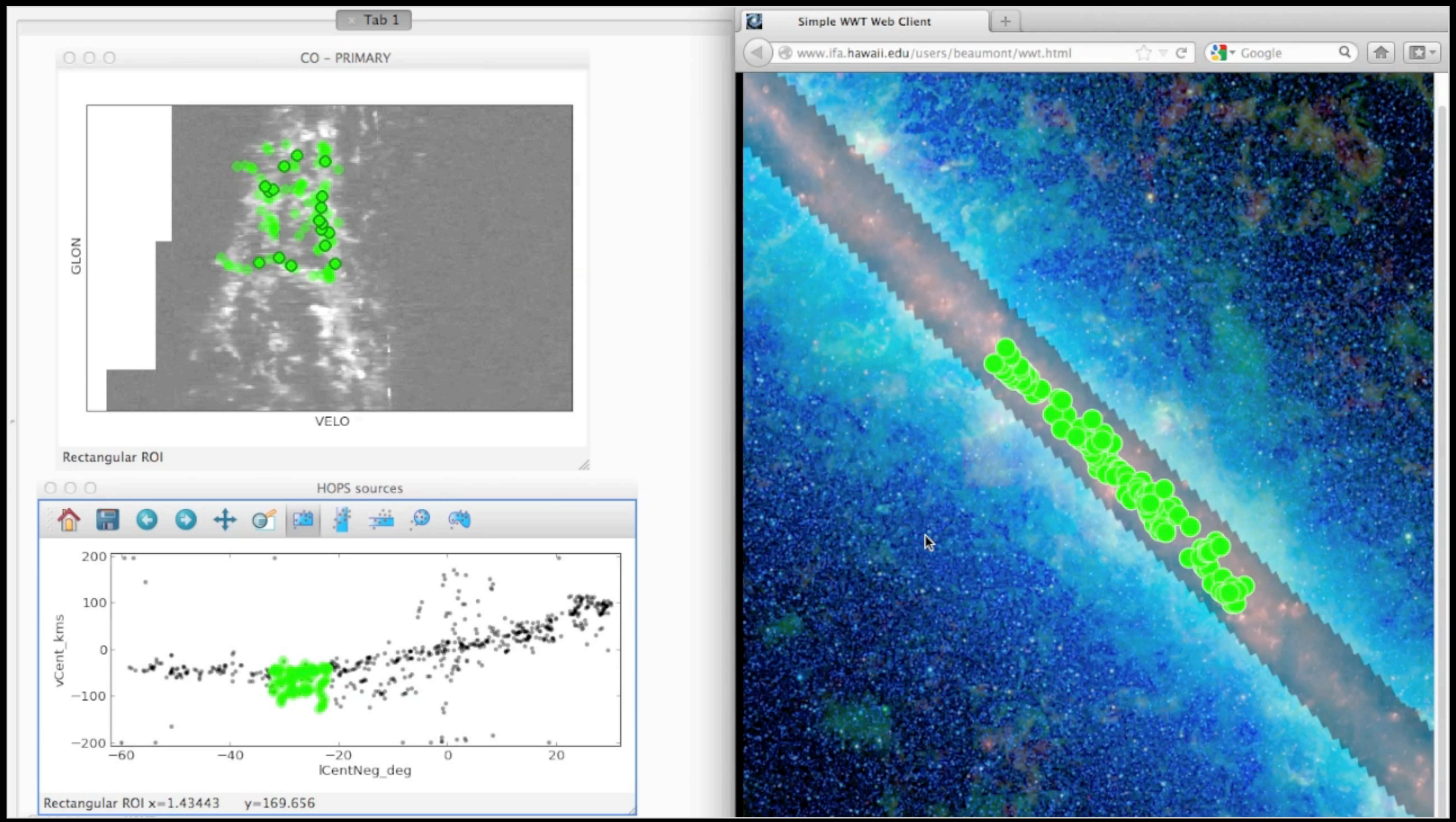
Tackling "wide data" with glue



Tackling "wide data" with glue



Tackling "wide data" with glue



Seamless Astronomy

>code

literature

Seamless Astronomy

```
>code
>code
>code
```

glueviz.org

Monster to Bone

	Monster	Bone
Mass (in "Suns")	~800,000 for dark part	2 million for "dark" part, 40 million for "all"
Role	Massive Star Forming Region	Bone of the Galaxy
Significance	Very, very, long filamnent	Way longer filament, telltale sign of Galactic Structure

There could be ~1000 more of these to find...a full skeleton perhaps?

