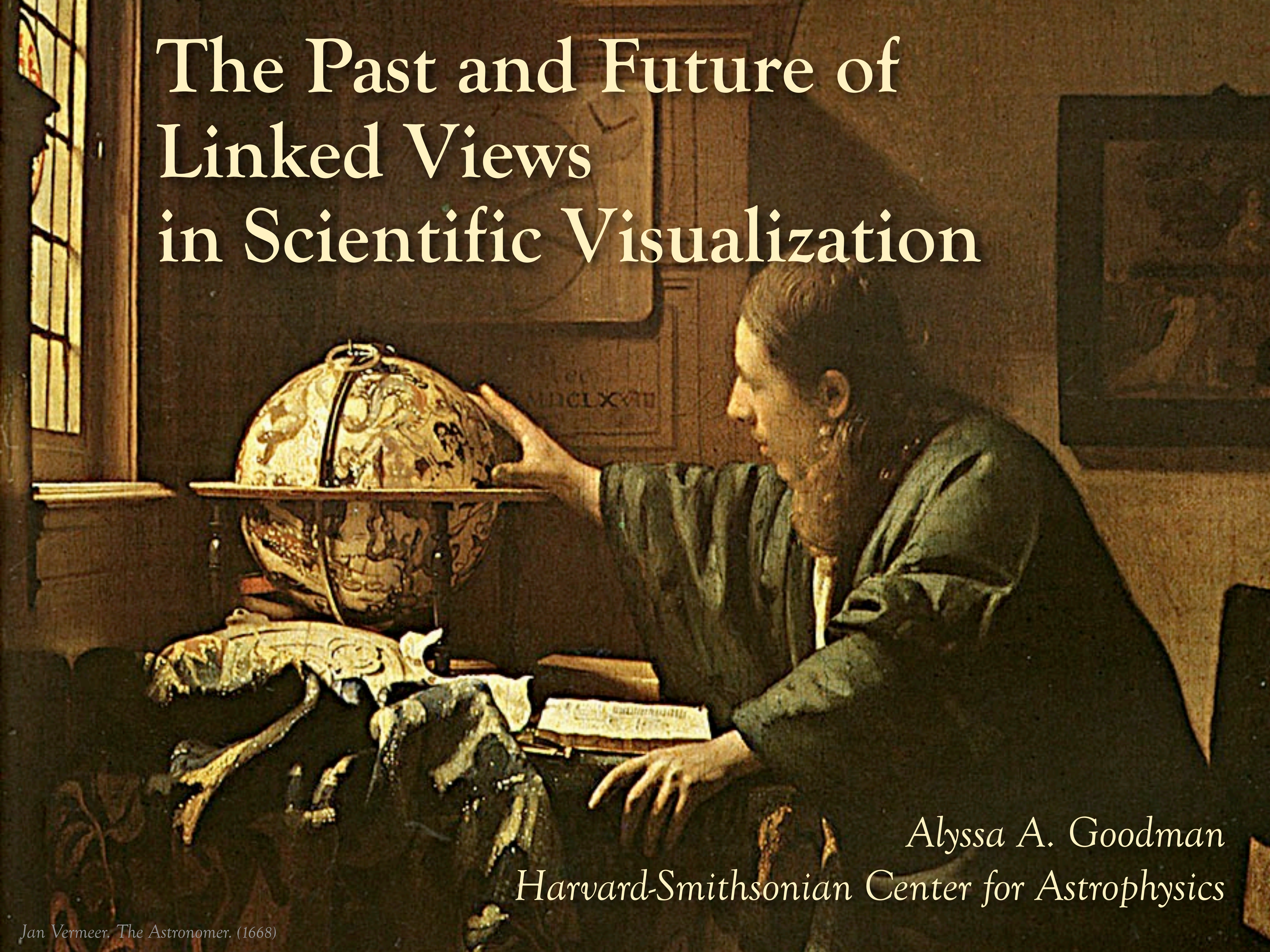
The Past and Future of Linked Views in Scientific Visualization

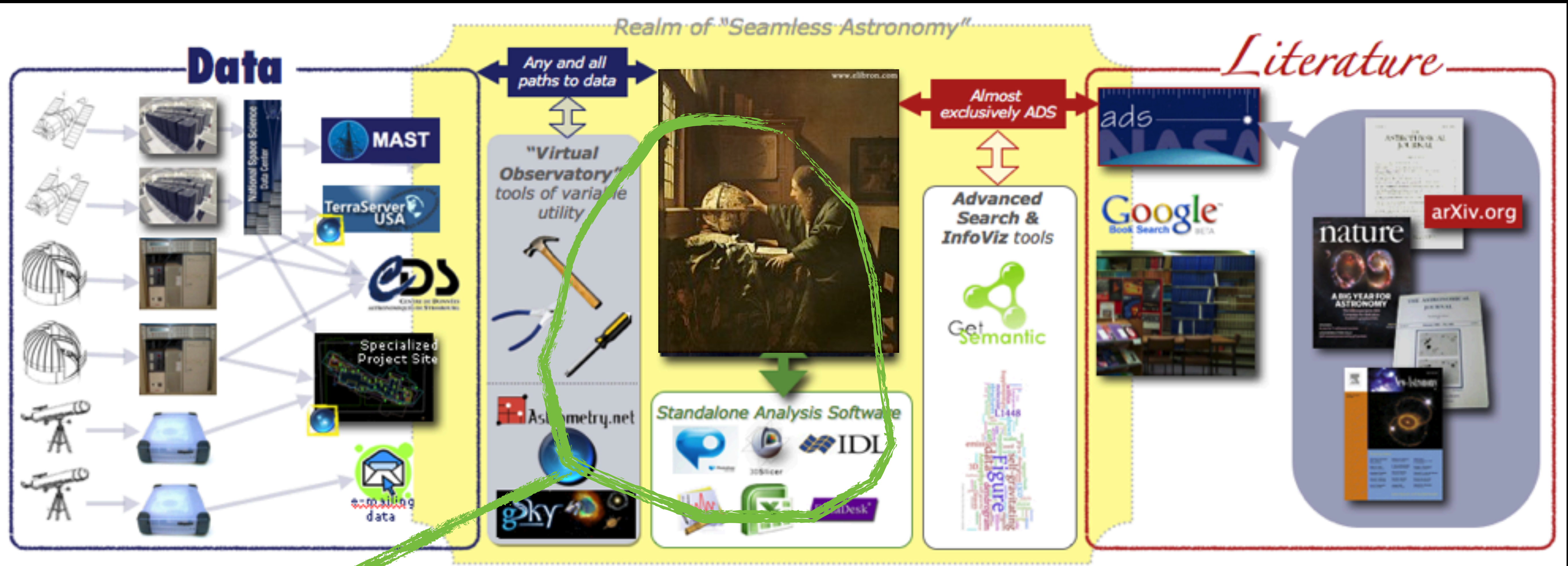


Alyssa A. Goodman
Harvard-Smithsonian Center for Astrophysics

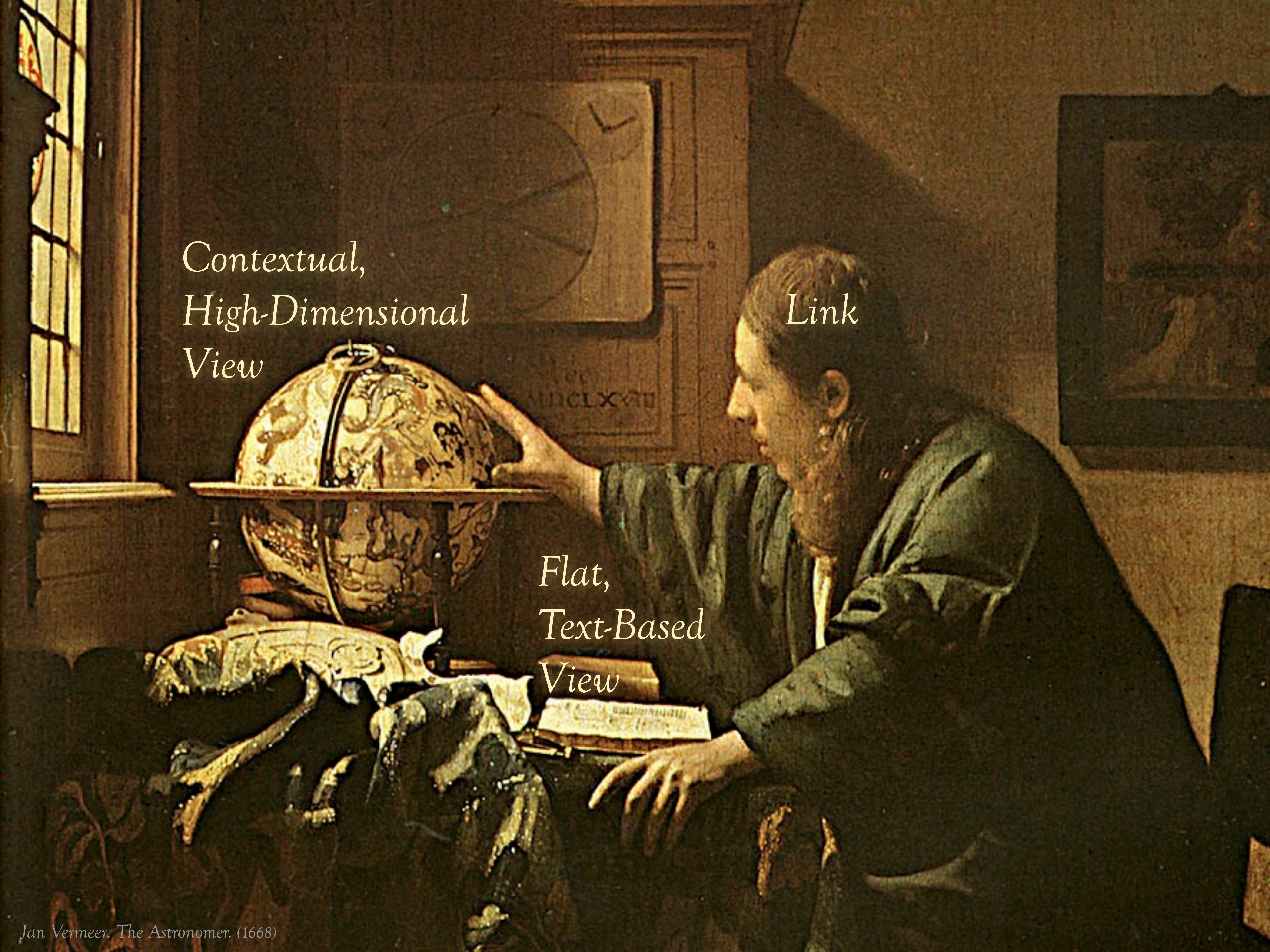
Jan Vermeer. The Astronomer. (1668)

Seamless Astronomy

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



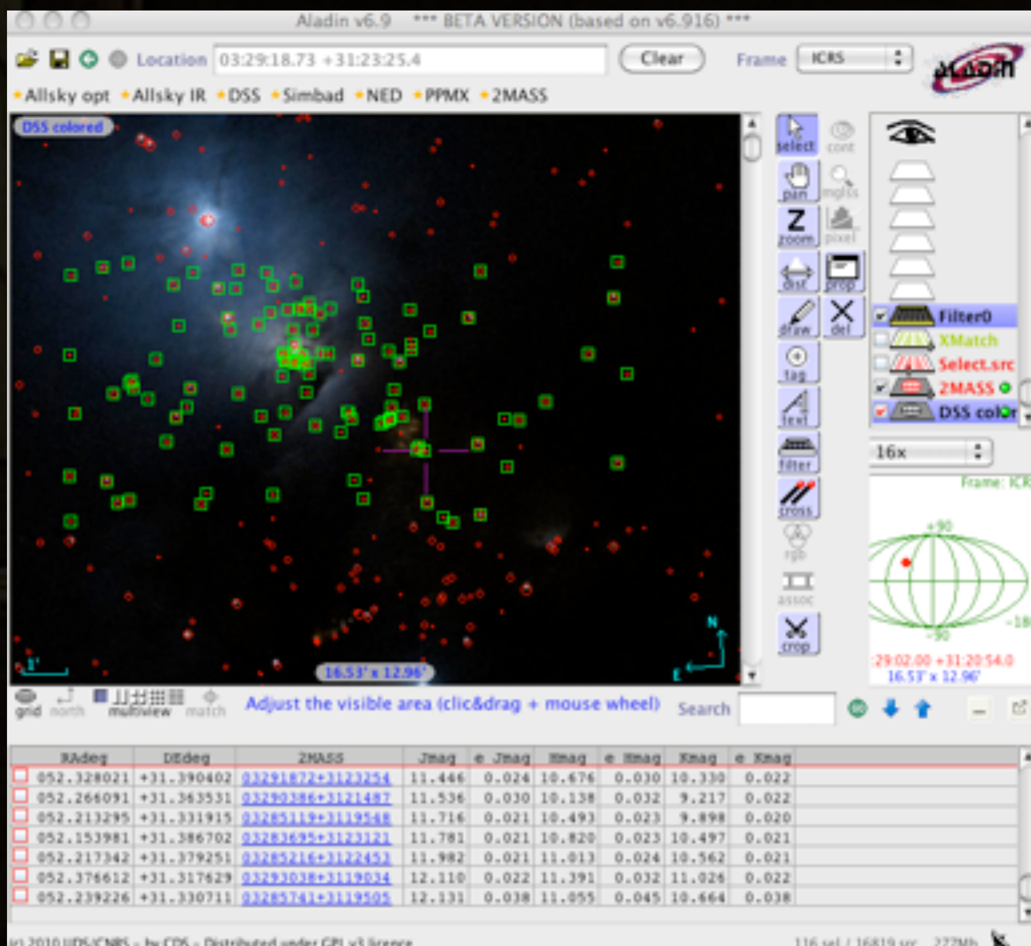
Today is about "Linked Views" *-- a New Project that adds Chris Beaumont, Michelle Borkin & Hanspeter Pfister*



