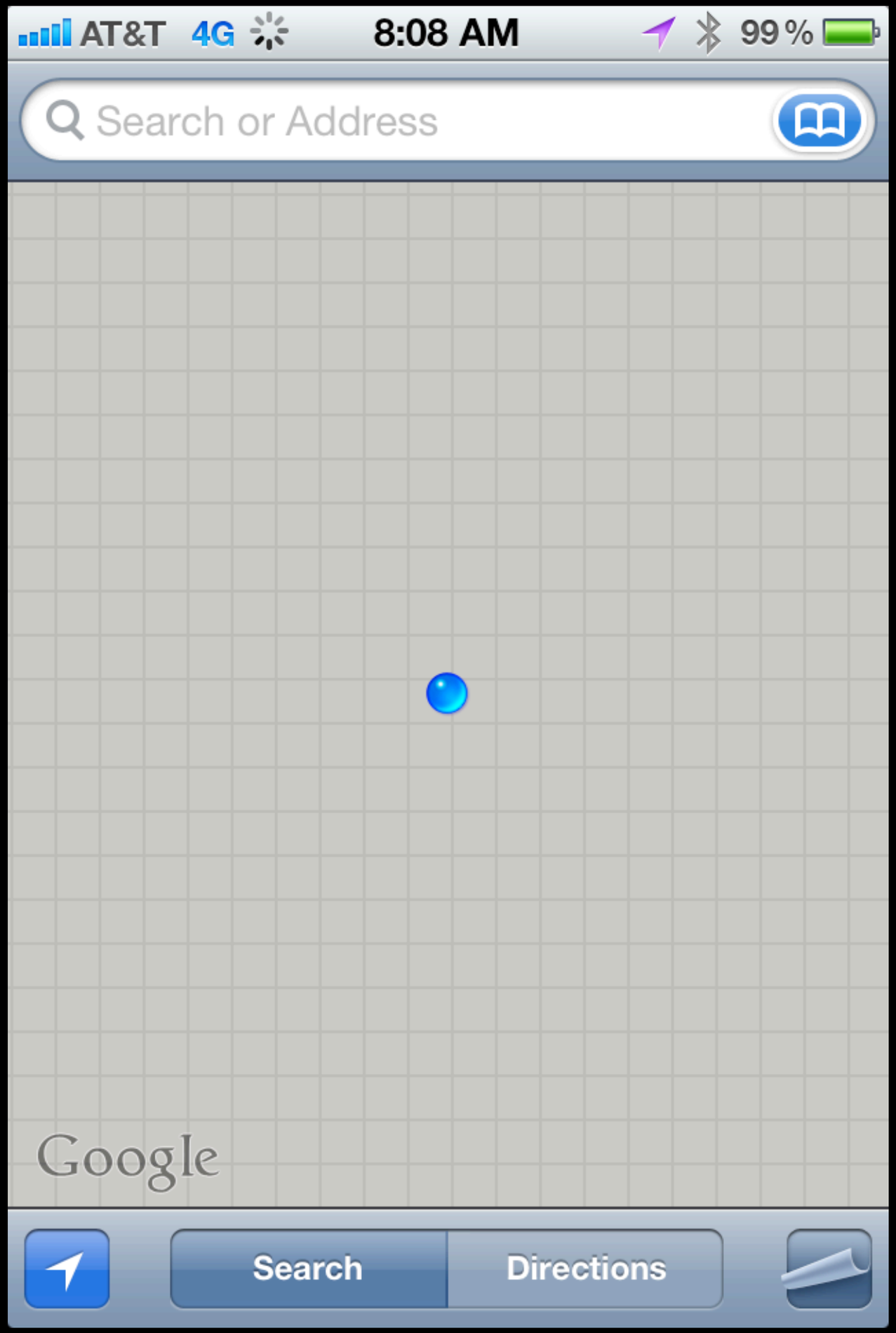
The Value of Context in Astronomy

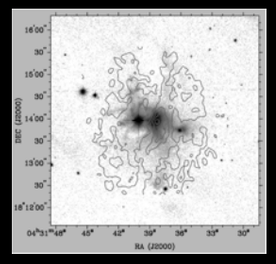
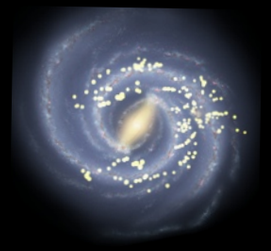
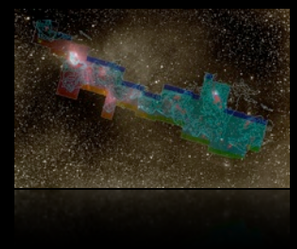
Alyssa Goodman
Harvard-Smithsonian Center for Astrophysics



The Value of Context in Astronomy

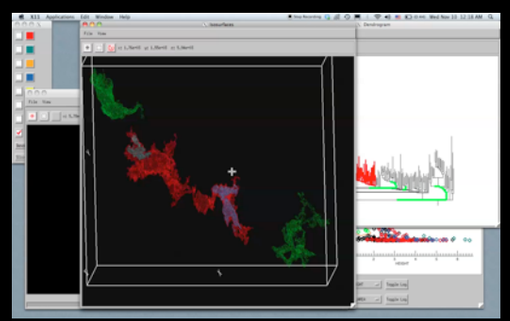
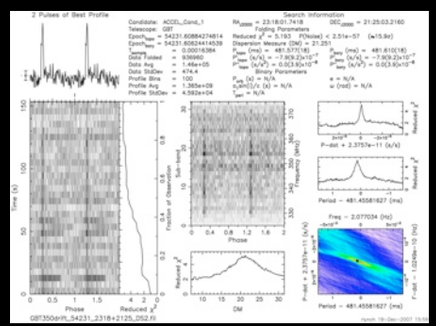
Value: *Compared to what?*

Validation & Discovery

Context

Spatial & Abstract

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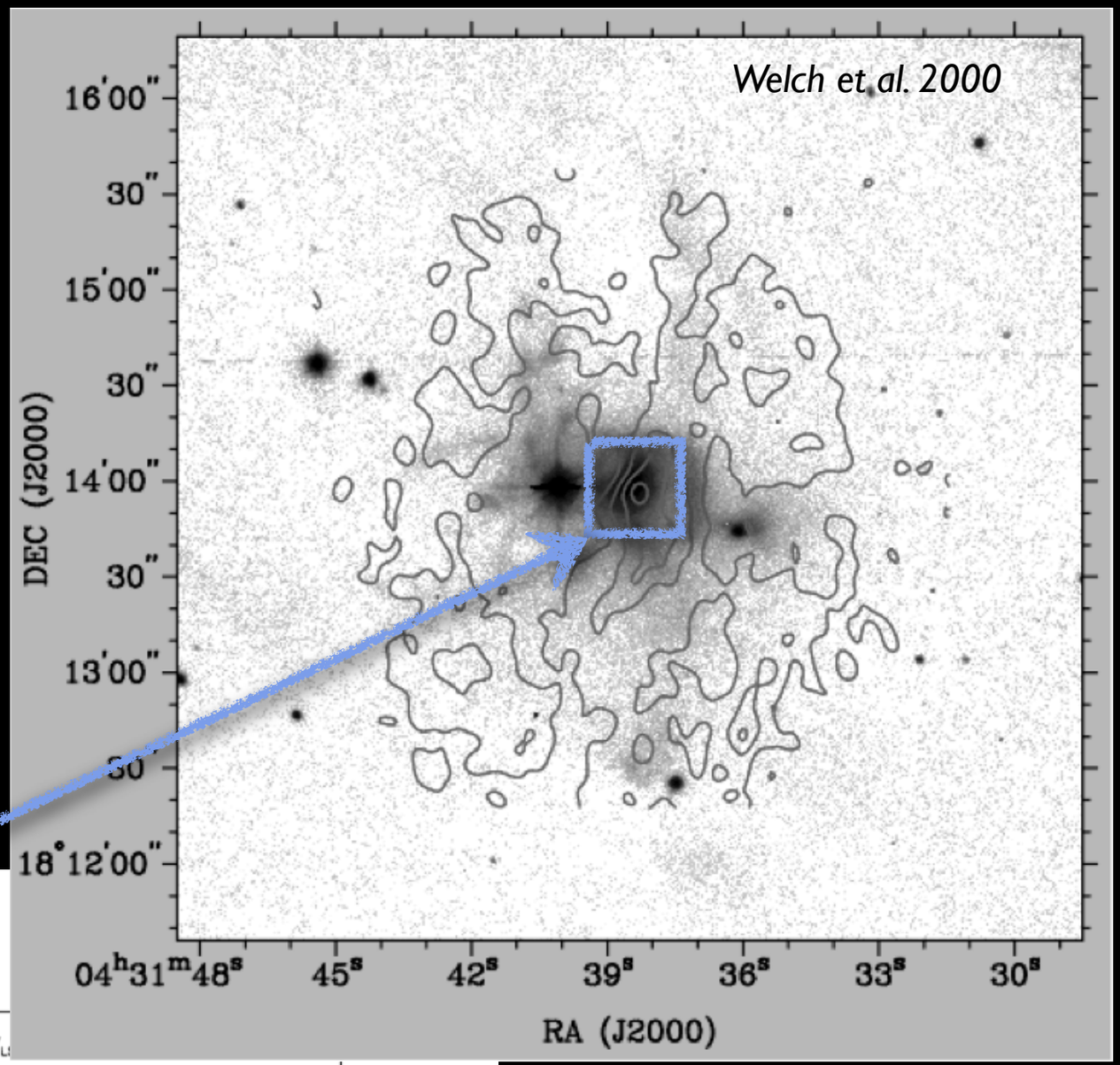


Sargent & Beckwith 1991

1991ApJ...382L..31S

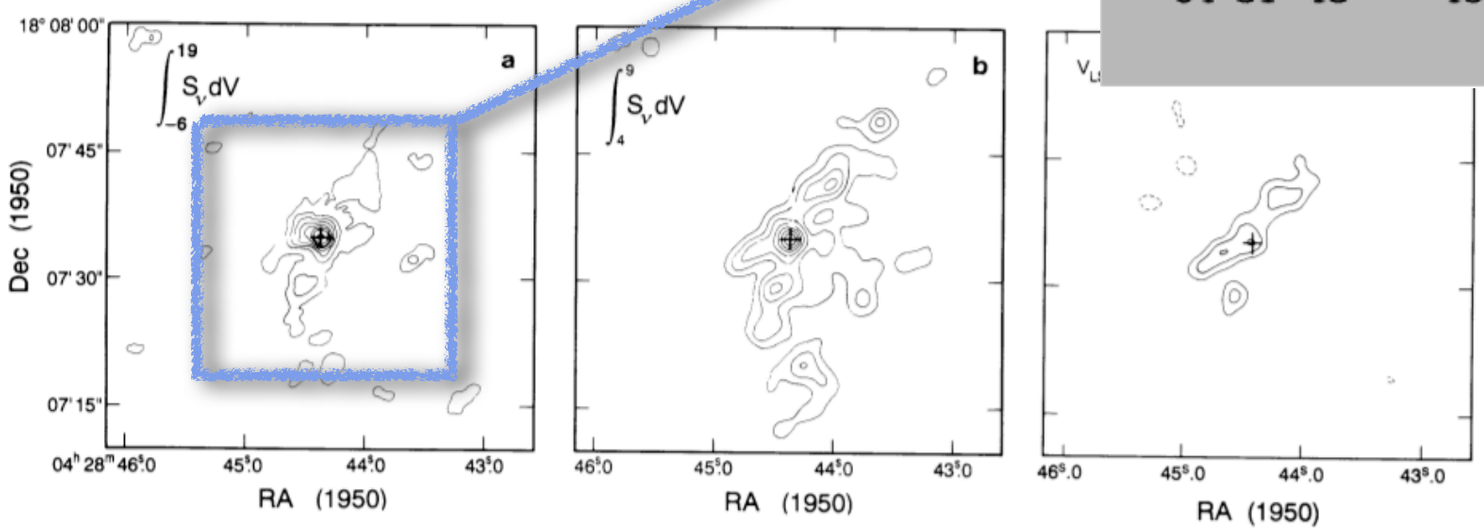


FIG. 1.—(*a*) A map of the ^{13}CO emission around HL Tau at 2".7 resolution integrated over the velocity range −22 to +27 km s^{-1}. Contours are at 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 90% of the peak flux, 7.2 Jy beam^{-1} km s^{-1}. This peak is coincident with the stellar position and is marked by a cross. (*b*) As 1*a*, but integrated over the velocity range 4.0–9.2 km s^{-1}. Contours begin at the 1 σ level, 250 mJy beam^{-1} km s^{-1} and are separated by 250 mJy beam^{-1} km s^{-1}. A cross at the position of peak emission, 2.0 Jy beam^{-1} km s^{-1}, again represents the star. (*c*) A 2".7 resolution, 1 MHz channel map centered on 5.3 km s^{-1} (encompassing the velocity range 4.0–6.6 km s^{-1}). Contours begin at the 3 σ level, 150 mJy beam^{-1}, and are separated by 100 mJy beam^{-1}. A cross represents the star.

“Taurus” Zoom...~100,000 times (25 pc to 75 AU)