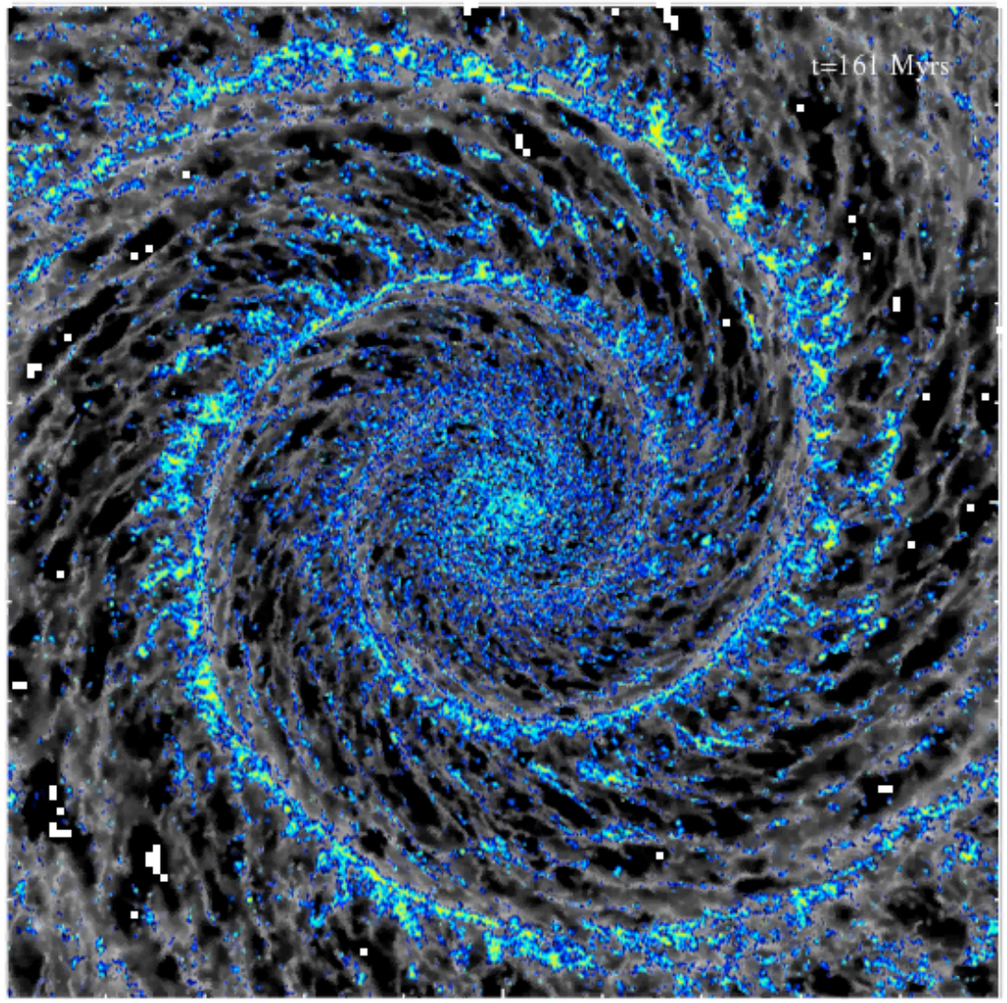
milkywaybones.org

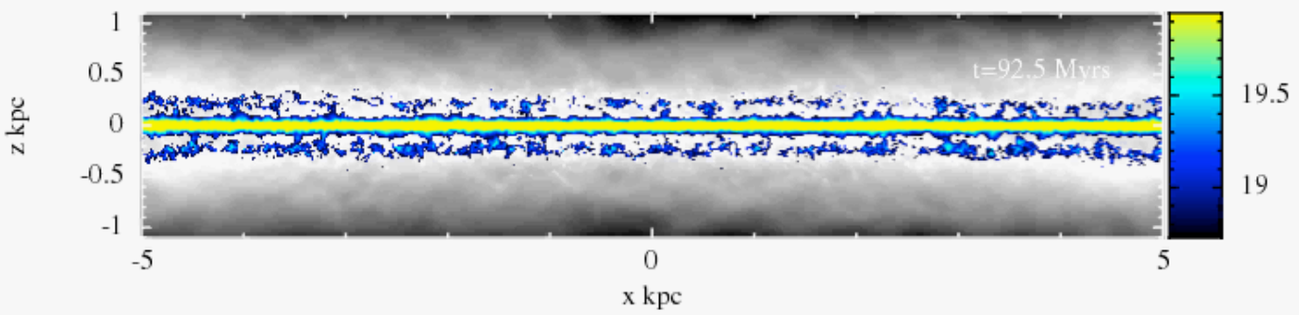
Nessie is a Bone of the Milky Way

(flipped) image of IC342 from Jarrett et al. 2012; WISE Enhanced Resolution Galaxy Atlas

What does that mean?

(flipped) image of IC342 from Jarrett et al. 2012; WISE Enhanced Resolution Galaxy Atlas





simulations courtesy Clare Dobbs

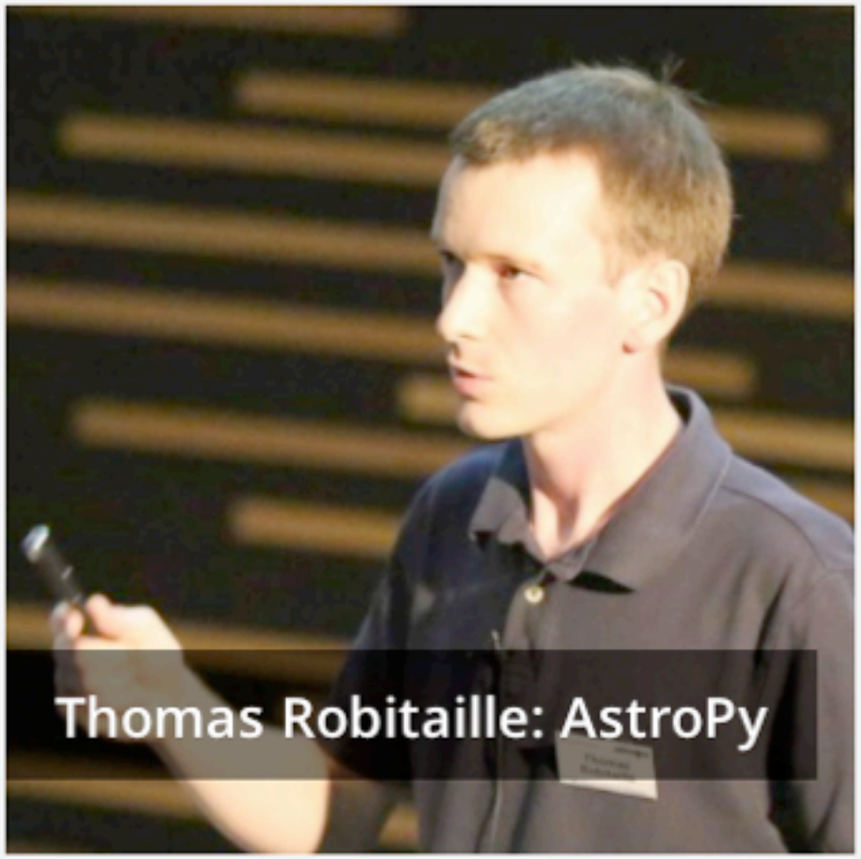
Figuring out why the Loch Ness Monster is Resting in the Milky Way, Online


The Astronomer, Vermeer


"Nessie", Spitzer Space Telescope

Alyssa A. Goodman

Harvard-Smithsonian Center for Astrophysics



Unproceedings of .Astronomy 4

We're very pleased to present the Unproceedings of the Fourth .Astronomy Conference (.Astronomy 4), which was held in Heidelberg, ...

Hack Day In New York

.Astronomy is all about sharing ideas and making astronomy happen. Sometimes this means producing code that can fit data really quickly ...

Come to Cambridge For .Astronomy 5

.Astronomy 5 will be hosted by Harvard's Seamless Astronomy group at Microsoft's NERD Center in Cambridge, MA, USA. Mark ...

Publishing with FigShare

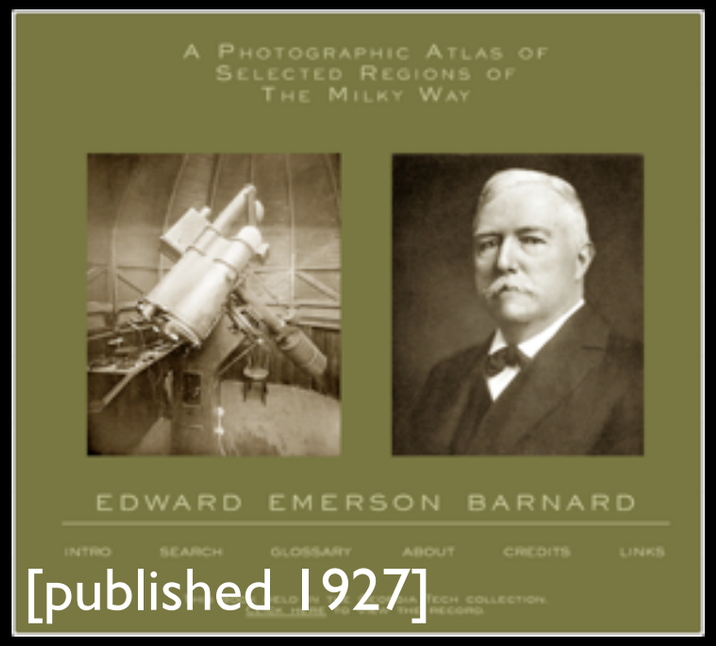
Posted: September 6th, 2012 | **Author:** Aleks Scholz | **Comments:** 0

"Publishing 2.0" was an unconference session at this year's dotastronomy conference, and FigShare was one of the new tools discussed in this session. In a nutshell, FigShare is a free online repository for scientific results from all

