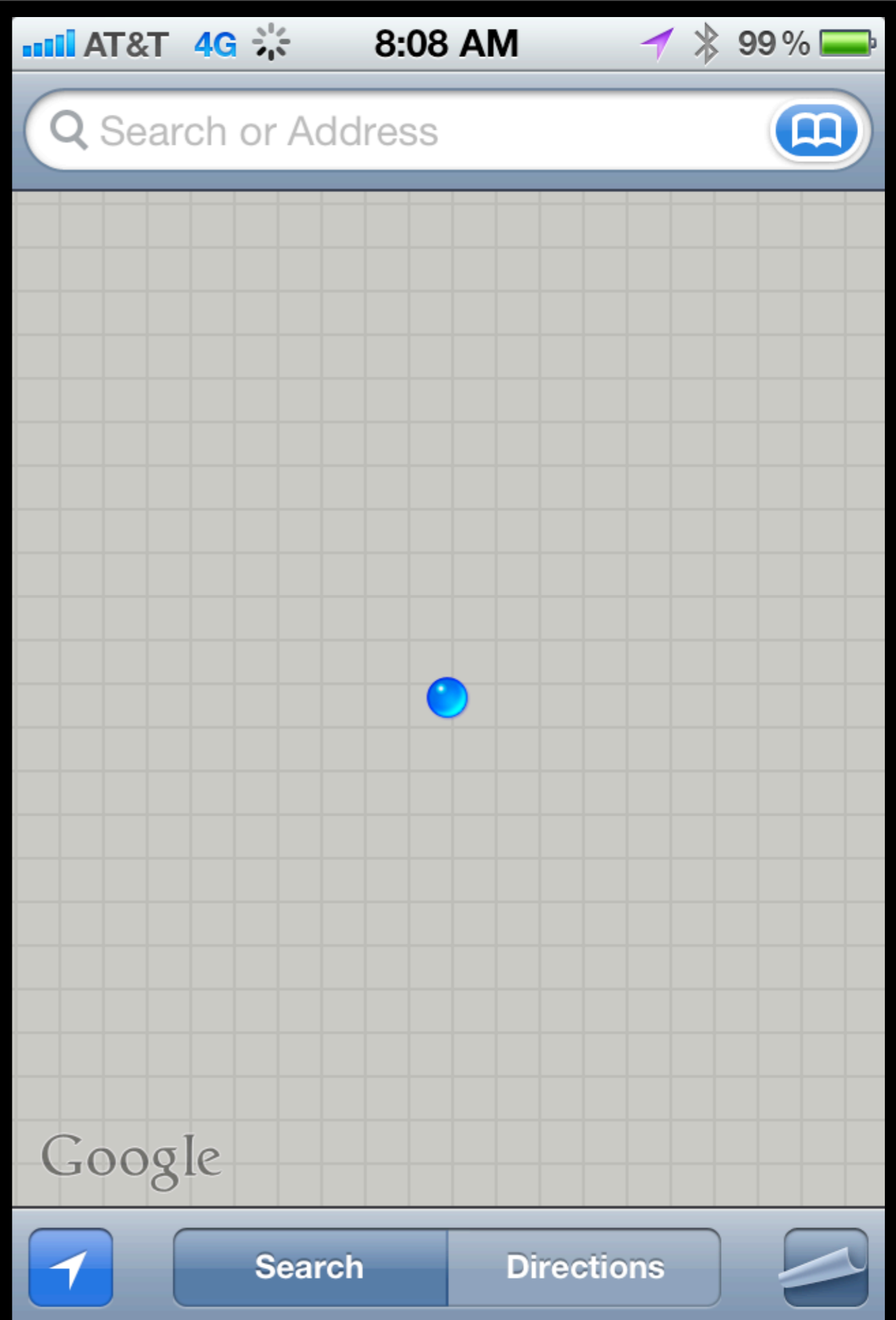


The Value of Context in Astronomy

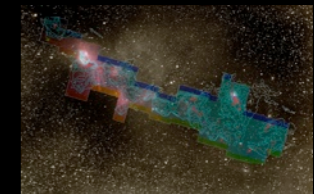
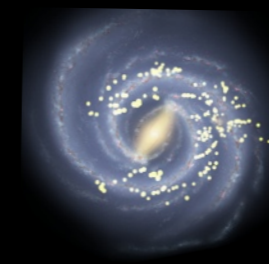
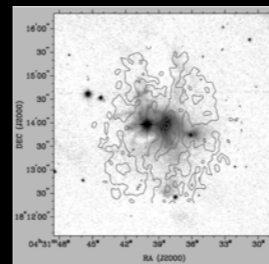
Alyssa Goodman
*Harvard-Smithsonian
Center for Astrophysics*



Value: *Compared to what?*

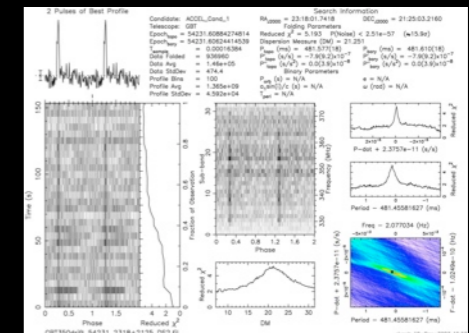
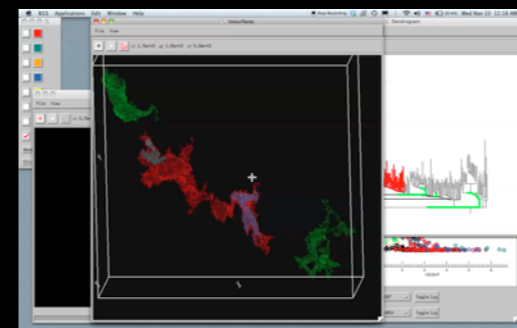
Validation & Discovery

The Value of Context in Astronomy

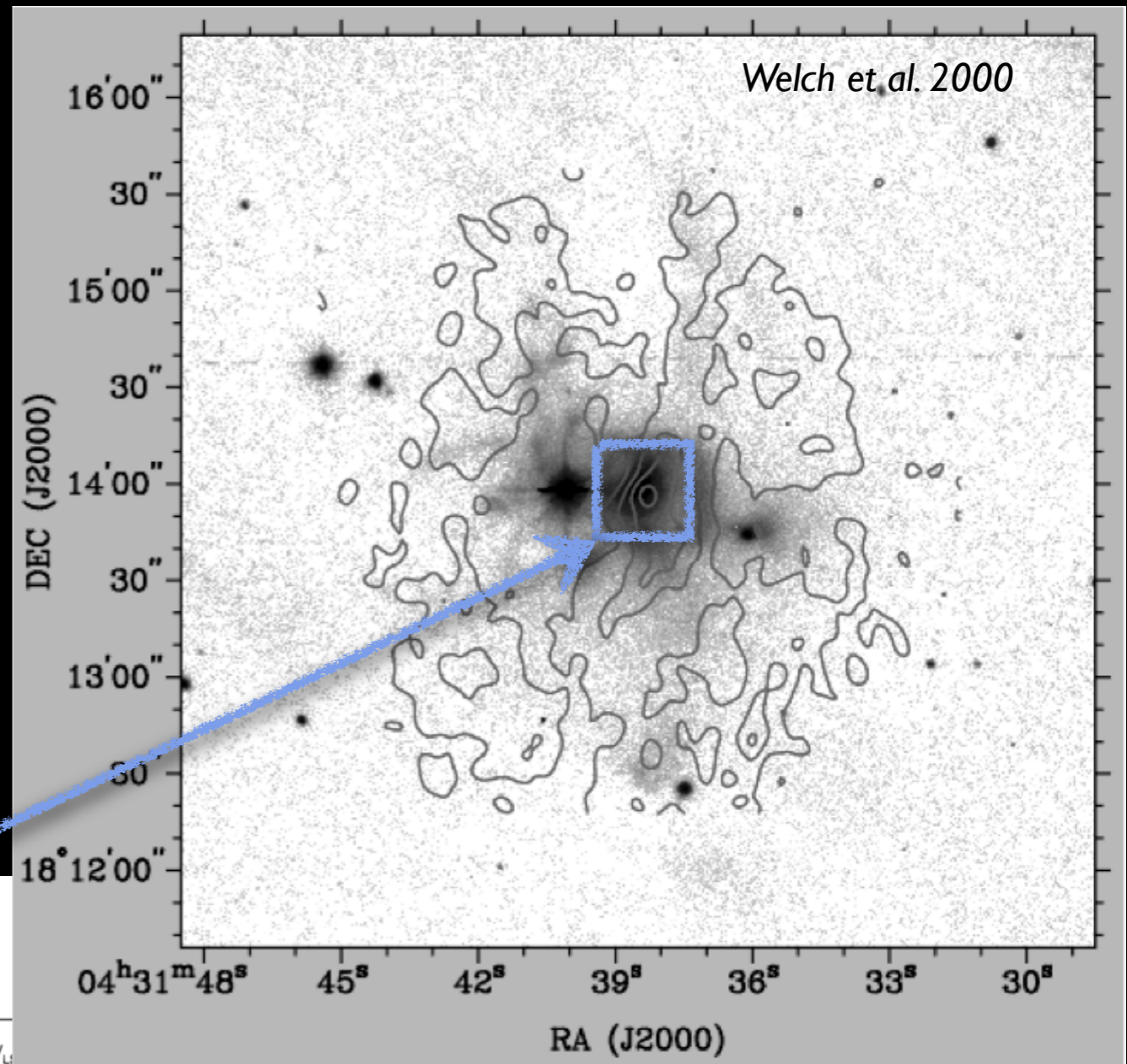


Context

Spatial & Abstract



The Value of Context in Astronomy



Sargent & Beckwith 1991

L32

SARGENT & BECKWITH

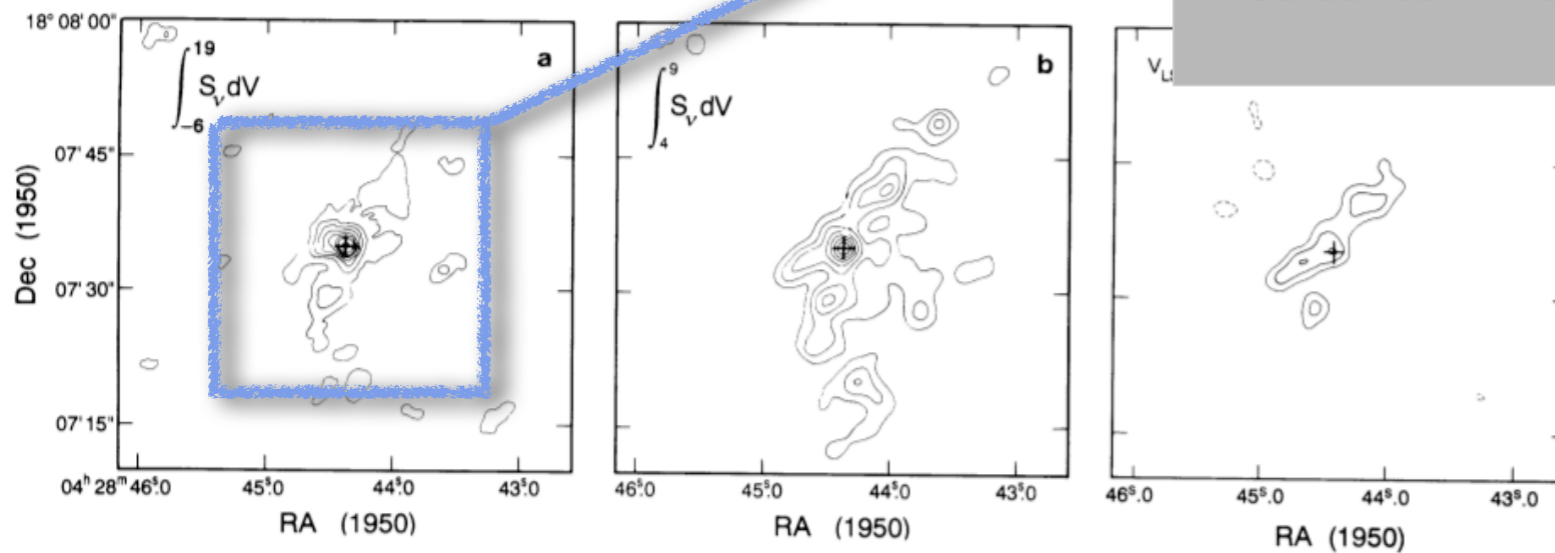
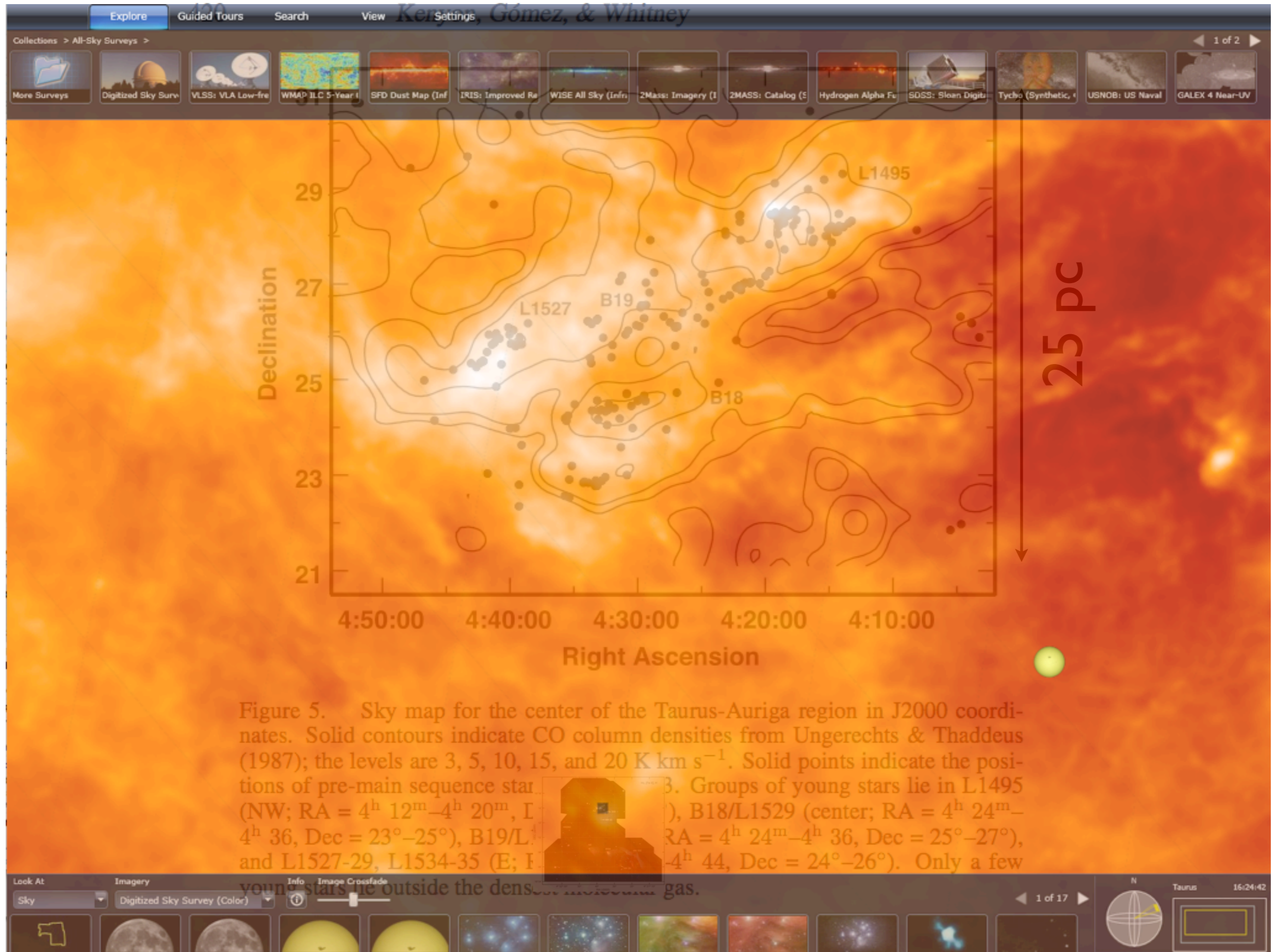
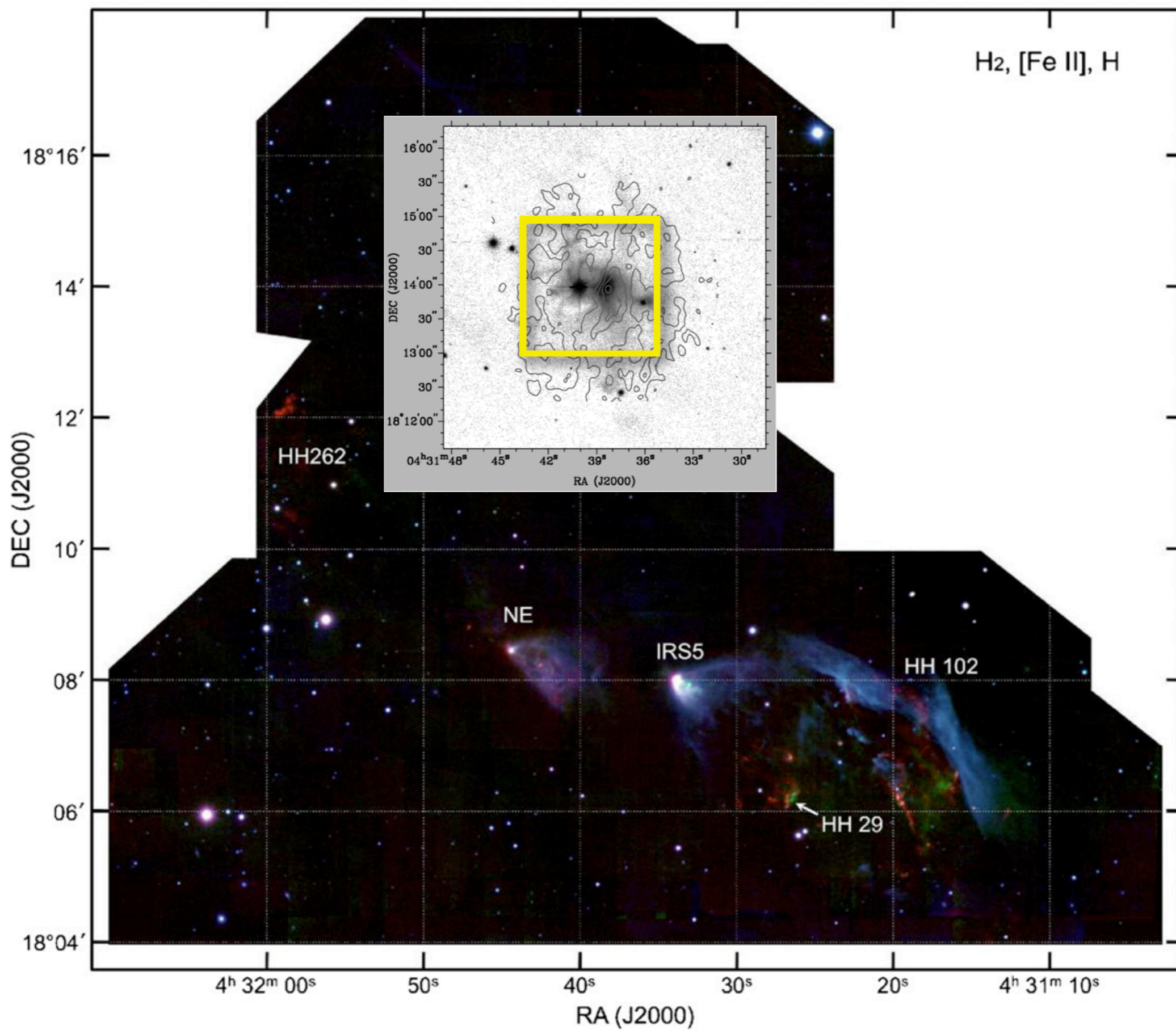