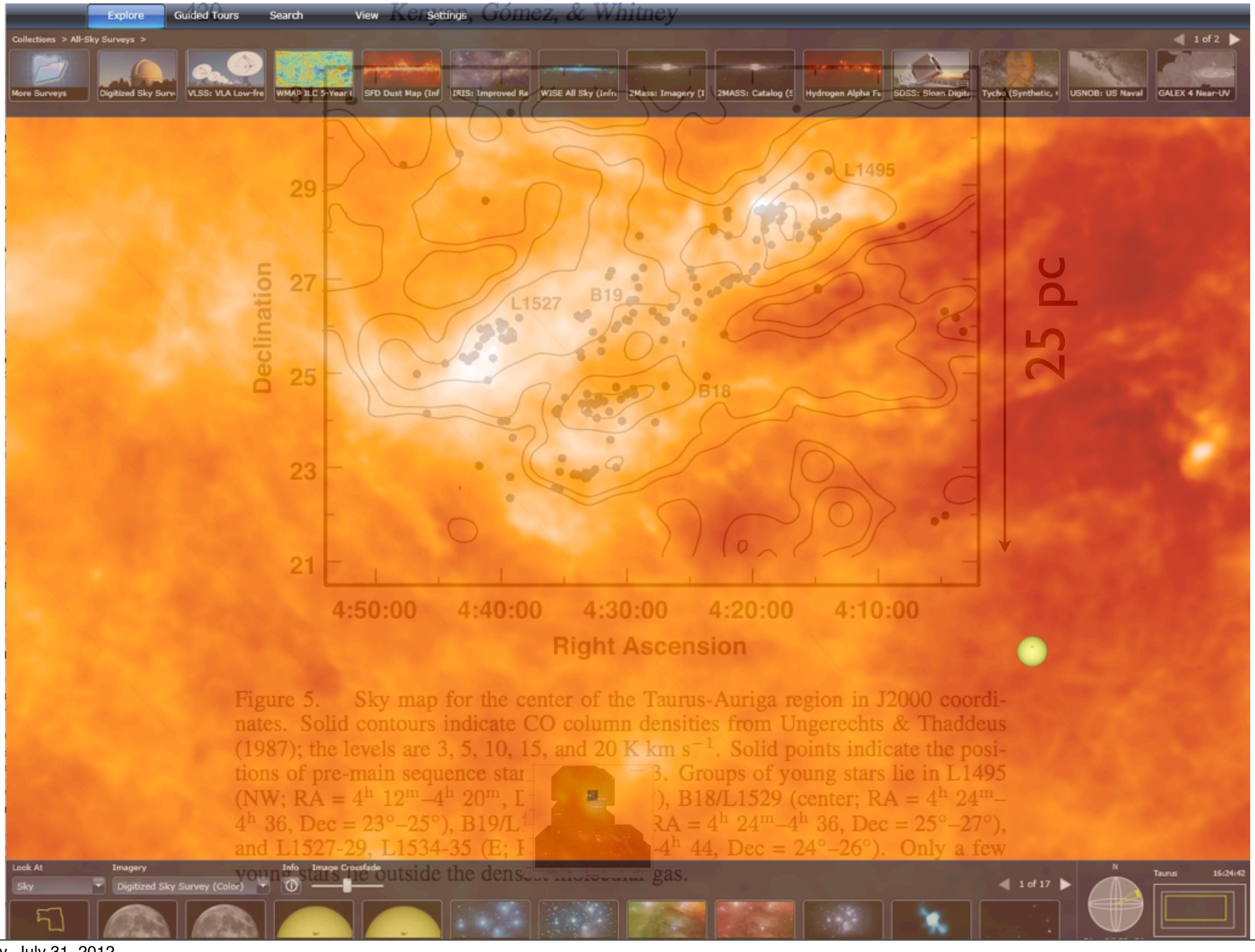
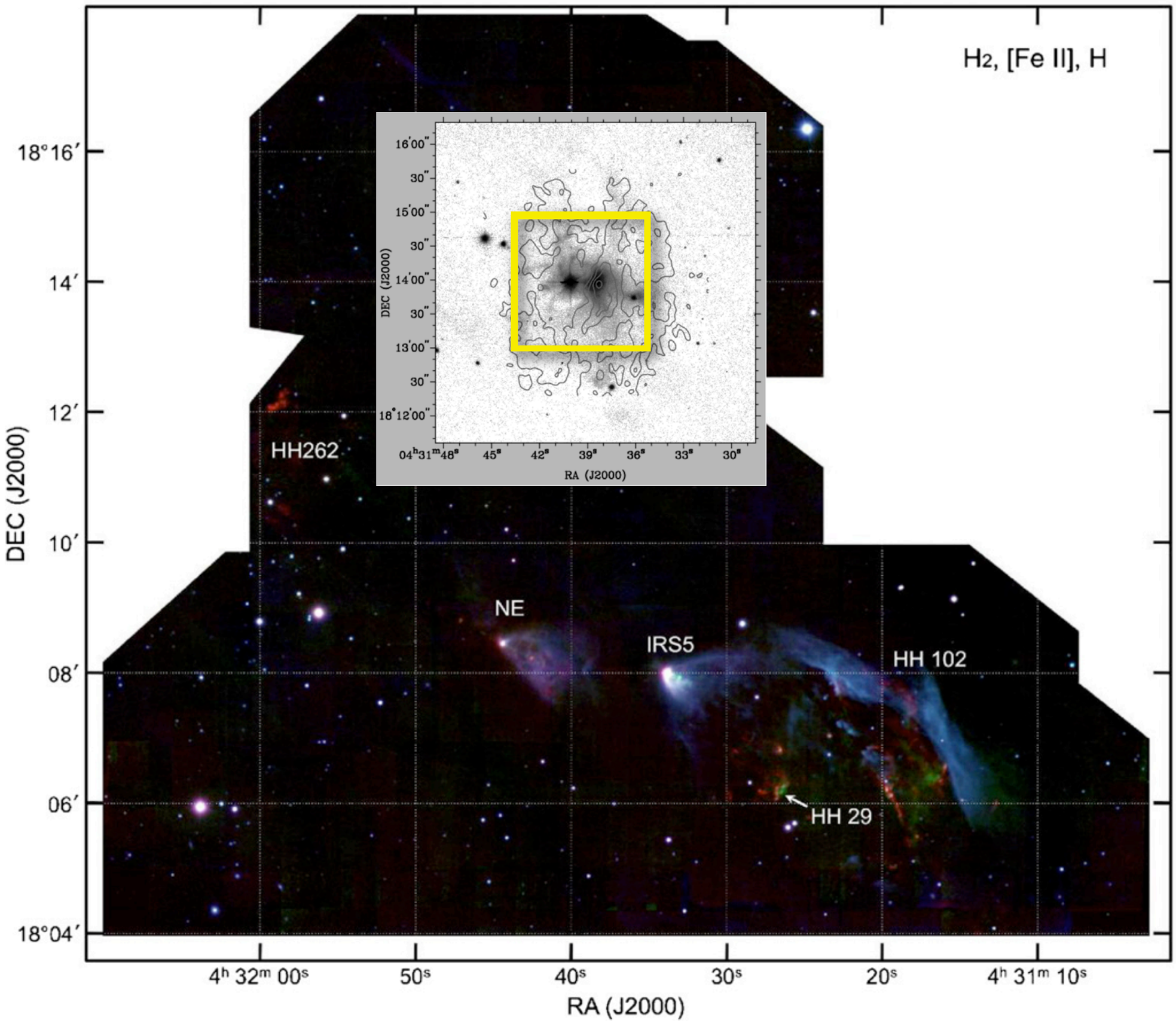


Figure 5. Sky map for the center of the Taurus-Auriga region in J2000 coordinates. Solid contours indicate CO column densities from Ungerechts & Thaddeus (1987); the levels are 3, 5, 10, 15, and 20 K km s^{-1}. Solid points indicate the positions of pre-main sequence star[illegible]3. Groups of young stars lie in L1495 (NW; RA = 4^h 12^m–4^h 20^m, D[illegible]), B18/L1529 (center; RA = 4^h 24^m–4^h 36, Dec = 23°–25°), B19/L[illegible]RA = 4^h 24^m–4^h 36, Dec = 25°–27°), and L1527-29, L1534-35 (E; R[illegible]-4^h 44, Dec = 24°–26°). Only a few young stars lie outside the densest molecular gas.


H2, [Fe II], H
HH262
NE
IRS5
HH 102
HH 29
DEC (J2000)
RA (J2000)
18°16′
14′
12′
10′
08′
06′
18°04′
4h 32m 00s
50s
40s
30s
20s
4h 31m 10s
16'00"
30"
15'00"
30"
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30"
18°12'00"
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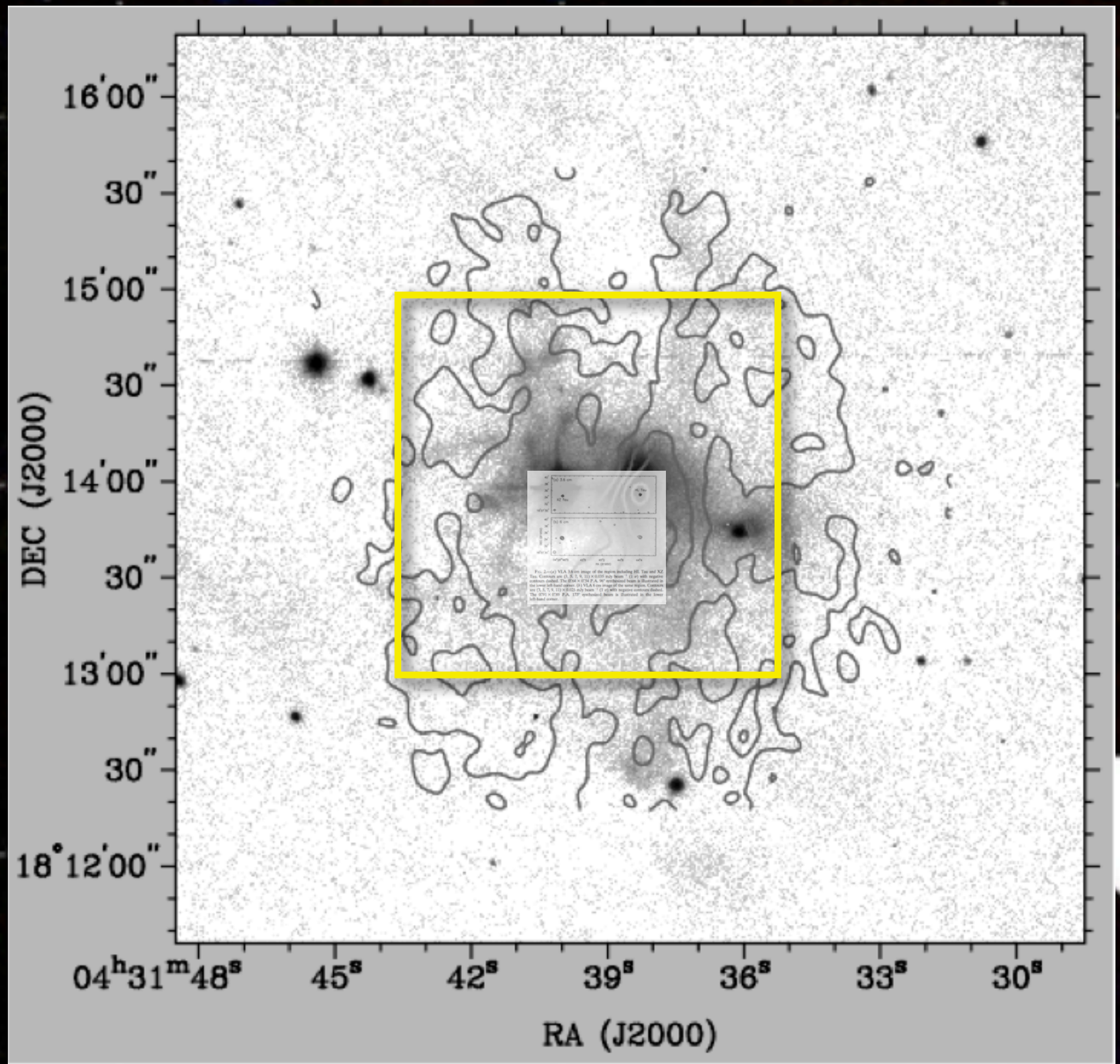
45s
42s
39s
36s
33s
30s


16'00"
30"
15'00"
30"
14'00"
30"
13'00"
30"
18°12'00"
DEC (J2000)
04h31m48s
45s
42s
39s
36s
33s
30s
RA (J2000)

HH262

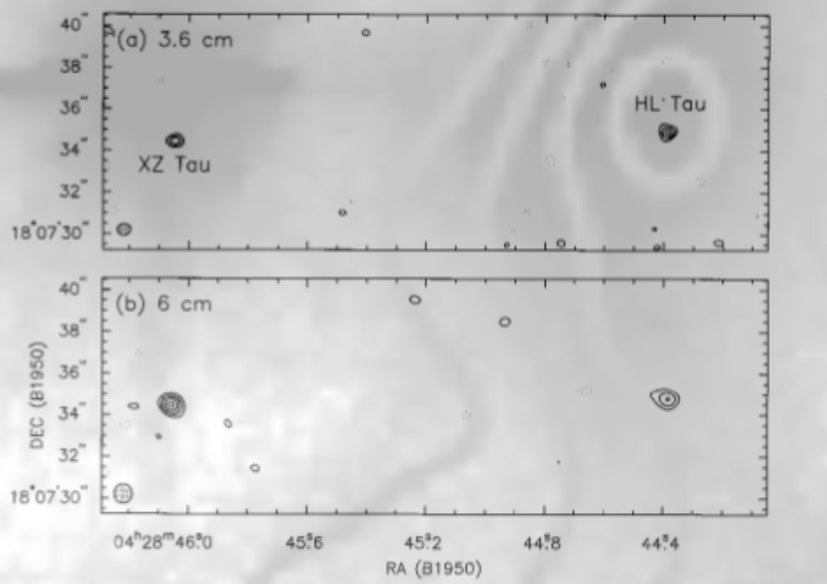
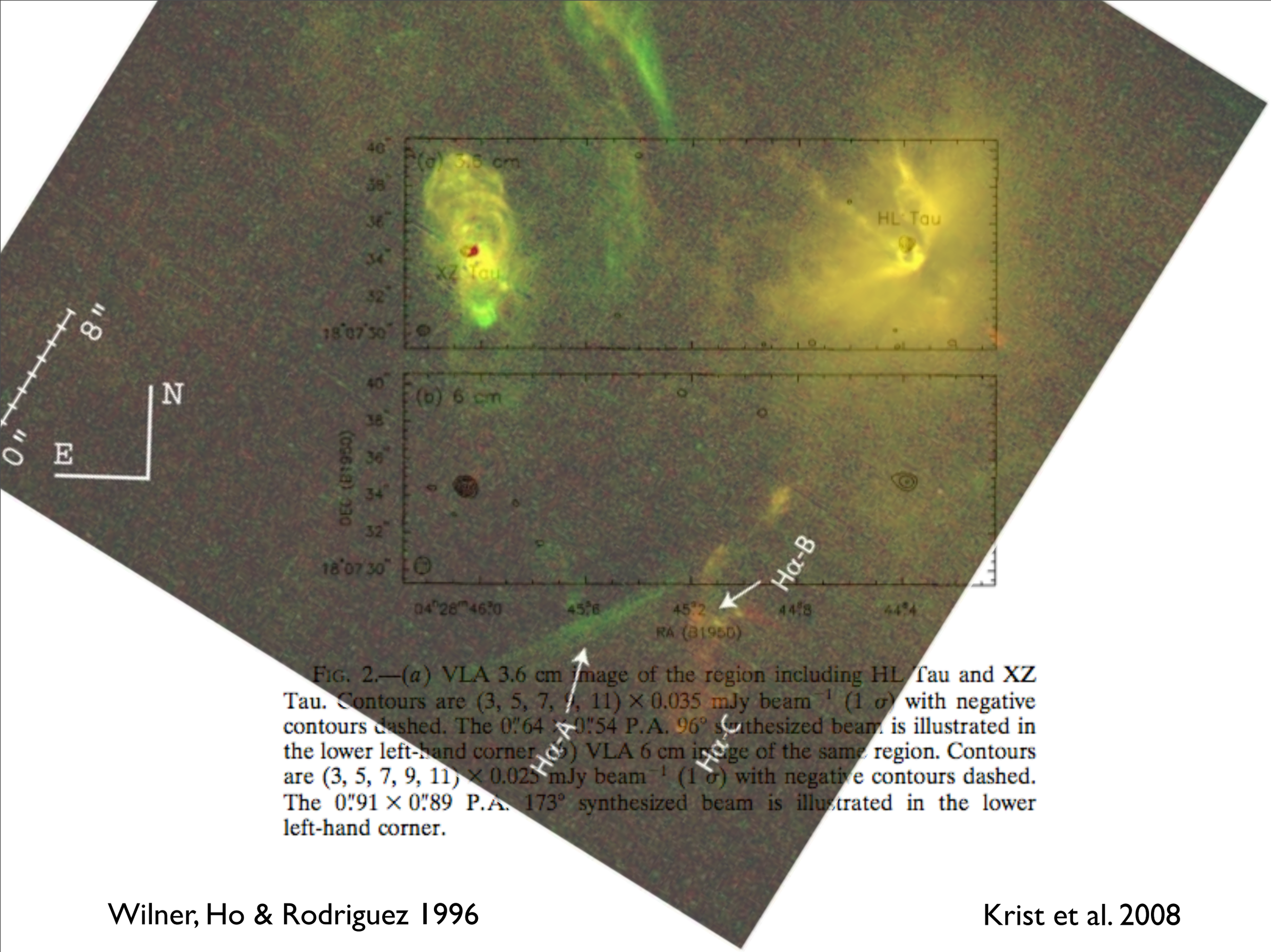


FIG. 2.—(*a*) VLA 3.6 cm image of the region including HL Tau and XZ Tau. Contours are (3, 5, 7, 9, 11) × 0.035 mJy beam^{-1} (1 σ) with negative contours dashed. The 0".64 × 0".54 P.A. 96° synthesized beam is illustrated in the lower left-hand corner. (*b*) VLA 6 cm image of the same region. Contours are (3, 5, 7, 9, 11) × 0.025 mJy beam^{-1} (1 σ) with negative contours dashed. The 0".91 × 0".89 P.A. 173° synthesized beam is illustrated in the lower left-hand corner.



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Wilner, Ho & Rodriguez 1996

Krist et al. 2008

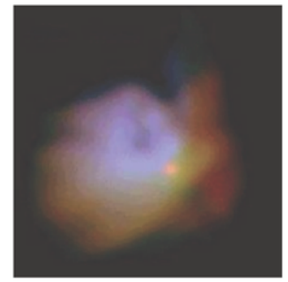

Figure 13. Image of HL Tauri in the I, J, and H filters from Close et al. (1997). The image is roughly 6″ on a side. Blue colors (I) trace material close to the outflow cavity; green colors (J) trace material in the disk and infalling envelope; red colors (H) trace scattered emission from the star and highly reddened light in the disk.