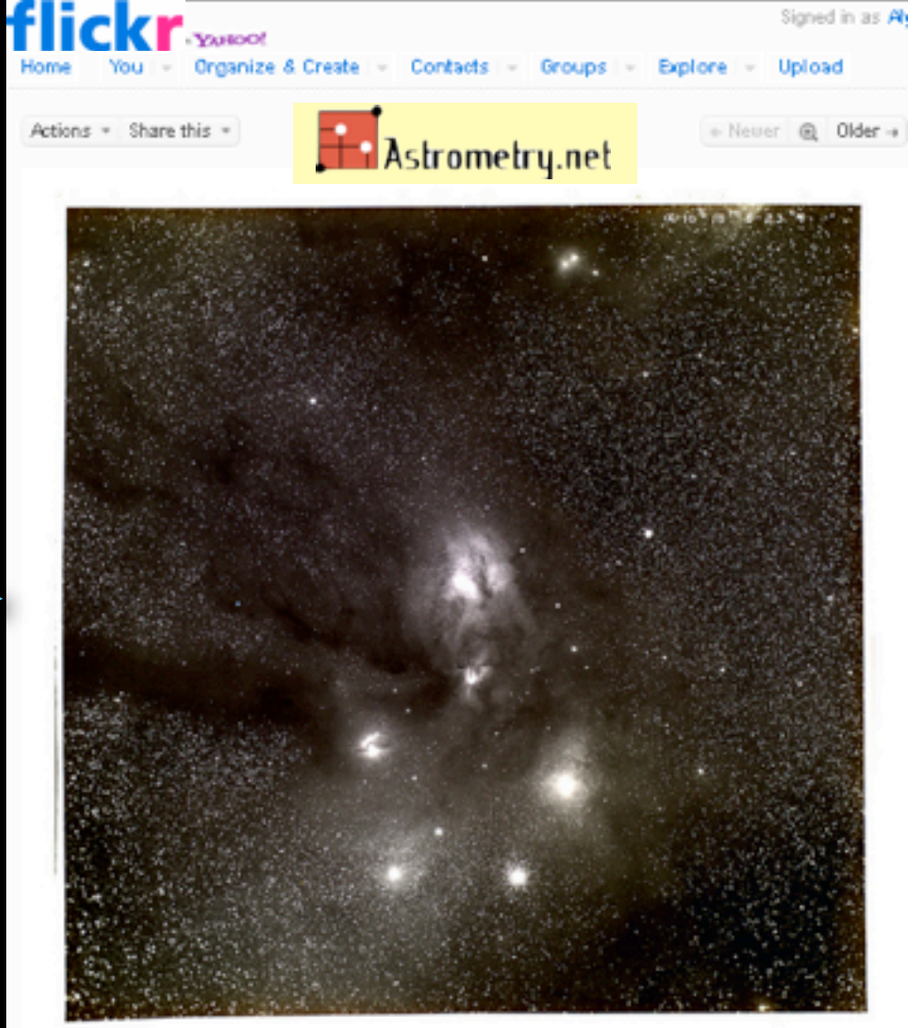
RECENT POSTS

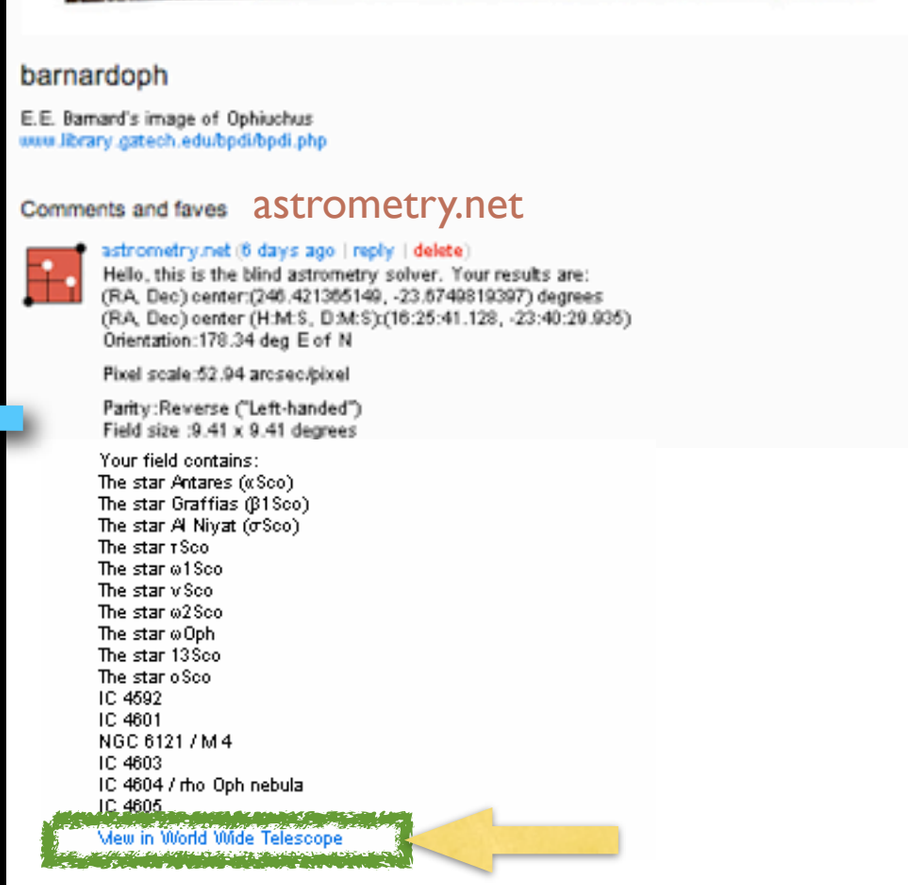
- Unproceedings of .Astronomy 4
- Hack Day In New York
- Come to Cambridge For .Astronomy 5

Reviving "Dead" Data



[published 1927]





barnardoph

E.E. Barnard's image of Ophiuchus
www.library.gatech.edu/bpdi/bpdi.php

Comments and faves astrometry.net

astrometry.net (6 days ago | reply | delete)
Hello, this is the blind astrometry solver. Your results are:
(RA, Dec) center:(246.421365149, -23.6749819397) degrees
(RA, Dec) center (H:M:S, D:M:S):(16:25:41.128, -23:40:29.935)
Orientation:178.34 deg E of N

Pixel scale:52.94 arcsec/pixel

Parity:Reverse ("Left-handed")
Field size :9.41 x 9.41 degrees

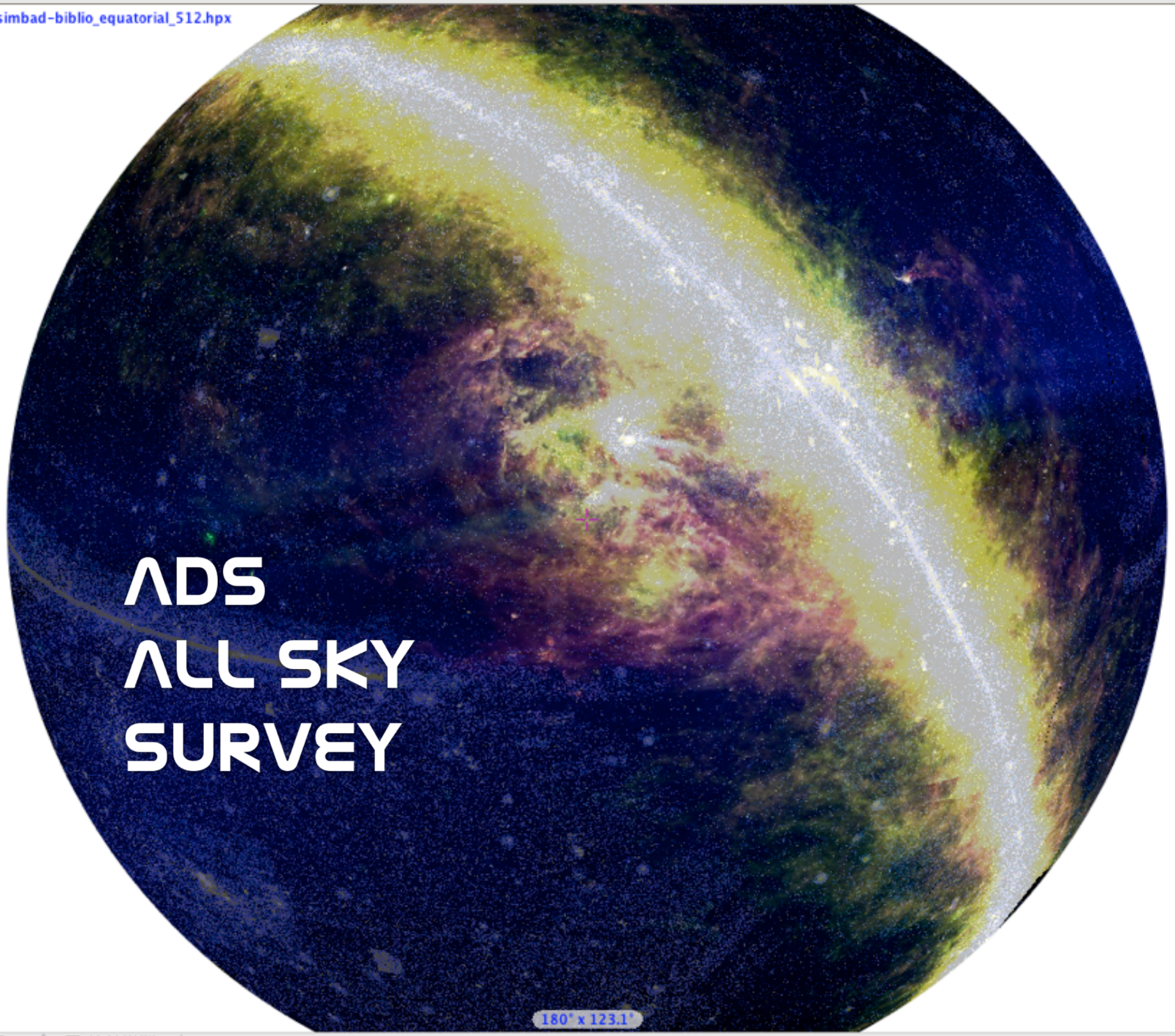
Your field contains:
The star Antares (αSco)
The star Graffias (β1Sco)
The star Al Niyat (σSco)
The star τSco
The star ω1Sco
The star νSco
The star ω2Sco
The star ωOph
The star 13Sco
The star οSco
IC 4592
IC 4601
NGC 6121 / M 4
IC 4603
IC 4604 / rho Oph nebula
IC 4605