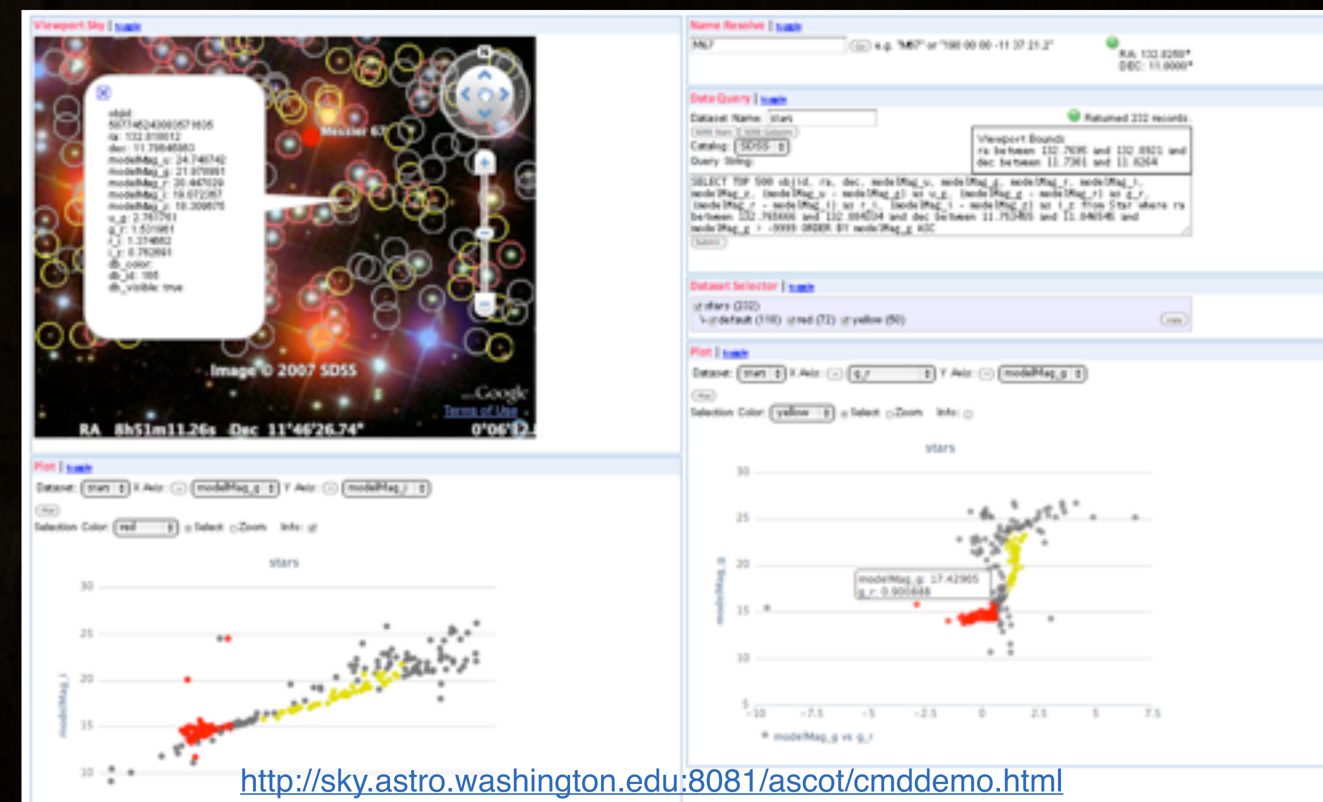
Jan Vermeer. The Astronomer. (1668)

We've seen Linked Views *at least twice at ADASS 2010...*

Aladin (Thomas Boch's demo)



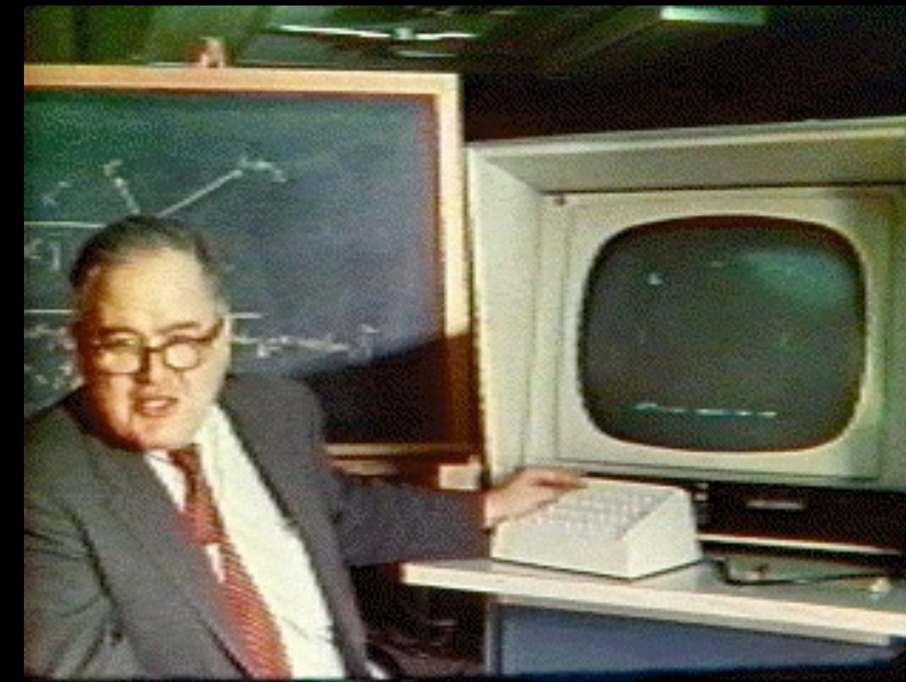
ASCOT (Andy Connolly's talk)



And options are many, re:SAMP...

(see Boch & Cambrésy IVOA Victoria 2010)

JOHN TUKEY'S LEGACY



PRIM-9 → DataDesk® →

PRIM-H

XGobi → GGobi →

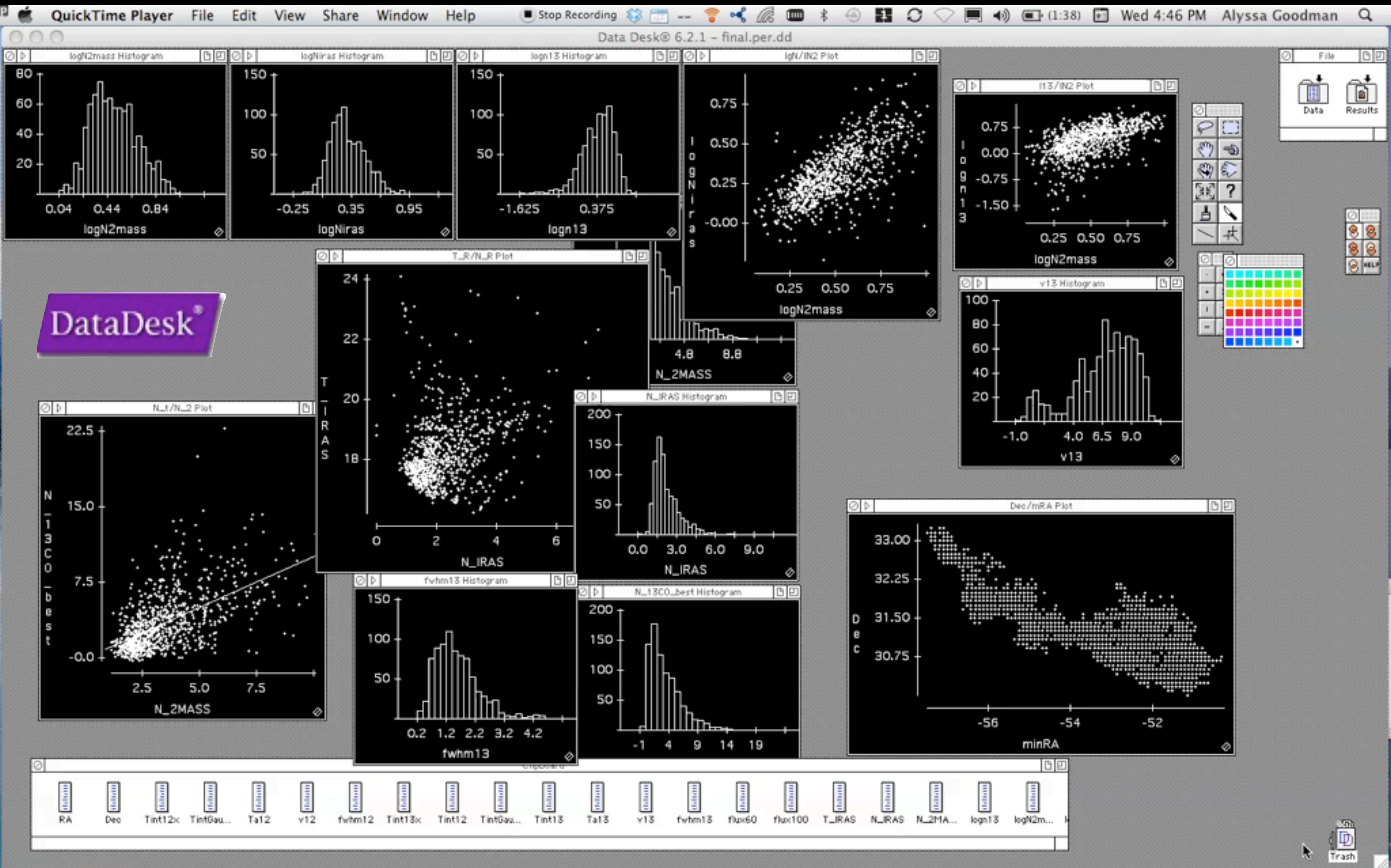
RGGobi

Spotfire® →

Polaris → tableau SOFTWARE

1970 1980 1990 2000 2010

DataDesk (est. 1986)



Tukey's "Four Essentials" (c.1972)

Picturing | Rotation | Isolation | Masking

Selection

and these *"need to work together"*
in a *"dynamic display"*

Brushing | Linking

Results...

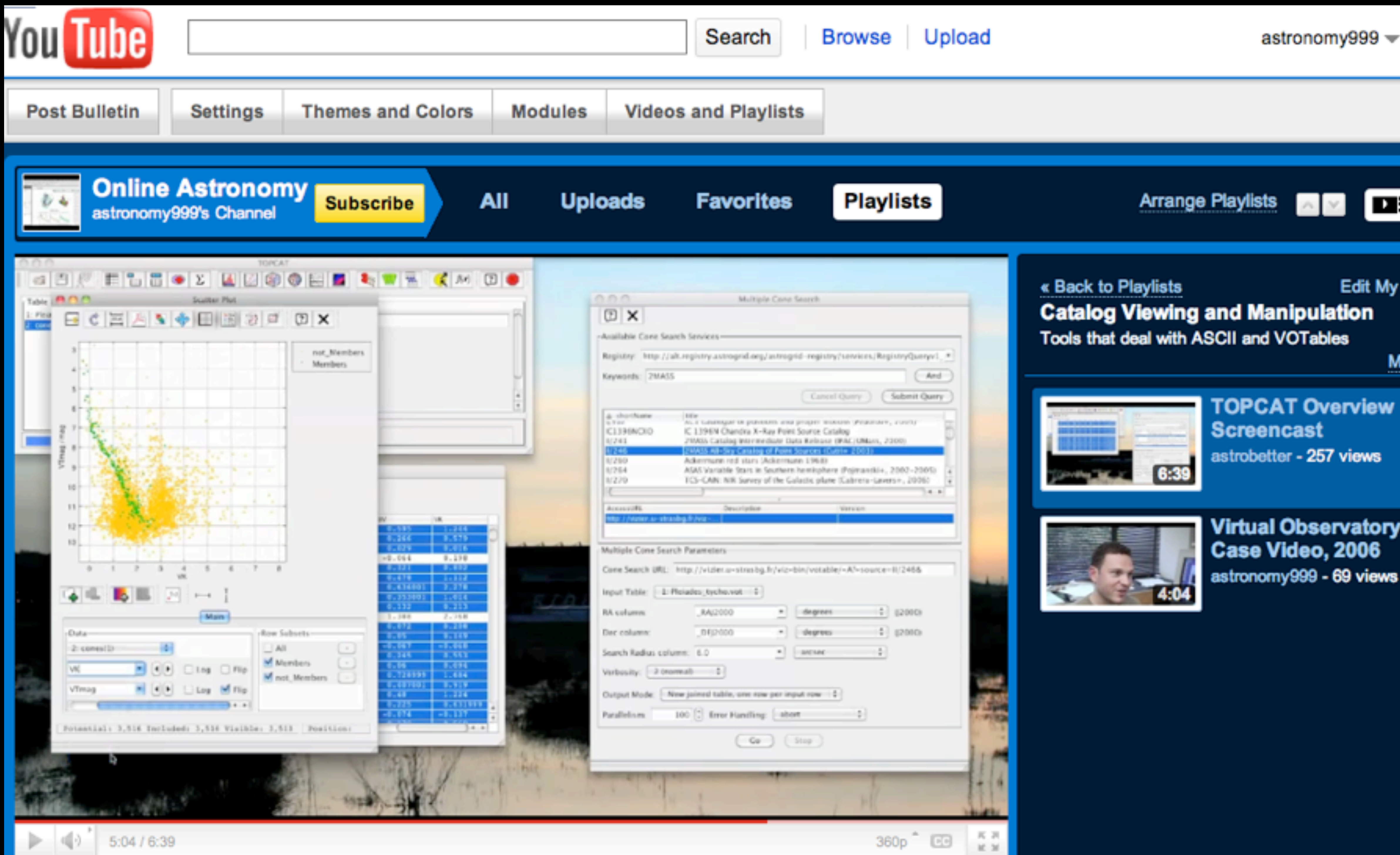
1. for immediate insight
2. as visual source of ideas for statistical algorithms (...relation to SVM)

Warning

"details of control can make or break such a system"