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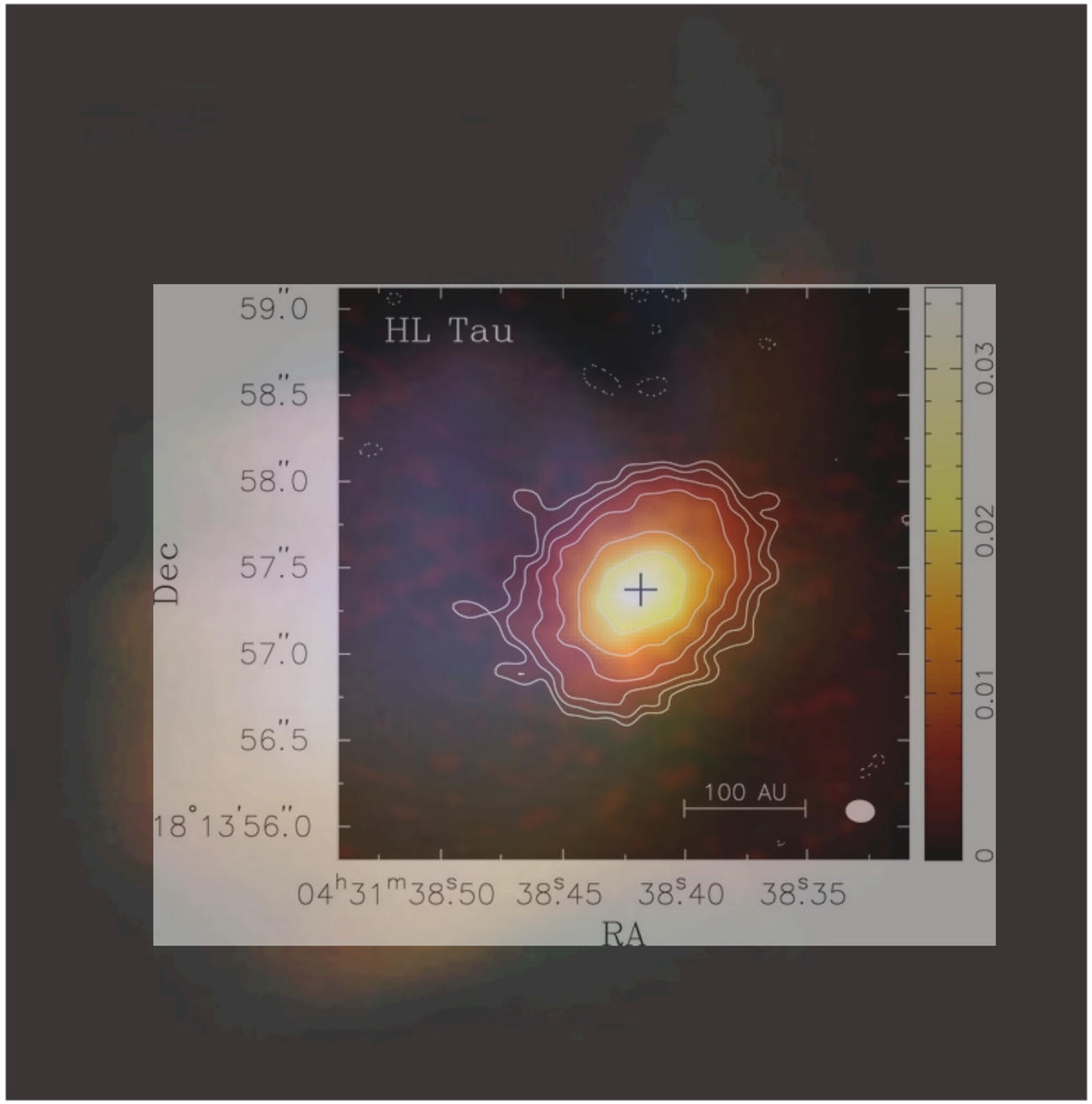

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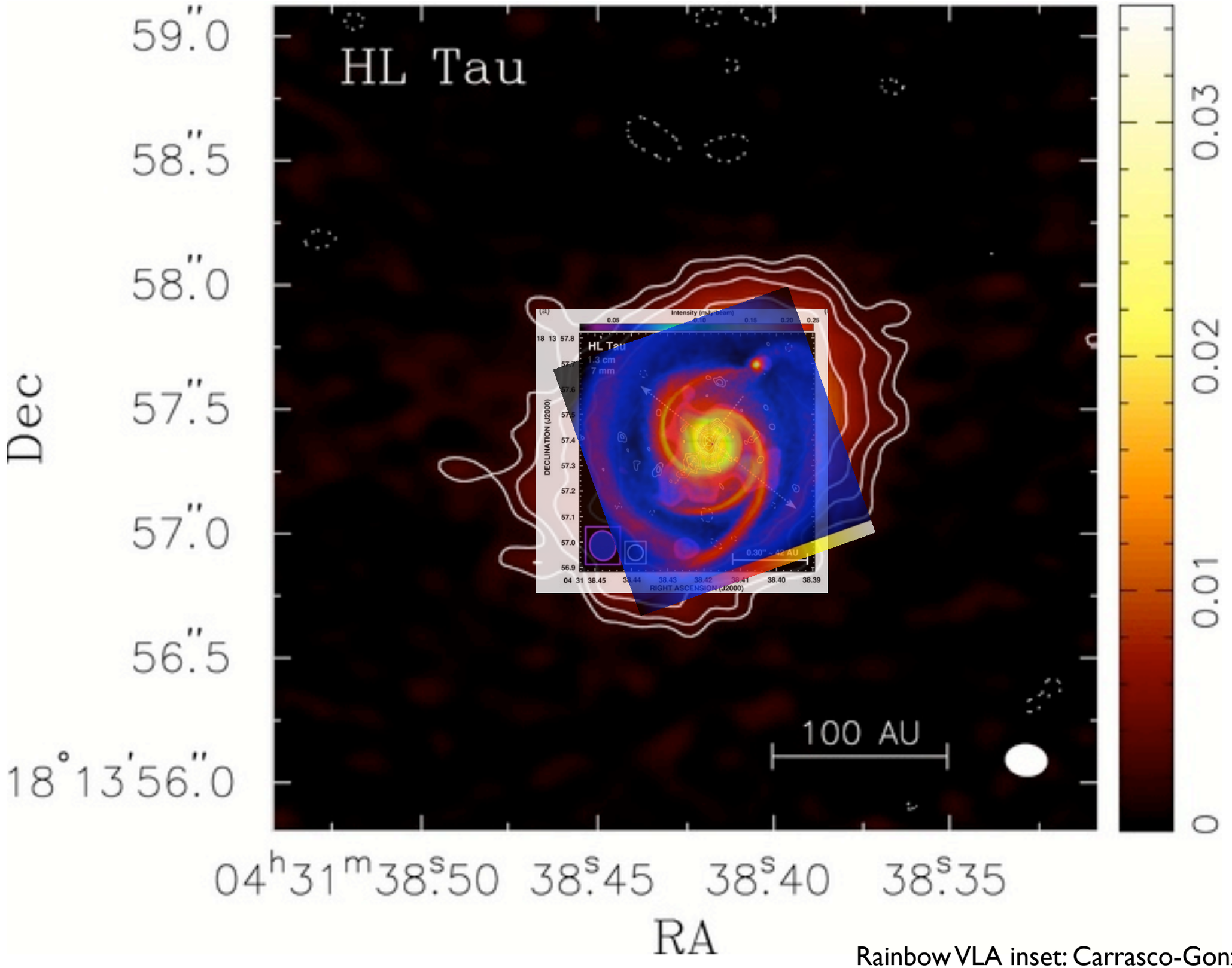
Orange CARMA inset: Kwan, Looney & Mundy 2011

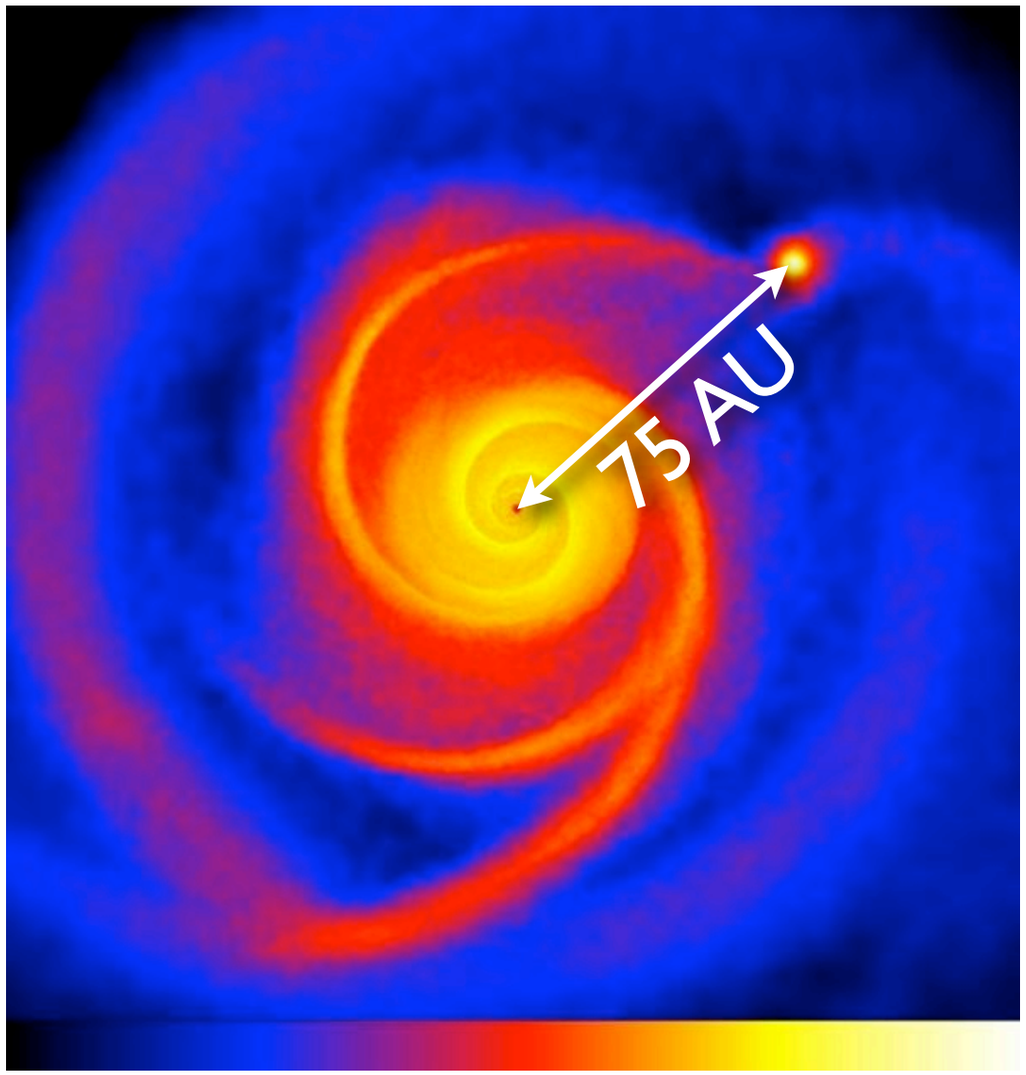


Rainbow VLA inset: Carrasco-González et al. 2009

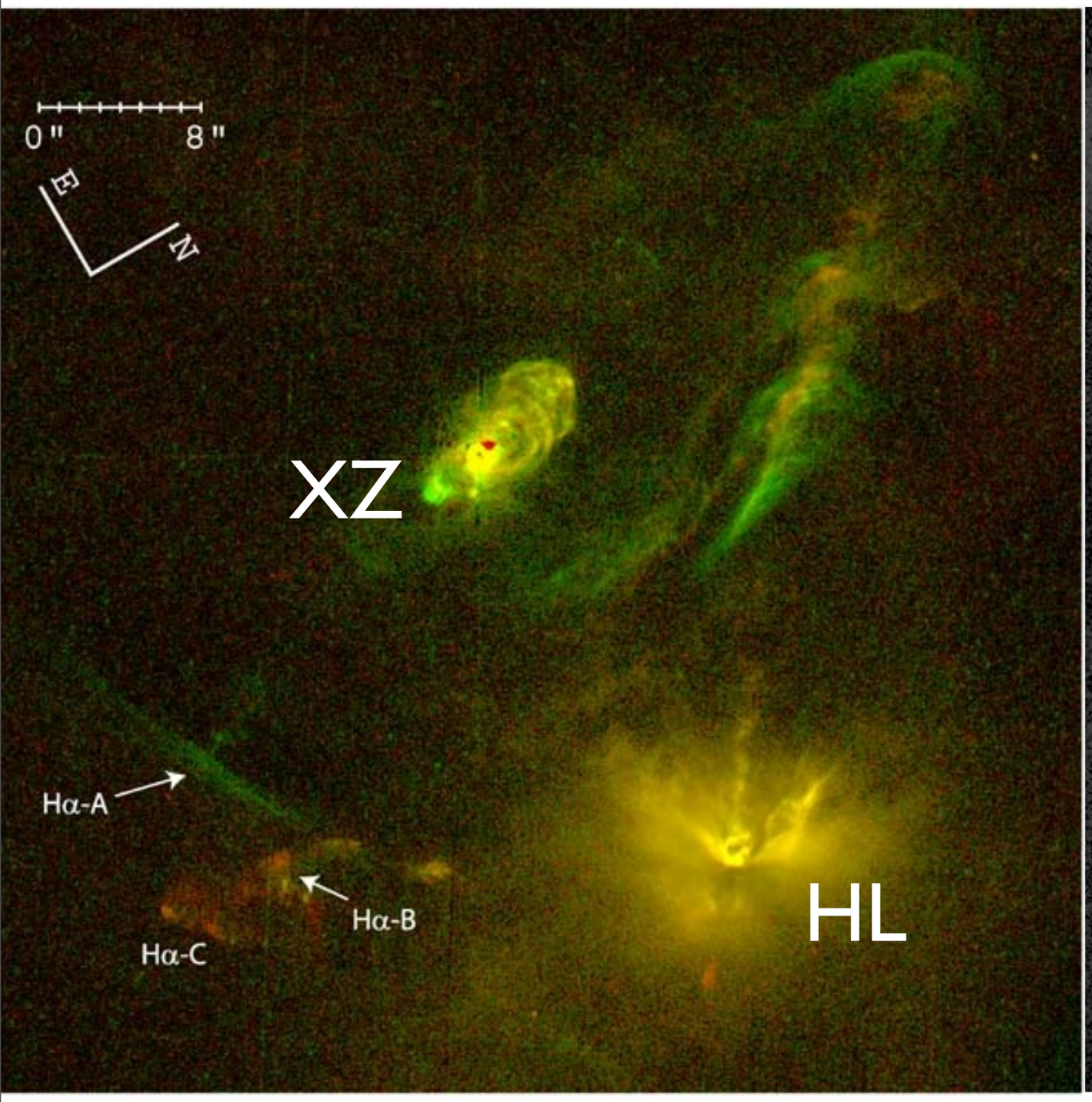
Orange CARMA inset: Kwan, Looney & Mundy 2011

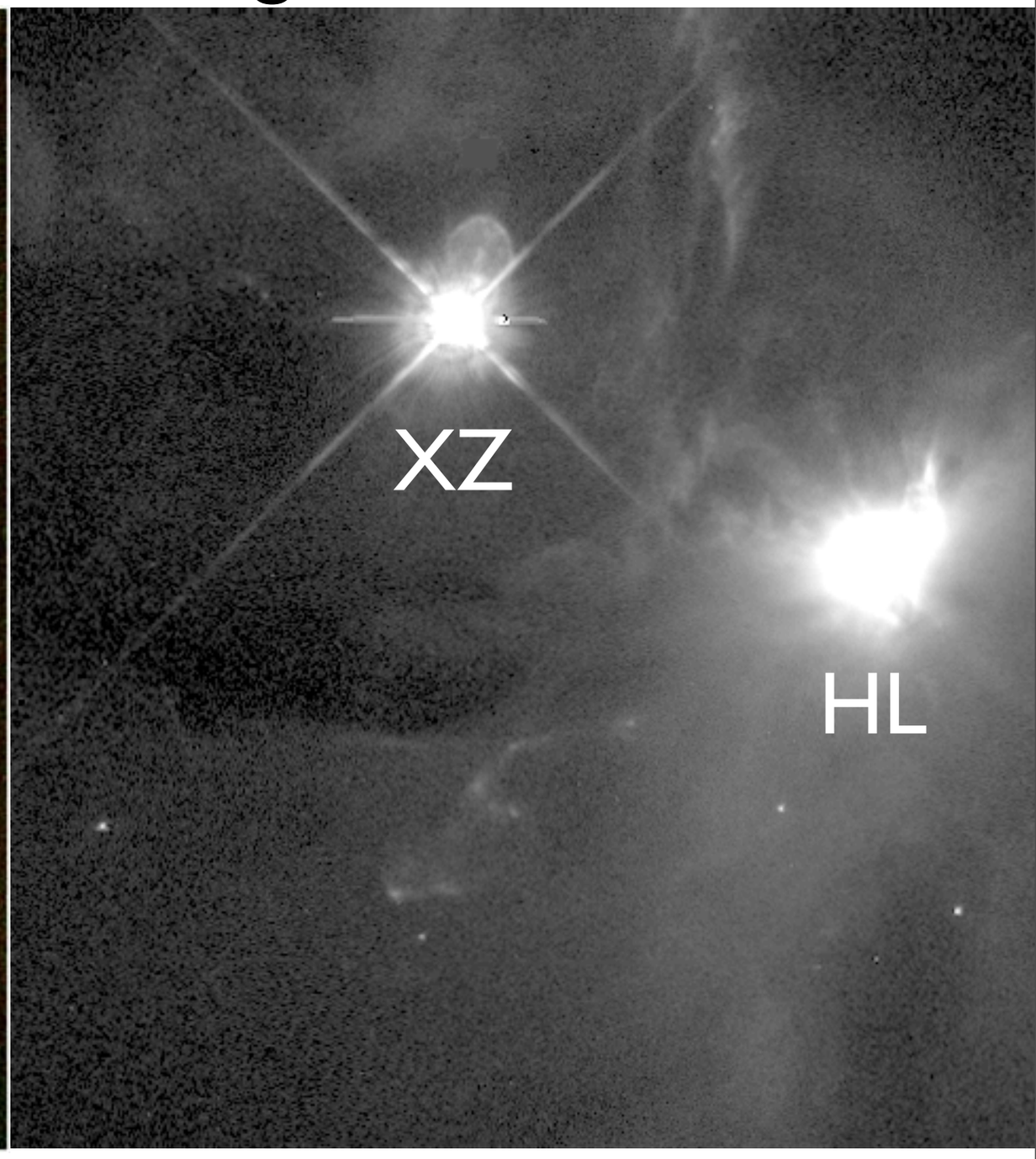
Disk/Planet Model: Greaves et al. 2008

“Taurus” Zoom...~100,000 times (25 pc to 75 AU)



Adding a time dimension...