View in World Wide Telescope

Location Clear Frame ICRS

Allsky opt Allsky IR DSS Simbad NED PPMX 2MASS

simbad-biblio_equatorial_512.hpx



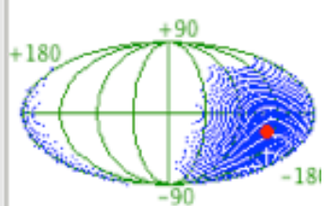
180° x 123.1°

select pan zoom dist phot draw tag filter cross rgb assoc crop cont mgiss pixel prop del

IRAS-IRIS color
DSS colored
simbad-biblio_

om 1/16x

Frame: ICRS



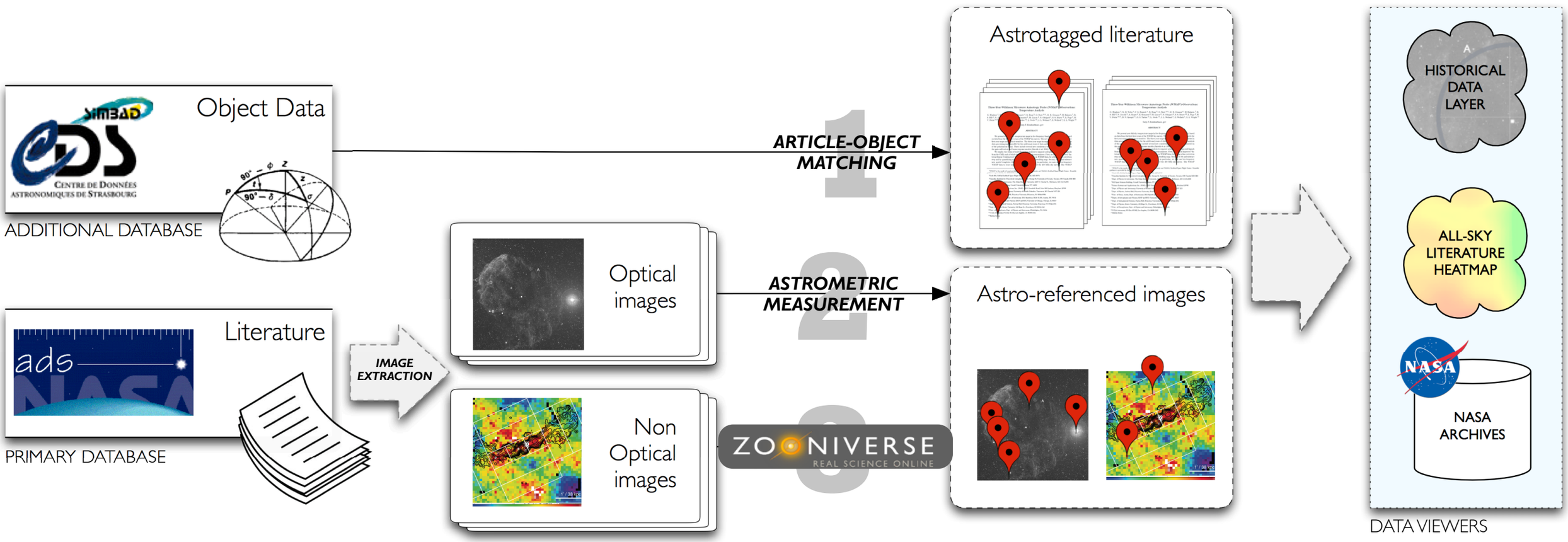
16:08:09.03 -17:03:35.7
180° x 123.1°

grid north multiview match

Search

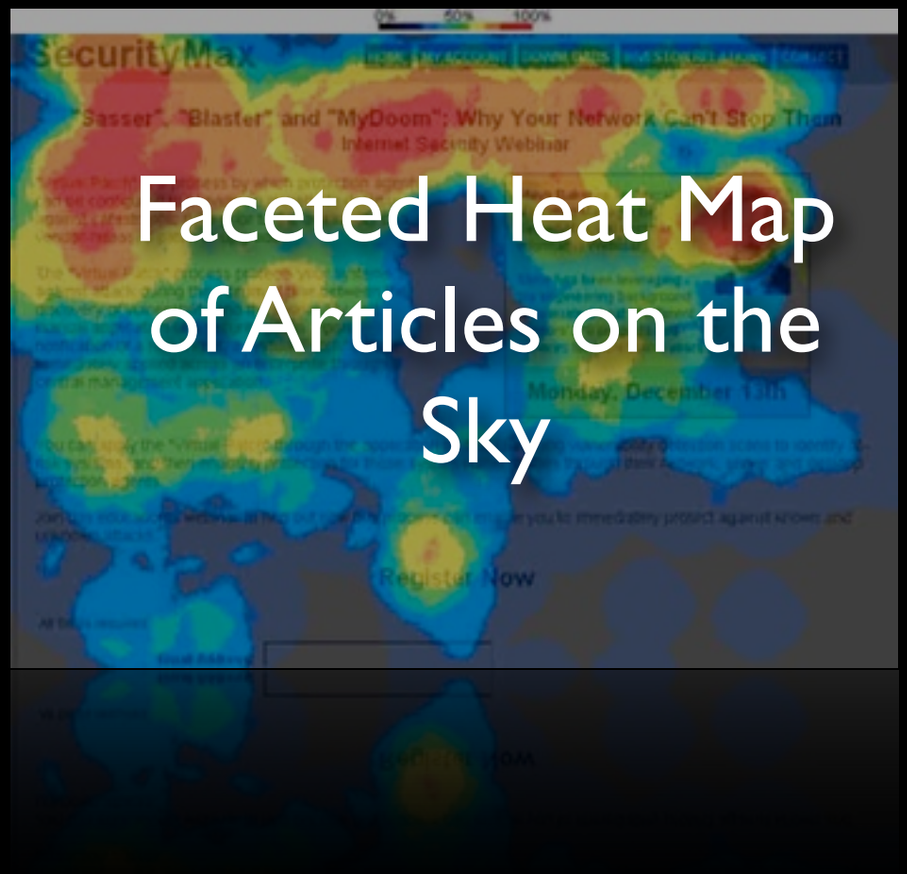
0 sel / 0 src 189Mb

Seamless Astronomy: ADS All Sky Survey