Watch the PRIM-9 video at: http://stat-graphics.org/movies/prim9.html

TOPCAT
first "DataDesk" of Astronomy

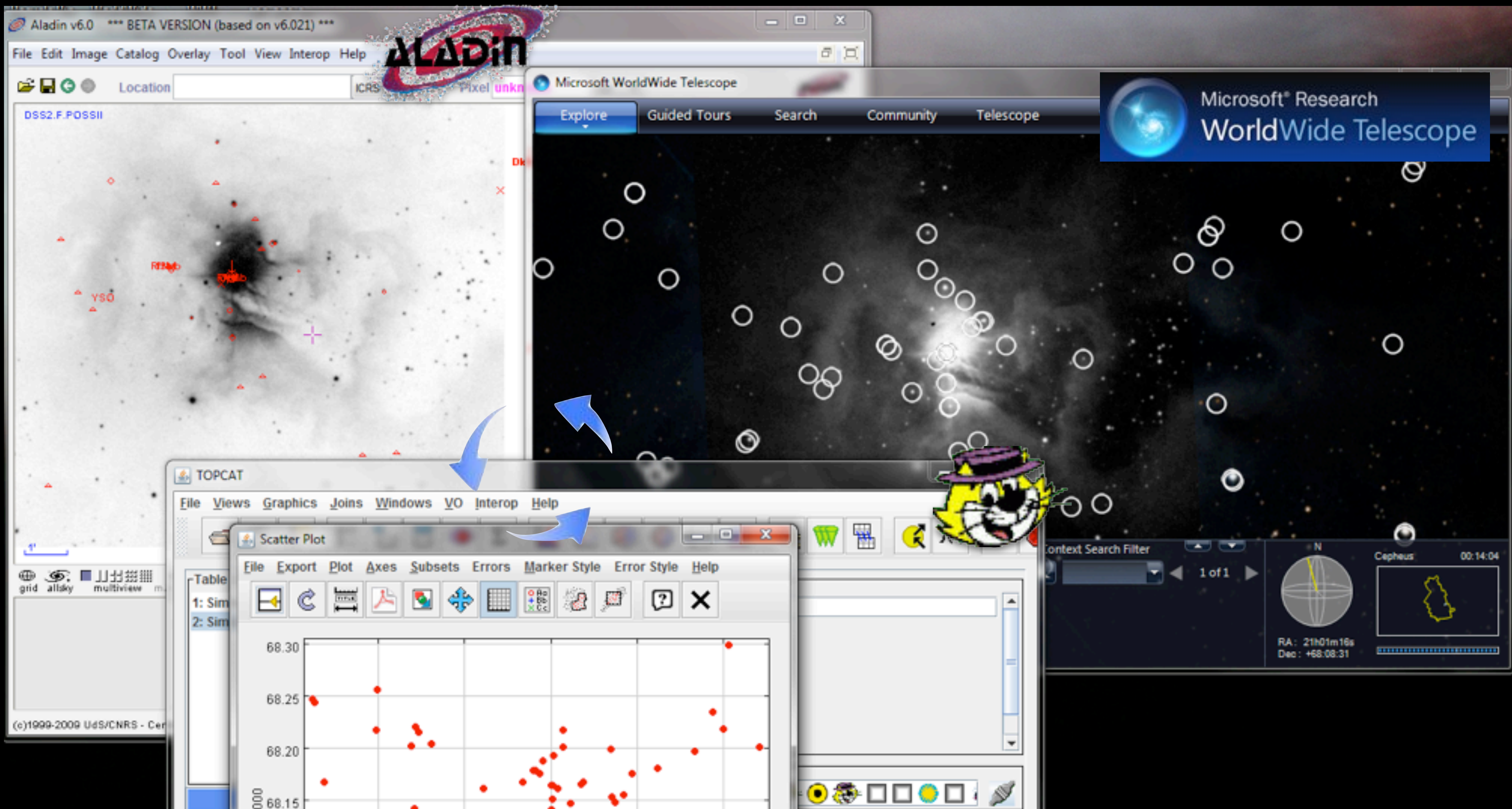


Learn more on YouTube "Online Astronomy" channel

www.youtube.com/user/astronomy999

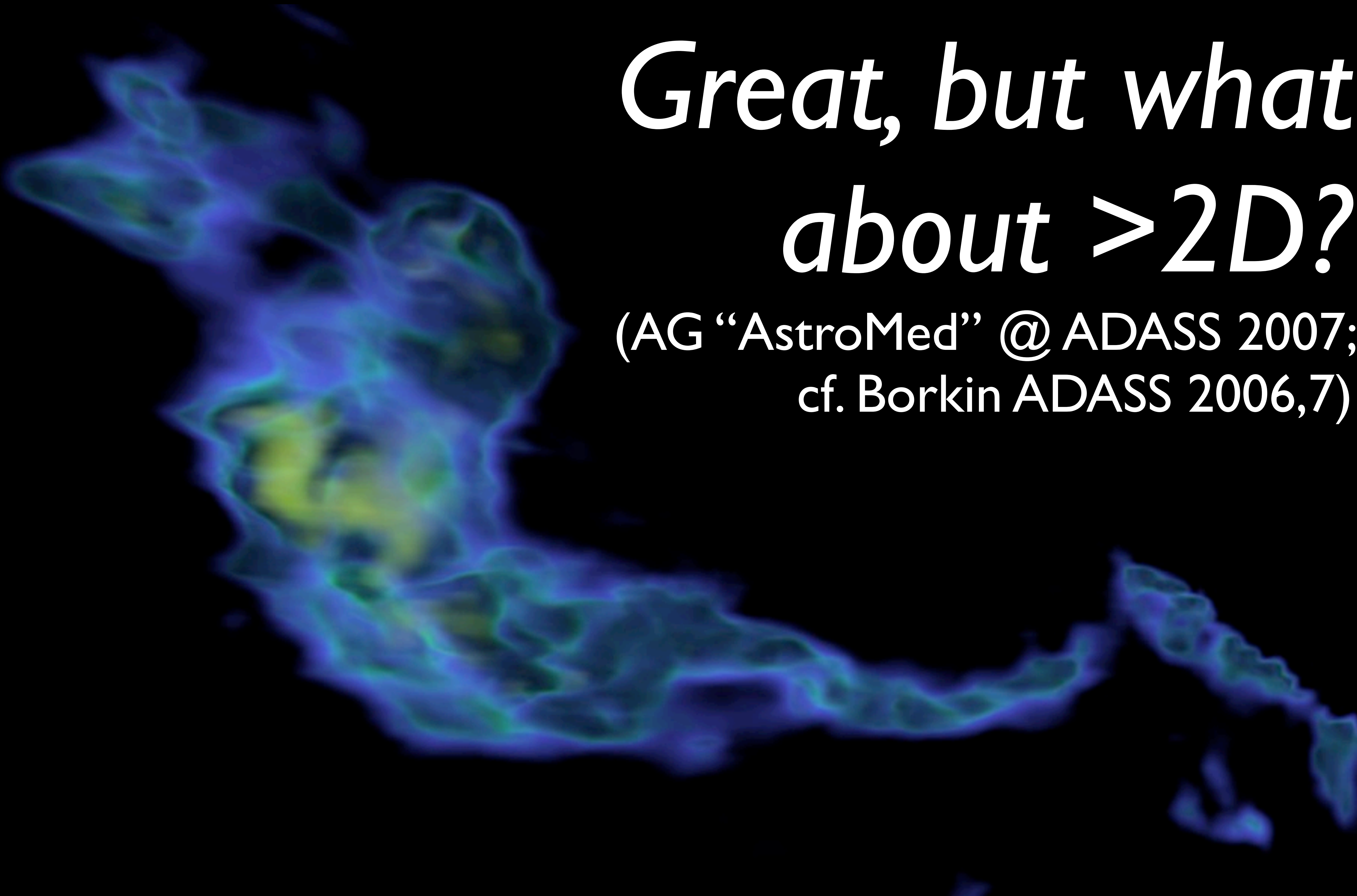
SAMP + VO offers Linked Views

Simple Application Messaging Protocol



www.ivoa.net/Documents/latest/SAMP.html

Also SAMP-enabled... ASTRO WISE, ds9 ...

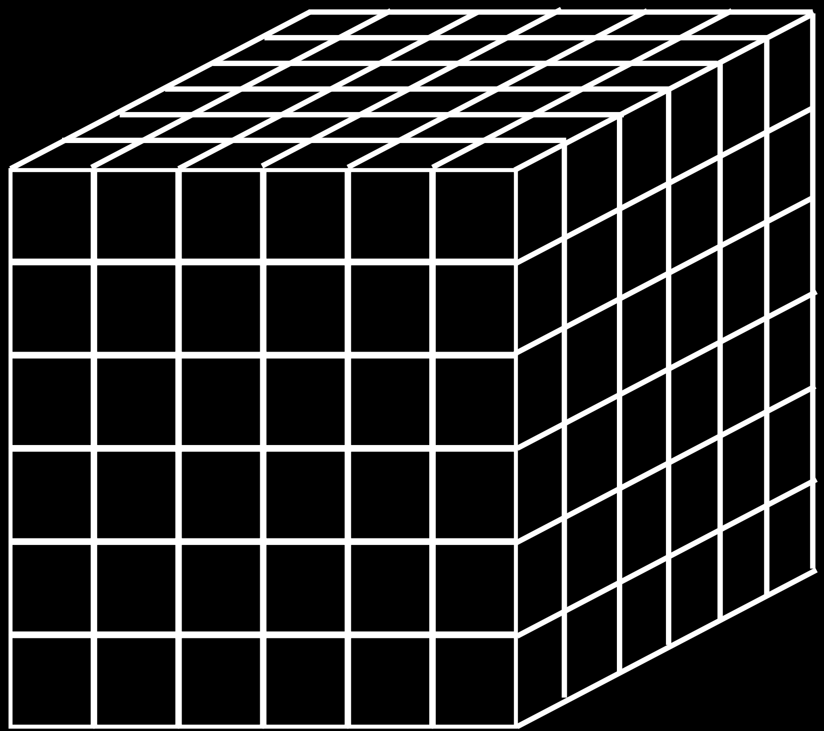


Great, but what about >2D?

(AG "AstroMed" @ ADASS 2007; cf. Borkin ADASS 2006,7)

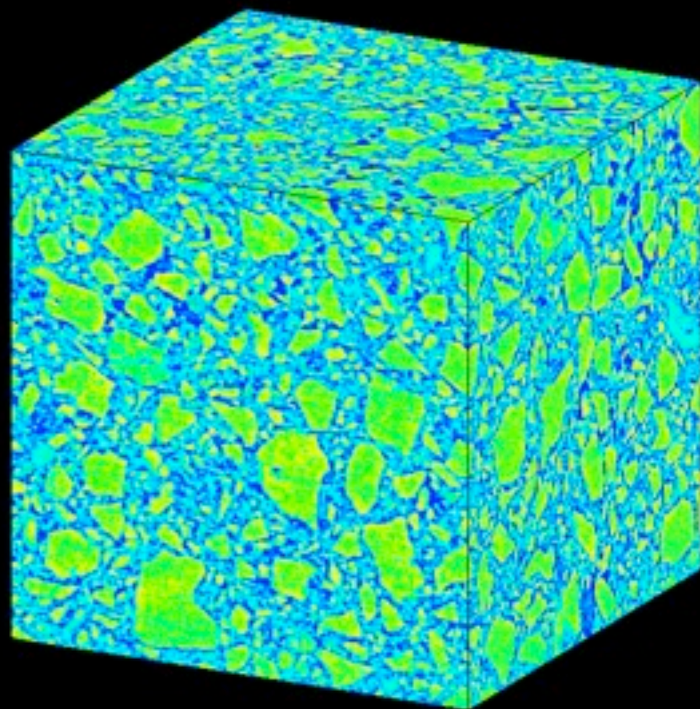
The “arraytional” future...