Krist et al. 2008

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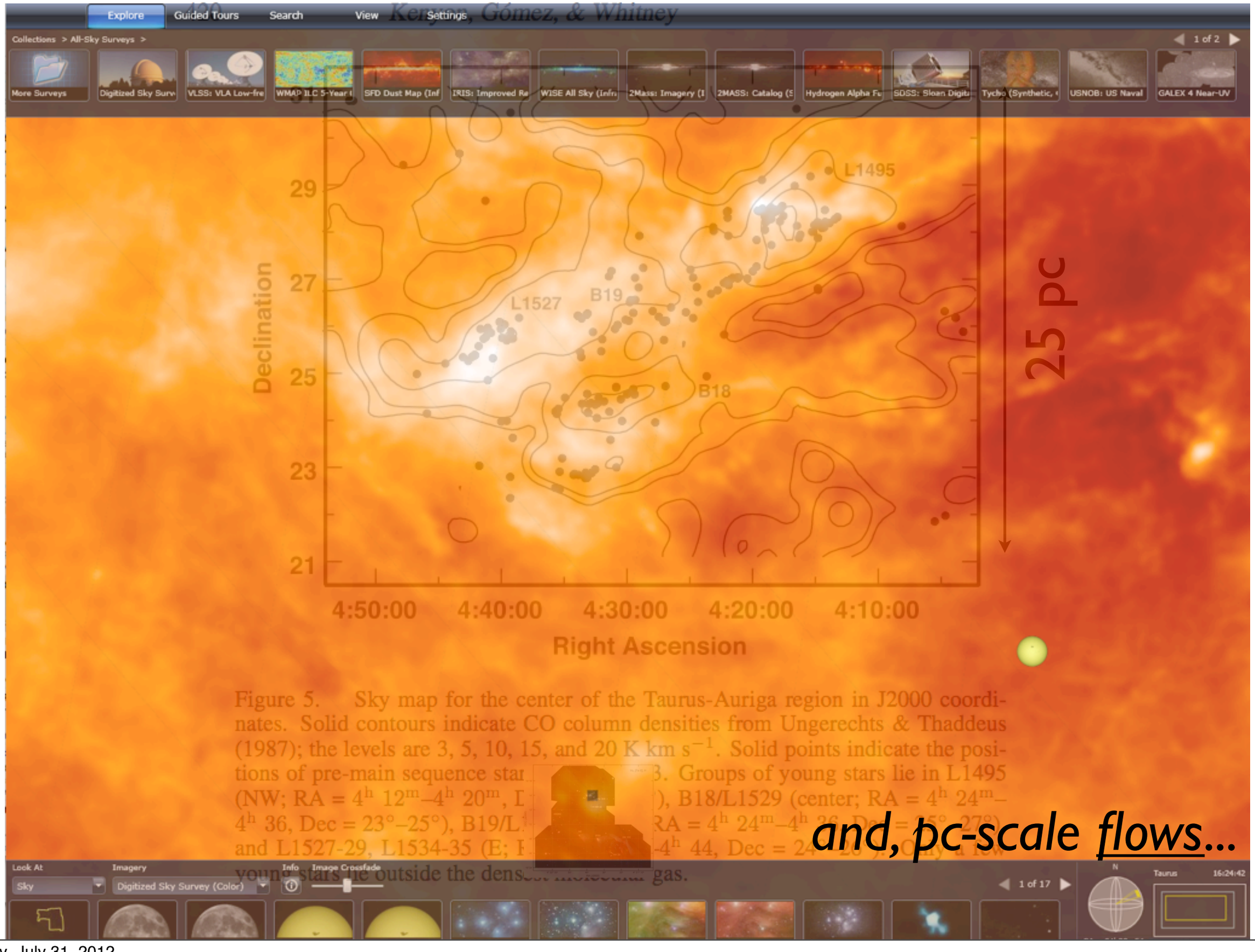

and, pc-scale flows...

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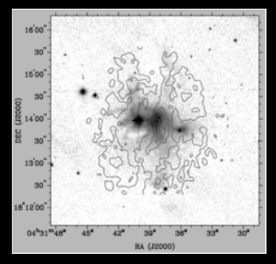
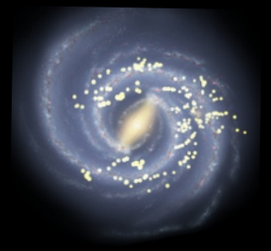
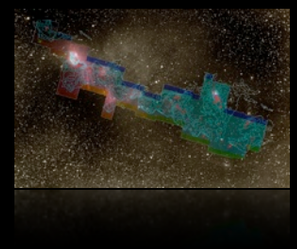

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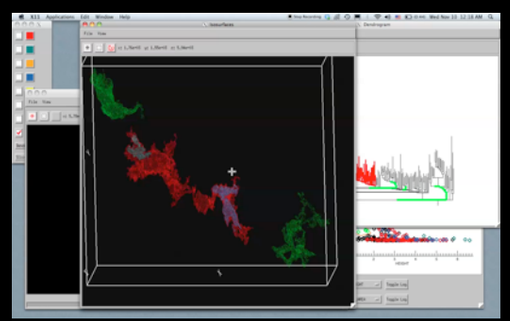
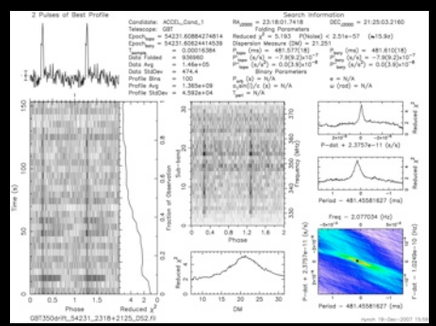
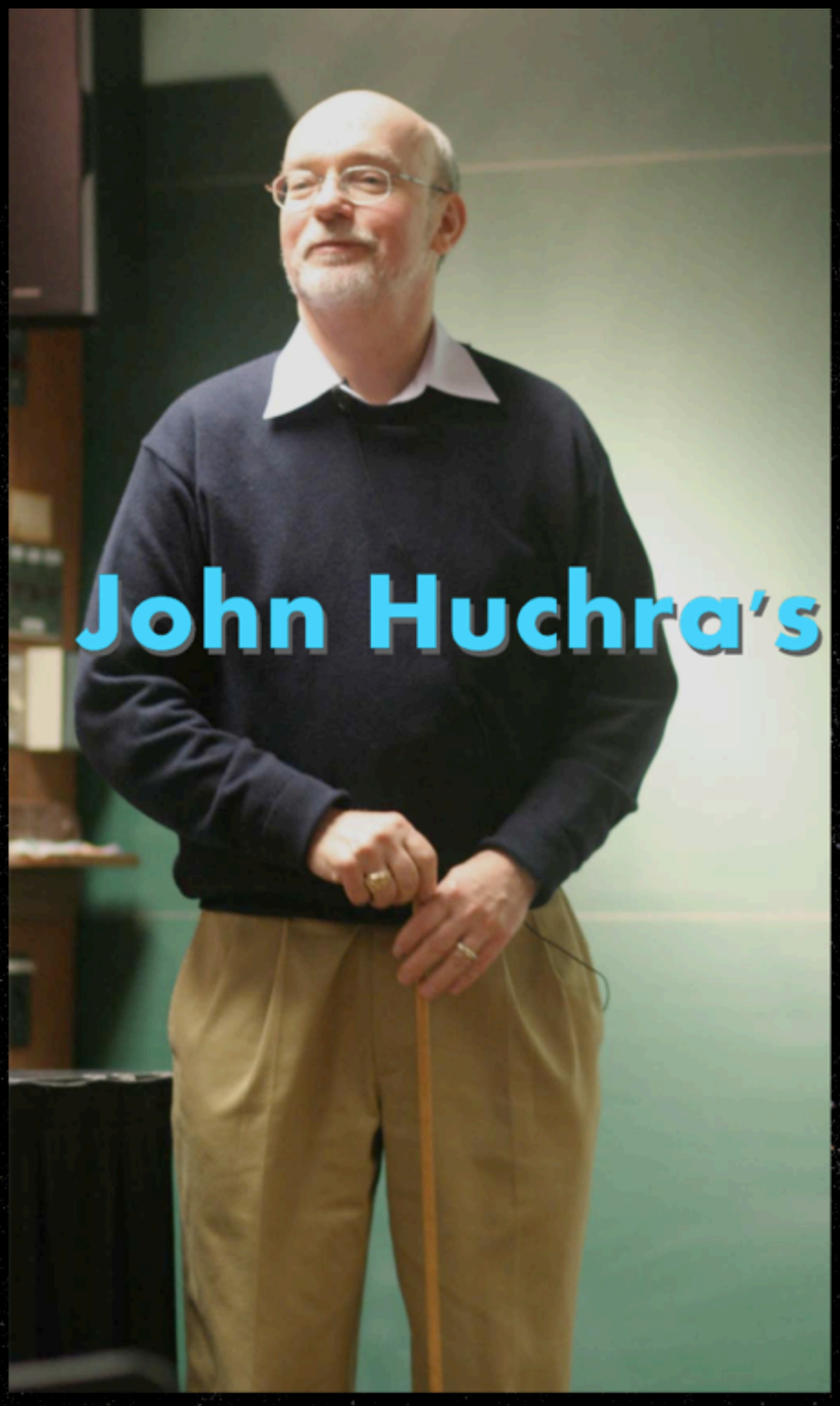
Spatial & Abstract



John Huchra's Universe

How John Huchra
fixed the Universe...

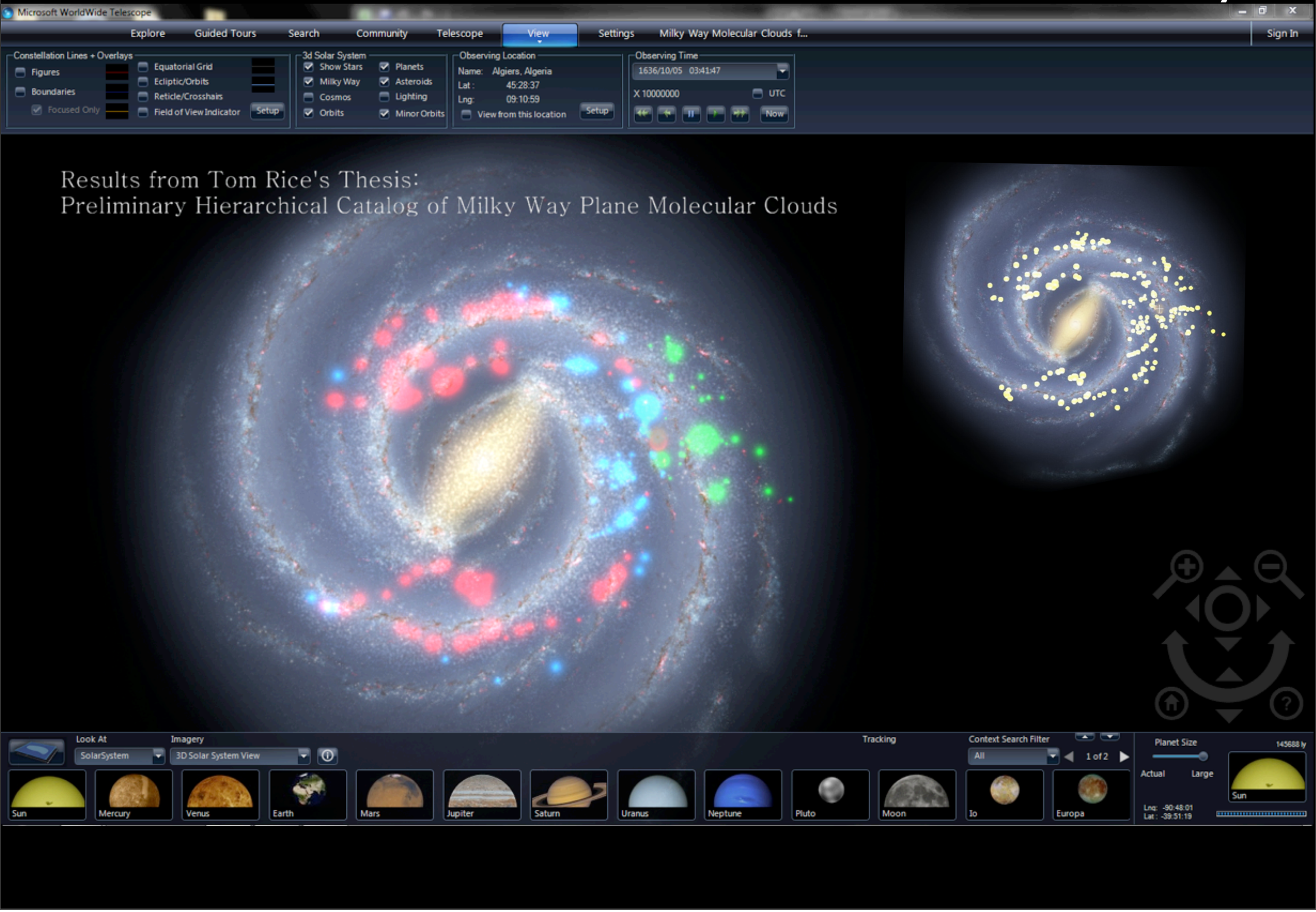
This WorldWide Telescope Tour was created to thank
John Huchra (1948-2010) for the knowledge and cheer he gave us all.

How John Huchra fixed the Universe...

[demo]

This section cannot be "finished" until left-right reversal is addressed by Jonathan. Here, I've spun the Universe around 180 degrees to make everything match.

and the Galaxy...