slide courtesy of Alberto Pepe

Seamless Astronomy: ADS All Sky Survey



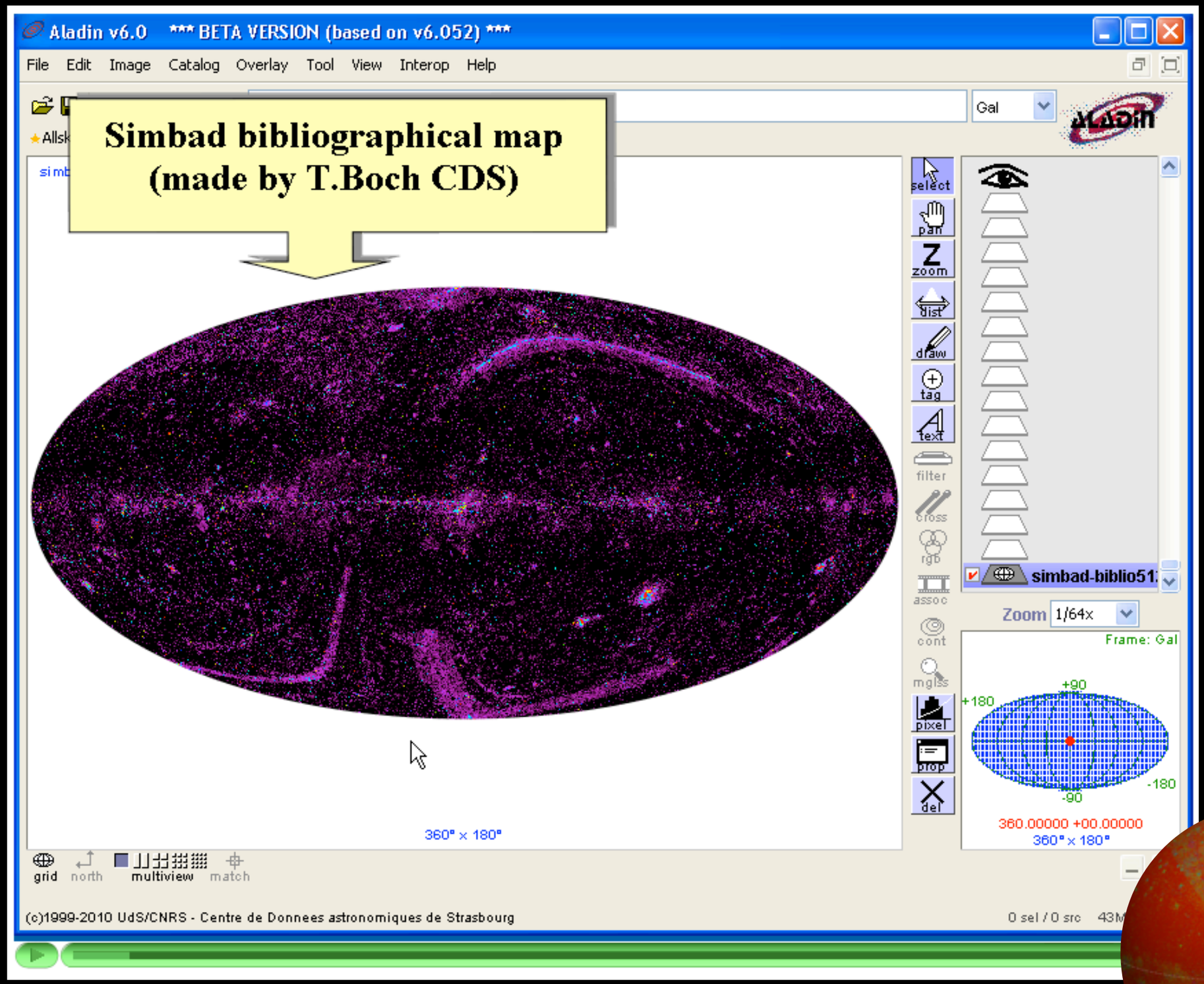
Faceted Heat Map of Articles on the Sky

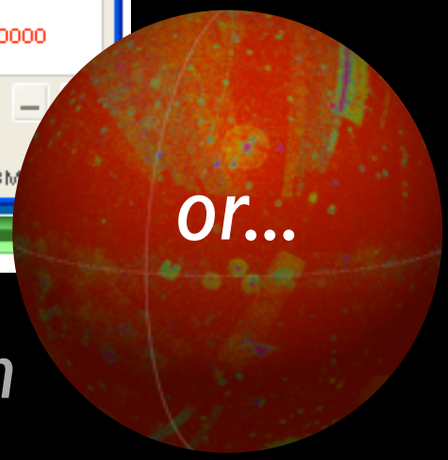
ADS-CDS-Seamless-MSR collaboration

Historical Image Layer Extracted from ALL ADS holdings (astrometry.net & Zooniverse)

ADS-Seamless-astrometry.net-MSR-Zooniverse collaboration

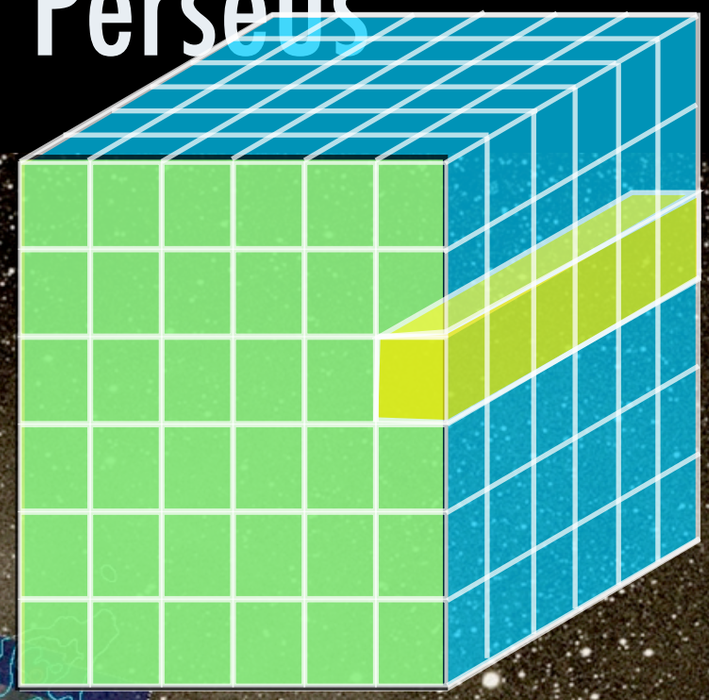
Prototype of Articles on the Sky (2010)





with thanks to CDS/Pierre Fernique/Thomas Boch

Star Formation in Perseus



COMPLETE

mm peak (Enoch et al. 2006)