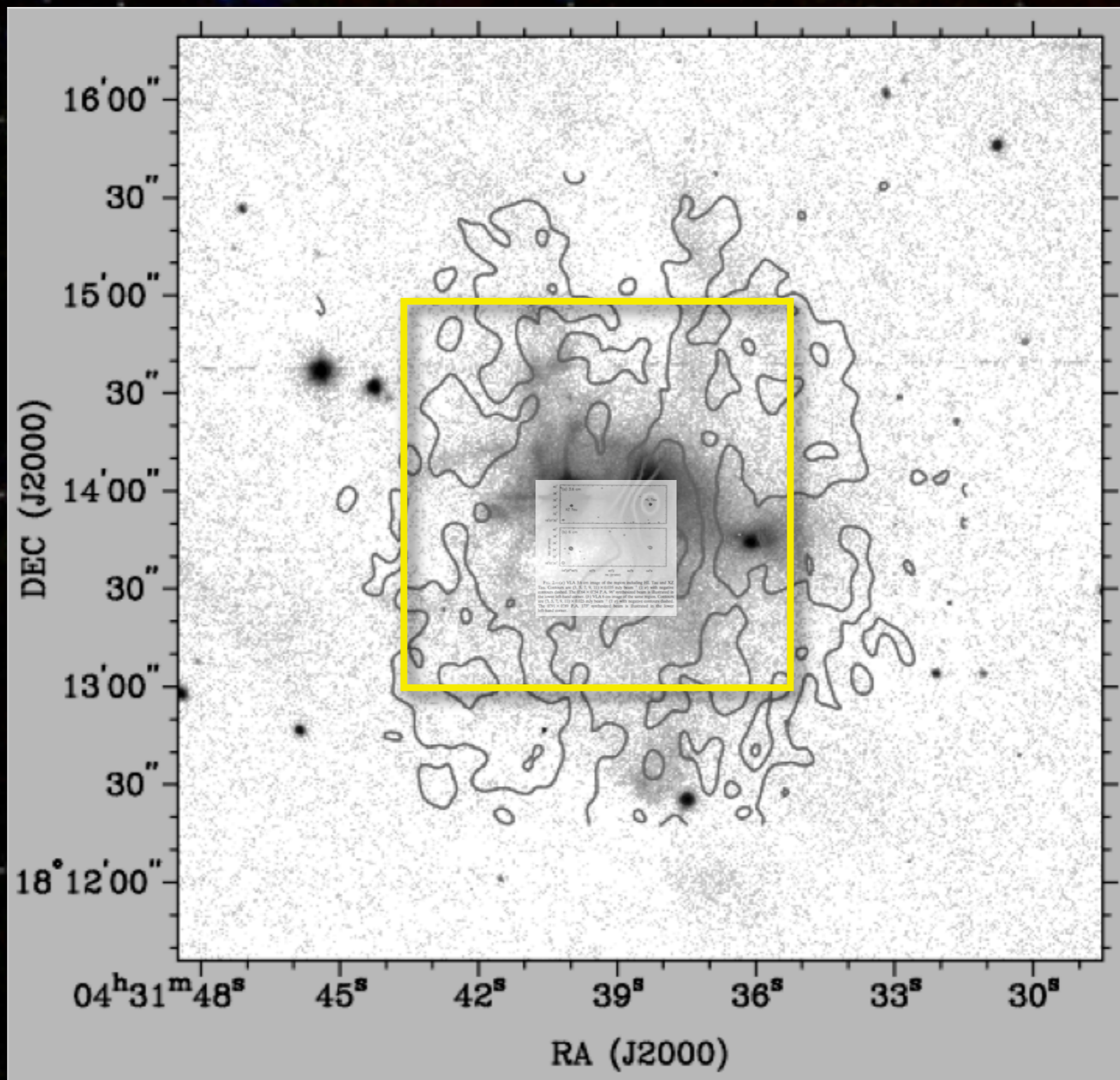
FIG. 1.—(a) A map of the ^{13}CO emission around HL Tau at $2''.7$ resolution integrated over the velocity range -22 to $+27$ km s^{-1} . Contours are at 10%, 20%, 30%, 40%, 50%, 60%, 70%, and 90% of the peak flux, $7.2 \text{ Jy beam}^{-1} \text{ km s}^{-1}$. This peak is coincident with the stellar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

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





HH262



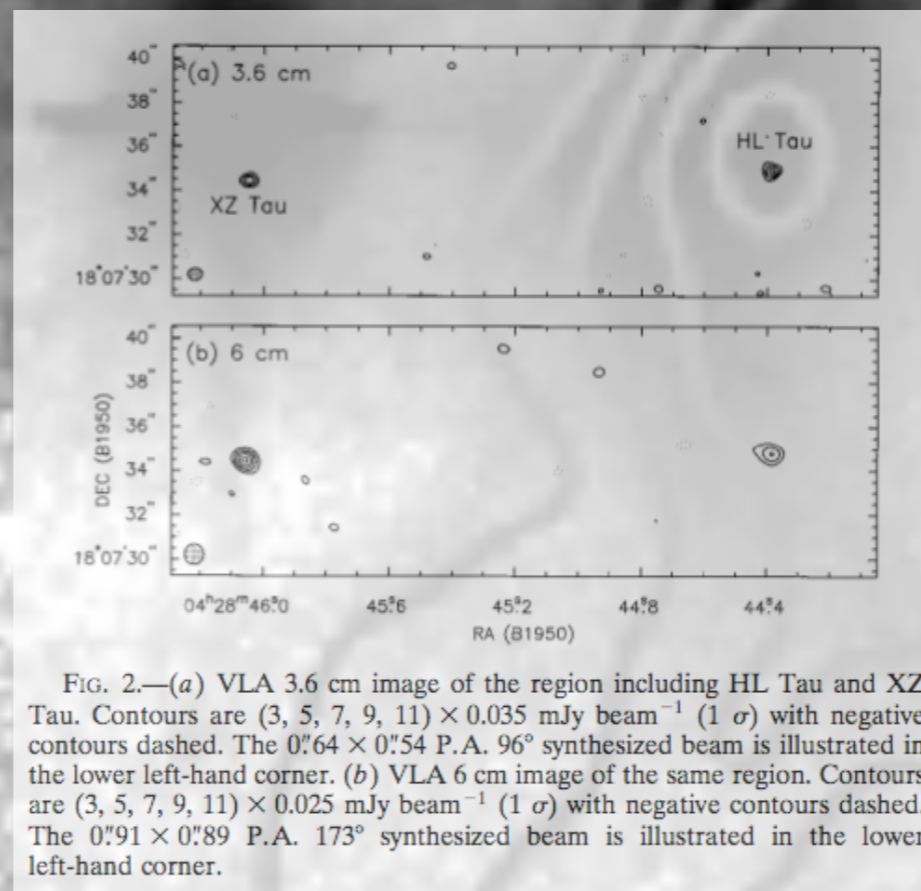


FIG. 2.—(a) VLA 3.6 cm image of the region including HL Tau and XZ Tau. Contours are $(3, 5, 7, 9, 11) \times 0.035 \text{ mJy beam}^{-1}$ (1σ) with negative contours dashed. The $0''.64 \times 0''.54$ P.A. 96° synthesized beam is illustrated in the lower left-hand corner. (b) VLA 6 cm image of the same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

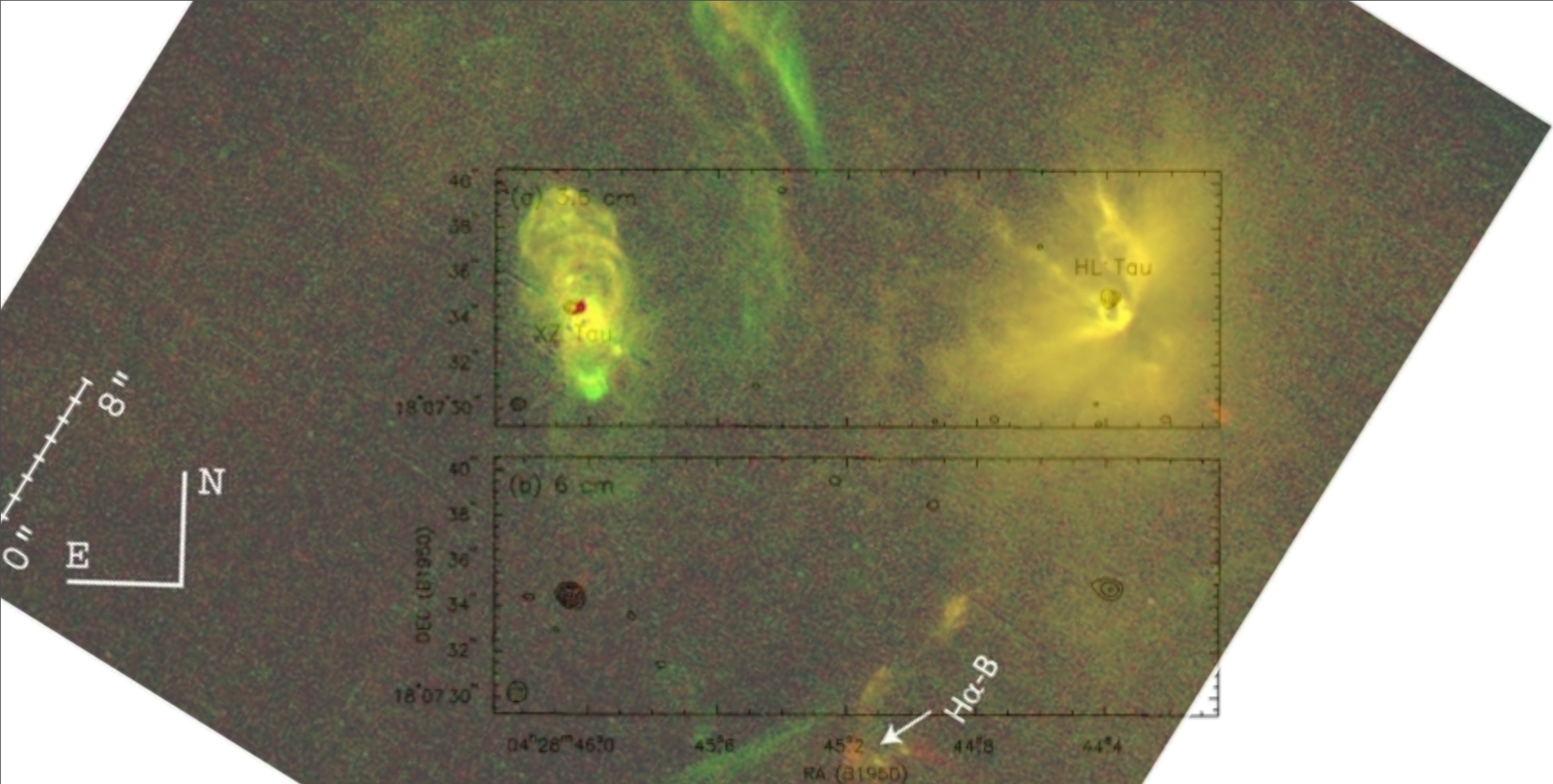


FIG. 2.—(a) VLA 3.6 cm image of the region including HL Tau and XZ Tau. Contours are $(3, 5, 7, 9, 11) \times 0.035 \text{ mJy beam}^{-1}$ (1σ) with negative contours dashed. The $0".64 \times 0".54$ P.A. 96° synthesized beam is illustrated in the lower left-hand corner. (b) VLA 6 cm image of the same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