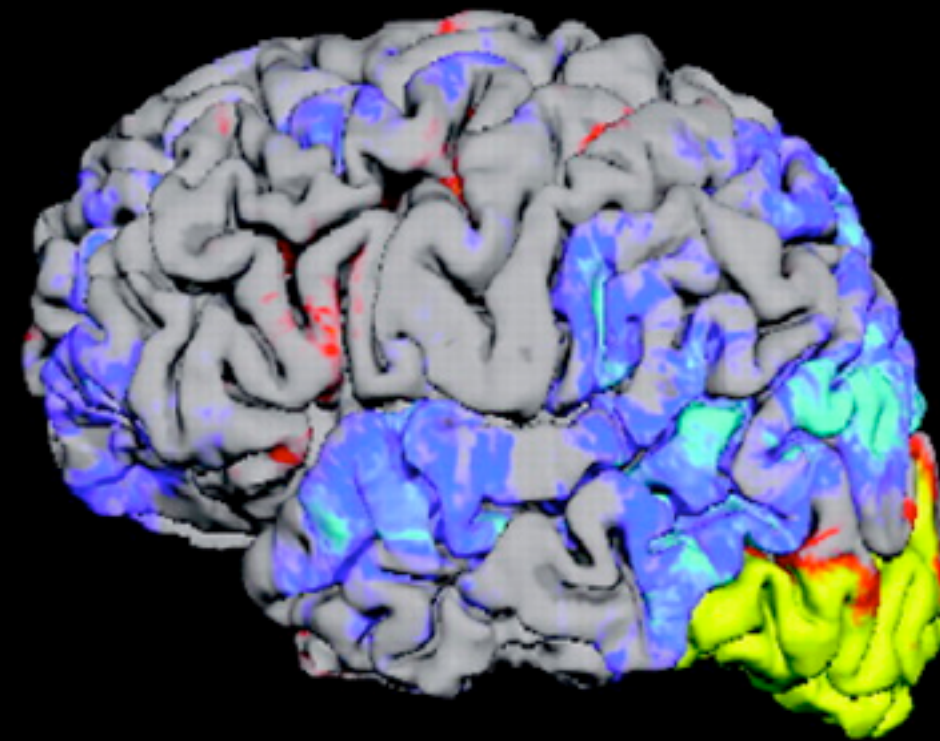
www.scidb.org

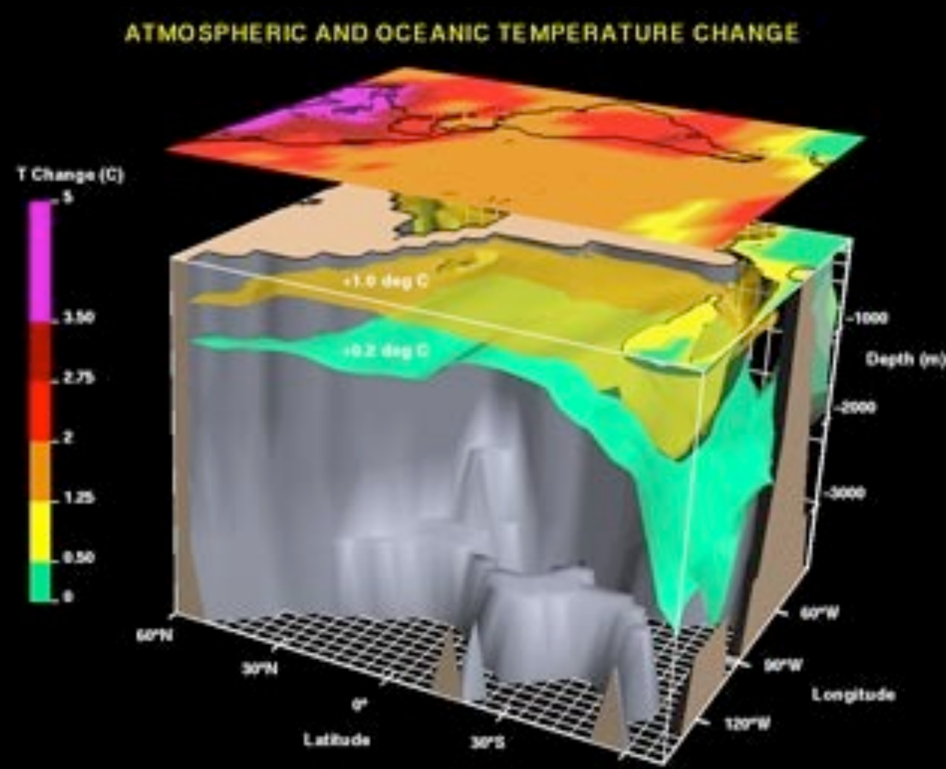


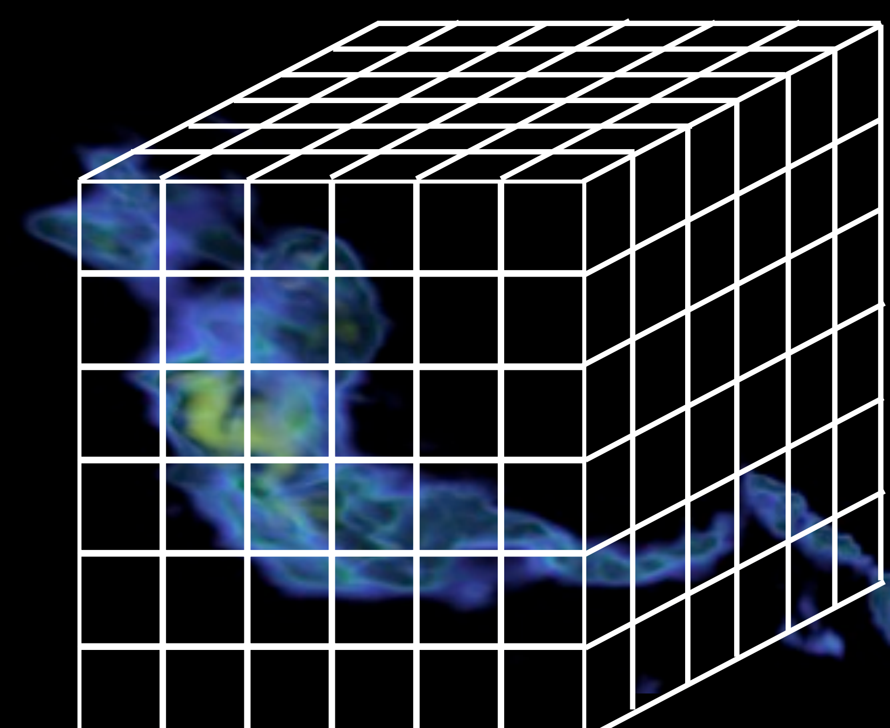
“Complex analytics will be simplified with SciDB because arrays and vectors are first-class objects with built-in optimized operations. Spatial operators and time-series analysis will be easy to express. Interfaces to common scientific tools like **R** and eventually **MATLAB** and **IDL**, as well as programming languages like **C++** and **Python**, will be provided.”

Thanks to Tim Clark for coining the phrase “arraytional” during early discussions of the SciDB concept at IIC with Mike Stonebraker.



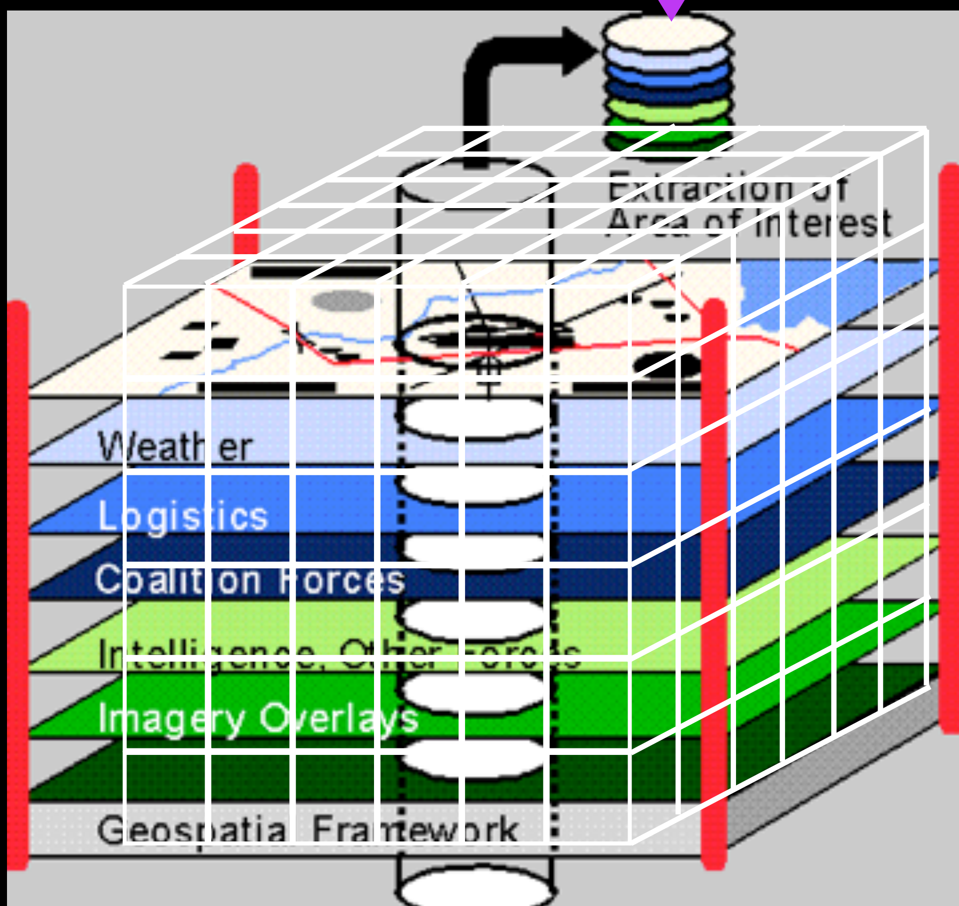


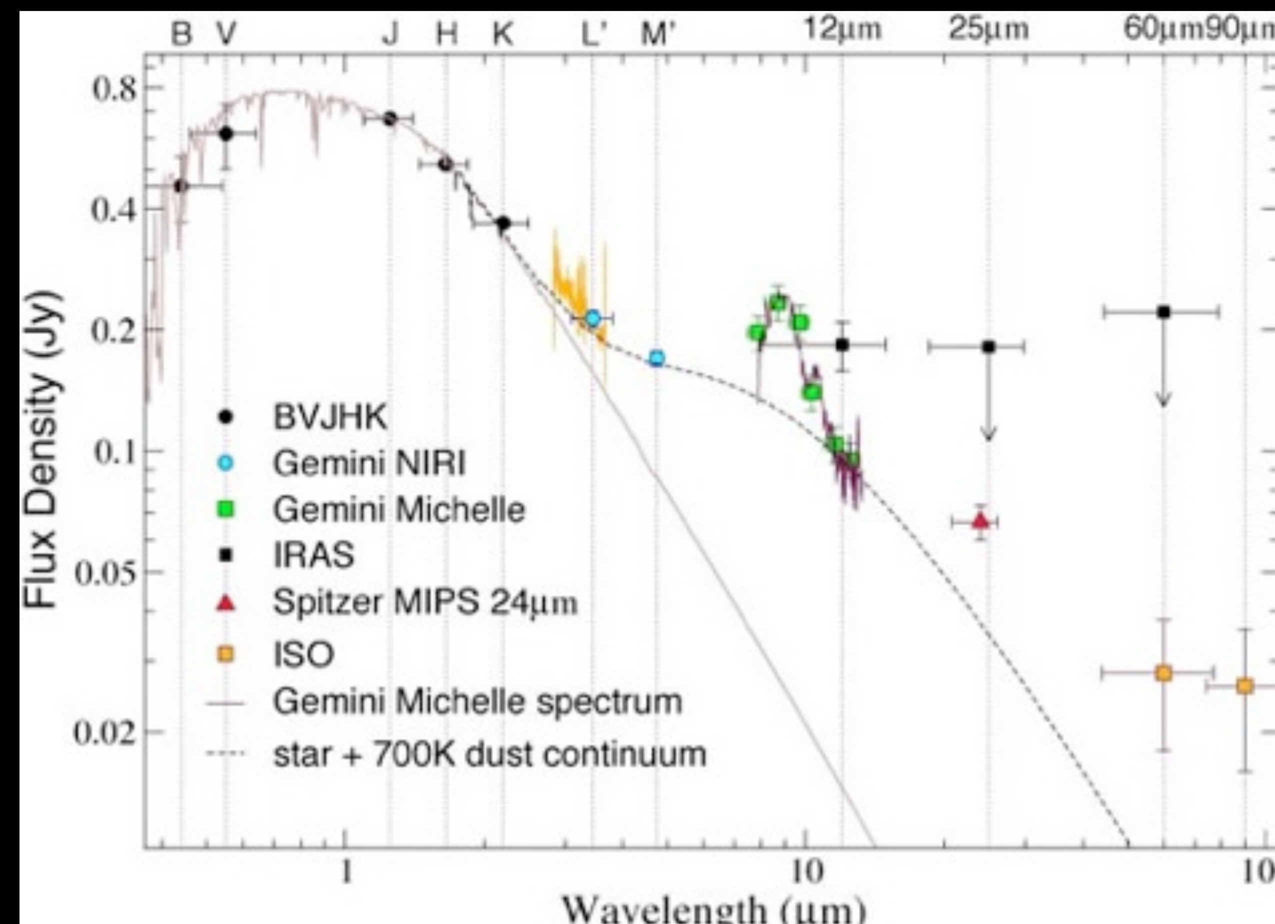

ATMOSPHERIC AND OCEANIC TEMPERATURE CHANGE
T Change (C)
5
3.50
2.75
2
1.25
0.50
0
+1.0 deg C
+0.2 deg C
-1000
Depth (m)
-2000
-3000
60°N
30°N
0°
Latitude
30°S
60°W
90°W
Longitude
120°W

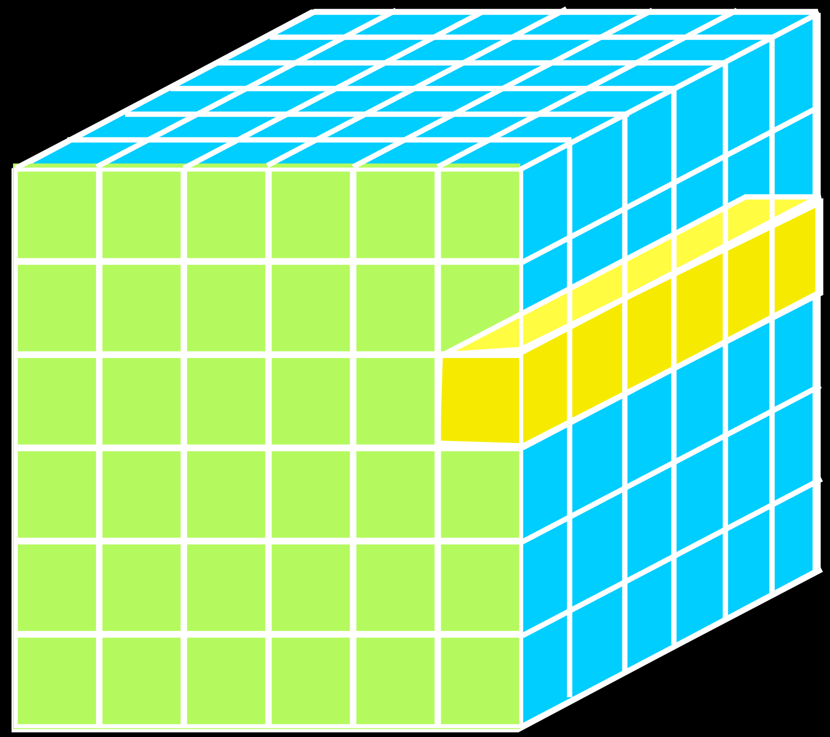


This

is a "spectral energy distribution"







GENERALLY

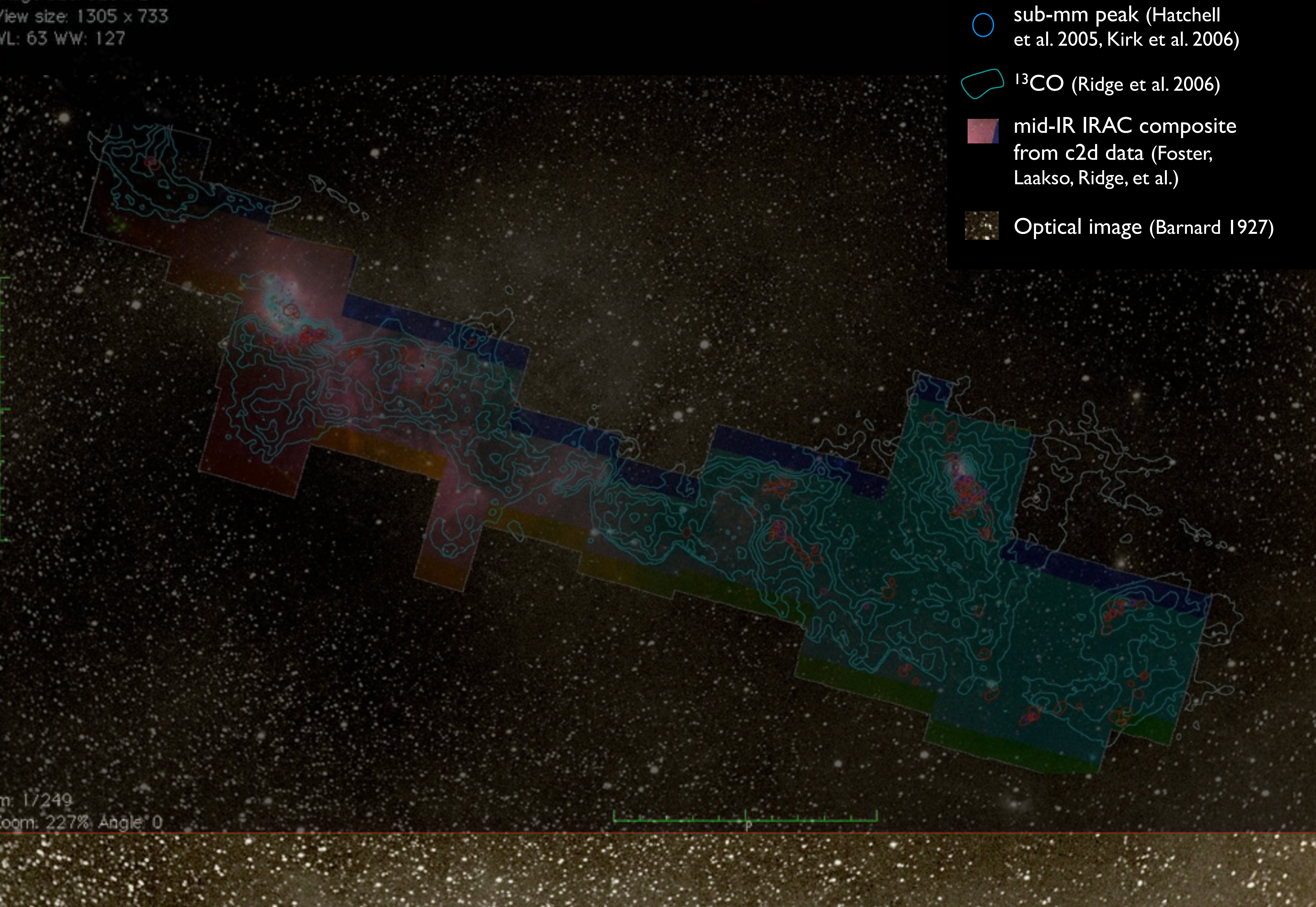
1D: Columns = “Spectra”, “SEDs” or “Time Series”