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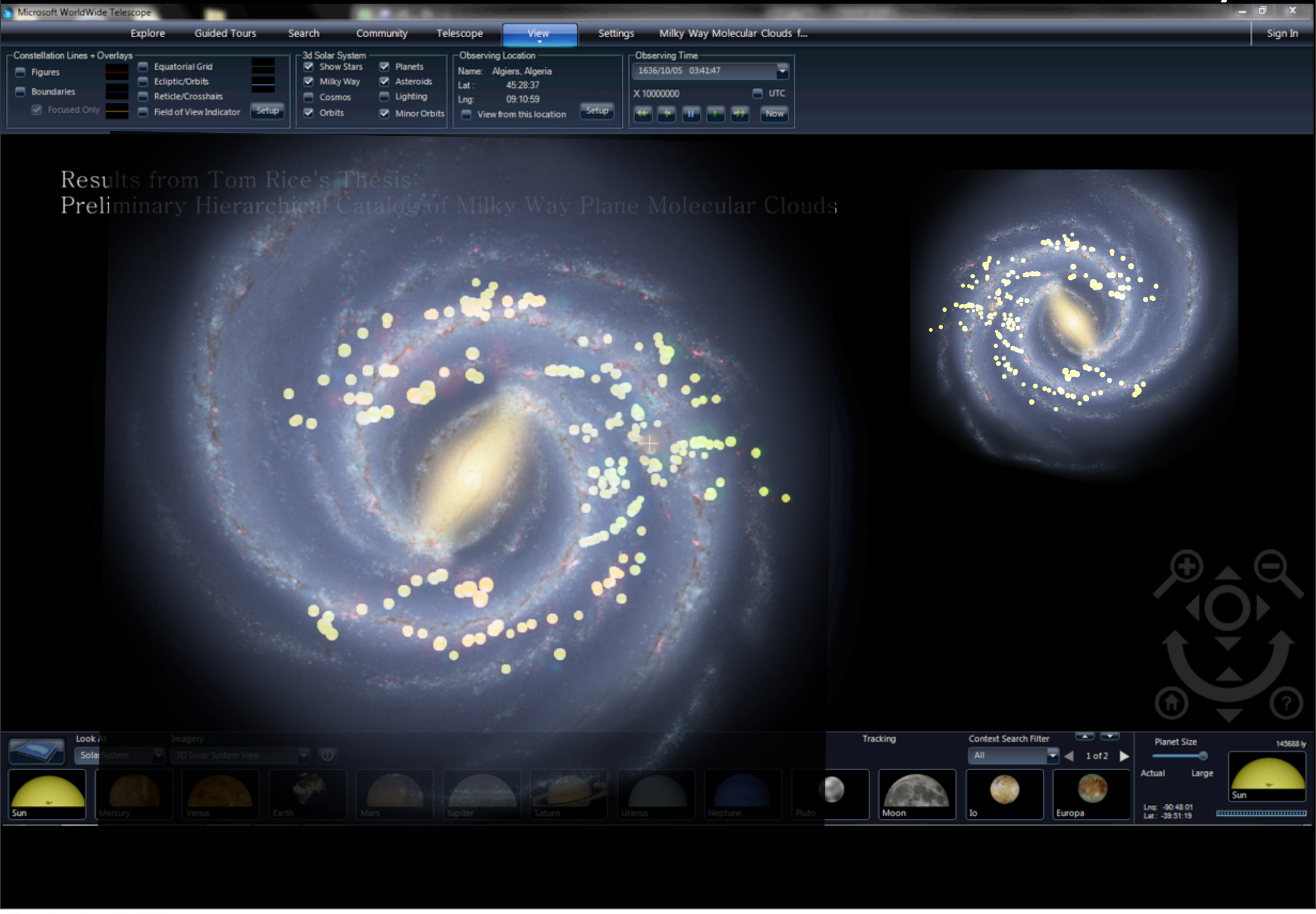
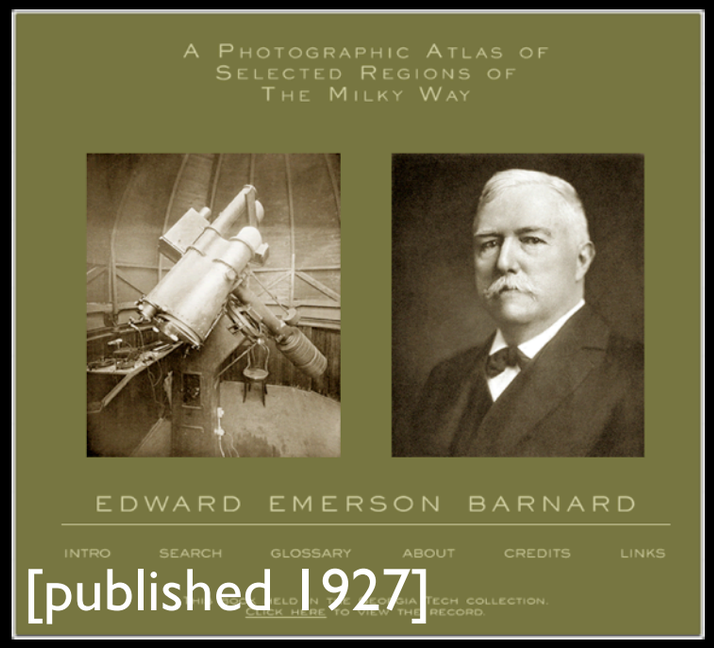
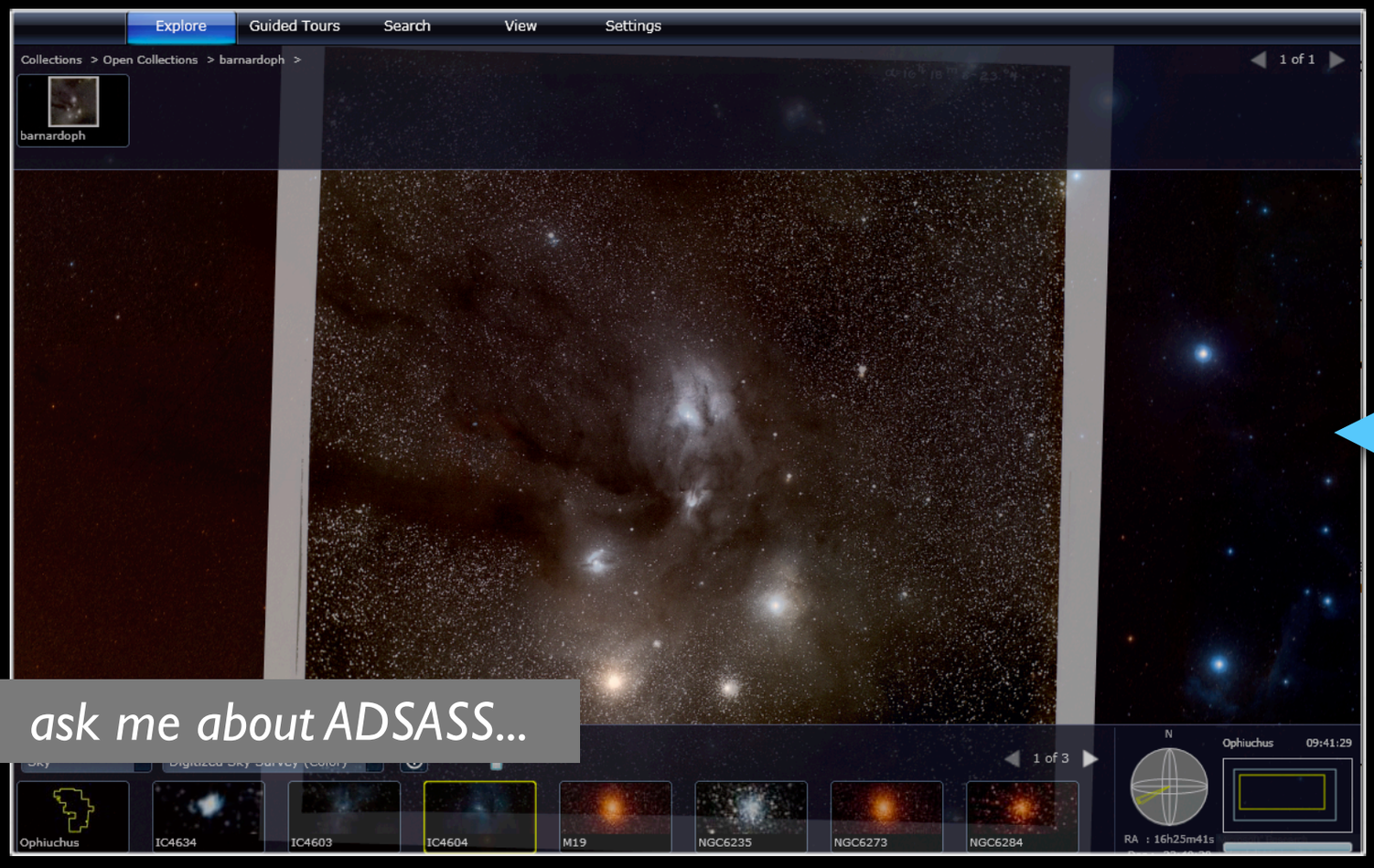


“Seamless Astronomy”...

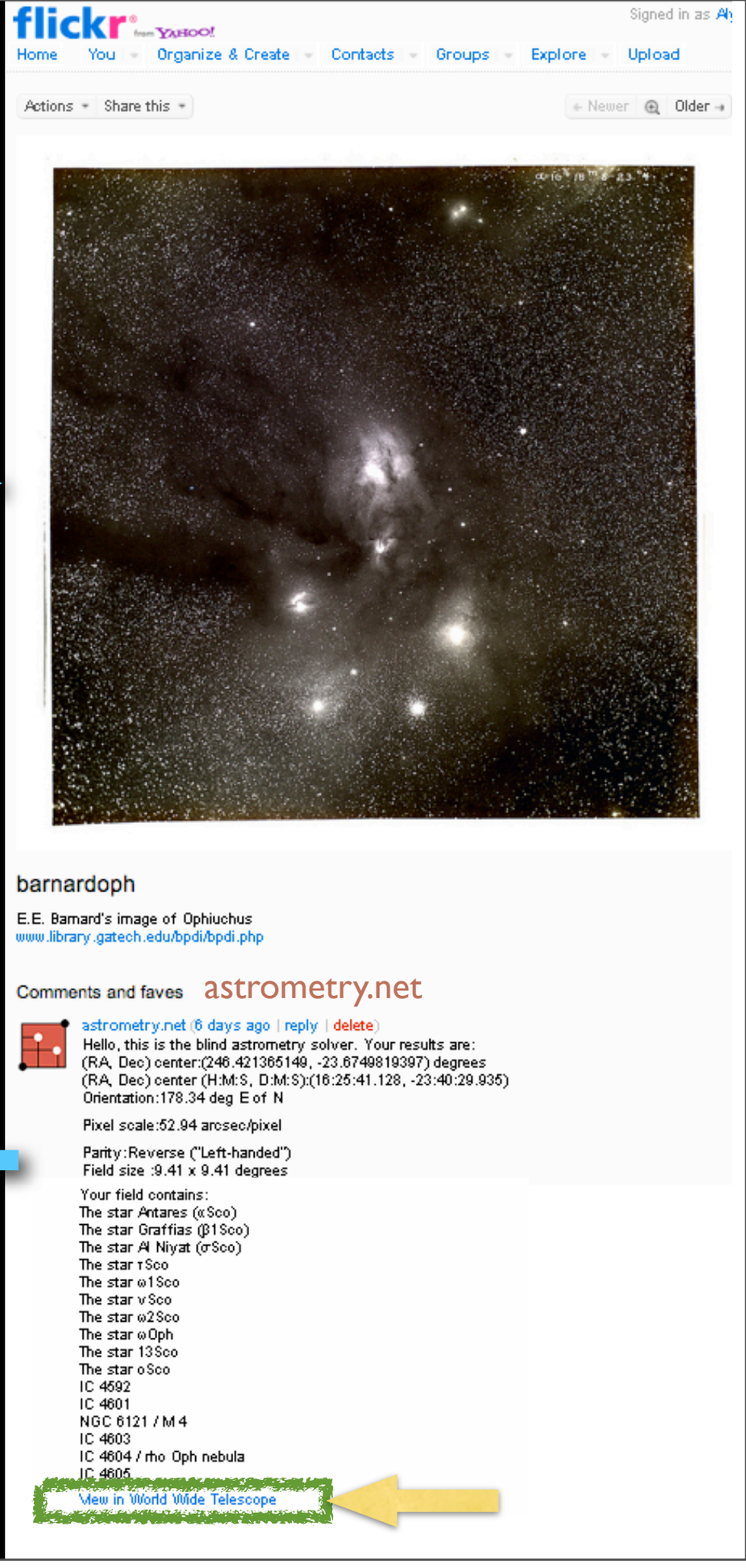
astrometry.net + flickr + WWT



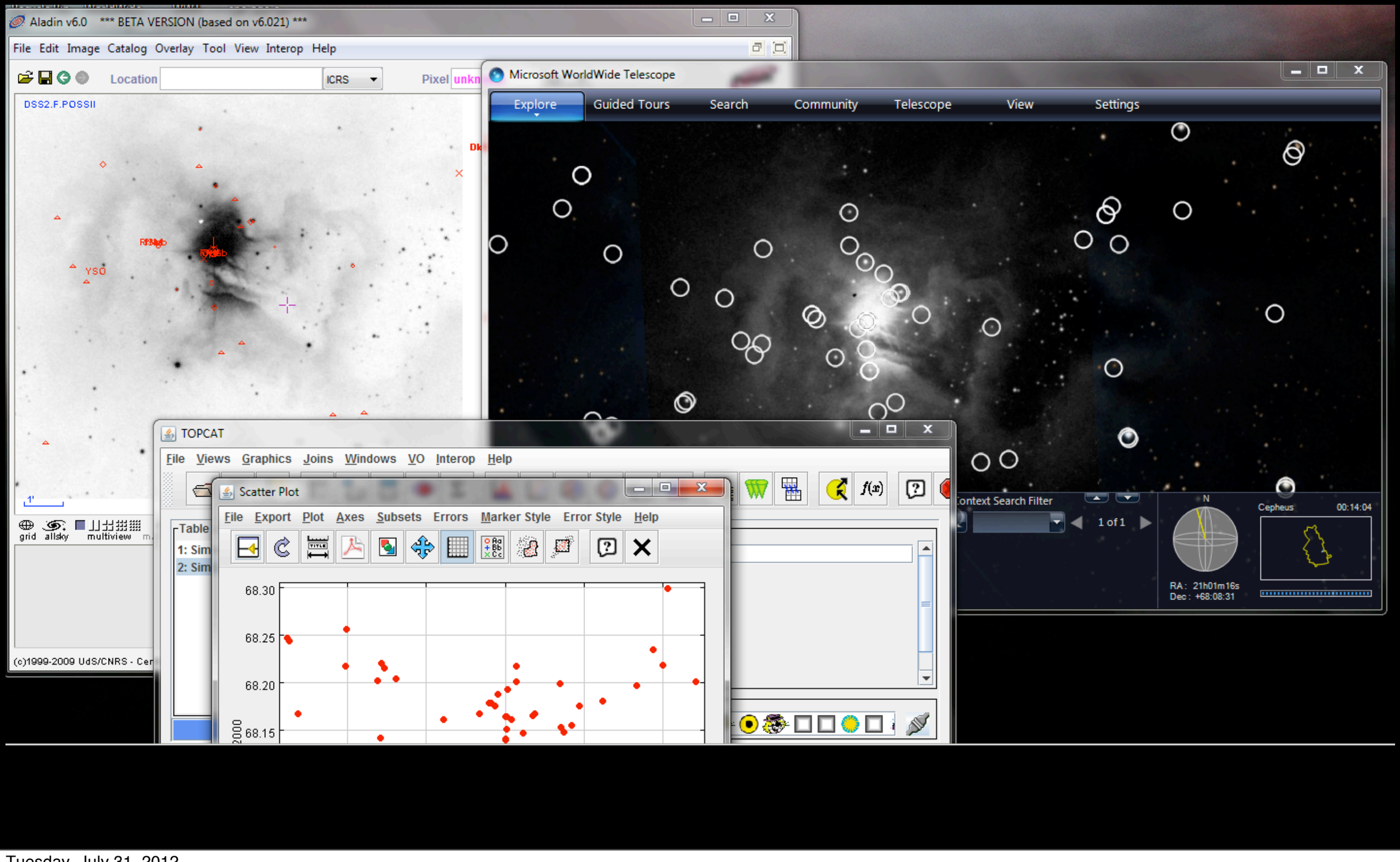
[published 1927]



ask me about ADSASS...