Wilner, Ho & Rodriguez 1996

Krist et al. 2008

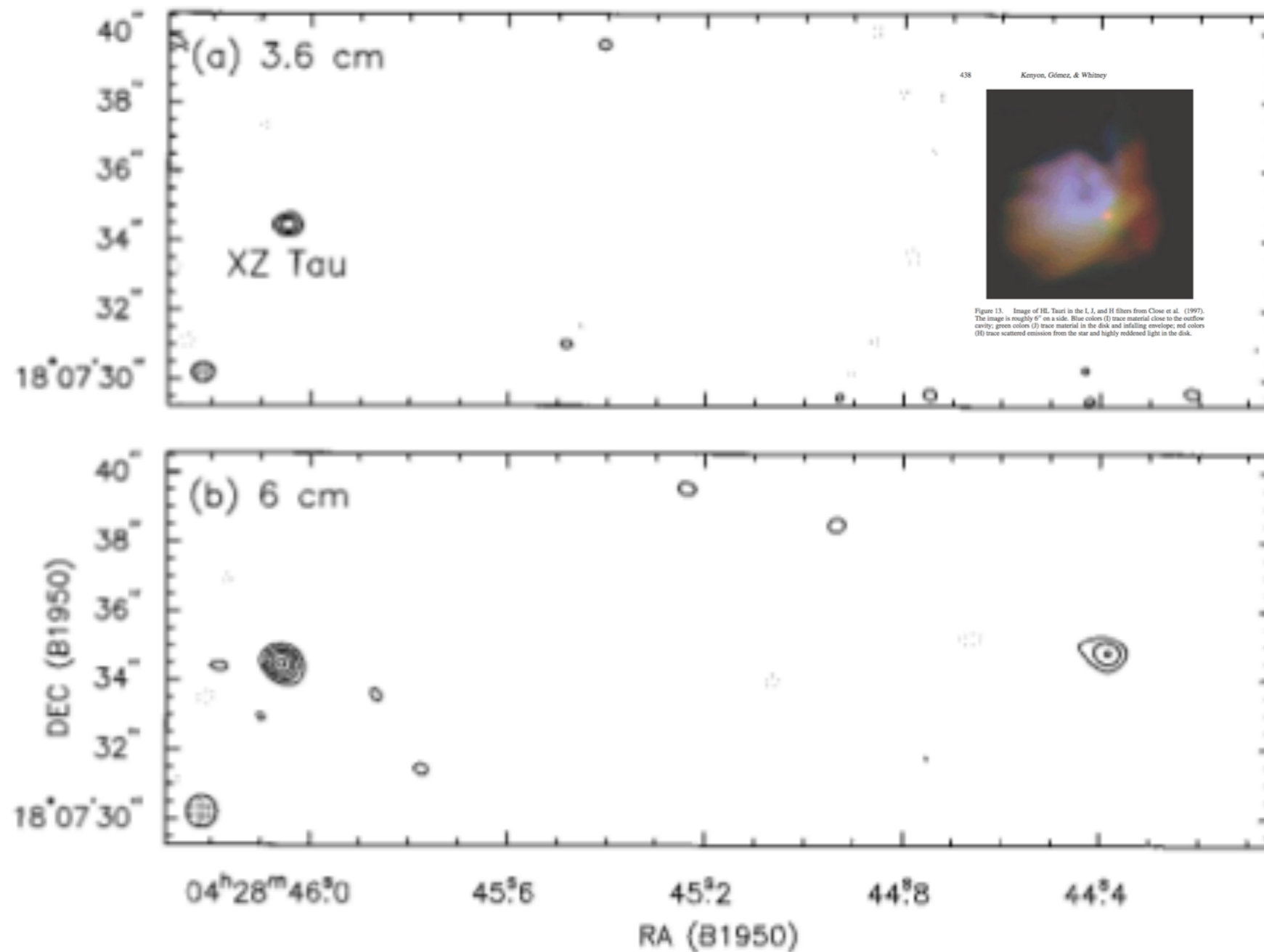


FIG. 2.—(a) VLA 3.6 cm image of the region including HL Tau and XZ Tau. Contours are $(3, 5, 7, 9, 11) \times 0.035 \text{ mJy beam}^{-1}$ (1σ) with negative contours dashed. The $0''.64 \times 0''.54$ P.A. 96° synthesized beam is illustrated in the lower left-hand corner. (b) VLA 6 cm image of the same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

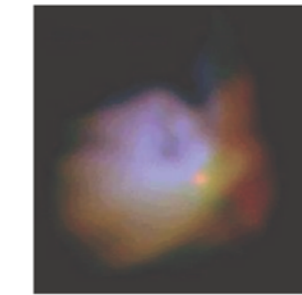


Figure 13. Image of HL Tau in the I, J, and H filters from Close et al. (1997). The image is roughly $6''$ on a side. Blue colors trace material close to the outflow cavity; green colors trace material in the disk and infalling envelope; red colors trace scattered emission from the star and highly reddened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

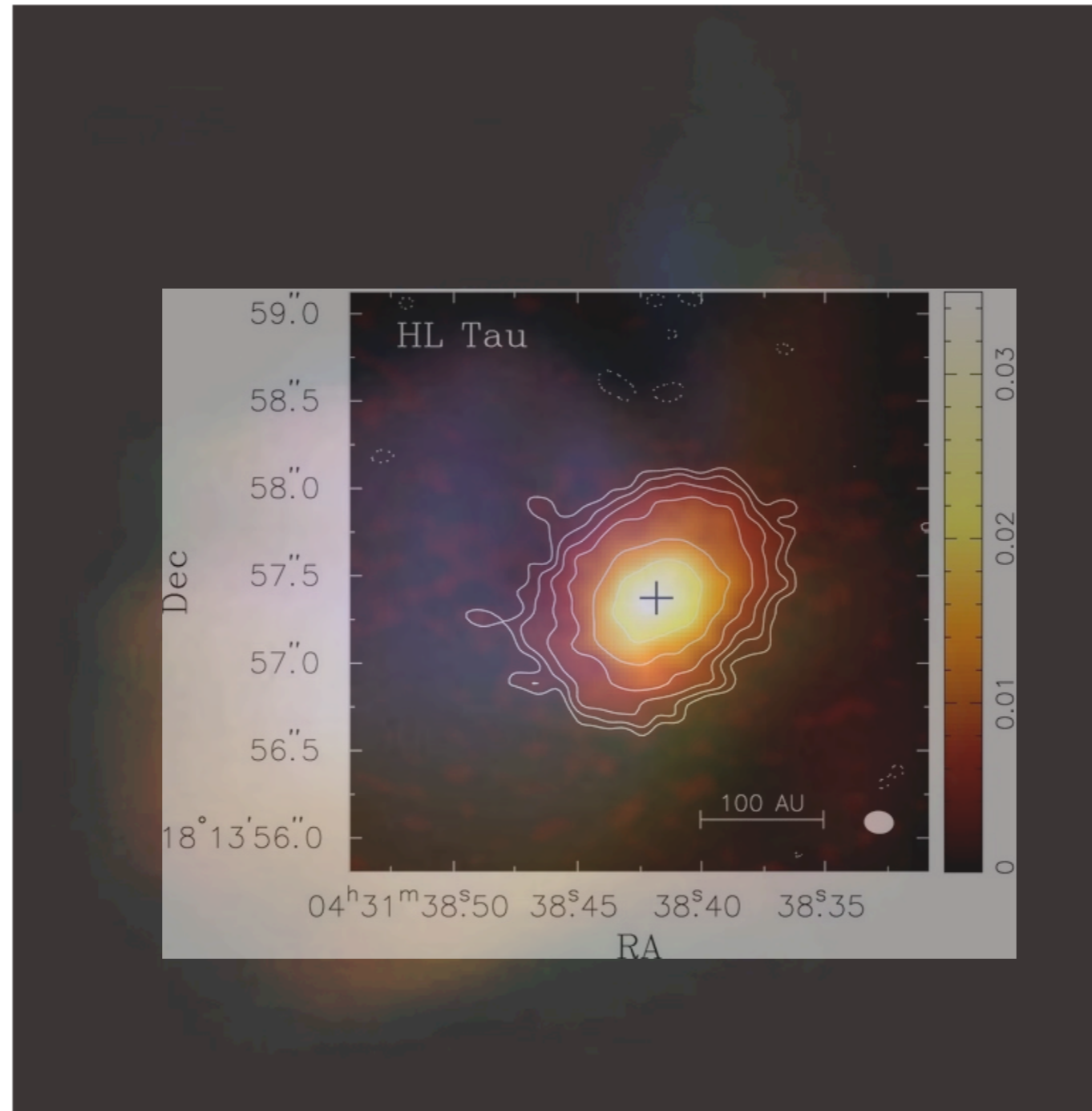
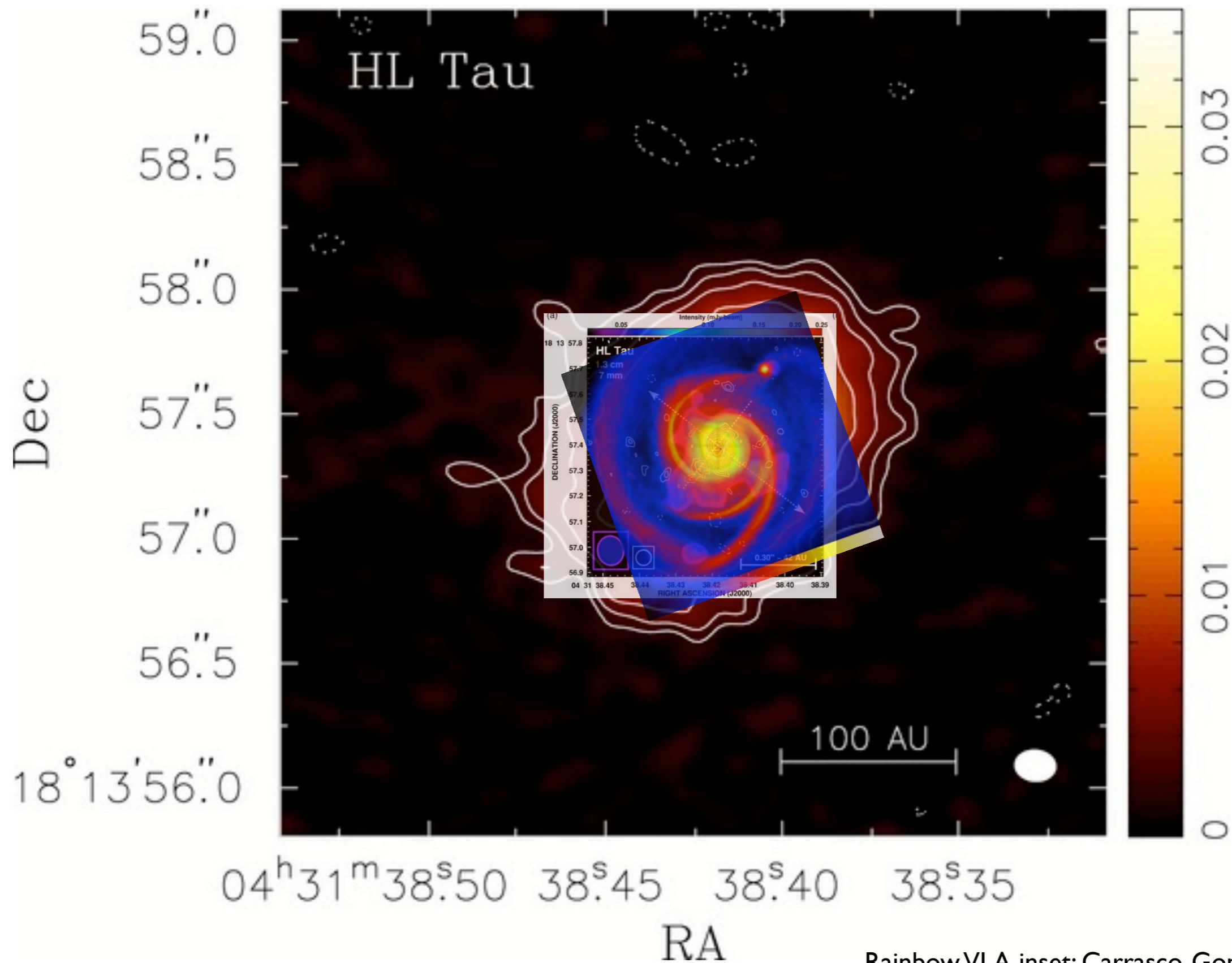


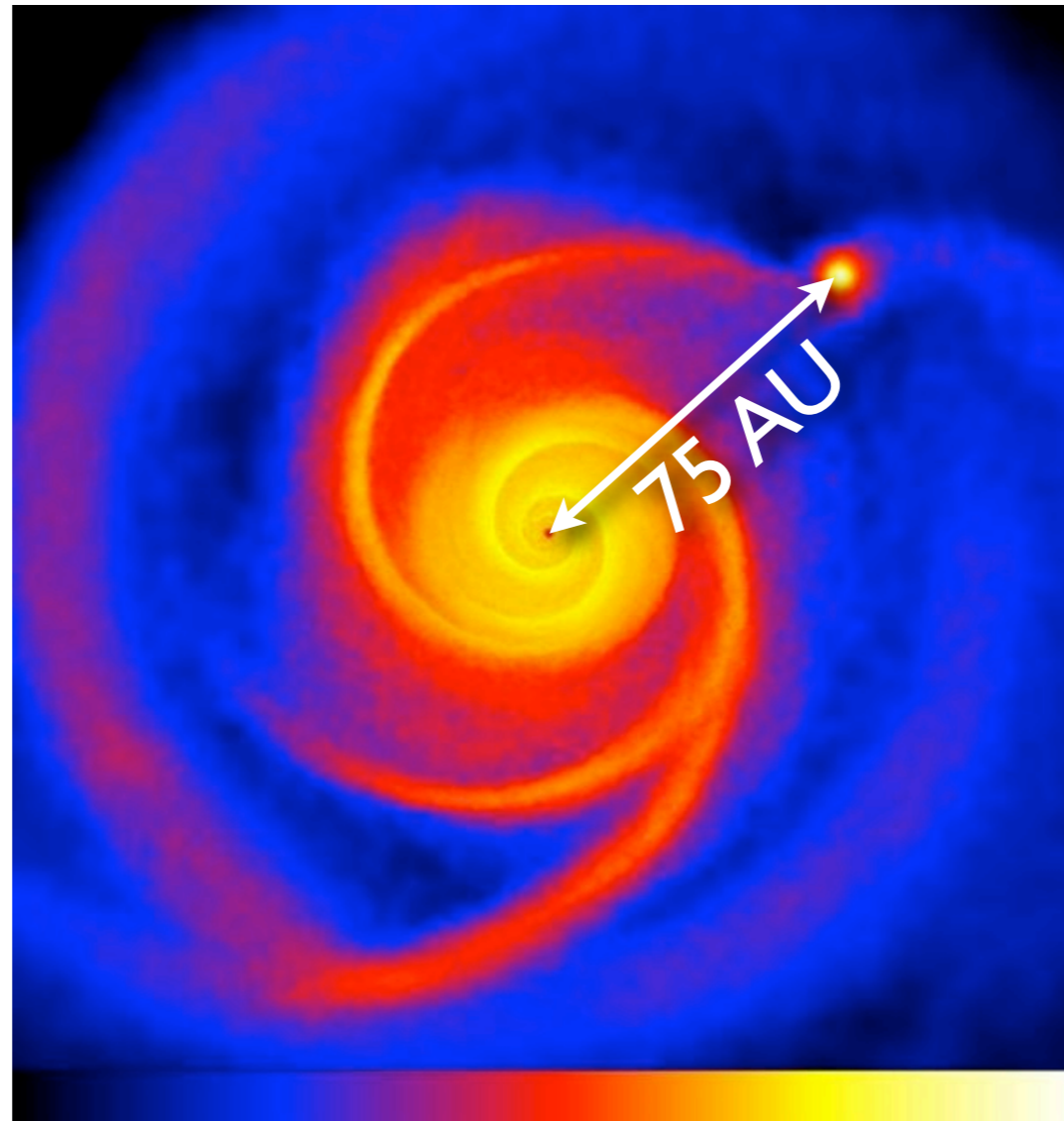
Figure 13. Image of HL Tauri in the I, J, and H filters from [Close et al. \(1997\)](#). The image is roughly 6'' on a side. Blue colors (I) trace material close to the outflow cavity; green colors (J) trace material in the disk and infalling envelope; red colors (H) trace scattered emission from the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