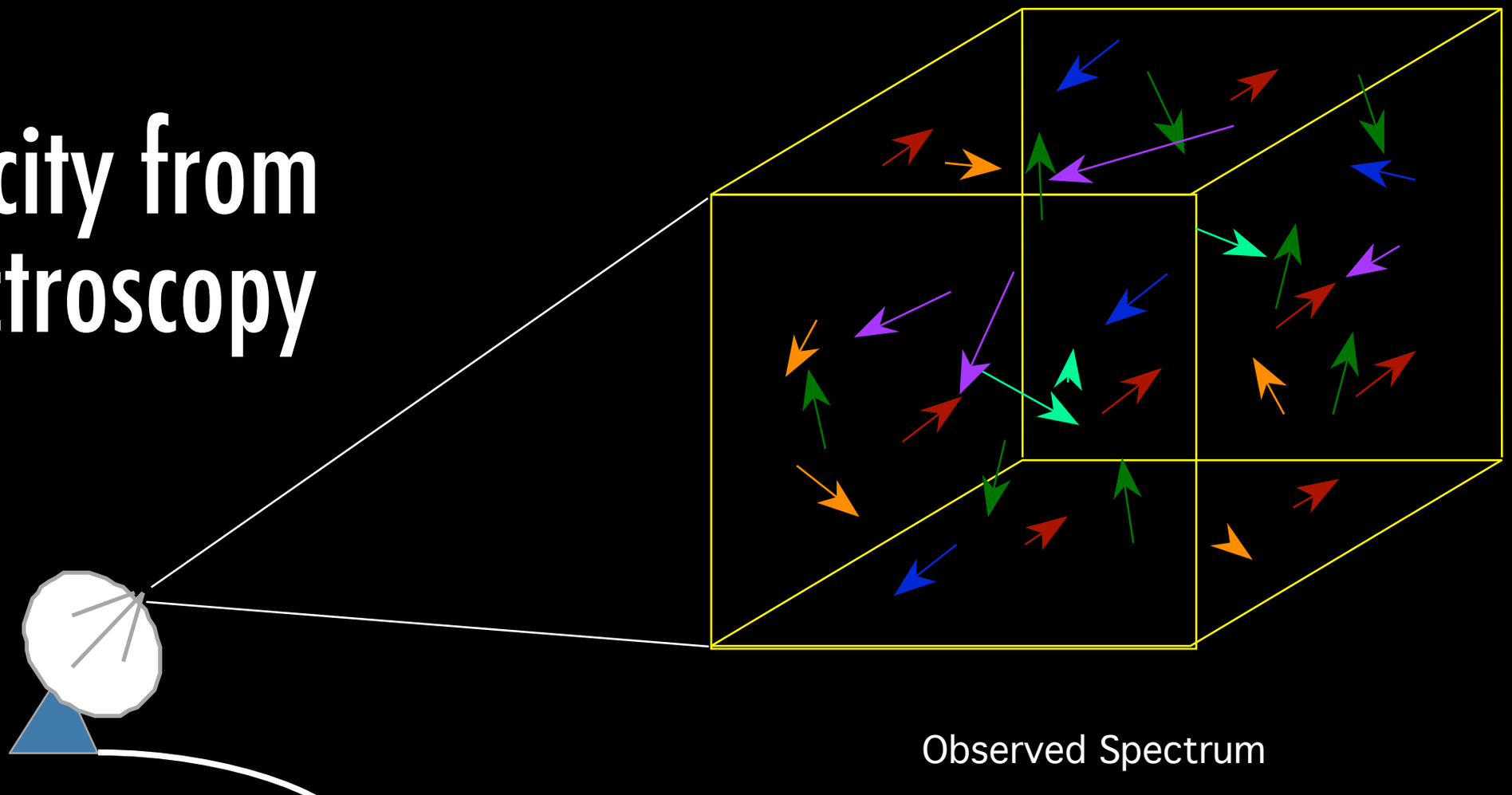
sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)

^{13}CO (Ridge et al. 2006)

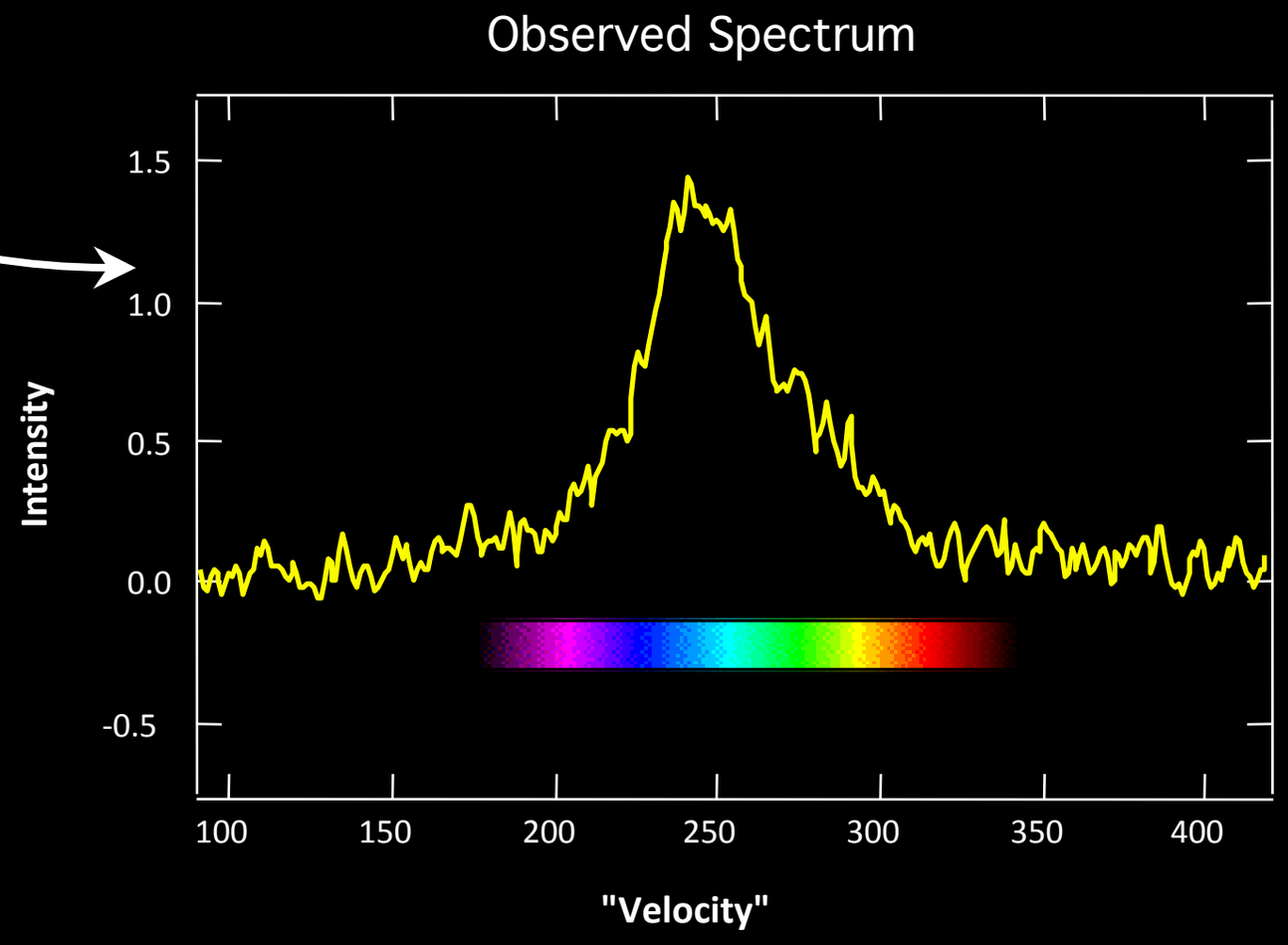
mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al.)