2D: Faces or Slices = “Images”

3D: Volumes = “3D Renderings”

4D: Time Series of Volumes = “3D Movies”

COMPLETE Perseus

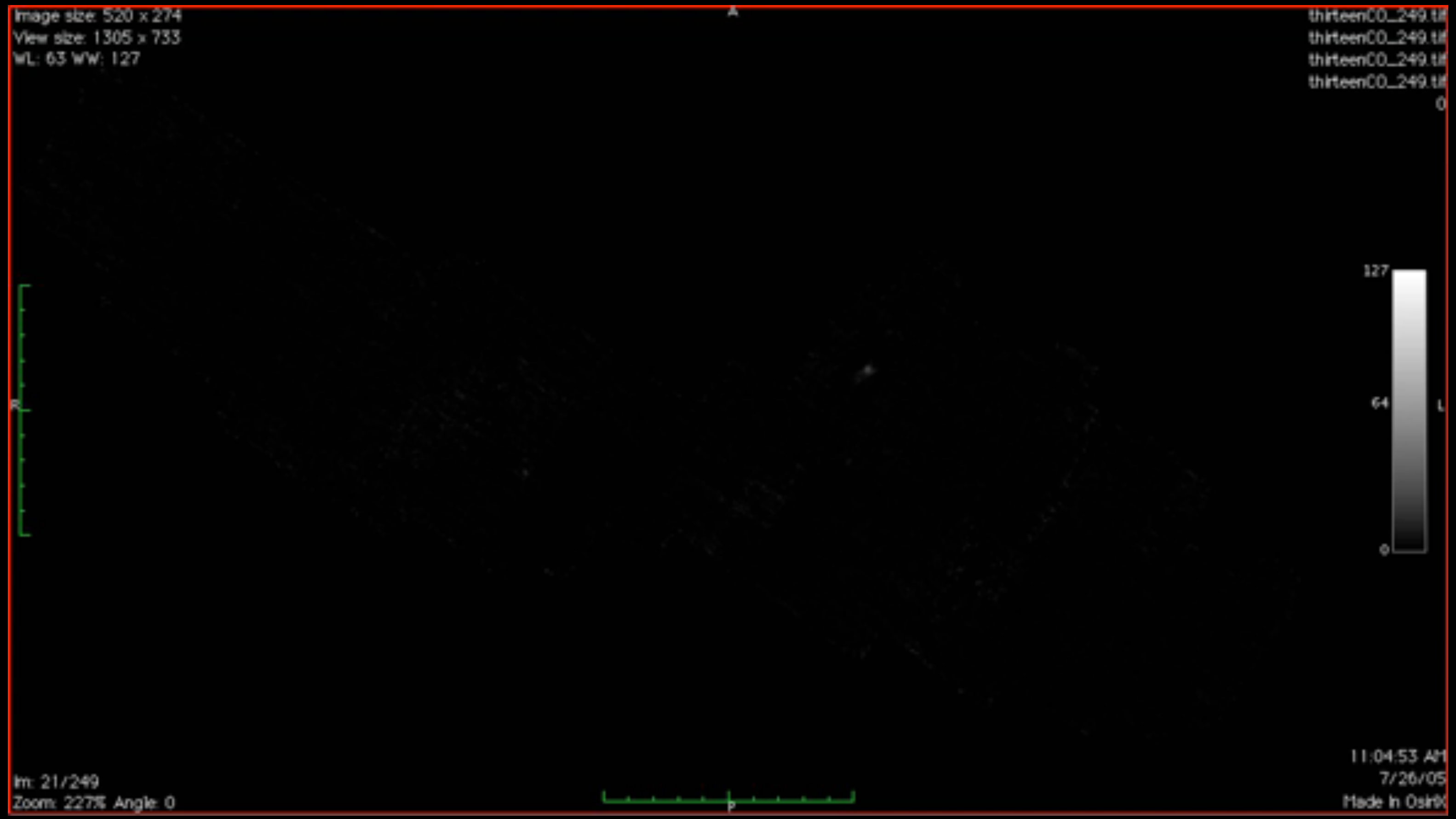


“Astronomical Medicine”

“KEITH”

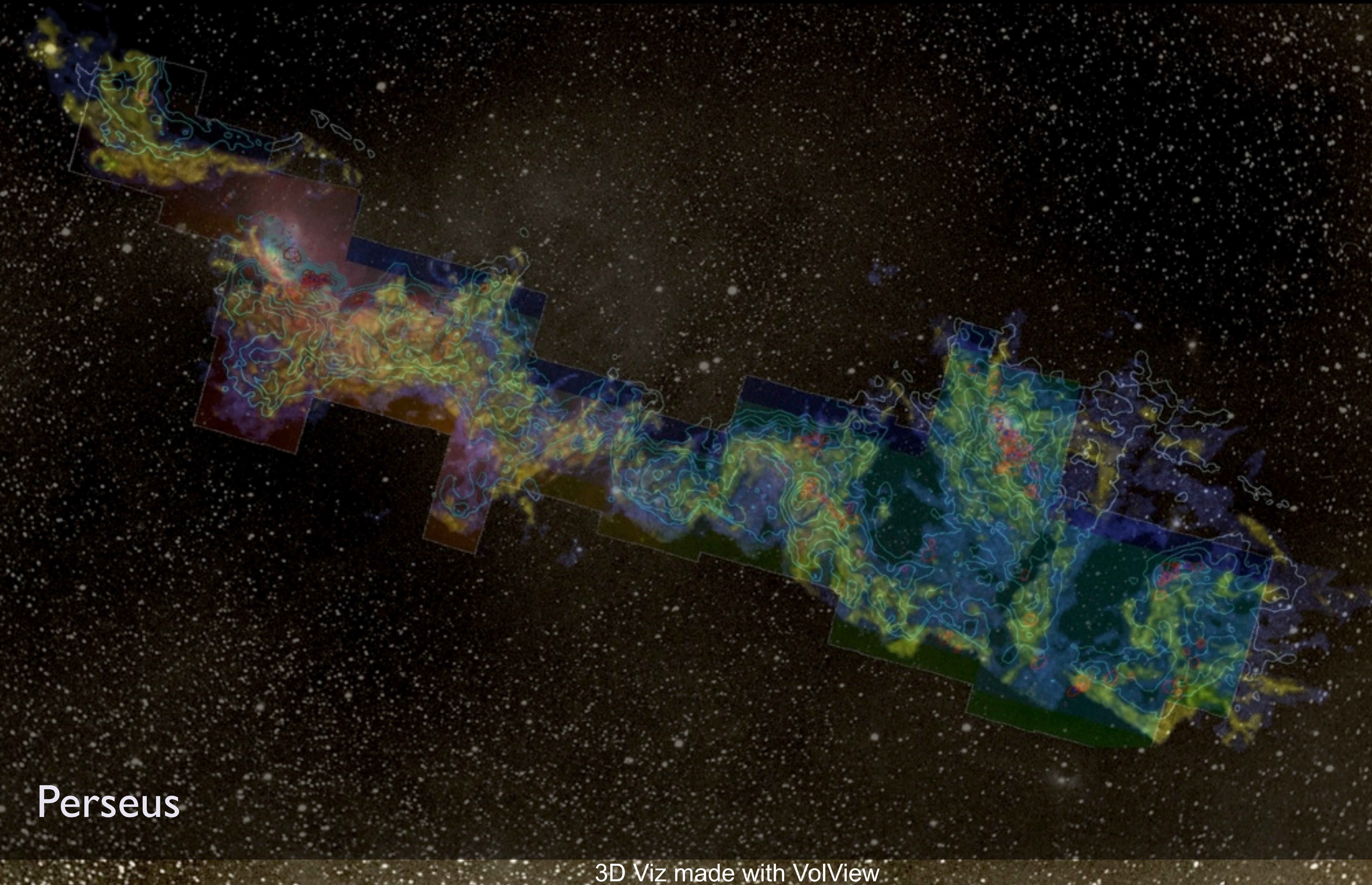
“z” is depth into head

“PERSEUS”



“z” is line-of-sight velocity

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


Perseus
3D Viz made with VolView

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www.physics.usyd.edu.au/astromed09/

...to be continued, I think!

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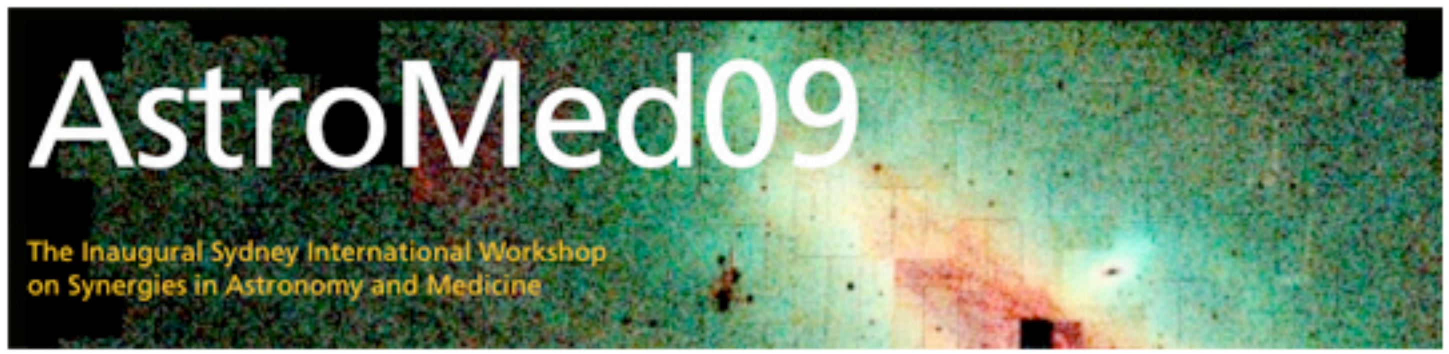

Download talks and photos here!

The final Scientific Program is now available.

The Conference Dinner is now fully booked!

Abstract submissions have now closed.

The Inaugural Sydney International Workshop on Synergies in Astronomy and Medicine

Sydney, Australia, 14-16 December 2009

Astronomy and Medicine share many similar demands for increasingly sophisticated and diverse imaging techniques as well as associated cutting-edge instrumentation technologies and advanced software tools for multi-dimensional data storage, manipulation and processing. This workshop will provide an international forum for exploring and consolidating these synergies, exchanging ideas and identifying opportunities for knowledge and technology transfer across the two research disciplines, and on to industry and academia.

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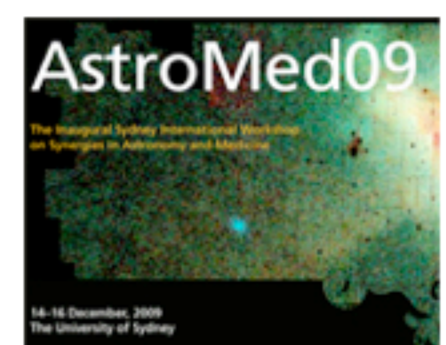