Orange CARMA inset: Kwan, Looney & Mundy 2011

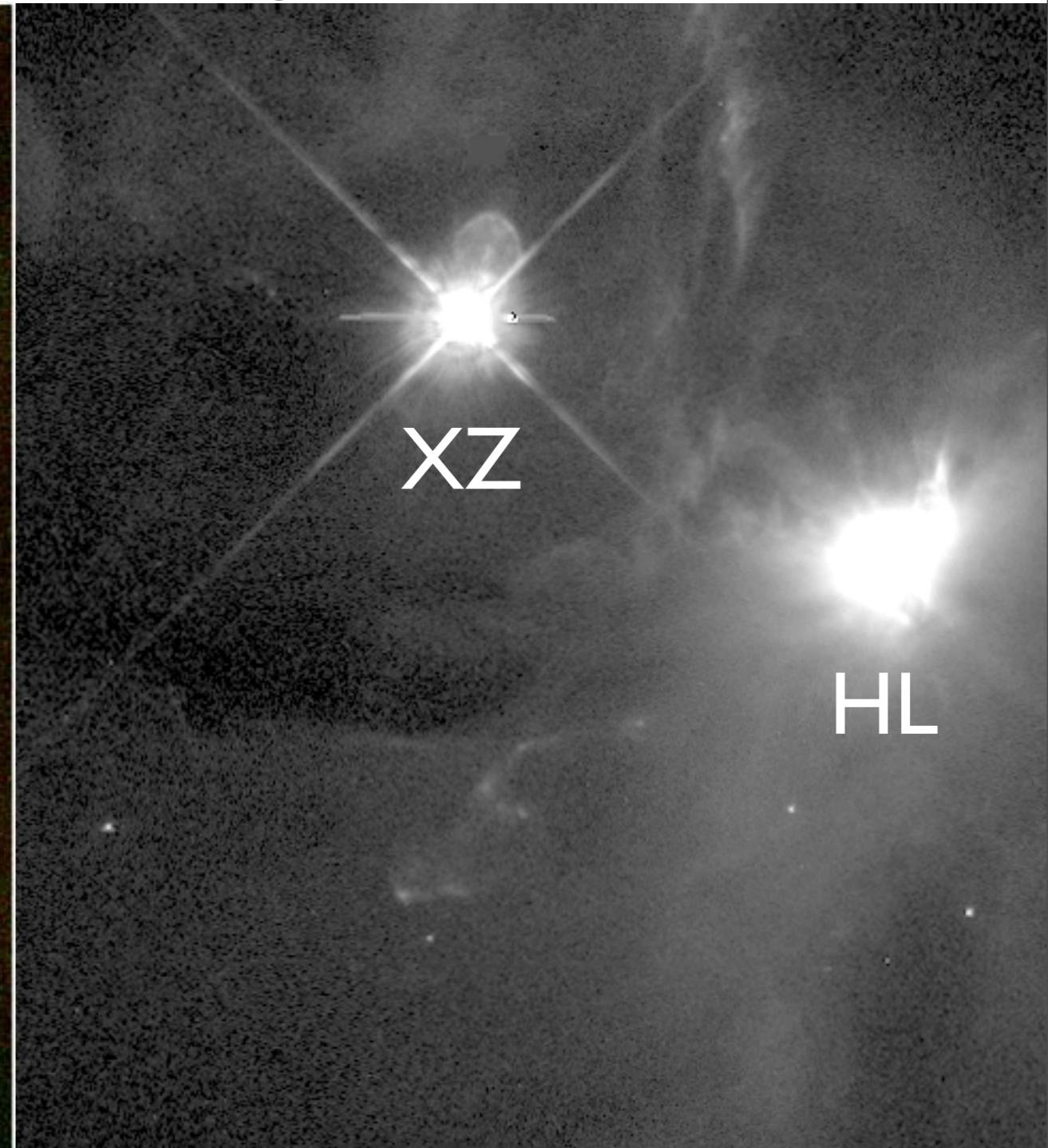
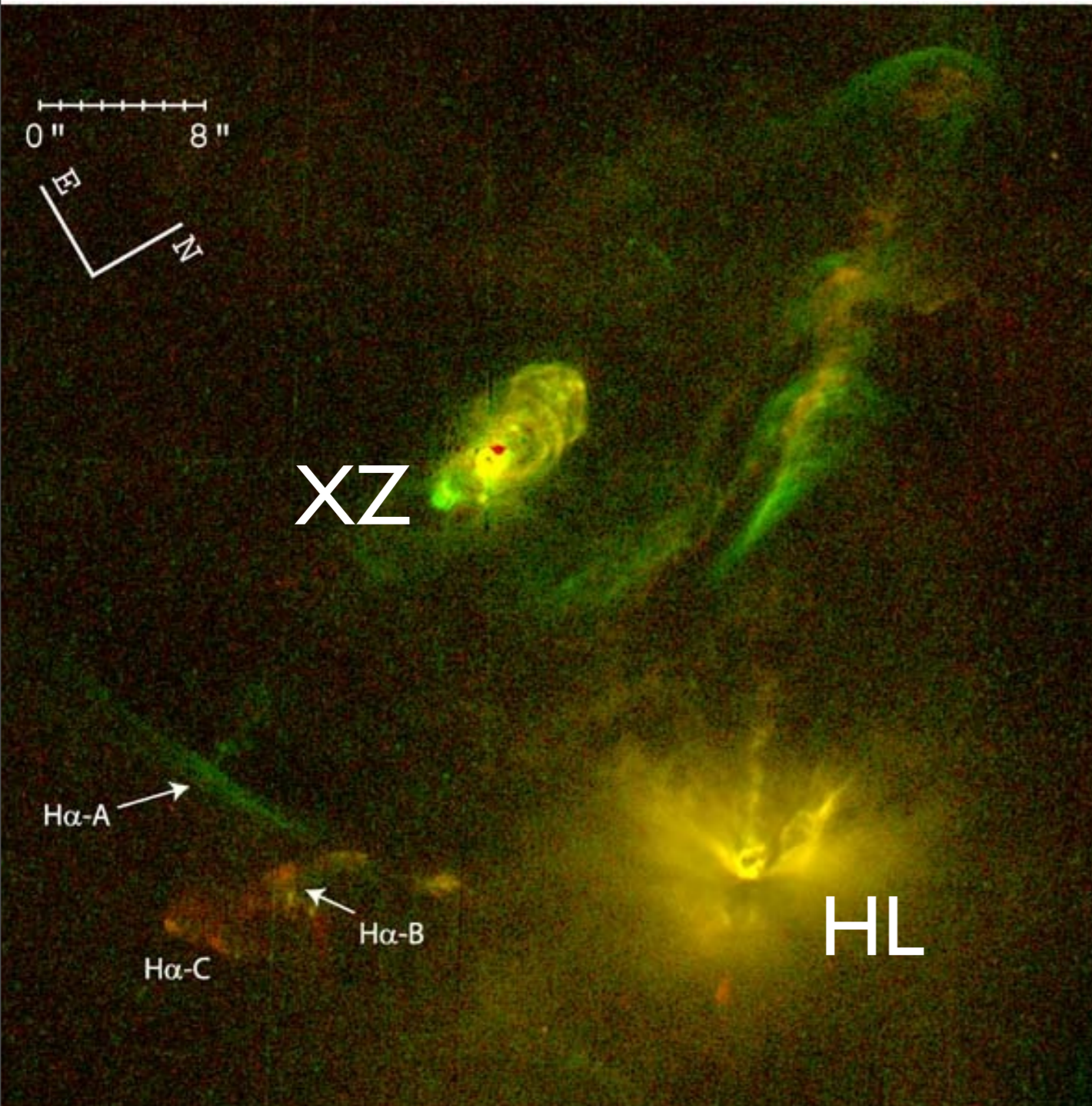


Rainbow VLA inset: Carrasco-González et al. 2009
 Orange CARMA inset: Kwan, Looney & Mundy 2011
 Disk/Planet Model: Greaves et al. 2008

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

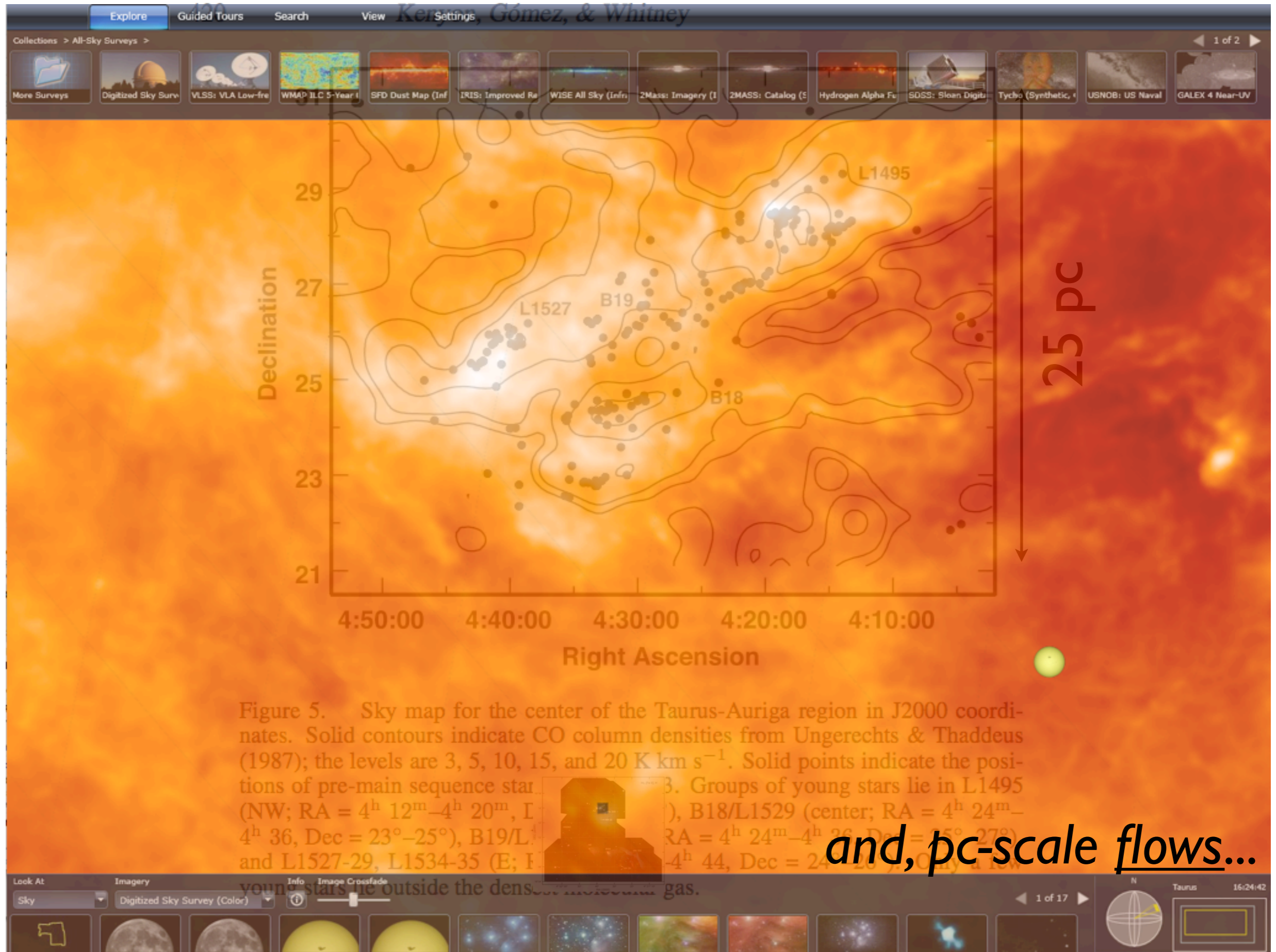


Adding a time dimension...



Krist et al. 2008

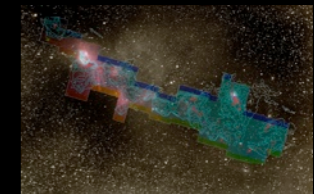
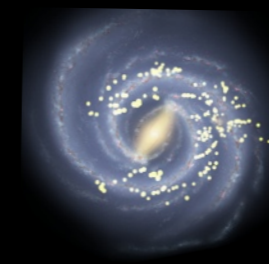
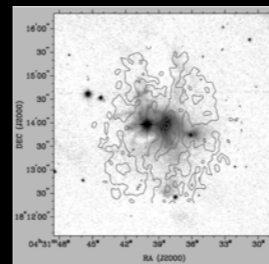
“Taurus” Zoom...~100,000 times (25 pc to 75 AU)



Value: *Compared to what?*

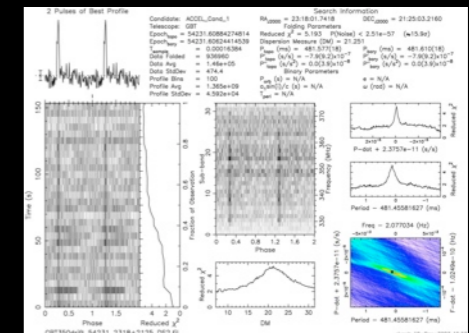
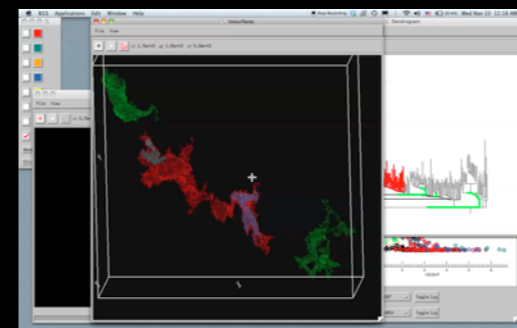
Validation & Discovery

The Value of Context in Astronomy



Context

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.

Explore Guided Tours Search Community Telescope View Settings John Huchra's Universe

Run Time 13:00

CIA2 Paper 0:07.0
 CIA2PaperExcerpt 0:07.0
 First Slice Graphic 0:19.50
 First Slice Geometry 0:13.0
 2D view 0:07.0
 CIA slice only 0:15.0
Edge on Slice 0:13.0
 Overlay Stickman 0:04.0
 CIA slice only 0:10.0
 John Quote 0:13.0
 John Quote 0:13.0
 Stickman and Gra... 0:05.0
 Coma Vstretch 0:23.0

Tour Properties Save
 Show Safe Area
 Music: Browse...
 Voiceover: Browse...
 Text Shapes Picture

Layers

- Sun
- Mercury
- Venus
- Earth
 - John's Places
 - Moon
 - ISS
- Mars
- Jupiter
 - Io
 - Europa
 - Ganymede
 - Callisto
- Saturn
- Uranus
- Neptune
- Pluto
- Sky
 - 1983 CfA1
 - 1990CfA2Slice1
 - FirstSlice3D**
 - For2DZcat
 - For3DZcat

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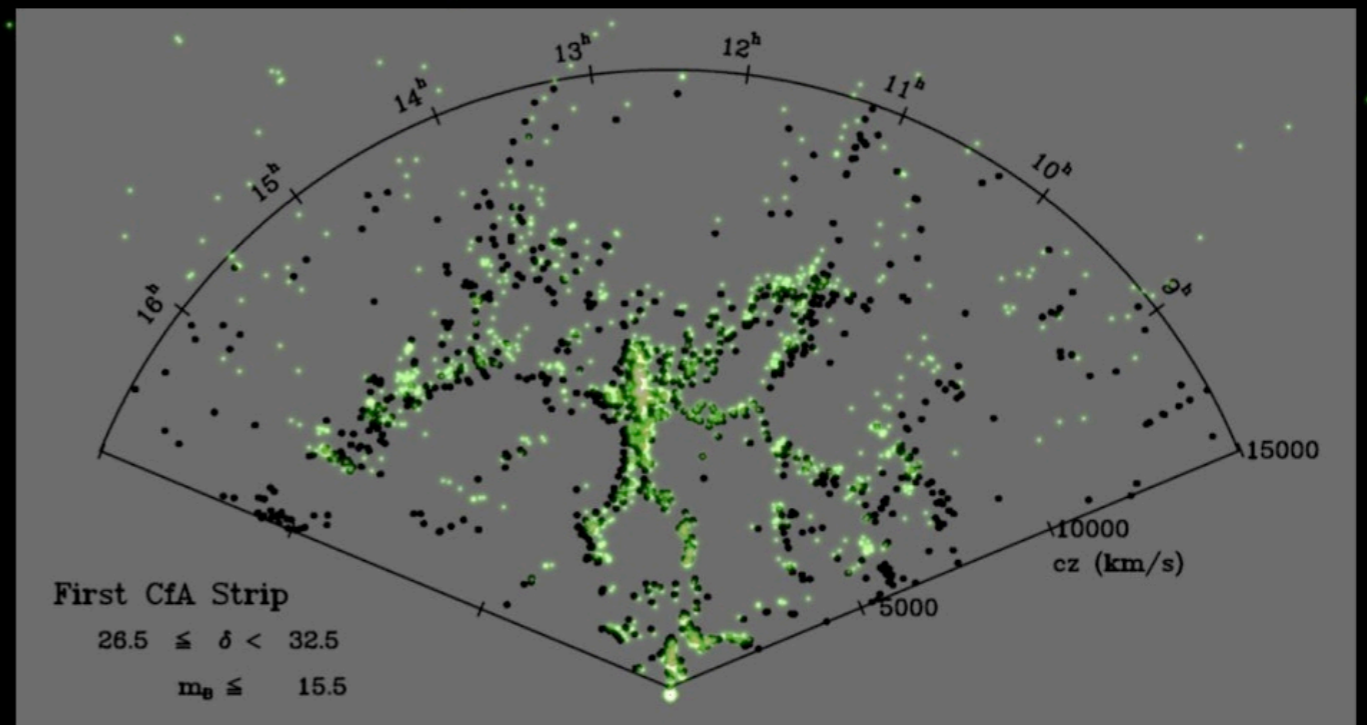
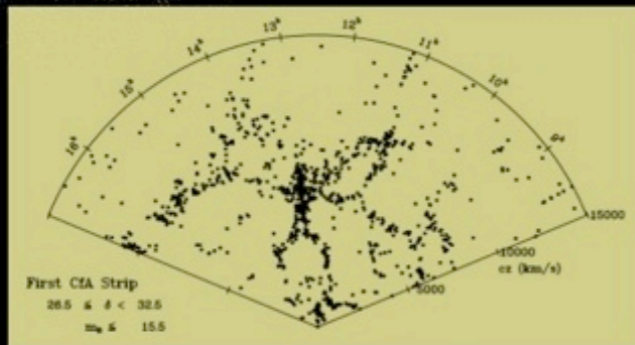
Delete Add Paste Reset

Look At Imagery Image Crossfade

SolarSystem 3D Solar System View

Google 26°

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..