“Seamless Astronomy”...
SAMP connections



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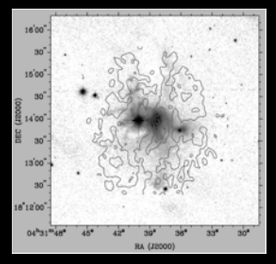
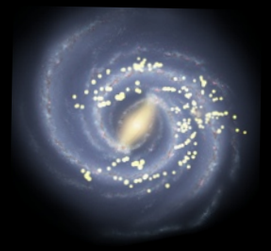
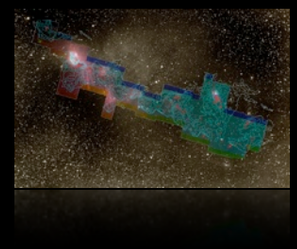

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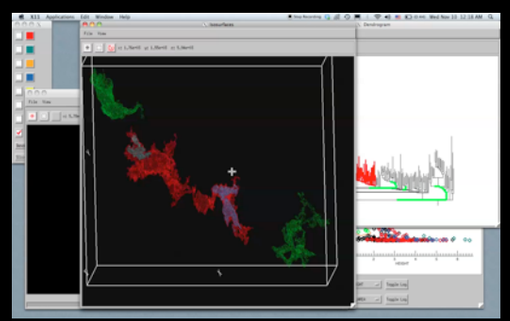
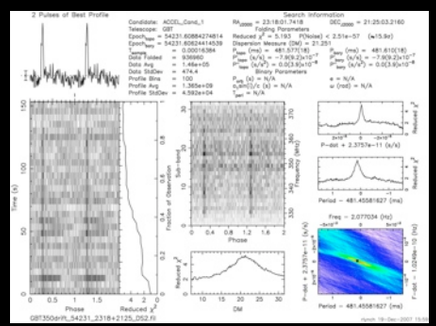

Data • Dimensions • Display

Astron. Nachr. / AN **xxx**, No. xx, 001 – 10 (2012) / **DOI** ***please set DOI!***

Principles of High-Dimensional Data Visualization in Astronomy

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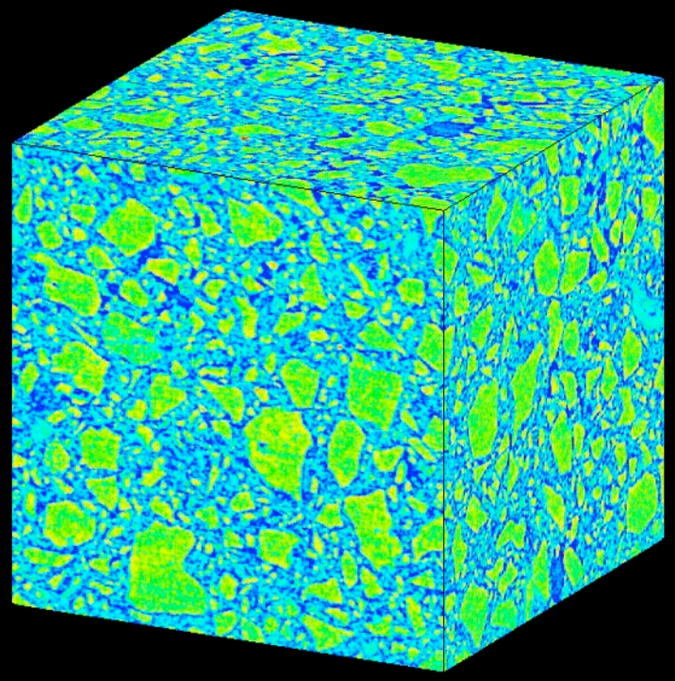
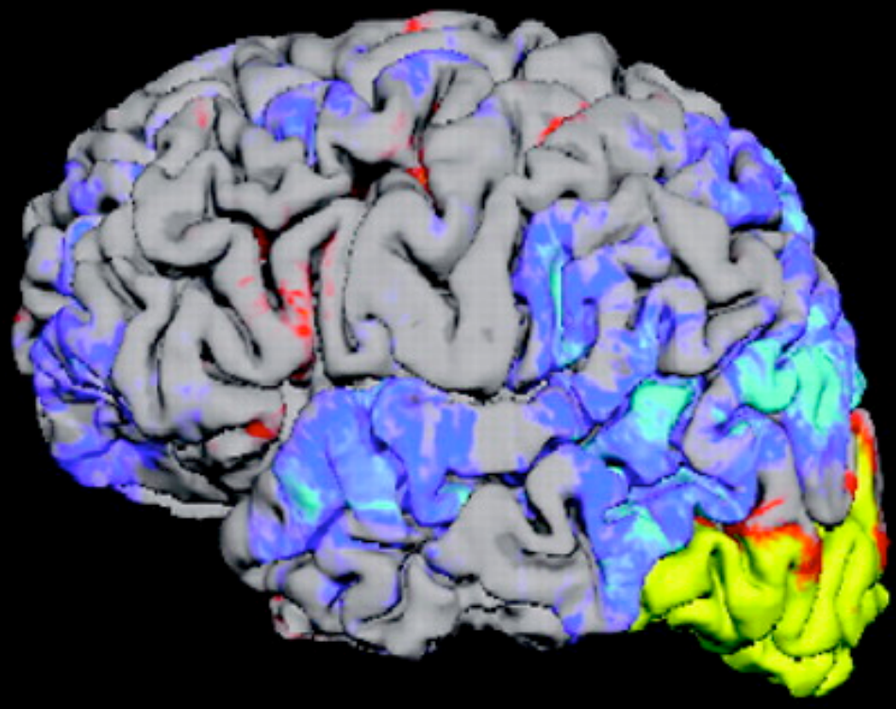
Published online later

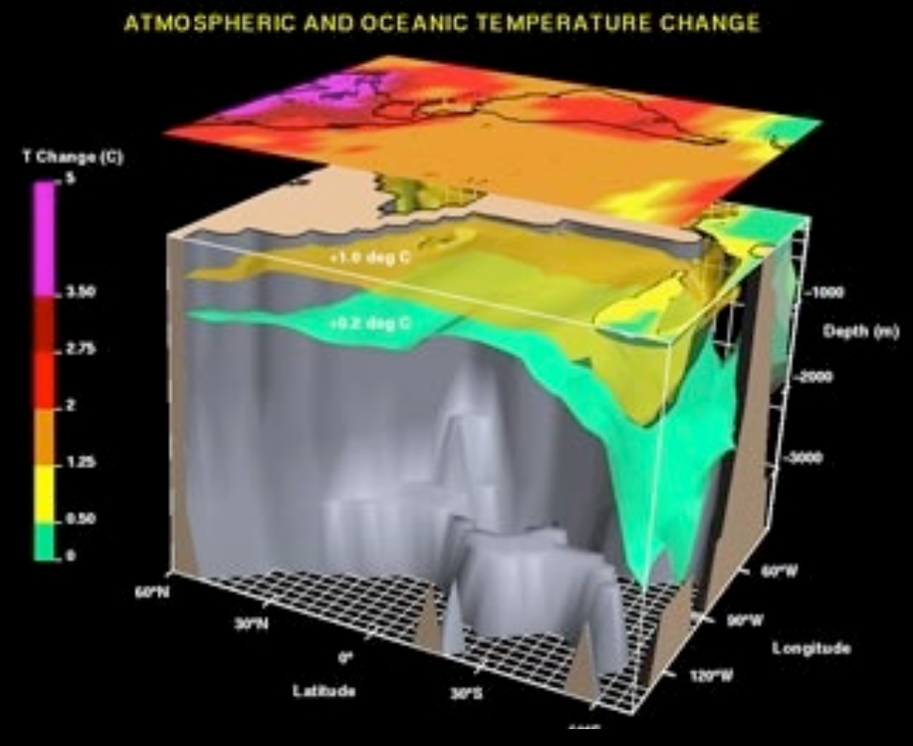
Key words techniques: image processing; methods: data analysis; techniques: radial velocities; cosmology: large-scale structure; ISM: clouds

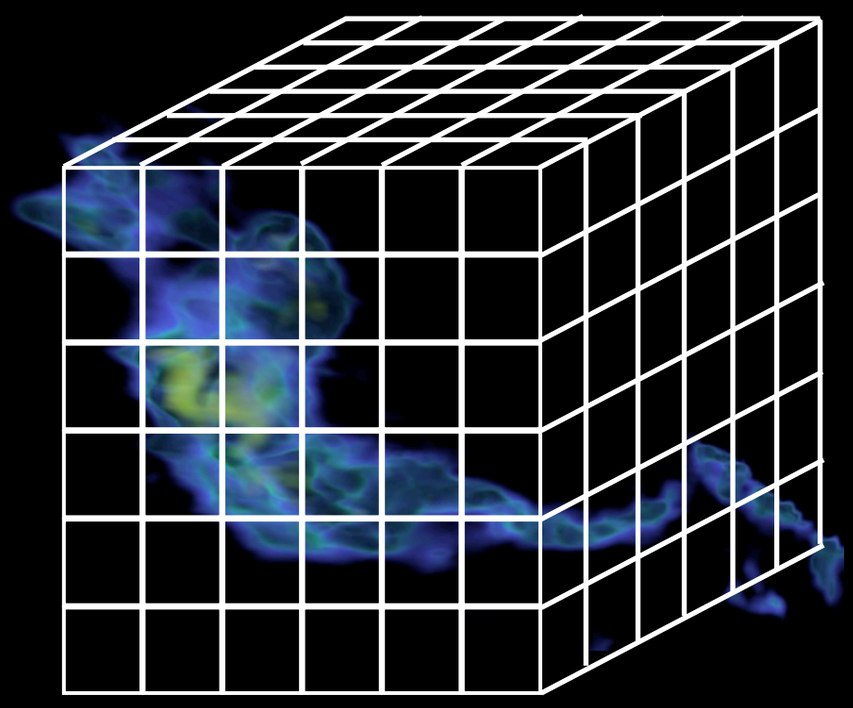
Astronomical researchers often think of analysis and visualization as separate tasks. In the case of high-dimensional data sets, though, interactive *exploratory data visualization* can give far more insight than an approach where data processing and statistical analysis are followed, rather than accompanied, by visualization. This paper attempts to charts a course toward "linked view" systems, where multiple views of high-dimensional data sets update live as a researcher selects, highlights, or otherwise manipulates, one of several open views. For example, imagine a researcher looking at a 3D volume visualization of simulated or observed data, and simultaneously viewing statistical displays of the data set's properties (such as an x-y plot of temperature vs. velocity, or a histogram of vorticities). Then, imagine that when the researcher selects an interesting group of points in any one of these displays, that the same points become a highlighted subset in all other open displays. Selections can be graphical or algorithmic, and they can be combined, and saved. For tabular (ASCII) data, this kind of analysis has long been possible, even though it has been under-used in Astronomy. The bigger issue for Astronomy and several other "high-dimensional" fields is the need systems that allow full integration of images and data cubes within a linked-view environment. The paper concludes its history and analysis of the present situation with suggestions that look toward cooperatively-developed open-source modular software as a way to create an evolving, flexible, high-dimensional, linked-view visualization environment useful in astrophysical research.

“High-Dimensional” Data

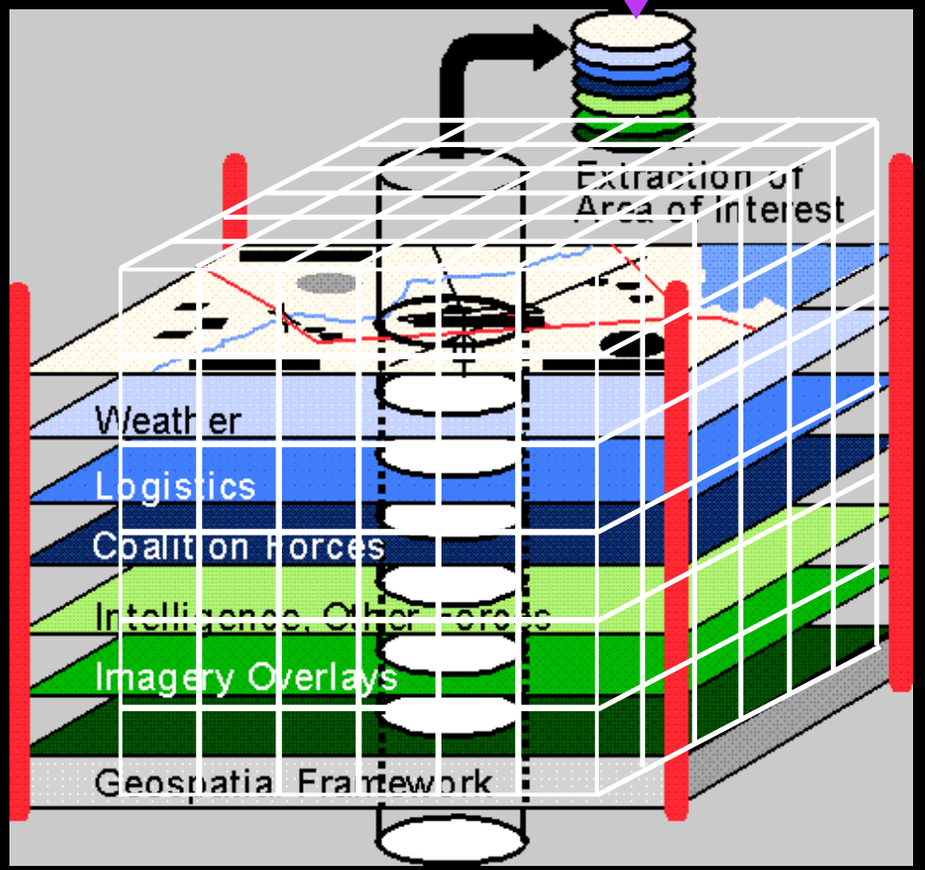




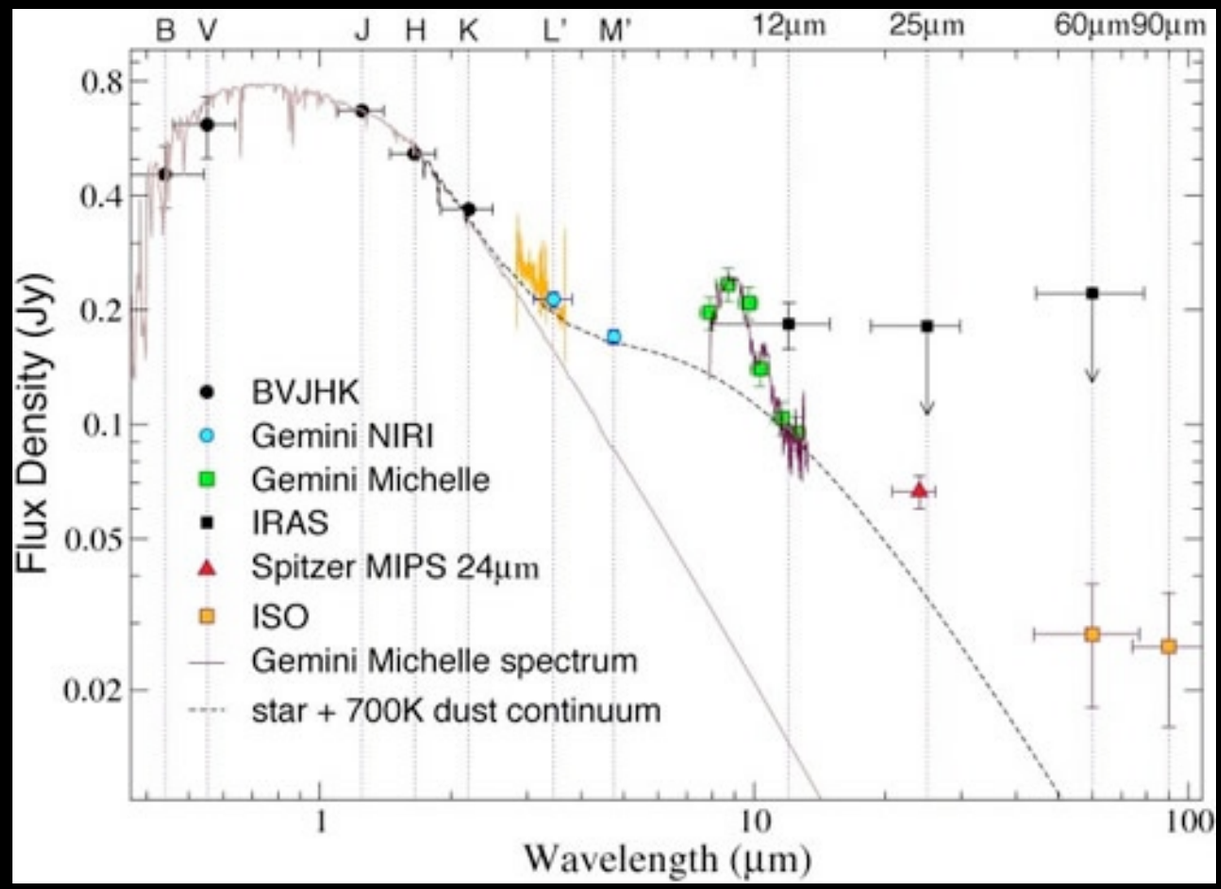


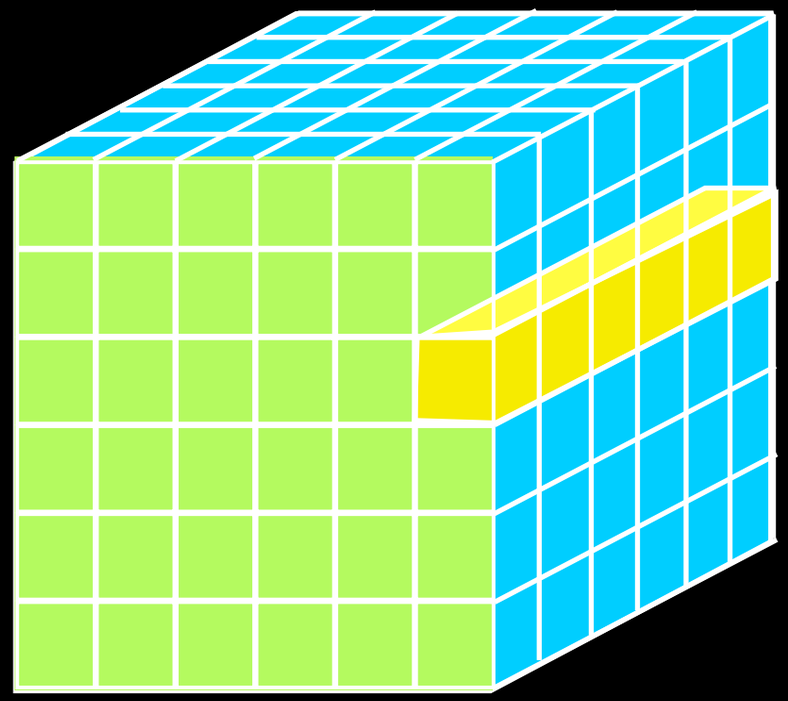


This



is a "spectral energy distribution"