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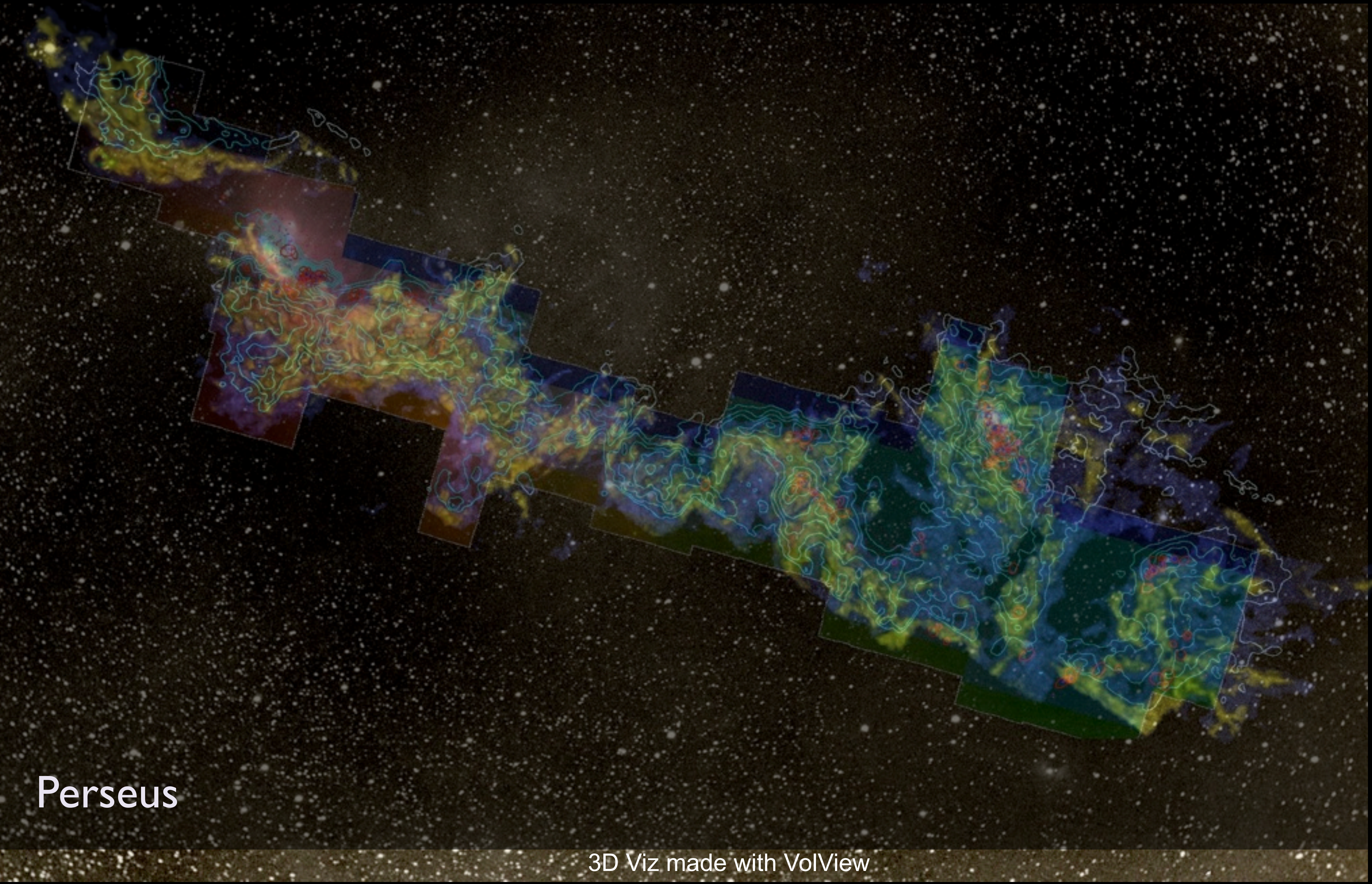
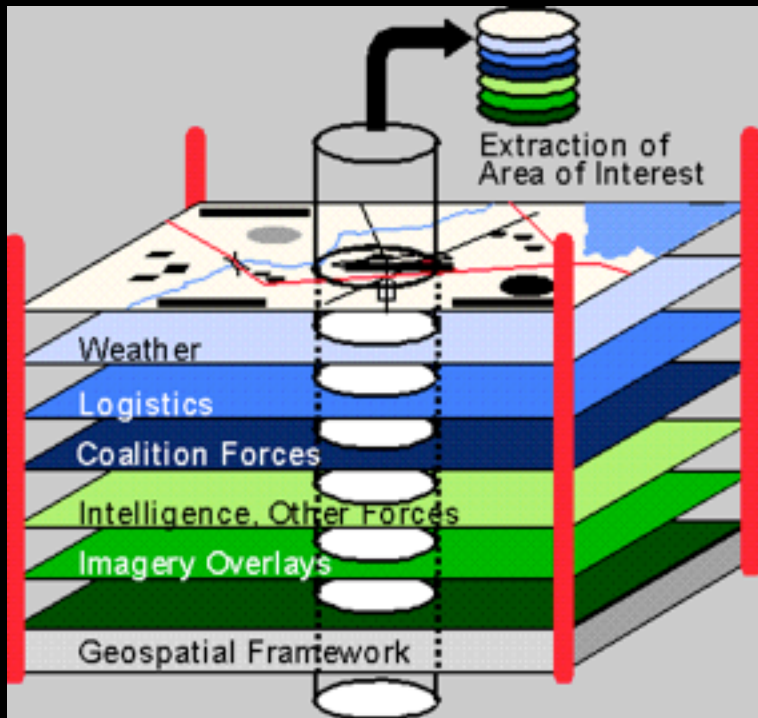

Perseus
3D Viz made with VolView



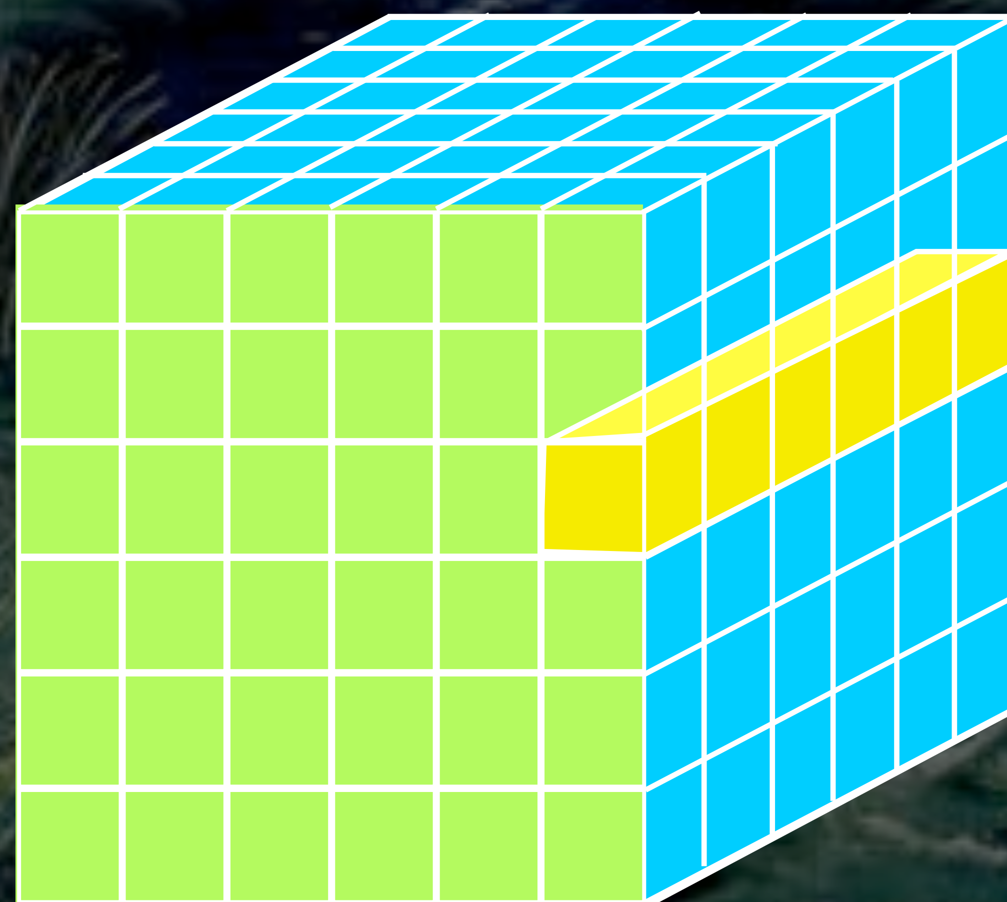
COMPLETE

COMPLETE Data Available

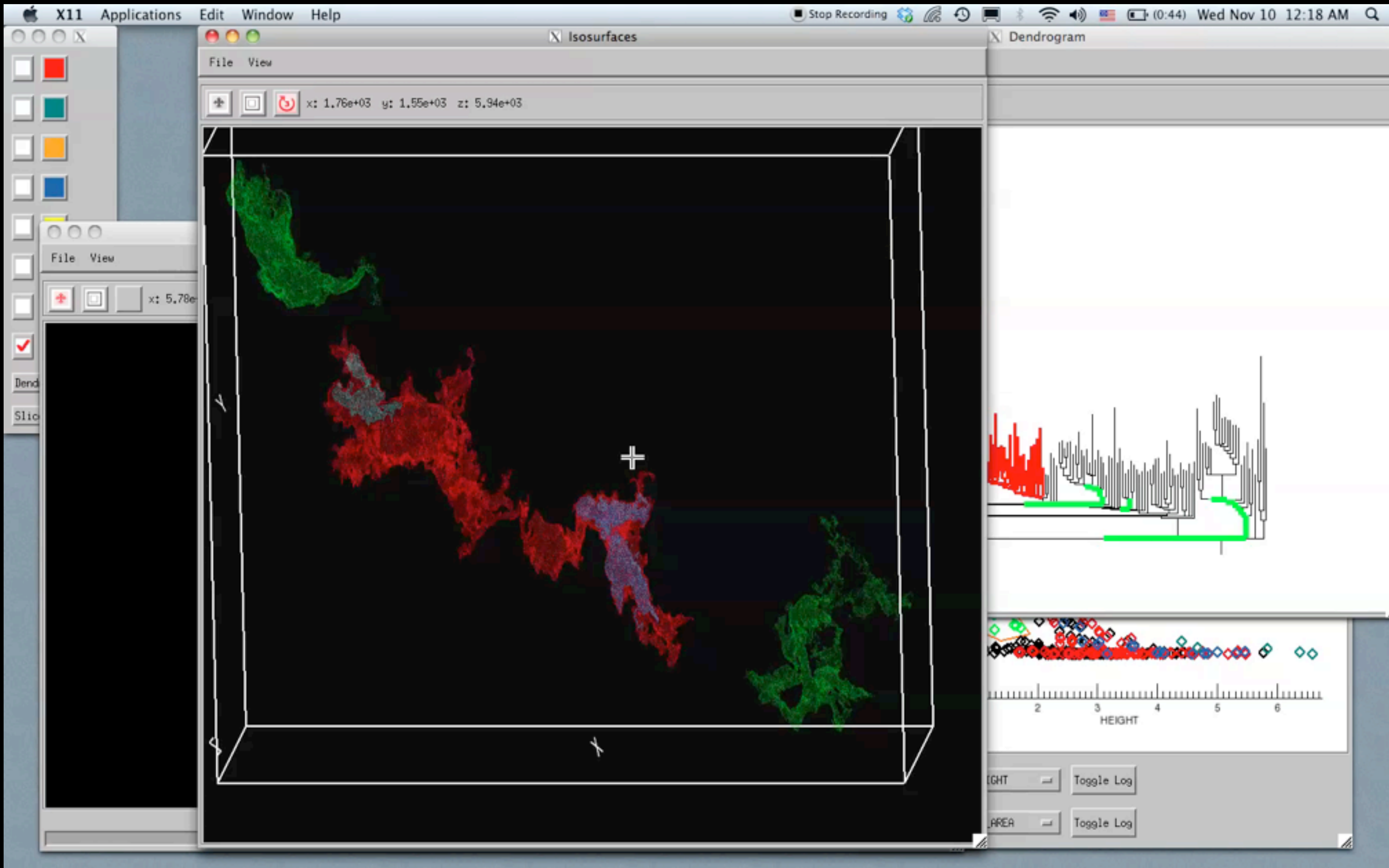
Center on Perseus | Center on Ophiuchus | Center on Serpens

Dataset	Show	Perseus	Ophiuchus	Serpens	Link
Full-Cloud Data (Phase I, All Data Available)					
GBT: HI Data Cube	☑	√	√	Ø	Data
IRAS: Av/Temp Maps	☑	√	√	√	Data
FCRAO: 12CO	☑	√	√	√	Data
FCRAO: 13CO		√	√	√	Data
JCMT: 850 microns	☑	√	√	Ø	Data
Spitzer c2d: IRAC 1,3 (3.6,5.8 µm)	☑	√	√	√	Data
Spitzer c2d: IRAC 2,4 (4.5,8 µm)	☑	√	√	√	Data
CSO/Bolocam: 1.2-mm	☑	√	Ø	Ø	Data
Spitzer MIPS: Derived Dust Map	☑	√	Ø	Ø	Data
Targeted Regions (Phase II, Some Data Not Yet Available)					
CTIO/Calar Alto: NIR (J,H,Ks)	☑	√	√	Ø	Data
IRAM 30-m: N2H+ and C18O	☑	√	Ø	Ø	Data
IRAM 30-m: 1.1-mm continuum	☑	√	Ø	Ø	Data
Megacam/MMT: r,i,z images	☑	√	Ø	Ø	Data
Catalogs & Pointed Surveys					
NH3 Pointed Survey	☐	√	Ø	Ø	Data
YSO Candidate list (c2d)	☐	√	√	√	Data

The dream scenario...



Exemplar: Linked Dendrogram Views in IDL



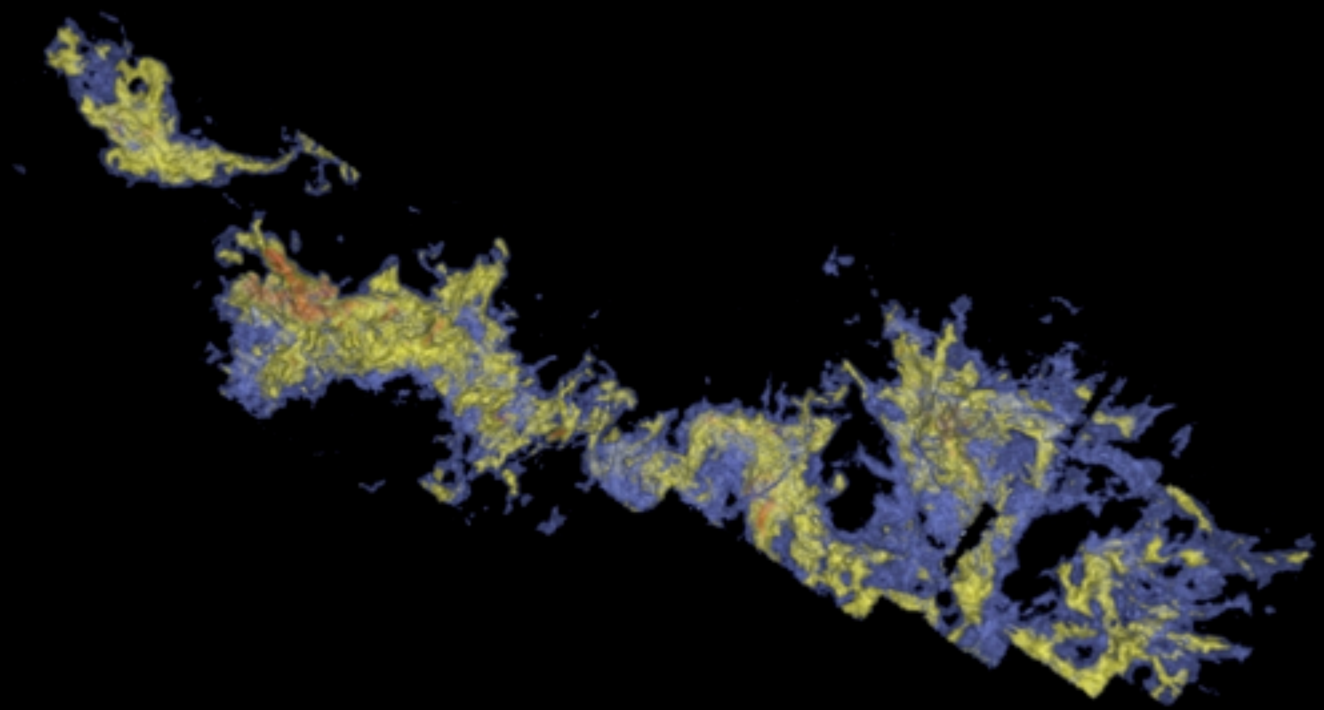
Video & implementation: Christopher Beaumont, CfA/UHawaii;
inspired by AstroMed work of Douglas Alan, Michelle Borkin, AG, Michael Halle, Erik Rosolowsky