Microsoft WorldWide Telescope

Explore Guided Tours Search Community Telescope View Settings Milky Way Molecular Clouds f... Sign In

Constellation Lines + Overlays

- Figures
- Boundaries
- Focused Only
- Equatorial Grid
- Ecliptic/Orbits
- Reticle/Crosshairs
- Field of View Indicator

3d Solar System

- Show Stars
- Milky Way
- Cosmos
- Orbits
- Planets
- Asteroids
- Lighting
- Minor Orbits

Observing Location

Name: Algiers, Algeria
Lat: 45:28:37
Lng: 09:10:59

View from this location Setup

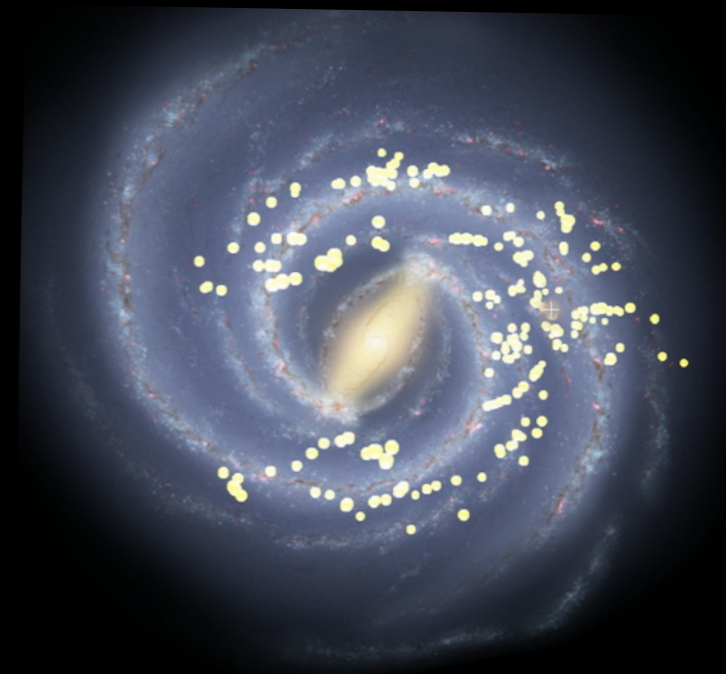
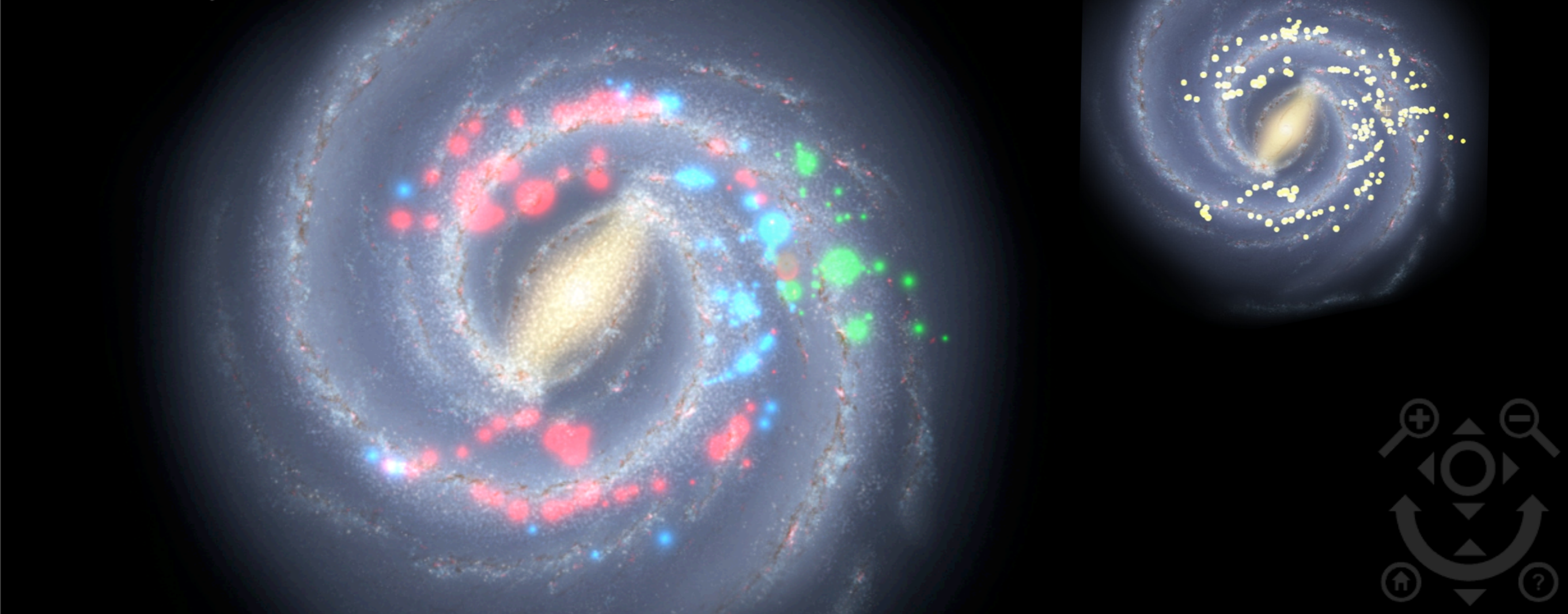
Observing Time

1636/10/05 03:41:47

X 10000000 UTC

Now

Results from Tom Rice's Thesis:
Preliminary Hierarchical Catalog of Milky Way Plane Molecular Clouds



Look At: SolarSystem Imagery: 3D Solar System View

Tracking: Context Search Filter: All 1 of 2

Planet Size: 145688 ly

Actual Large

Planet Size: Sun

Lng: -90:48:01 Lat: -39:51:19

Sun Mercury Venus Earth Mars Jupiter Saturn Uranus Neptune Pluto Moon Io Europa

and the Galaxy..

Microsoft WorldWide Telescope

Explore Guided Tours Search Community Telescope **View** Settings Milky Way Molecular Clouds f... Sign In

Constellation Lines + Overlays

- Figures
- Boundaries
- Focused Only
- Equatorial Grid
- Ecliptic/Orbits
- Reticle/Crosshairs
- Field of View Indicator

3d Solar System

- Show Stars
- Milky Way
- Cosmos
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Observing Location

Name: Algiers, Algeria
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View from this location Setup

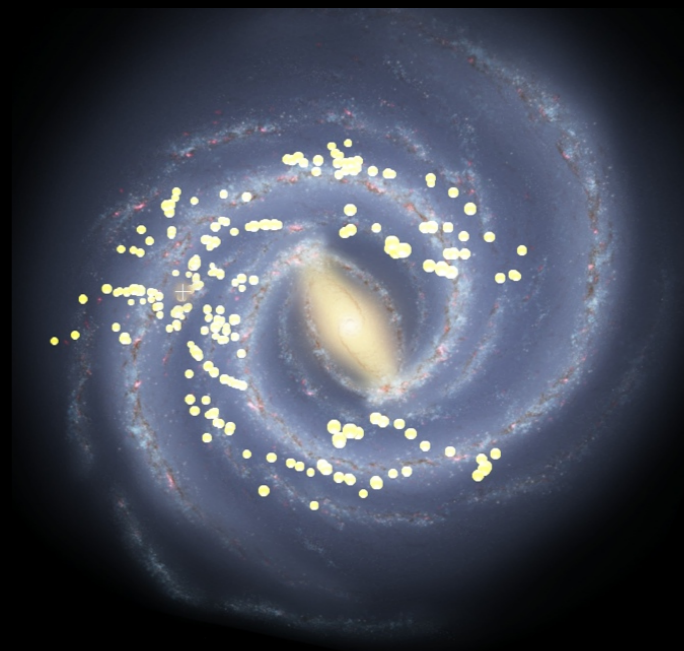
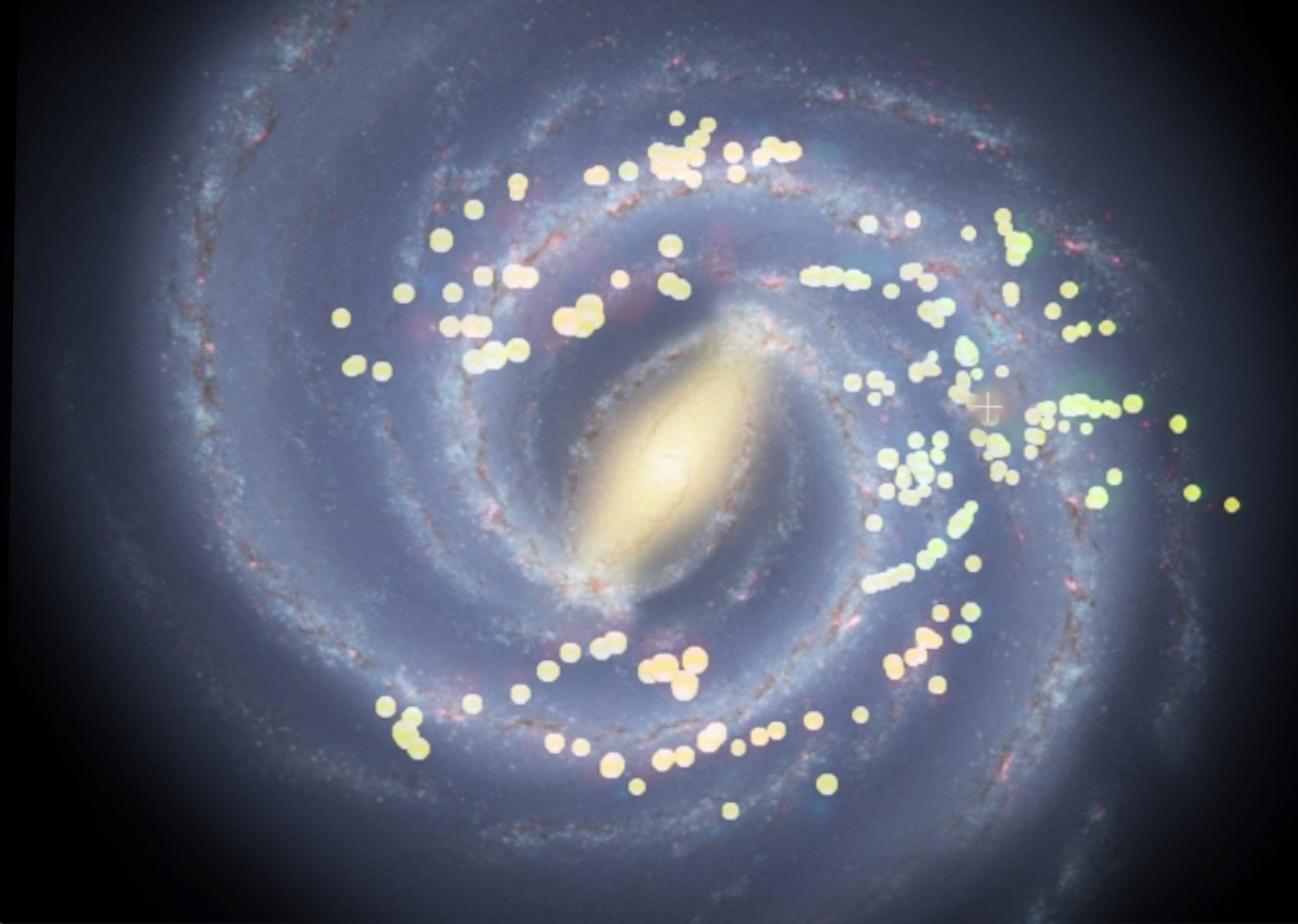
Observing Time

1636/10/05 03:41:47

X 10000000 UTC

Now

Results from Tom Rice's Thesis:
Preliminary Hierarchical Catalog of Milky Way Plane Molecular Clouds



Look At: Solar System Imagery: 3D Solar System View

Sun Mercury Venus Earth Mars Jupiter Saturn Uranus Neptune Pluto Moon Io Europa

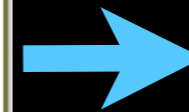
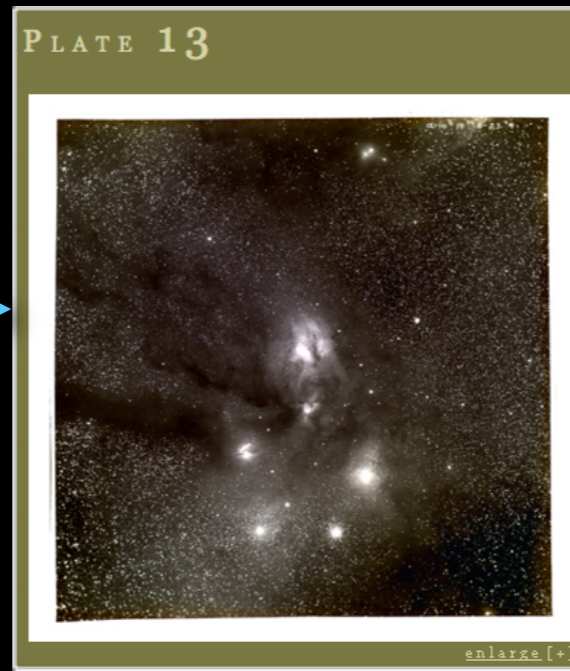
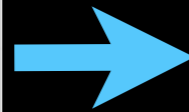
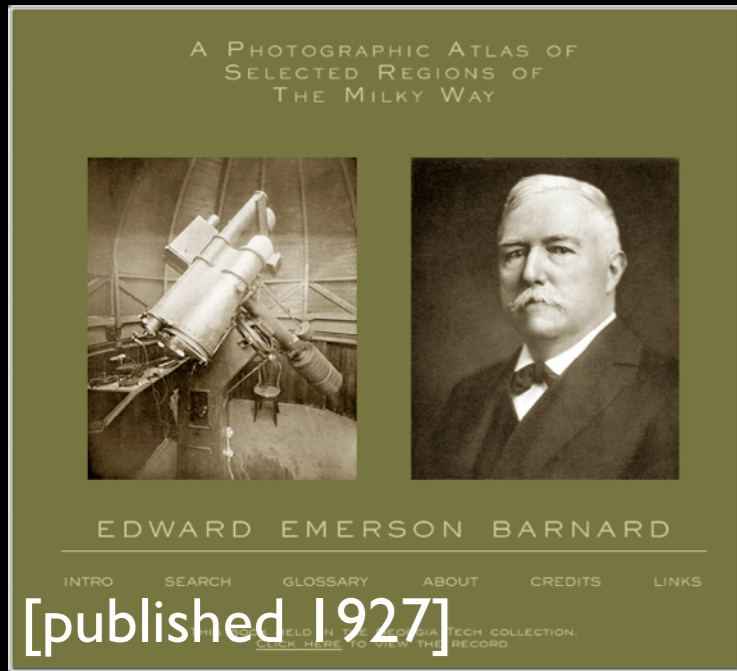
Tracking Context Search Filter: All 1 of 2 Planet Size: 145688 ly

Actual Large Sun

Lng: -90:48:01 Lat: -39:51:19

“Seamless Astronomy”...

astrometry.net + flickr + WWT



flickr from YAHOO!