Optical image (Barnard 1927)

Velocity from Spectroscopy

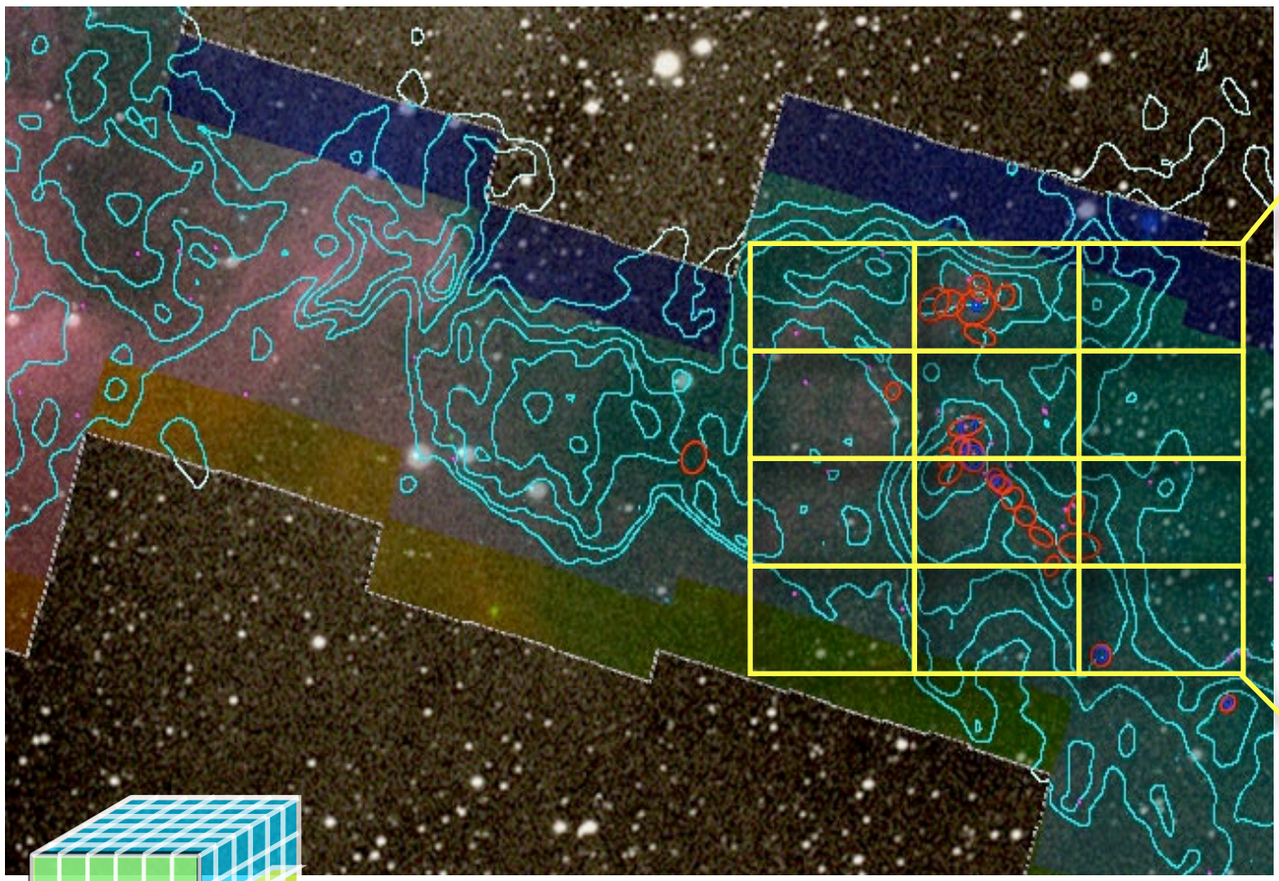


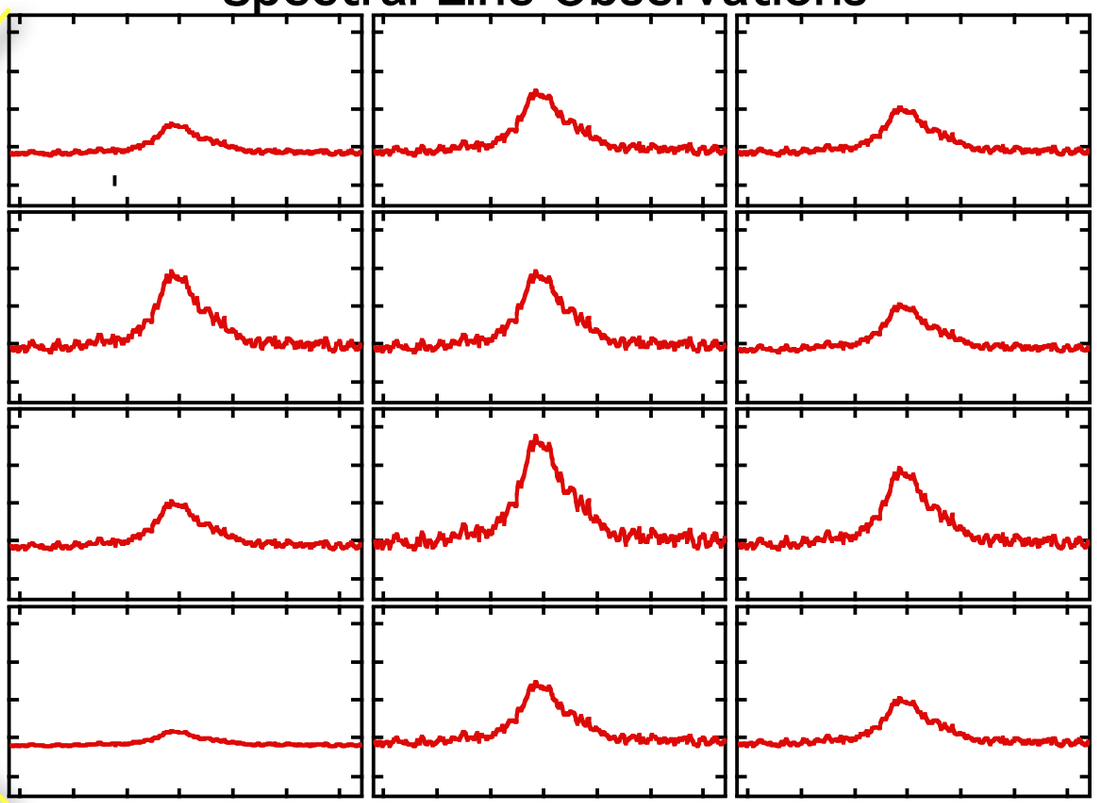
Telescope +
Spectrometer

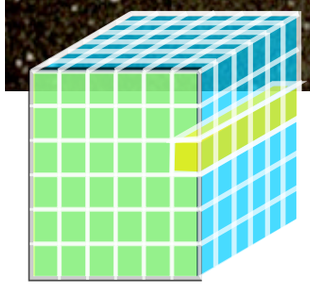


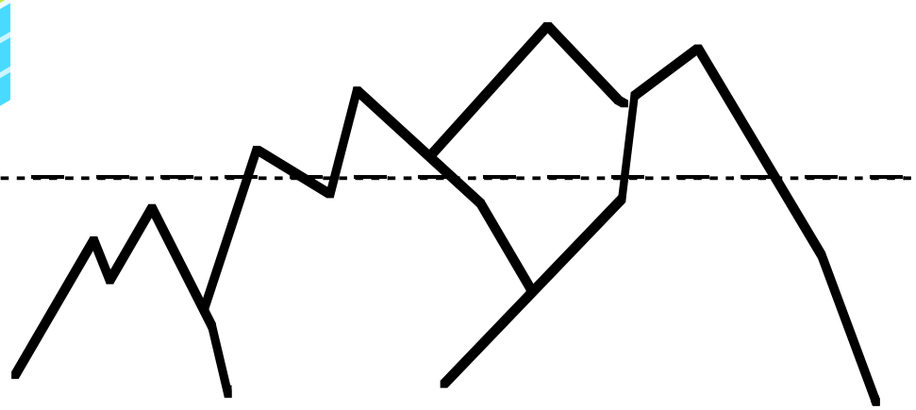
All thanks to Doppler

Spectral-Line Mapping









Mountain Range

No loss of information

Loss of 1 dimension

COMPLETE Perseus

mm peak (Enoch et al. 2006)

sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)