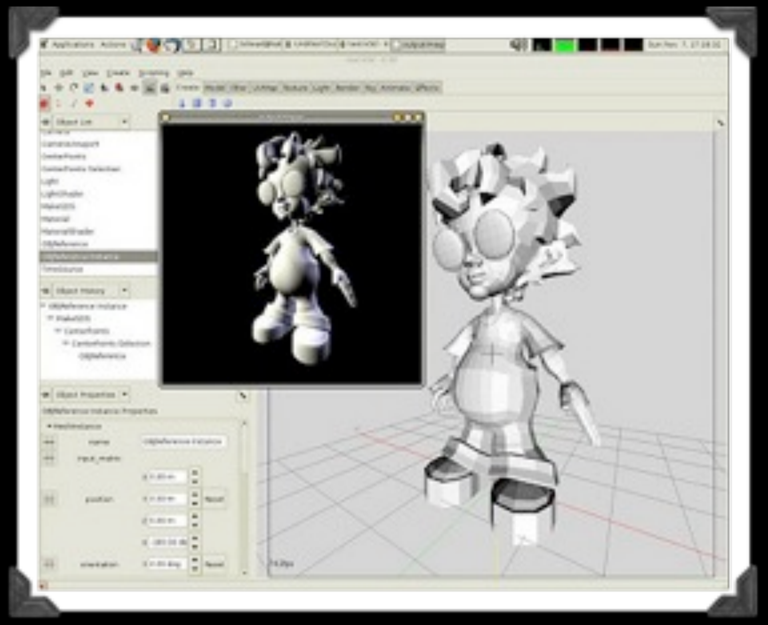
Challenge #1: 3D Selection

What's the 3D "magnetic lasso"?

How do you use it with a mouse?

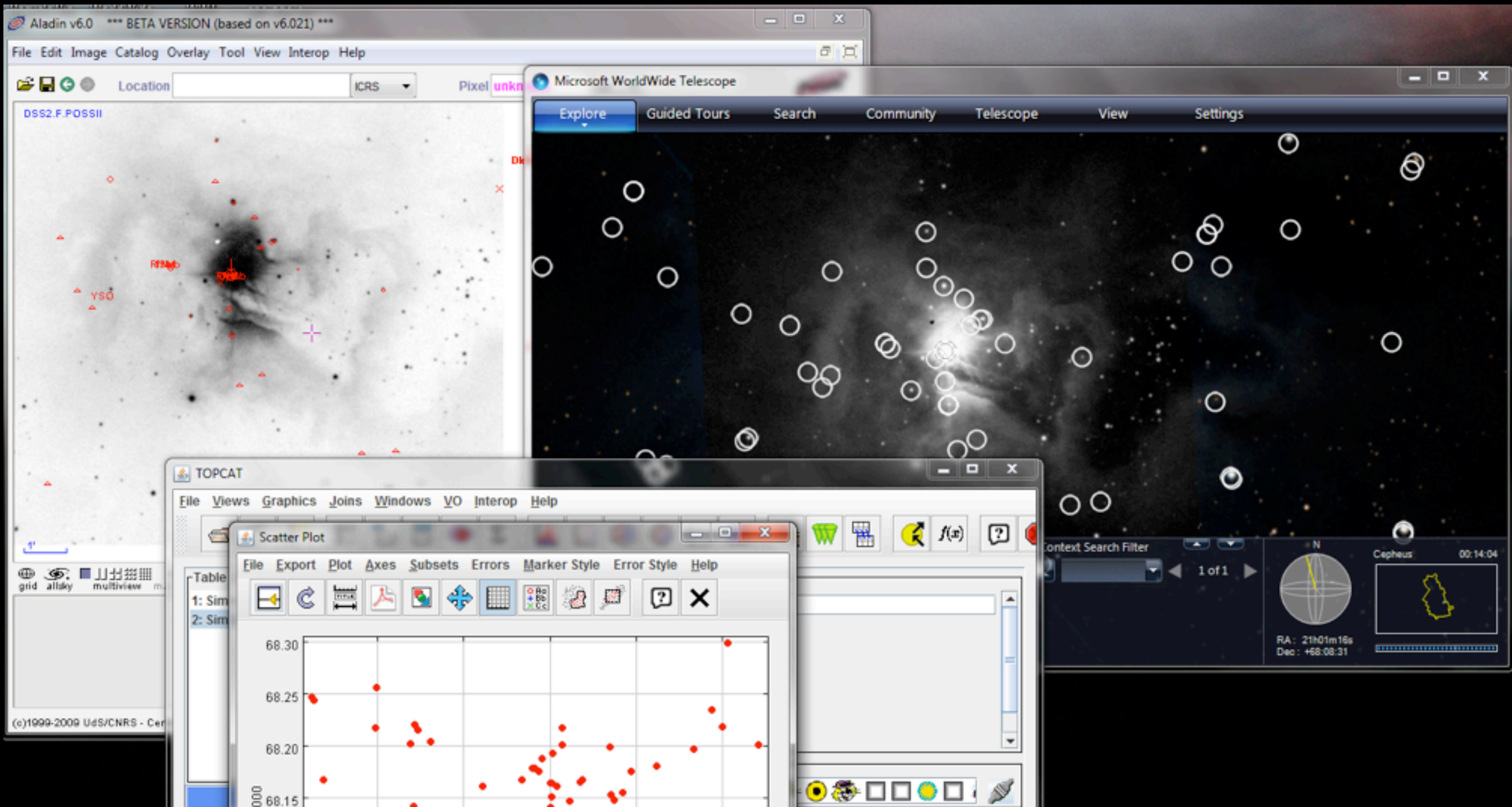
How can a human "steer" computer-aided selection?





see Michelle Borkin, Harvard Ph.D. student!

Challenge #2: Too many windows...



see Exposé, and yesterday's talk about ALMA monitoring GUI

Challenge #3:

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

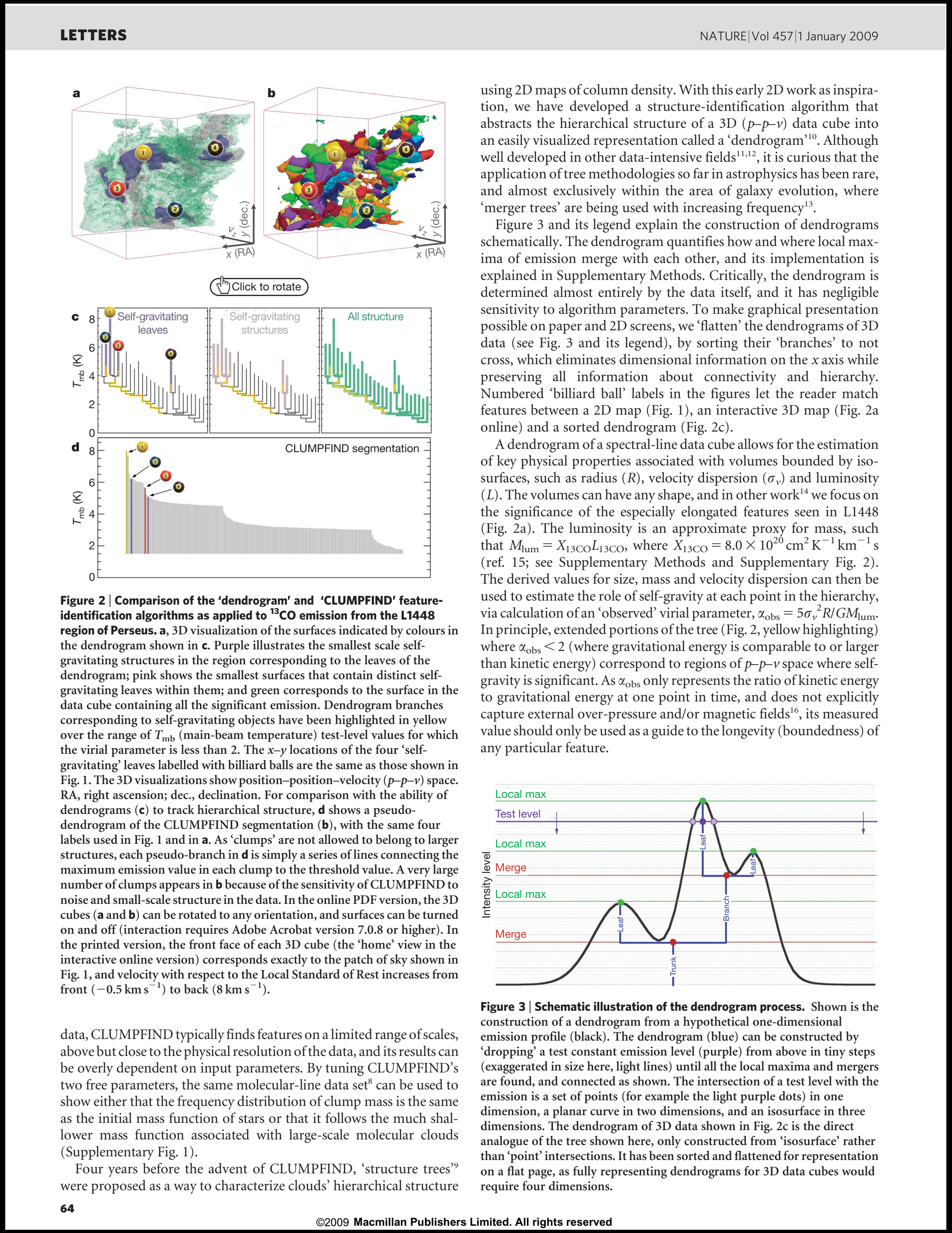

LETTERS NATURE|Vol 457|1 January 2009

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 this early 2D work as inspiration, we have developed a structure-identification algorithm that abstracts the hierarchical structure of a 3D (p–p–v) data cube into an easily visualized representation called a 'dendrogram'[10]. Although well developed in other data-intensive fields[11,12], it is curious that the application of tree methodologies so far in astrophysics has been rare, and almost exclusively within the area of galaxy evolution, where 'merger trees' are being used with increasing frequency[13].

Figure 3 and its legend explain the construction of dendrograms schematically. The dendrogram quantifies how and where local maxima of emission merge with each other, and its implementation is explained in Supplementary Methods. Critically, the dendrogram is determined almost entirely by the data itself, and it has negligible sensitivity to algorithm parameters. To make graphical presentation possible on paper and 2D screens, we 'flatten' the dendrograms of 3D data (see Fig. 3 and its legend), by sorting their 'branches' to not cross, which eliminates dimensional information on the x axis while preserving all information about connectivity and hierarchy. Numbered 'billiard ball' labels in the figures let the reader match features between a 2D map (Fig. 1), an interactive 3D map (Fig. 2a online) and a sorted dendrogram (Fig. 2c).

A dendrogram of a spectral-line data cube allows for the estimation of key physical properties associated with volumes bounded by isosurfaces, such as radius (R), velocity dispersion (σ_v) and luminosity (L). The volumes can have any shape, and in other work[14] we focus on the significance of the especially elongated features seen in L1448 (Fig. 2a). The luminosity is an approximate proxy for mass, such that $M_{lum} = X_{13CO}L_{13CO}$, 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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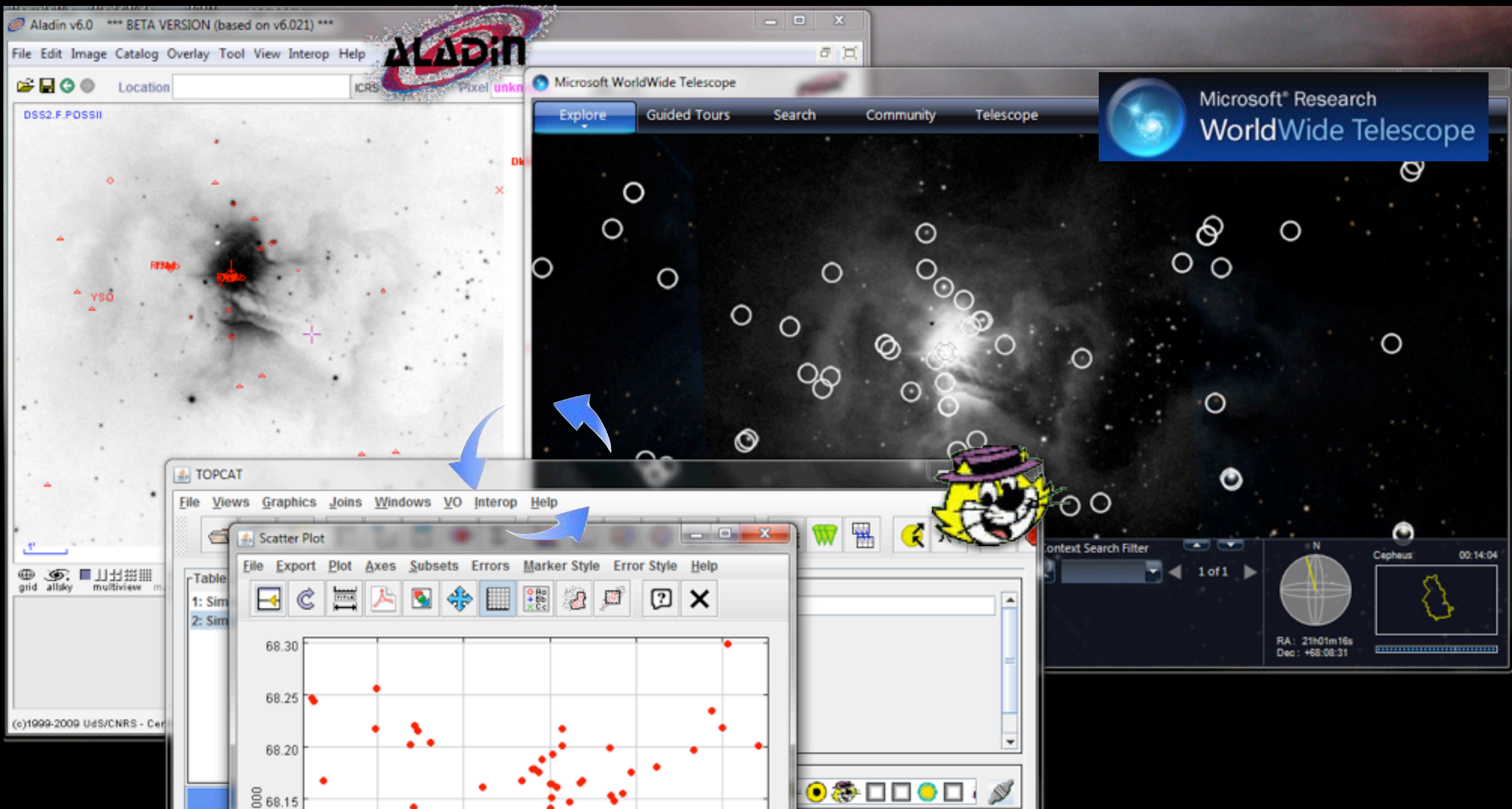
*Goodman, Rosolowsky, Borkin, Foster, Halle, Kauffmann & Pineda, **Nature**, 2009*

Will Astronomy lead or follow?