Home You Organize & Create Contacts Groups Explore Upload

Actions Share this

← Newer Older →

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 (α Sco)
The star Graffias (β 1 Sco)
The star Al Niyat (σ Sco)
The star τ Sco
The star ω 1 Sco
The star ν Sco
The star ω 2 Sco
The star ω Oph
The star 13 Sco
The star ρ Sco
IC 4592
IC 4601
NGC 6121 / M 4
IC 4603
IC 4604 / rho Oph nebula
IC 4605

[View in World Wide Telescope](#)

Explore Guided Tours Search View Settings

Collections > Open Collections > barnardoph >

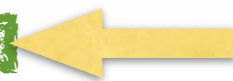
1 of 1

ask me about ADSASS...

Ophiuchus IC4634 IC4603 IC4604 M19 NGC6235 NGC6273 NGC6284

RA : 16h25m41s

Ophiuchus 09:41:29



“Seamless Astronomy”...

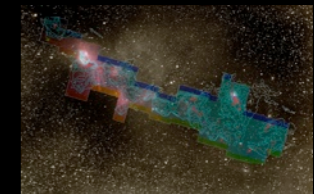
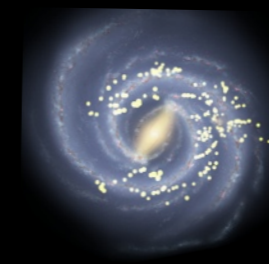
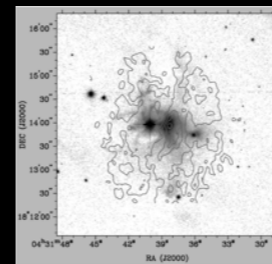
SAMP connections

The image displays a multi-window astronomical software interface. The main window is Aladin v6.0, showing a grayscale image of a star cluster with various markers. Overlaid on this is the Microsoft WorldWide Telescope window, which displays a similar view with white circles highlighting specific stars. In the foreground, the TOPCAT window is open, showing a scatter plot of data points. The scatter plot has a y-axis labeled '2000' with values 68.15, 68.20, 68.25, and 68.30. The x-axis is unlabeled but has a grid. The plot contains several red circular data points. The TOPCAT window also includes a menu bar with options like File, Views, Graphics, Joins, Windows, VO, Interop, and Help, and a toolbar with various icons. In the bottom right corner, there is a navigation panel with a search filter, a globe icon, and coordinates: RA: 21h01m16s and Dec: +68:08:31. The time 00:14:04 is also displayed.

Value: *Compared to what?*

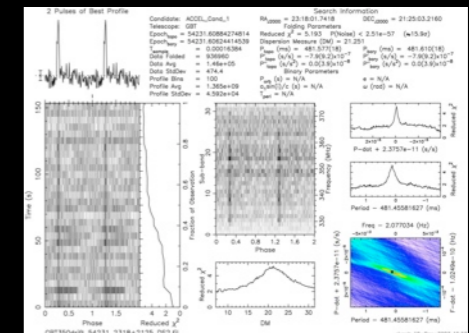
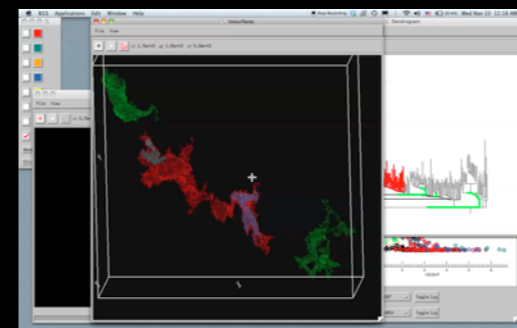
Validation & Discovery

The Value of Context in Astronomy



Context

Spatial & Abstract



Data • Dimensions • Display

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

Principles of High-Dimensional Data Visualization in Astronomy

Alyssa A. Goodman^{1,*}

Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA

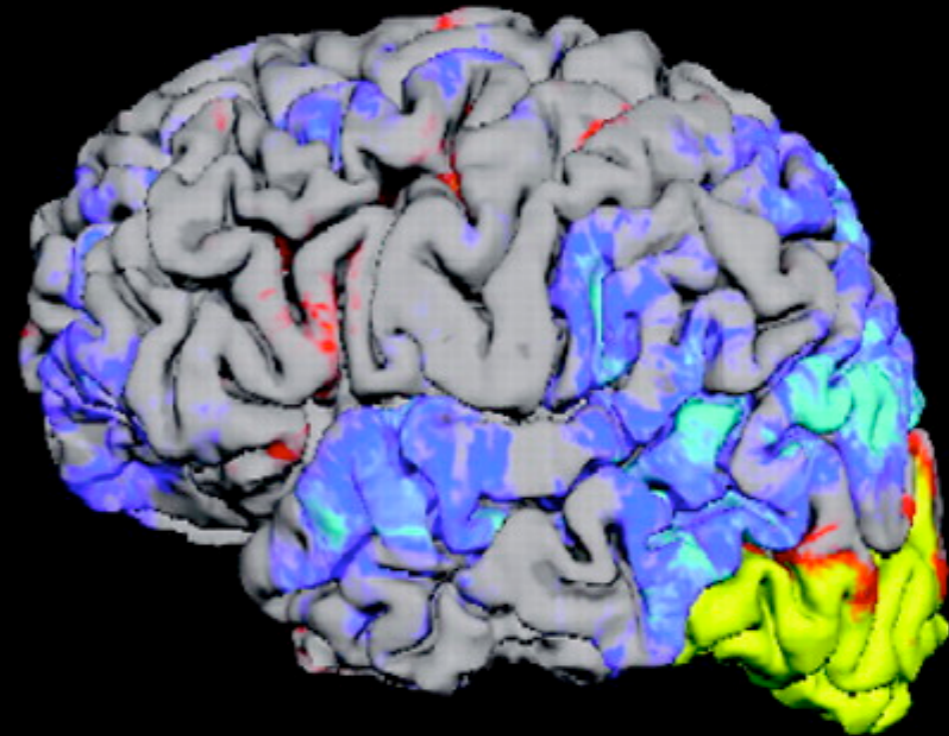
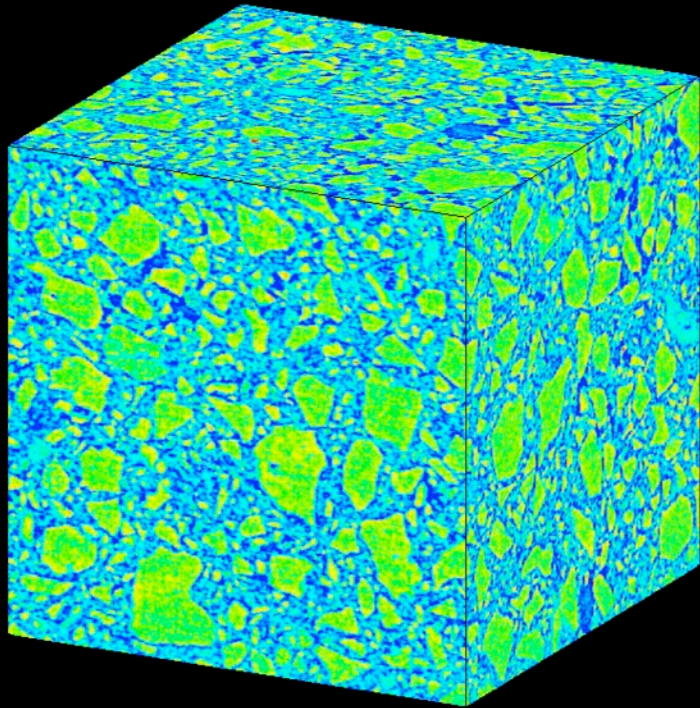
Received 20 Apr 2012, accepted 20 Apr 2012

Published online later

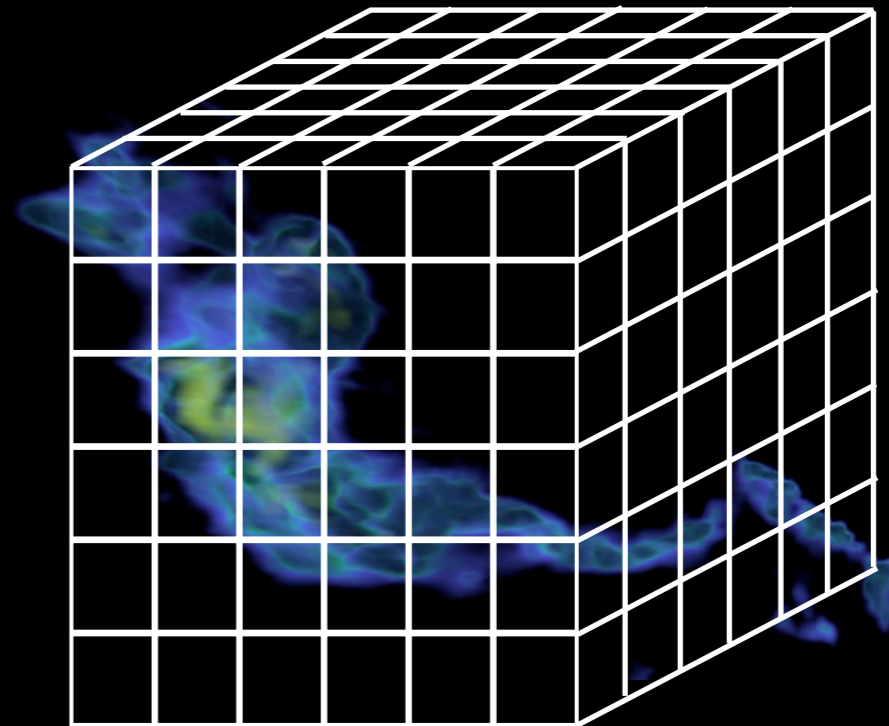
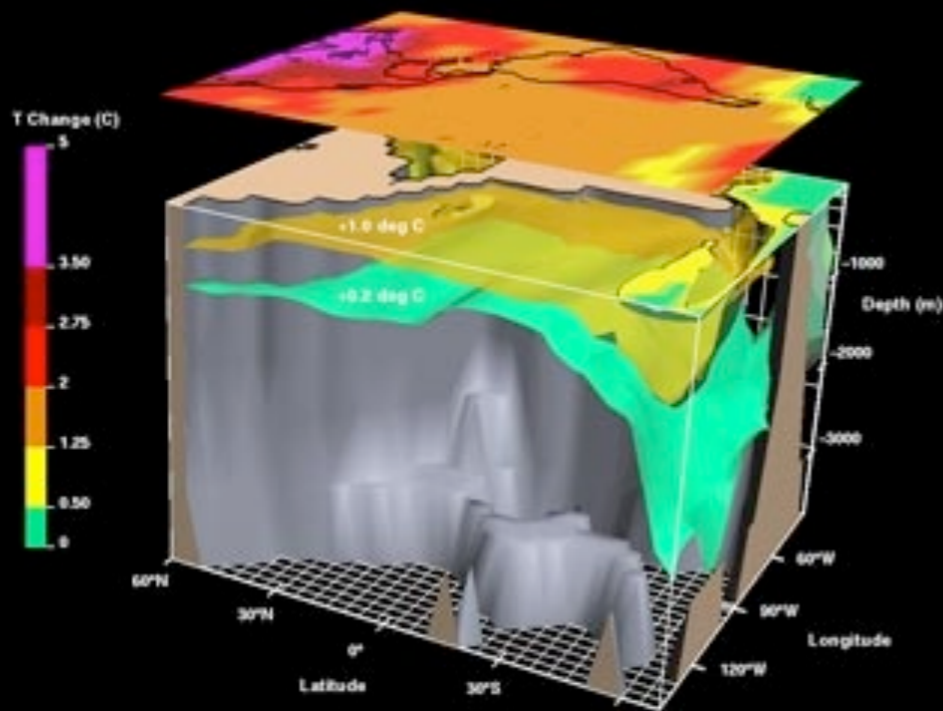
Key words techniques: image processing; methods: data analysis; techniques: radial velocities; cosmology: large-scale structure; ISM: clouds

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 chart 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



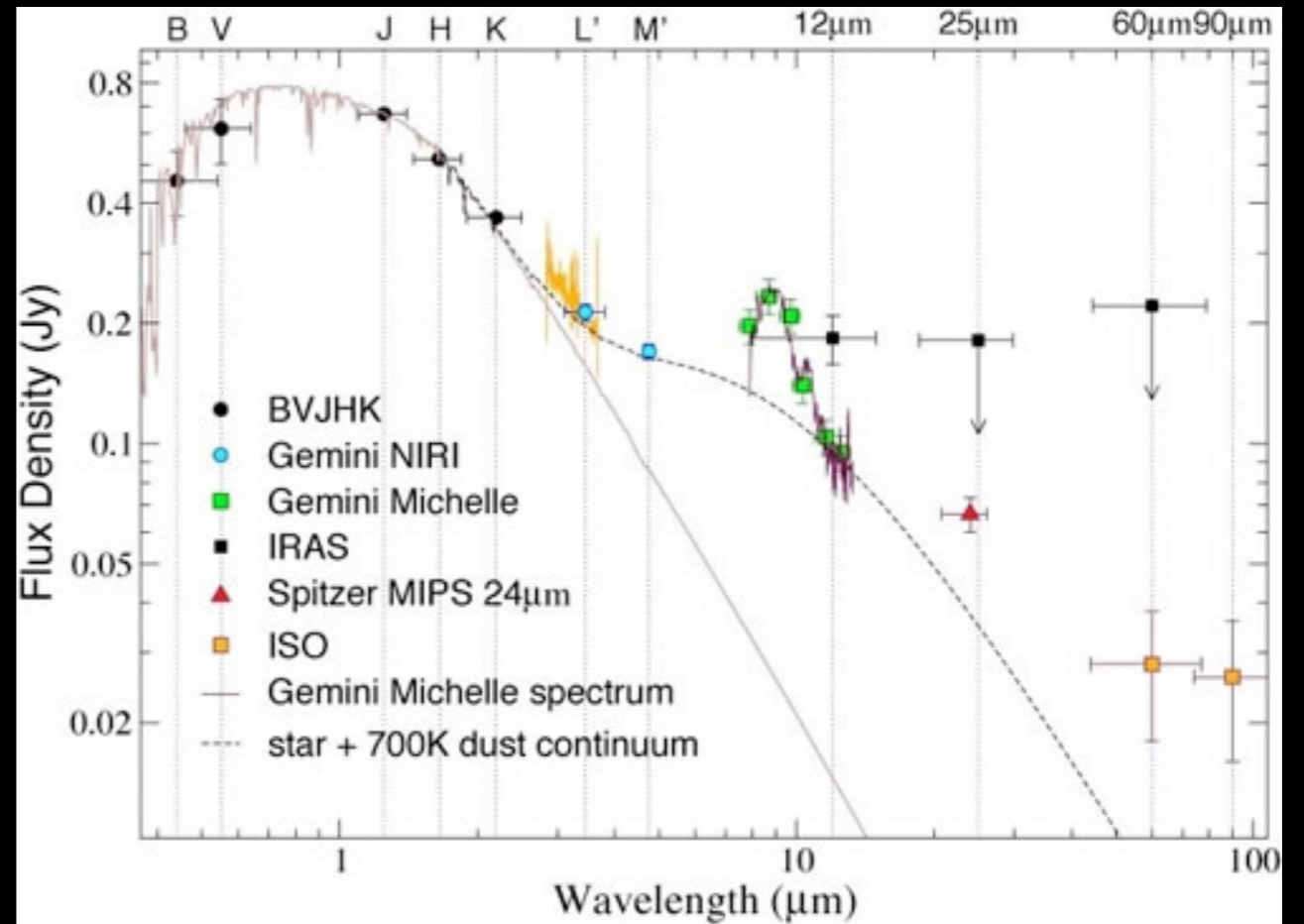
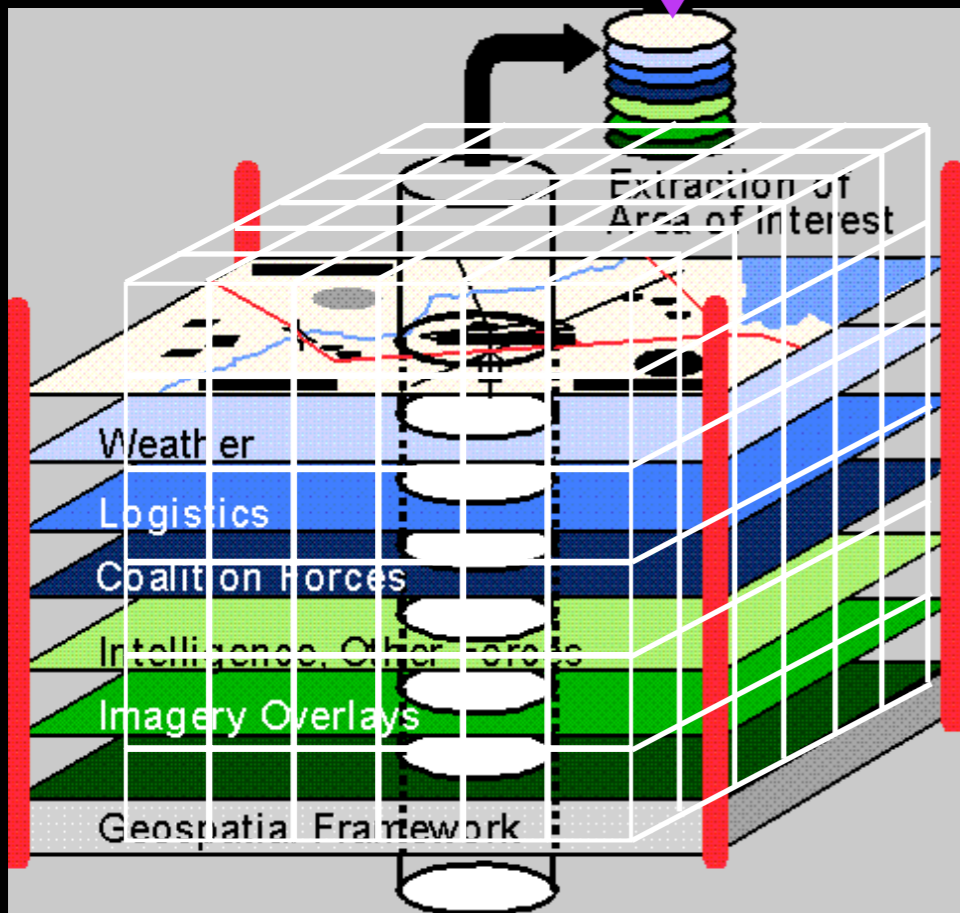
ATMOSPHERIC AND OCEANIC TEMPERATURE CHANGE