GENERALLY

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

2D: Faces or Slices = “Images”

3D: Volumes = “3D Renderings”, “2D Movies”

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

z = 2.4

dark matter density

gas density

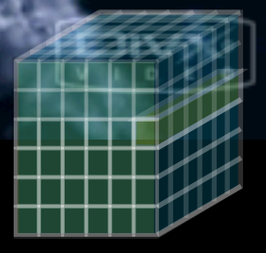
gas temperature

kinetic SZ

thermal SZ

gas shocks

4 Mpc/h



Movie: Volker Springel, formation of a cluster of galaxies

COMPLETE Perseus

mm peak (Enoch et al. 2006)

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

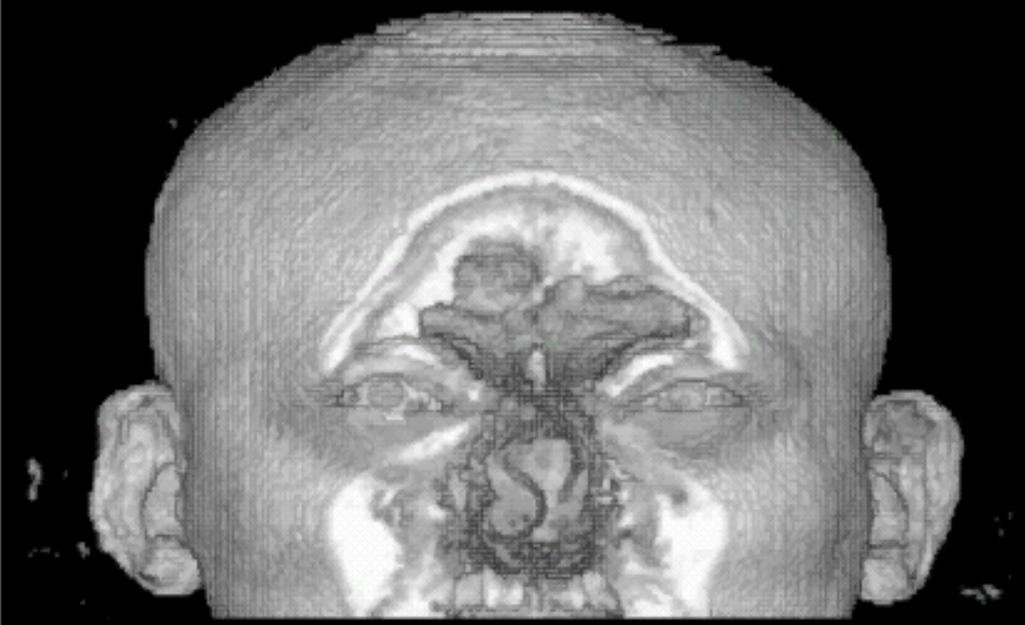
^{13}CO (Ridge et al. 2006)

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

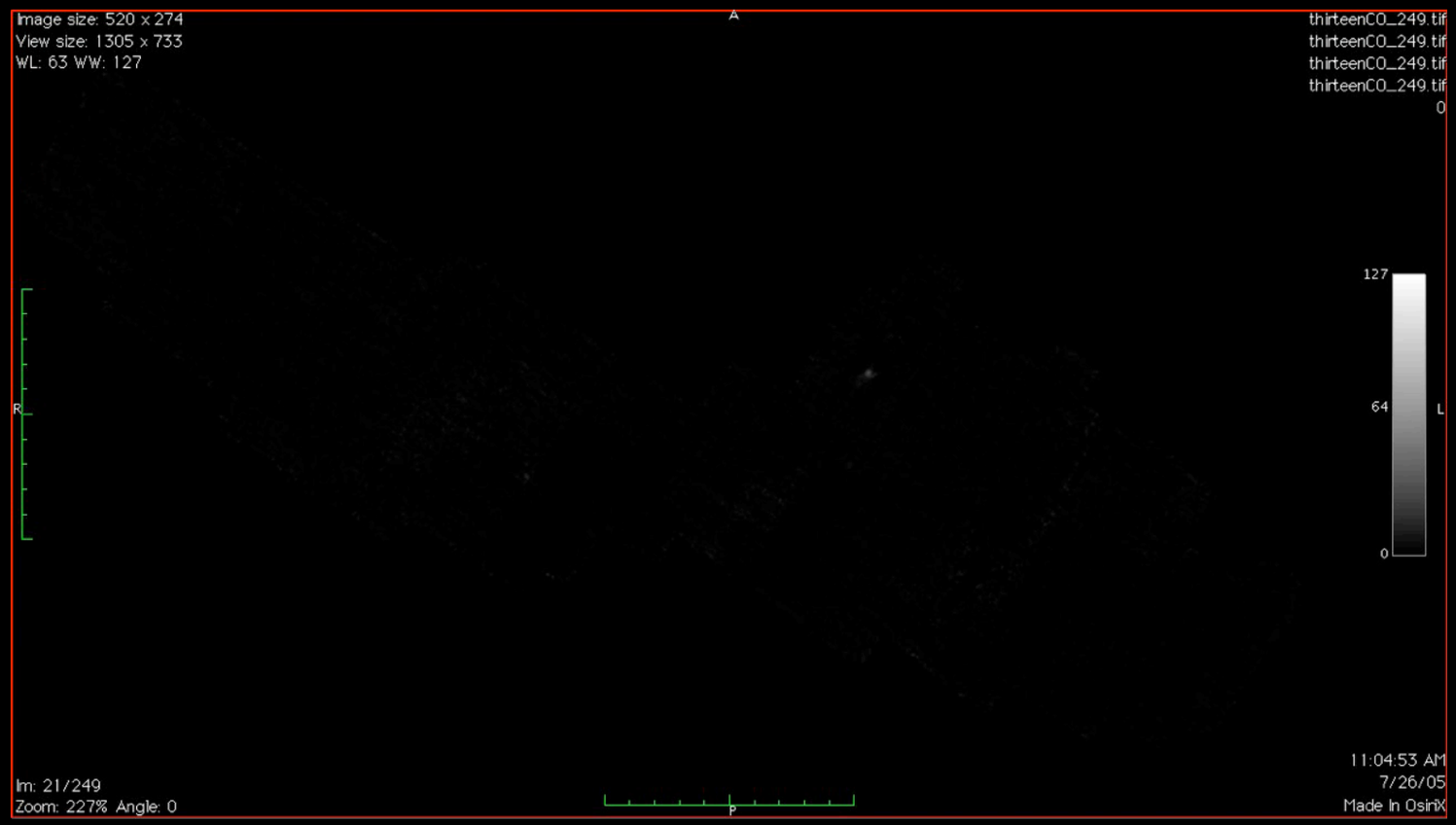
Optical image (Barnard 1927)

"Astronomical Medicine"

"KEITH"



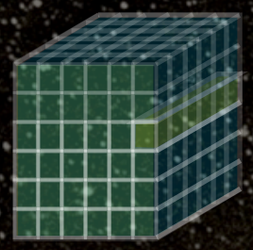
"PERSEUS"



"z" is depth into head

"z" is line-of-sight velocity

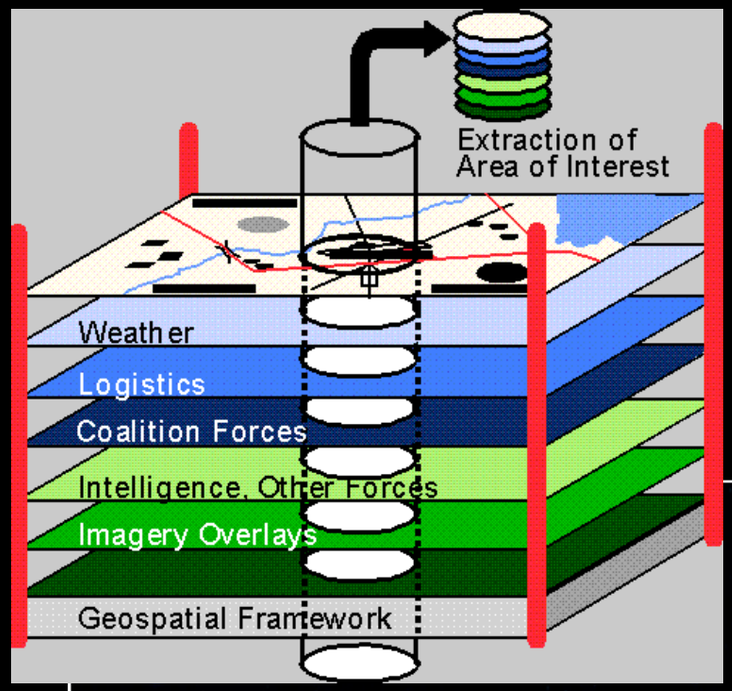
(This kind of "series of 2D slices view" is known in the Viz as "the grand tour")



3D Viz made with VolView

AstronomicalMedicine@IIG

COMPLETE



Data Dimensions Display

Open Data Open Tools

COMPLETE

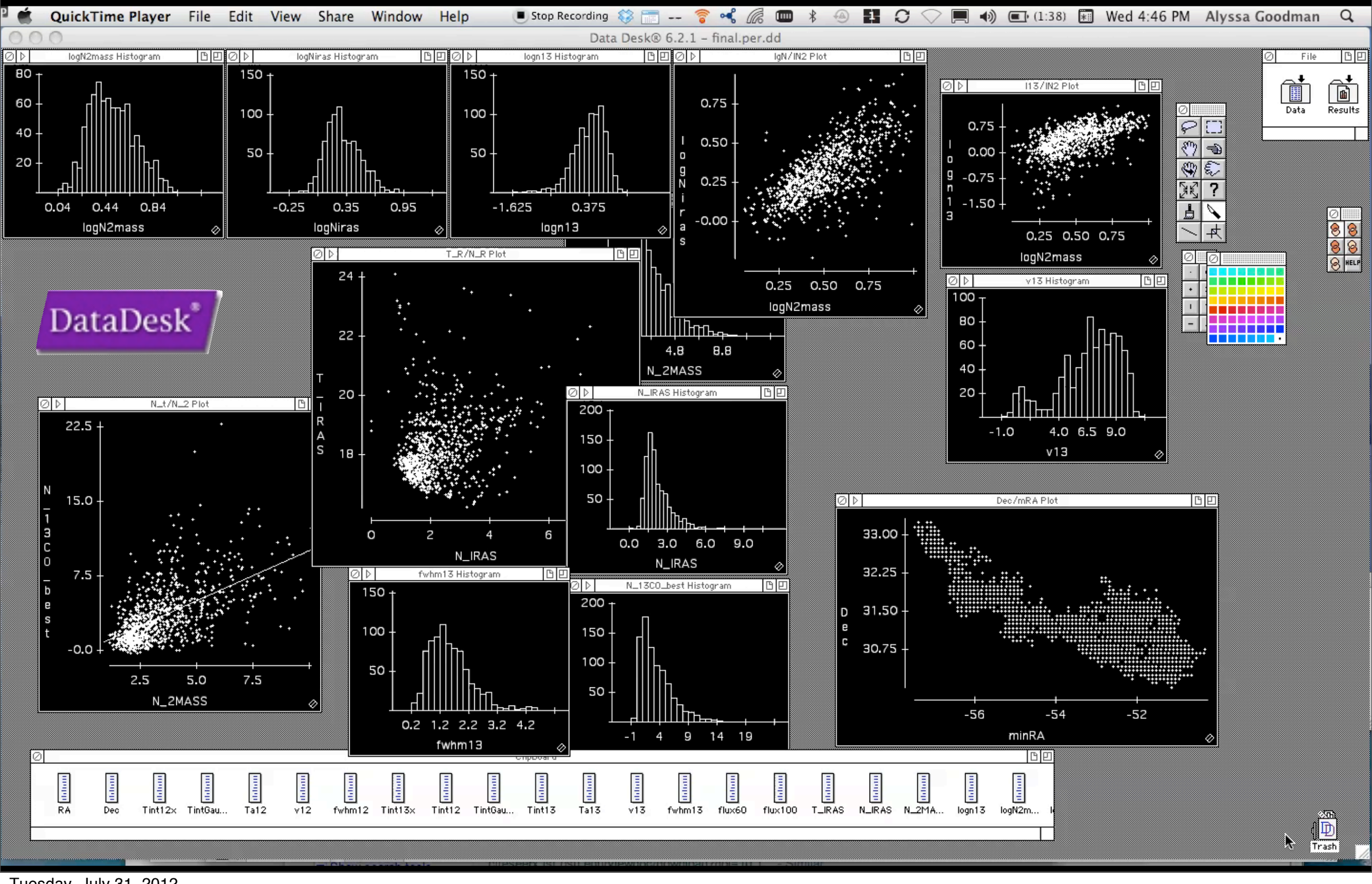
COMPLETE Data Available

Center on Perseus | Center on Ophichus | Center on Serpens

Full-Cloud Data (Phase I, All Data Available)

Dataset	Show	Perseus	Ophiuchus	Serpens	Link
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

DataDesk (est. 1986)



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

Picturing | Rotation | Isolation | Masking

Selection

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

Brushing | Linking

Results...