SAMP Will Astronomy lead or follow?

Simple Application Messaging Protocol



www.ivoa.net/Documents/latest/SAMP.html

Also SAMP-enabled... ASTRO WISE, ds9 ...

Huh?

Seems familiar...

Everyone knows...

Huh?

myexperiment

Taverna

zotero
Leveraging the long tail of scholarship.

Seems familiar...

TripIt

Everyone knows...

KAYAK

iGoogle

hulu

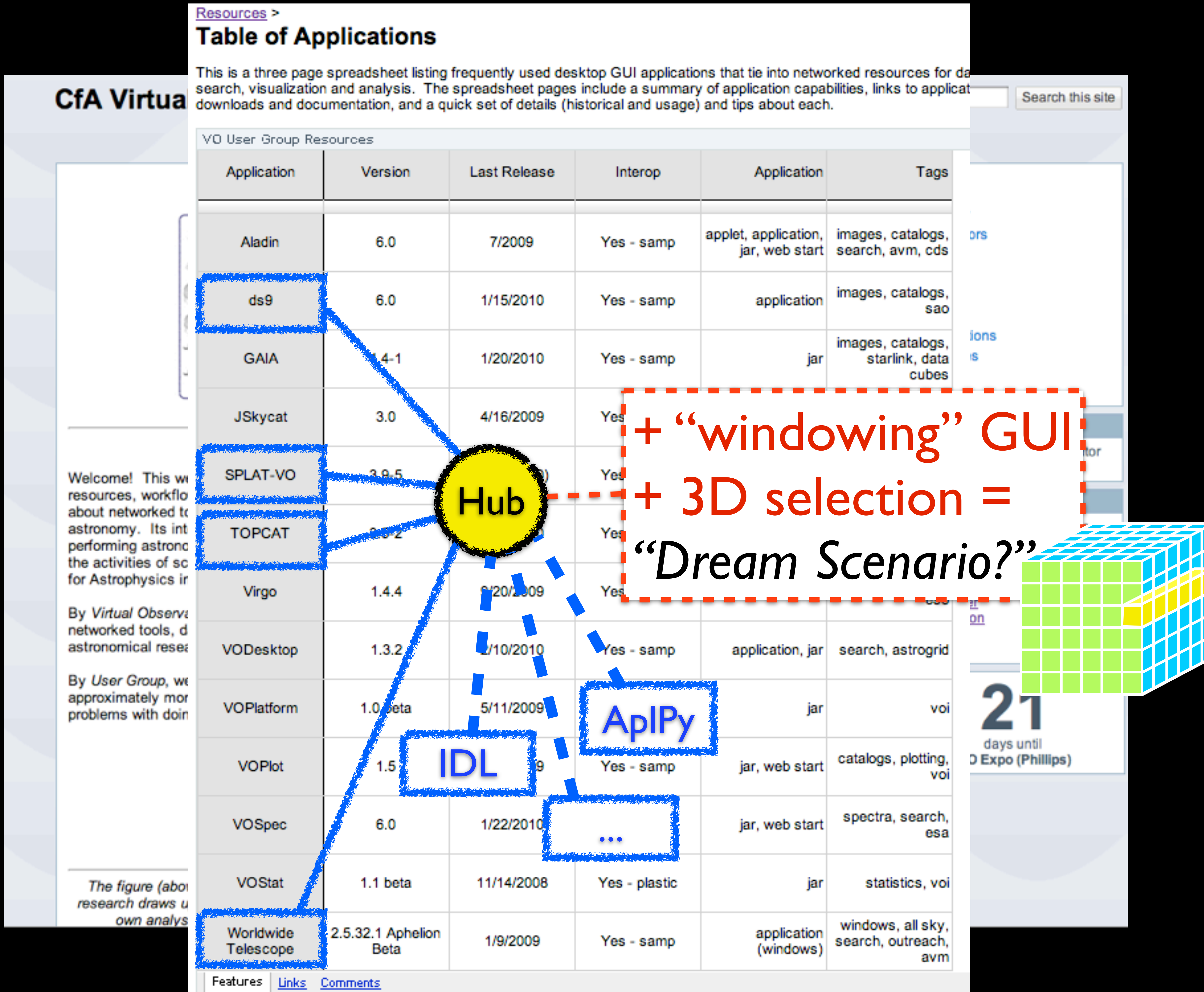
BOXEE

Microsoft® Research WorldWide Telescope

What “views” *astronomers* can use now...

summaries being prepared for VAO SAC by Alyssa Goodman, Eric Feigelson & Gus Muench *will be posted publicly*

	Aladin	DataDesk	ds9	Excel	IDL	Igor	TOPCAT	WorldWide Telescope	Amira	3D Slicer	VolView	Google Viz API	ManyEyes	R	Hanrahan	AplPy	CASA	Processing
2D scatterplot (ASCII data)	Y	Y	L	Y	Y	Y	Y	N	Y	N	?	Y	Y	Y	Y	Y	?	L
2D FITS displays (e.g. spectra)	N	N	Y	N	Y	L	N	N	?	?	?	N	N	Y	N	Y	Y	L
customizable symbols on 2D plots	L	L	N	L	Y	Y	L	N	Y	N	?	L	N	Y	?	Y	?	L
dynamic data labeling	N	N	N	L	Y	Y	?	N	?	N	?	Y	N	Y	?	?	?	L
binned (greyscale) scatterplot	N	N	N	N	Y	L	?	N	?	N	?	?	N	Y	?	?	?	L
line plot	N	N	N	L	Y	Y	Y	N	Y	N	?	Y	Y	Y	Y	Y	?	L
stacked line plots	N	N	N	L	Y	Y	L	N	?	N	?	L	L	Y	?	?	?	L
error bars/boxes	N	N	N	L	Y	Y	L	N	Y	N	?	L	N	Y	Y			L
manual histogram (bar chart)	N	Y	N	Y	Y	Y	Y	N	Y	N	?		Y	Y				L
auto histogram (adjustable binning)	N	Y	N	L	Y	Y	Y	N	?	N	?	?	Y	Y	?	?	?	L
pie chart	N	Y	N	Y	Y	Y	?	N		N	?		Y	Y				L
3D scatterplot	N	Y	N	N	?	N	N	N	?	N	?	?	N	Y	?	?	?	L
2D image plotting	Y	Y				L				L	?		N	Y				L
2D image processing	Y	N	Y	N	Y	L	N	L	Y	L	?	L	N	Y	N	?	Y	N
standard points on 2D images	Y	Y				Y				L	?			Y				L
custom points on 2D images	L	N				Y				N	?			Y				L
2D contour overlays on images	L	Y				L				L	?			Y				L
3D surface rendering	N	N				N				Y	?			Y				L
3D volume rendering	N	N				N				Y	?			N				L
Grand Tour (slices through 3D data)	N	L				L				Y	?			L				L
"2D" interactive brushing/linking	N	Y	N	N	N	N	Y	N			?			Y				N
"3D" interactive brushing/linking	N	N	N	N	N	N	N	N	N	N	?			L				N
SAMP enabled	Y	N	Y	N	N	N	Y	Y			?			N				N
tree diagrams	N	N	N	N	Y	N	N	N	?	N	N	?	N	Y	?	N	?	Y
treeplots	N	N	N	N	?	?	N	N	?	N	N	?	Y	Y				L
bubble plots ("motion charts")	N	N	N	N	N	N	N	N	N	N	N	Y	N	Y	?			L
maps of data on the Earth (points)	N	N	N	N	N	N	N	Y	N	N	N	N	L	Y	N	N	N	N
data on the Earth dist (w/in geo areas)														Y				
maps of data on the Earth (polygons)														Y				
maps of data on the Earth (images)								L						N				
maps of data on the Sky (points)							Y							L				



Resources >

Table of Applications

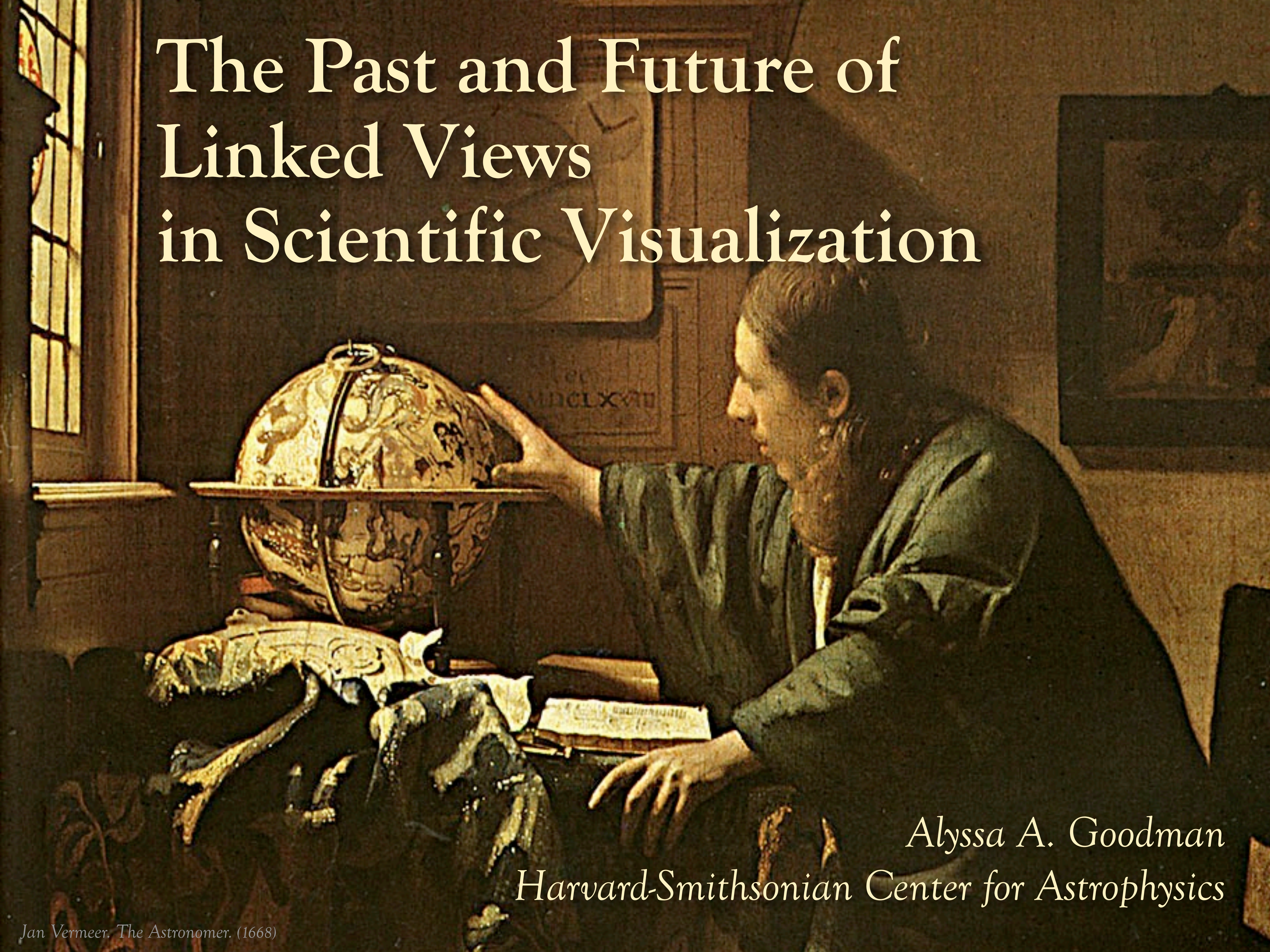
This is a three page spreadsheet listing frequently used desktop GUI applications that tie into networked resources for da search, visualization and analysis. The spreadsheet pages include a summary of application capabilities, links to applicat downloads and documentation, and a quick set of details (historical and usage) and tips about each.

VO User Group Resources

Application	Version	Last Release	Interop	Application	Tags
Aladin	6.0	7/2009	Yes - samp	applet, application, jar, web start	images, catalogs, search, avm, cds
ds9	6.0	1/15/2010	Yes - samp	application	images, catalogs, sao
GAIA	4.4-1	1/20/2010	Yes - samp	jar	images, catalogs, starlink, data cubes
JSkycat	3.0	4/16/2009	Yes	[illegible]	[illegible]
SPLAT-VO	3.9.5	[illegible]	Yes	[illegible]	[illegible]
TOPCAT	3.5-2	[illegible]	Yes	[illegible]	[illegible]
Virgo	1.4.4	9/20/2009	Yes	[illegible]	[illegible]
VODesktop	1.3.2	2/10/2010	Yes - samp	application, jar	search, astrogrid
VOPlatform	1.0 beta	5/11/2009	[illegible]	jar	voi
VOPlot	1.5	[illegible]	Yes - samp	jar, web start	catalogs, plotting, voi
VOSpec	6.0	1/22/2010	[illegible]	jar, web start	spectra, search, esa
VOStat	1.1 beta	11/14/2008	Yes - plastic	jar	statistics, voi
Worldwide Telescope	2.5.32.1 Aphelion Beta	1/9/2009	Yes - samp	application (windows)	windows, all sky, search, outreach, avm

Features Links Comments

The Past and Future of Linked Views in Scientific Visualization



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Jan Vermeer. The Astronomer. (1668)