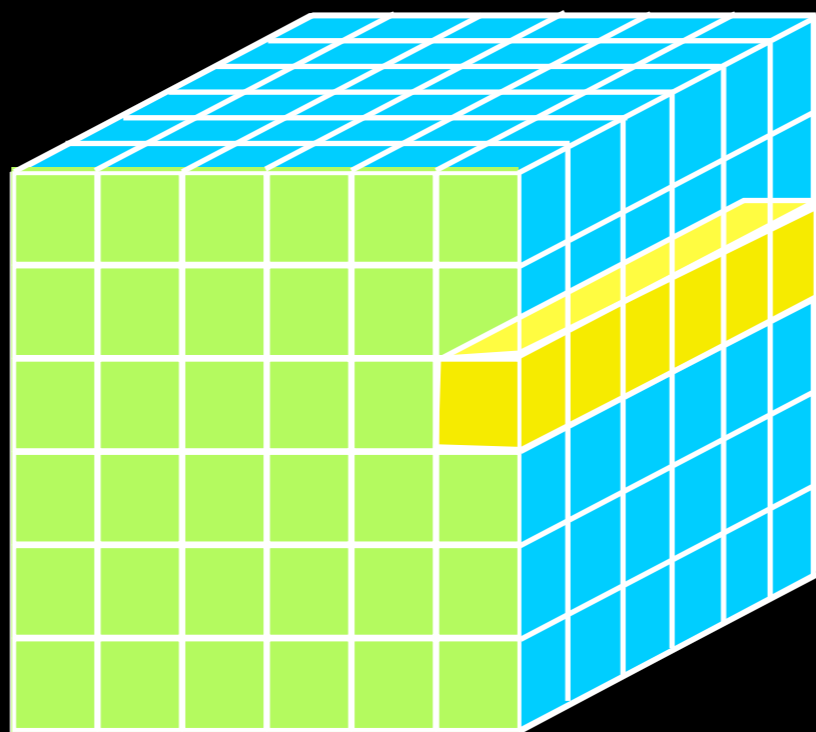


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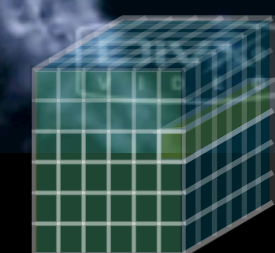
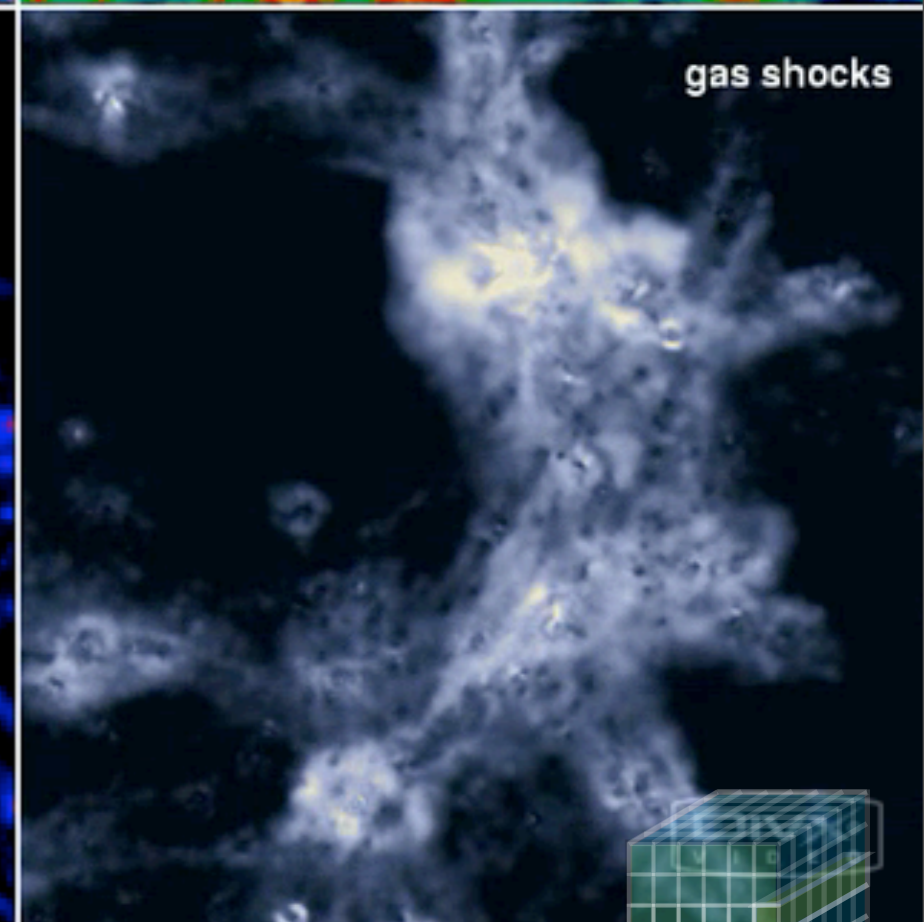
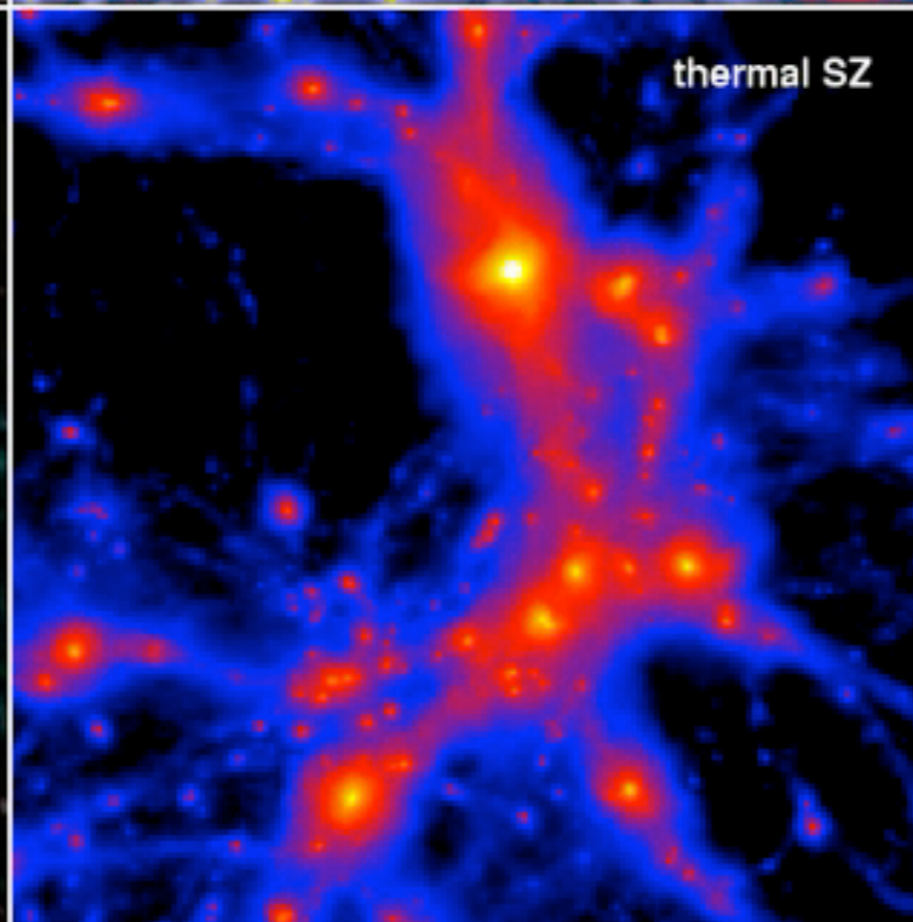
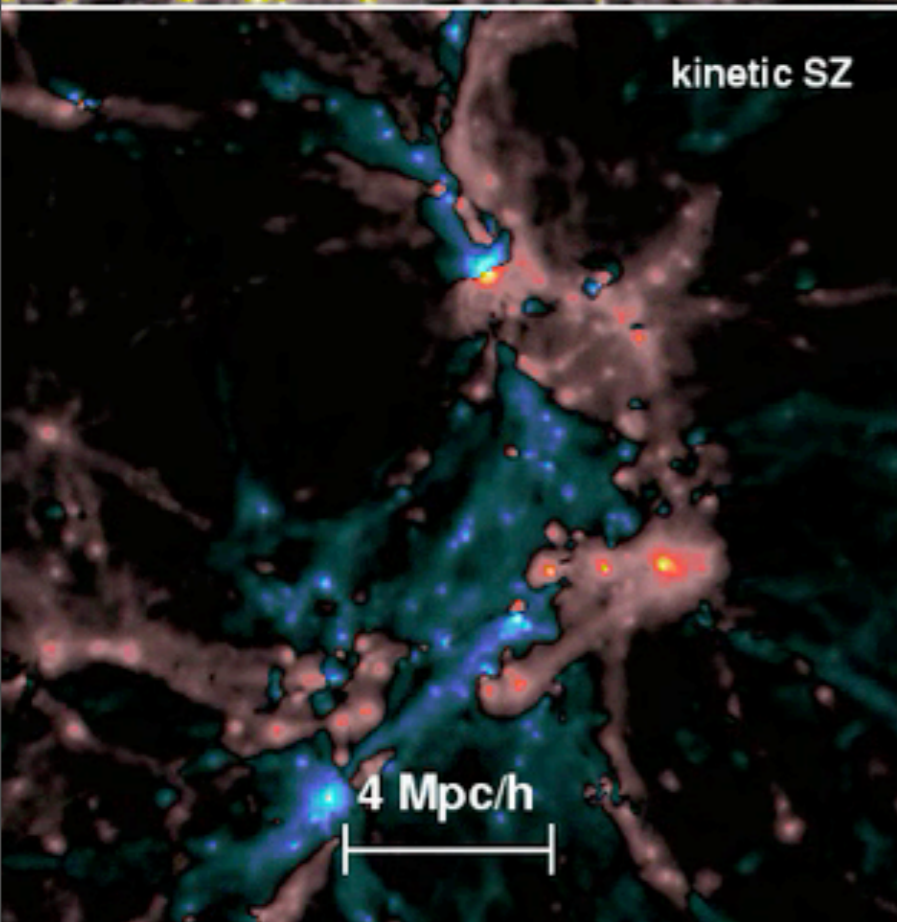
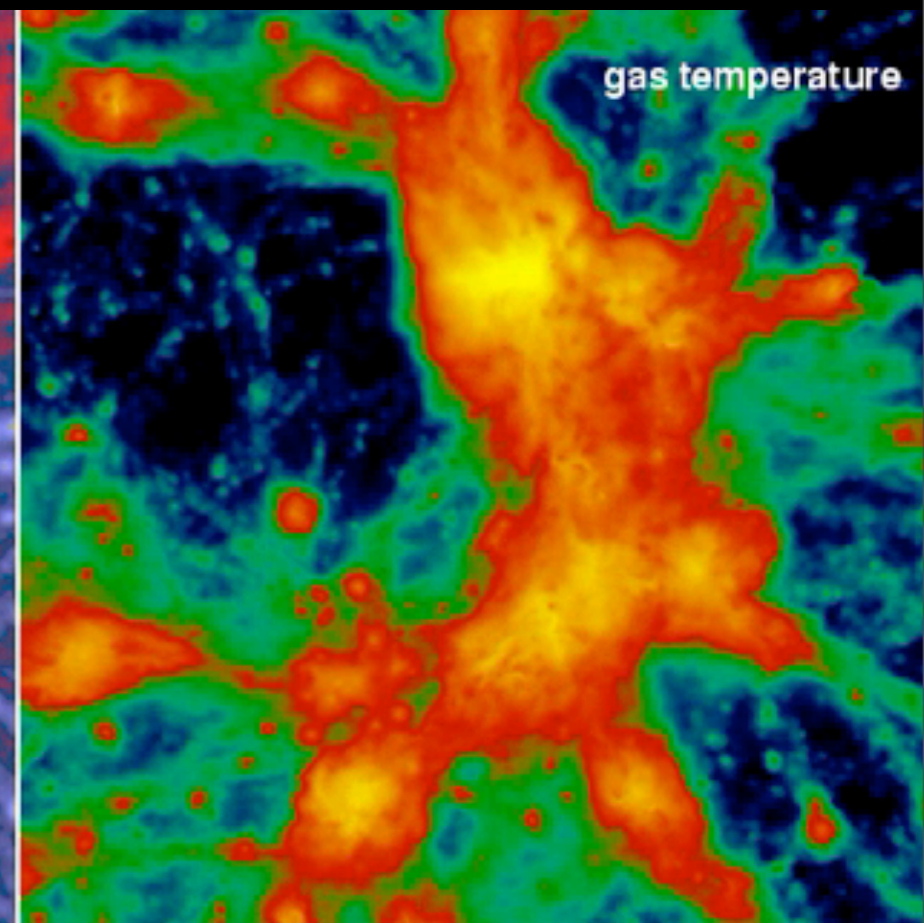
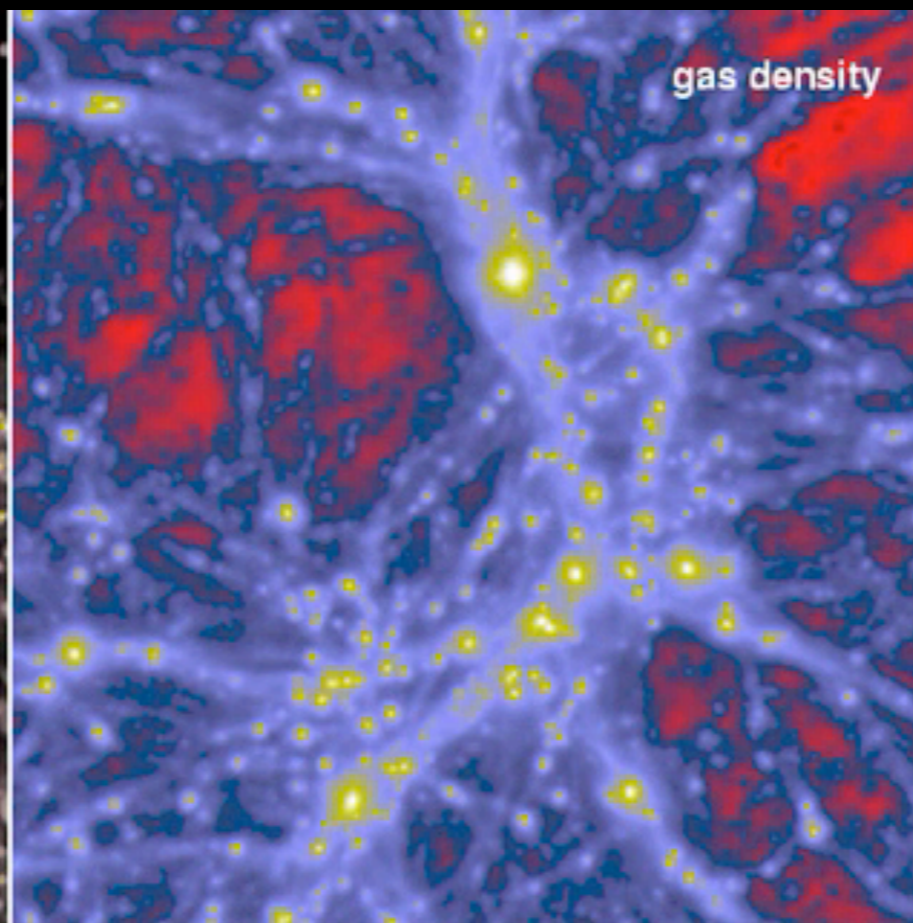
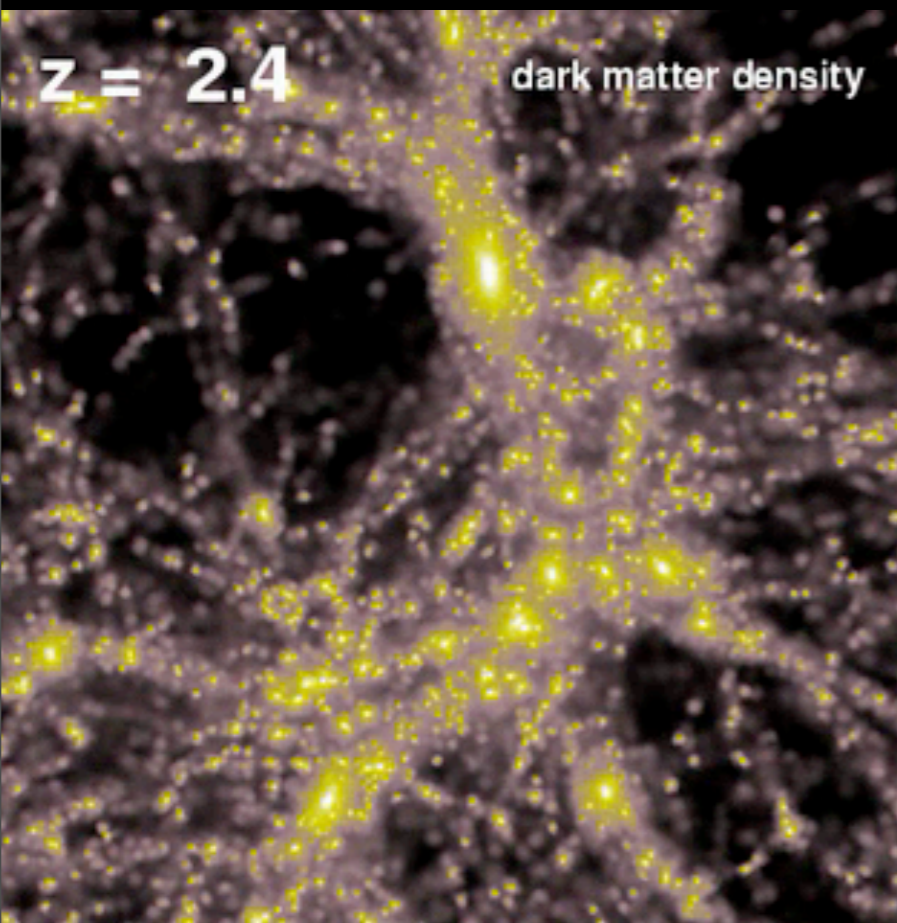
is a “spectral energy distribution”