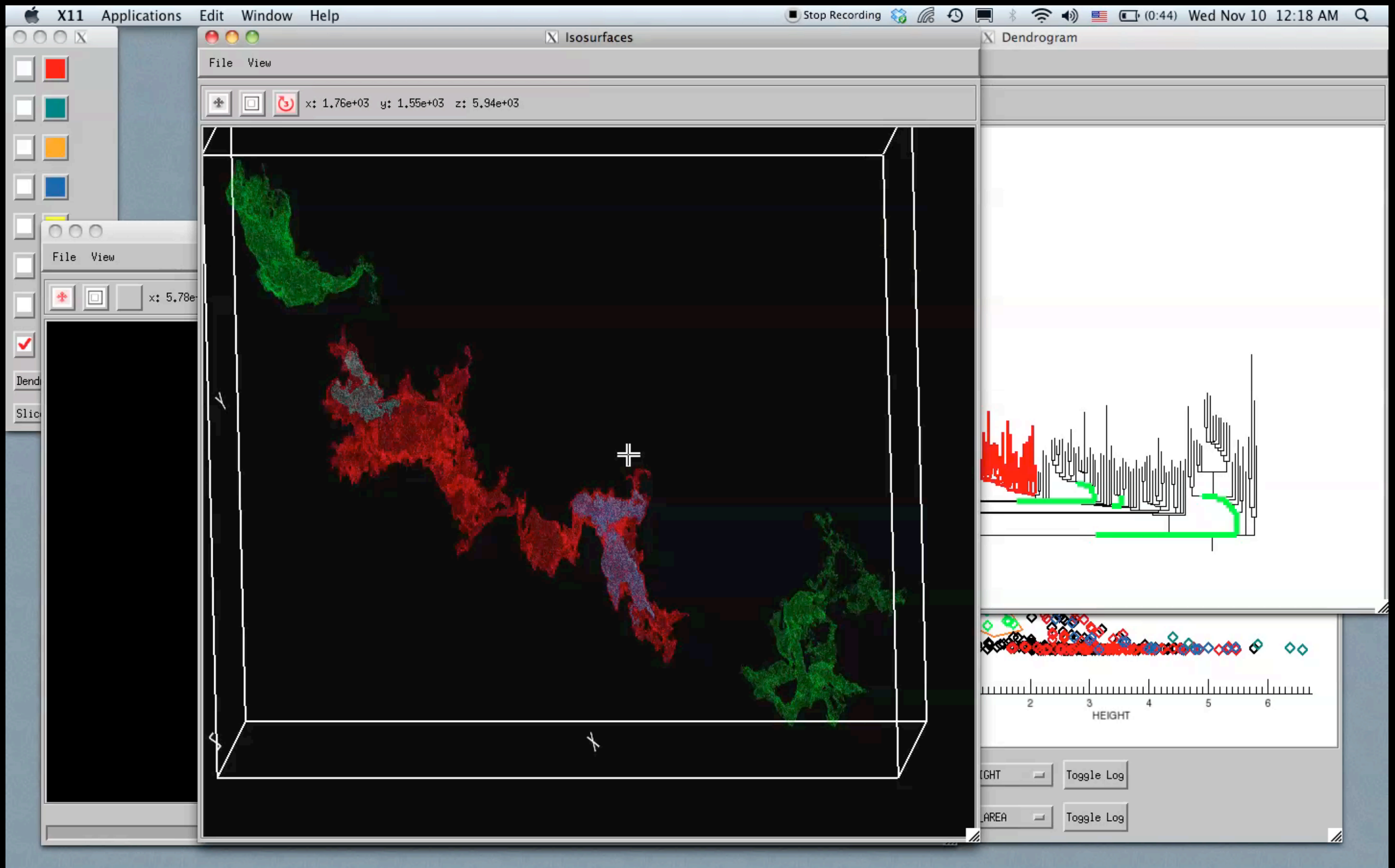
1. for immediate insight
2. as visual source of ideas for statistical algorithms (...relation to SVM)

Warning

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

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

Exemplar: Linked Dendrogram Views in IDL



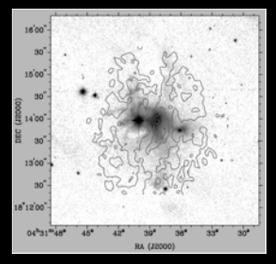
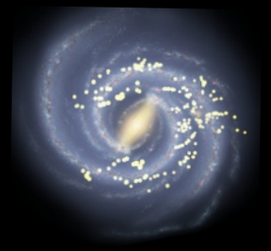
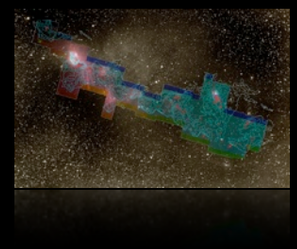
Video & implementation: Christopher Beaumont, CfA/UHawaii;

inspired by AstroMed work of Douglas Alan, Michelle Borkin, AG, Michael Halle, Erik Rosolowsky

The Value of Context in Astronomy

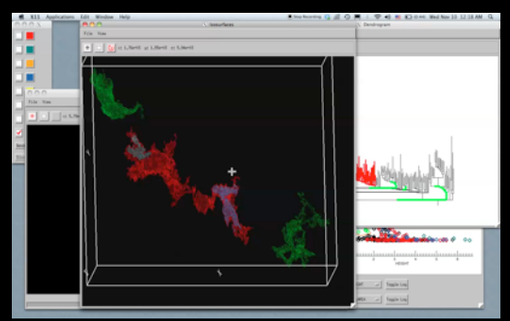
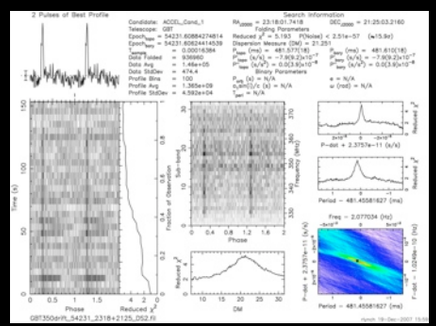
Value: *Compared to what?*

Validation & Discovery

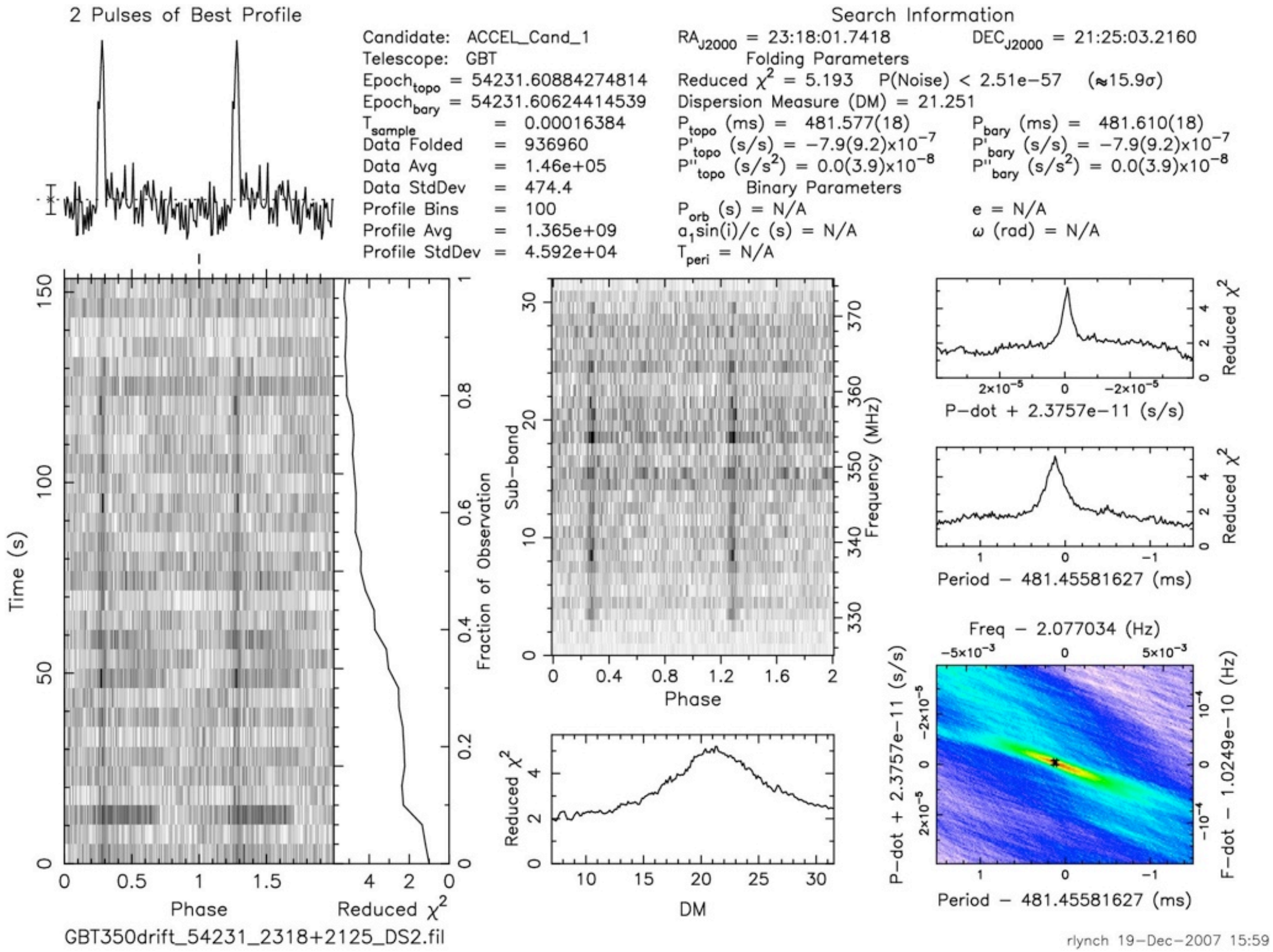




Context

Spatial & Abstract

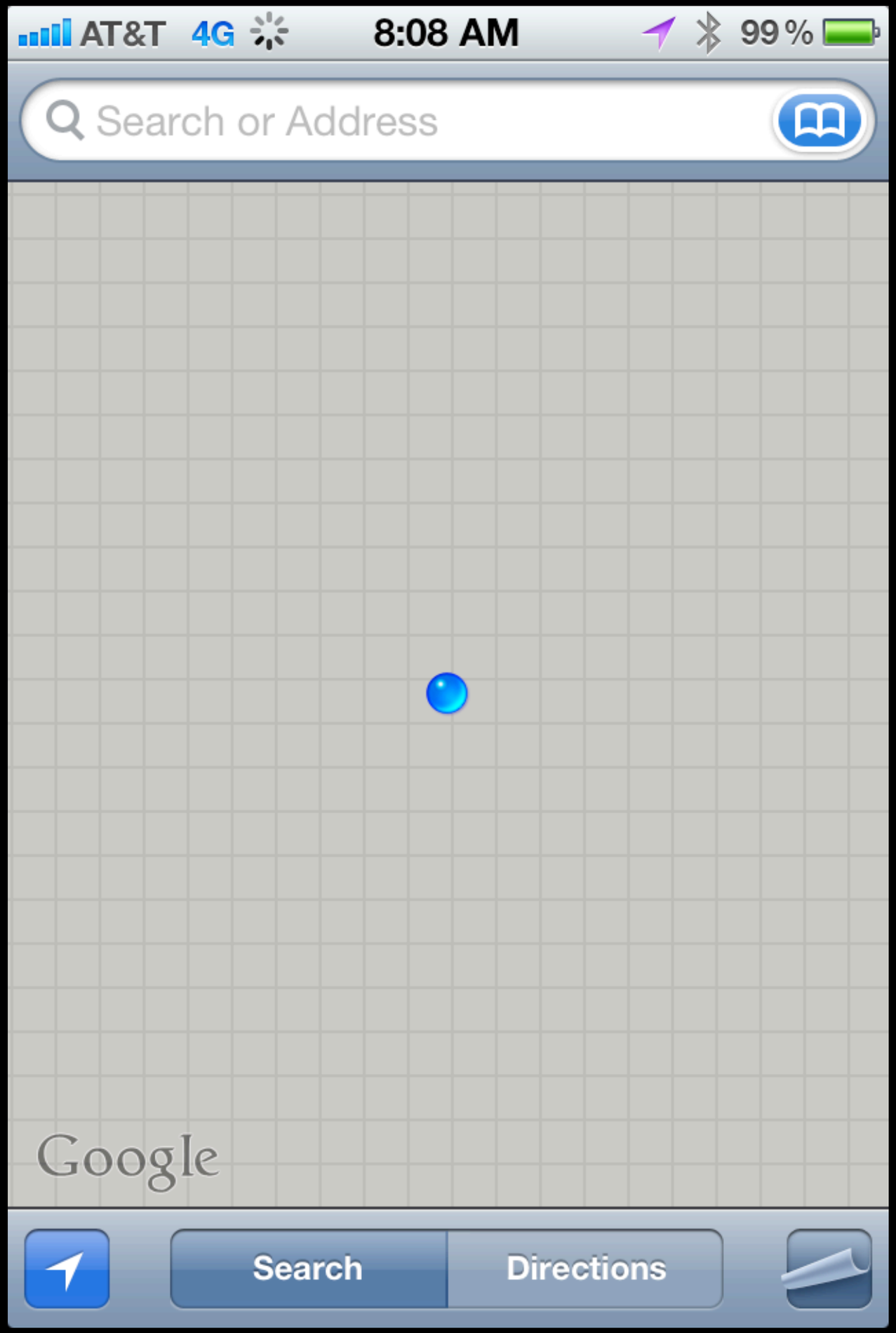
Abstract Context + Data, Dimensions, Display



From Pulsar Search Collaboratory: http://www.astro.virginia.edu/~rsl4v/PSC/intro.html

The Value of Context in Astronomy

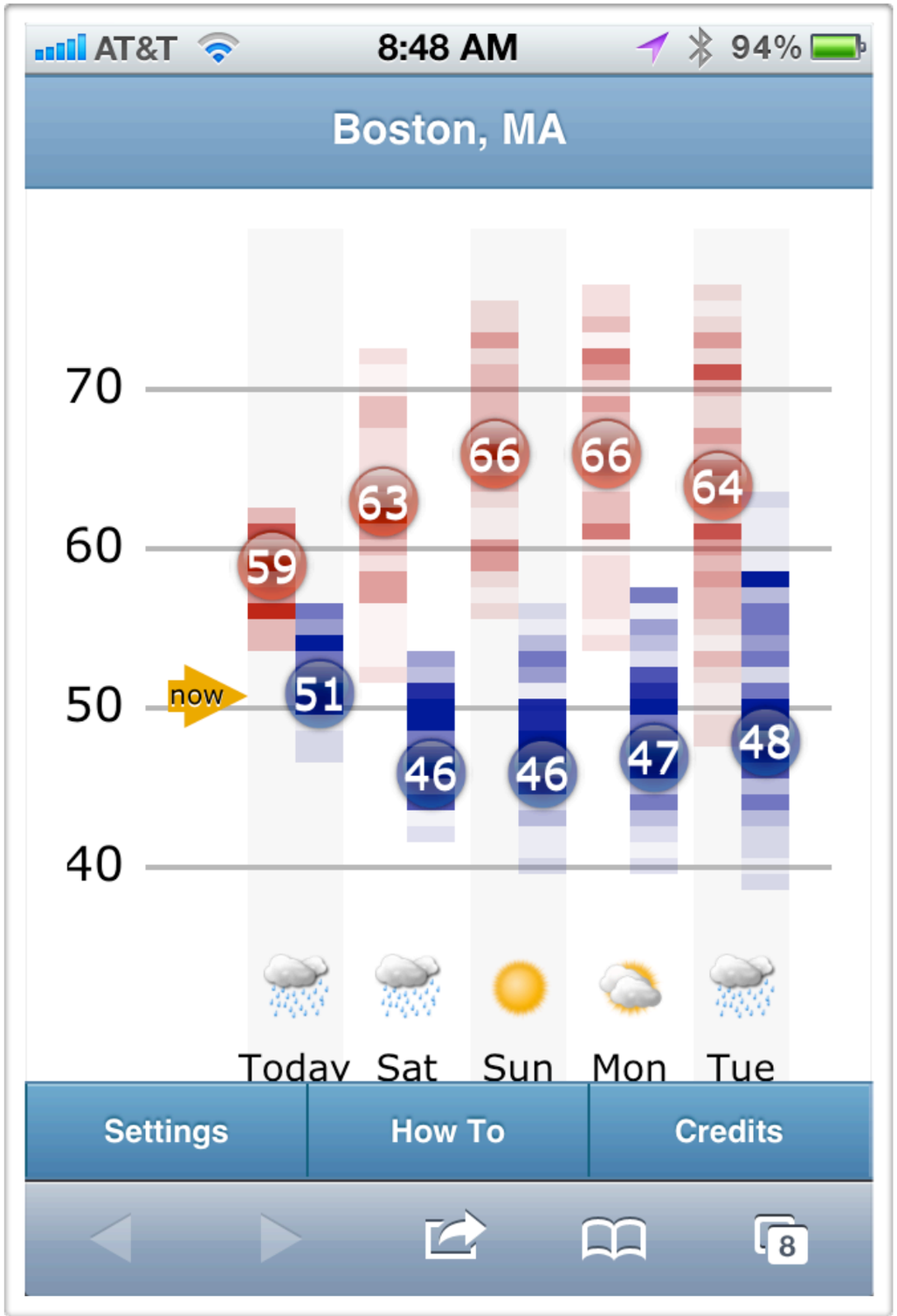
Alyssa Goodman
Harvard-Smithsonian Center for Astrophysics



EMR19/12

takeasweater?

Alyssa A. Goodman



Software development, 2010-12

Bill Barthelmy, Harvard FAS Academic Technology Group

WGBH collaborators, 2008-9

Annie Valva, Howard Cutler, et al.

Data provider, 2011-12

Eric Floehr of ForecastWatch