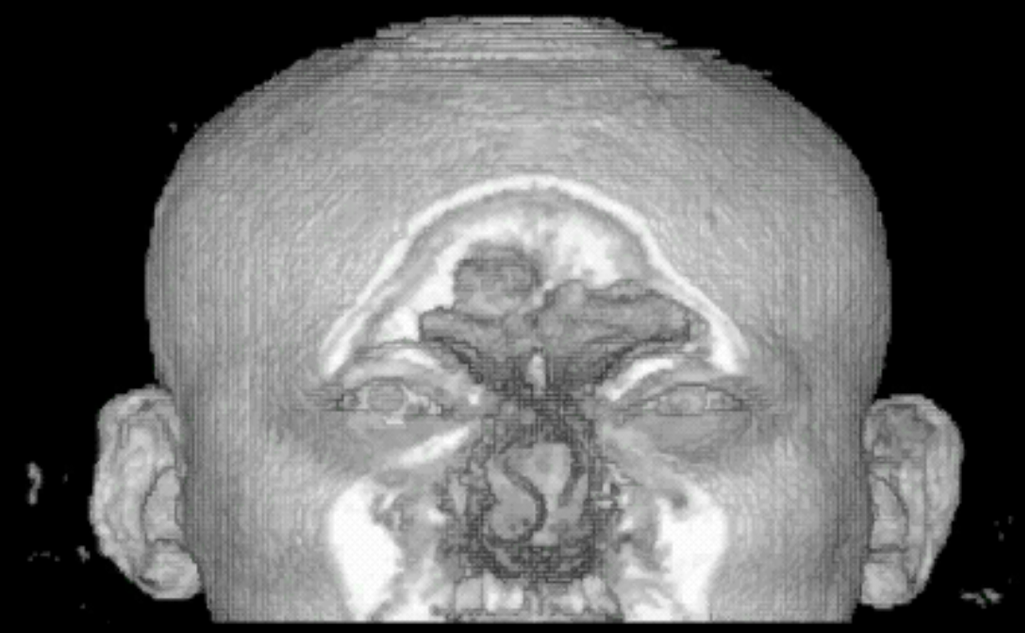
^{13}CO (Ridge et al. 2006)

mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al.)

Optical image (Barnard 1927)

"Astronomical Medicine"

"KEITH"



"PERSEUS"

"z" is depth into head

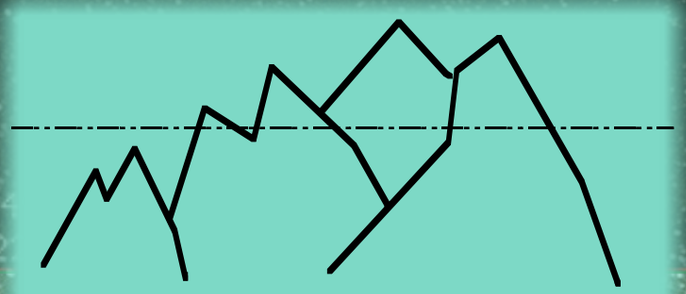
"z" is line-of-sight velocity

http://am.iic.harvard.edu/

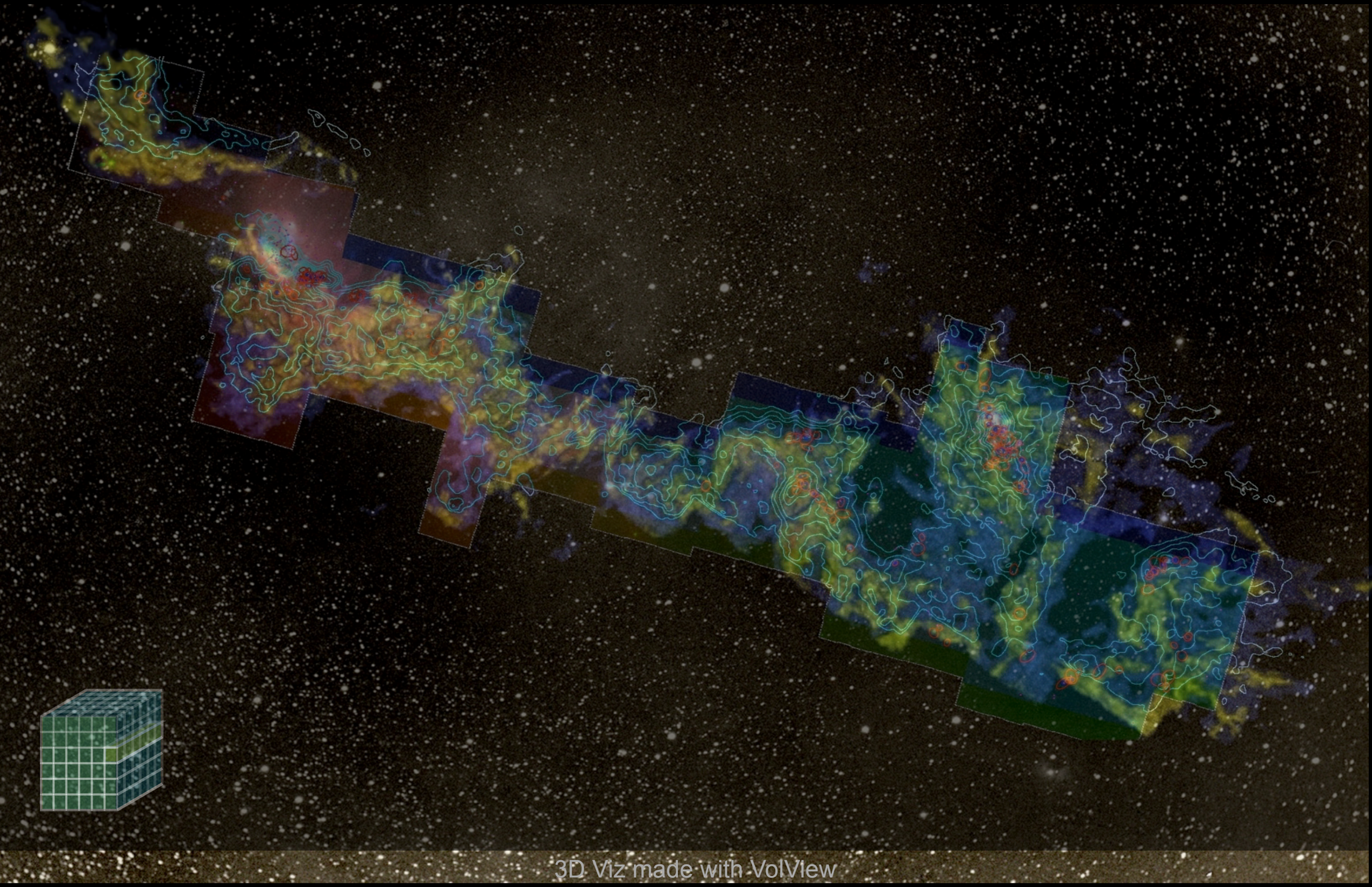
mage size: 520 x 274
iew size: 1305 x 733
VL: 63 WW: 127

COMPLETE Perseus

^{13}CO (Ridge et al. 2006)



Mountain Range



AstronomicalMedicine@IIG

COMPLETE