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”

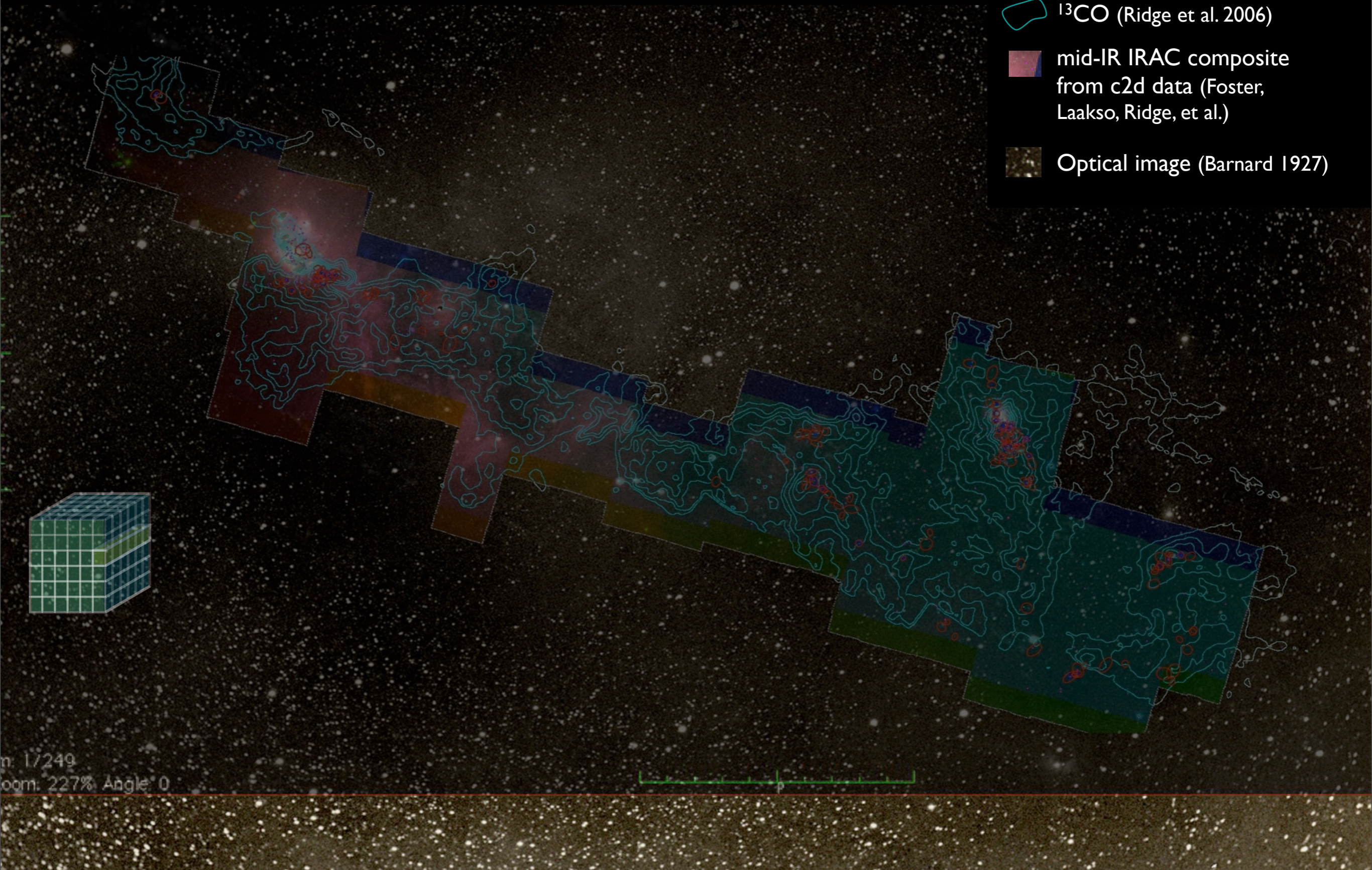


Movie: Volker Springel, formation of a cluster of galaxies

COMPLETE Perseus

Image size: 1305 x 733
VL: 63 WW: 127

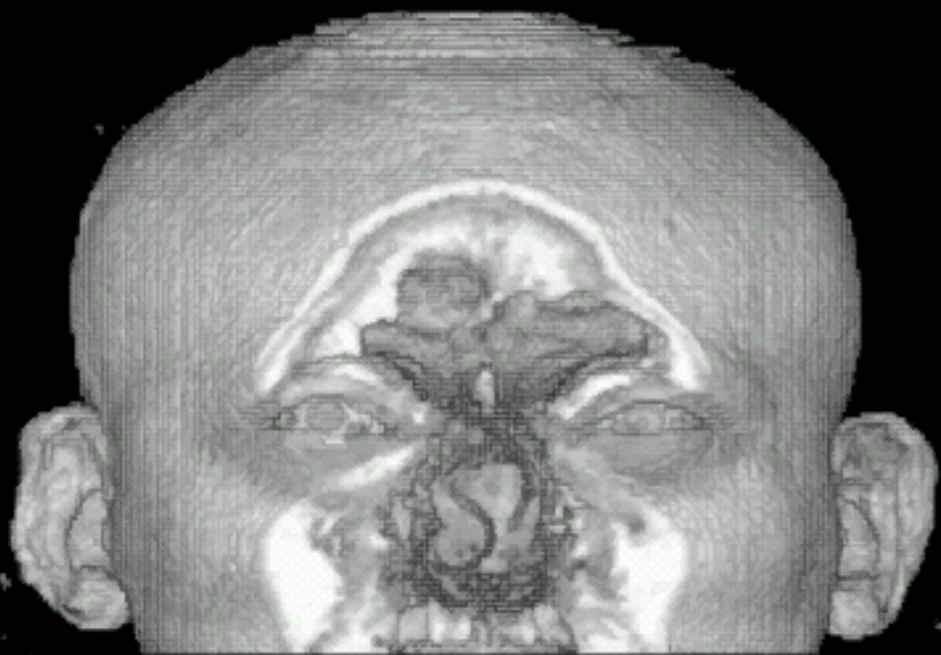
-  mm peak (Enoch et al. 2006)
-  sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)
-  ^{13}CO (Ridge et al. 2006)
-  mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al.)
-  Optical image (Barnard 1927)



m: 1/249
Zoom: 227% Angle: 0

“Astronomical Medicine”

“KEITH”



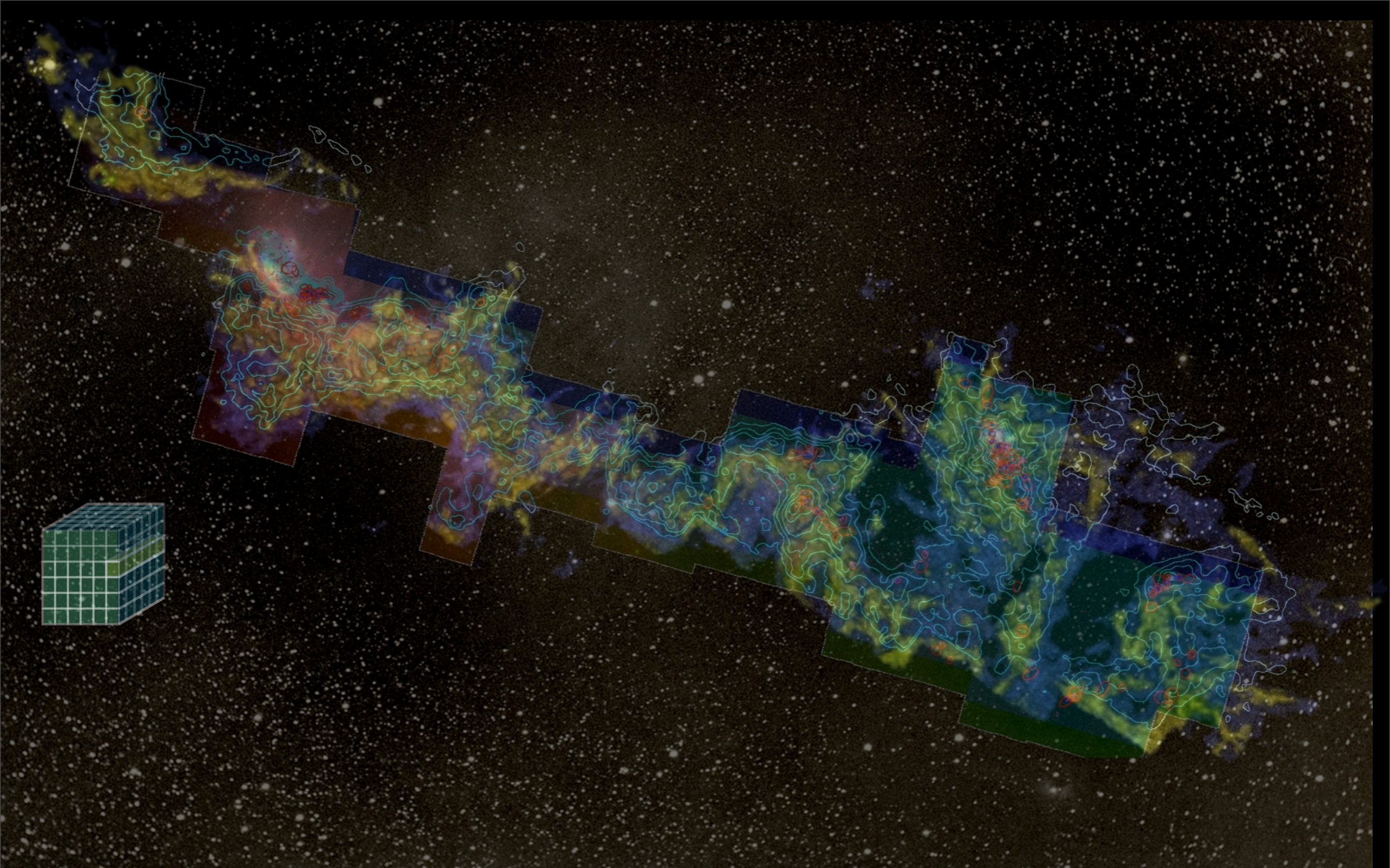
“z” is depth into head

“PERSEUS”



“z” is line-of-sight velocity

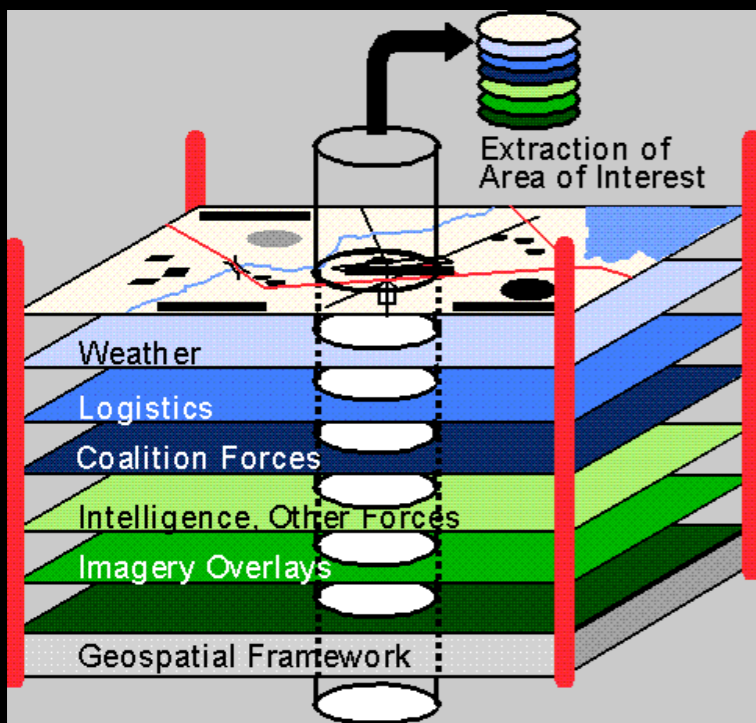
(This kind of “series of 2D slices view” is known in the Viz as “the grand tour”)



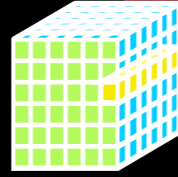
3D Viz made with VolView

Astronomical**Medicine**@iic

COMPLETE



Data
Dimensions
Display



Open Data
Open Tools



COMPLETE

COMPLETE Data Available

Center on Perseus Center on Ophiuchus Center on Serpens

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

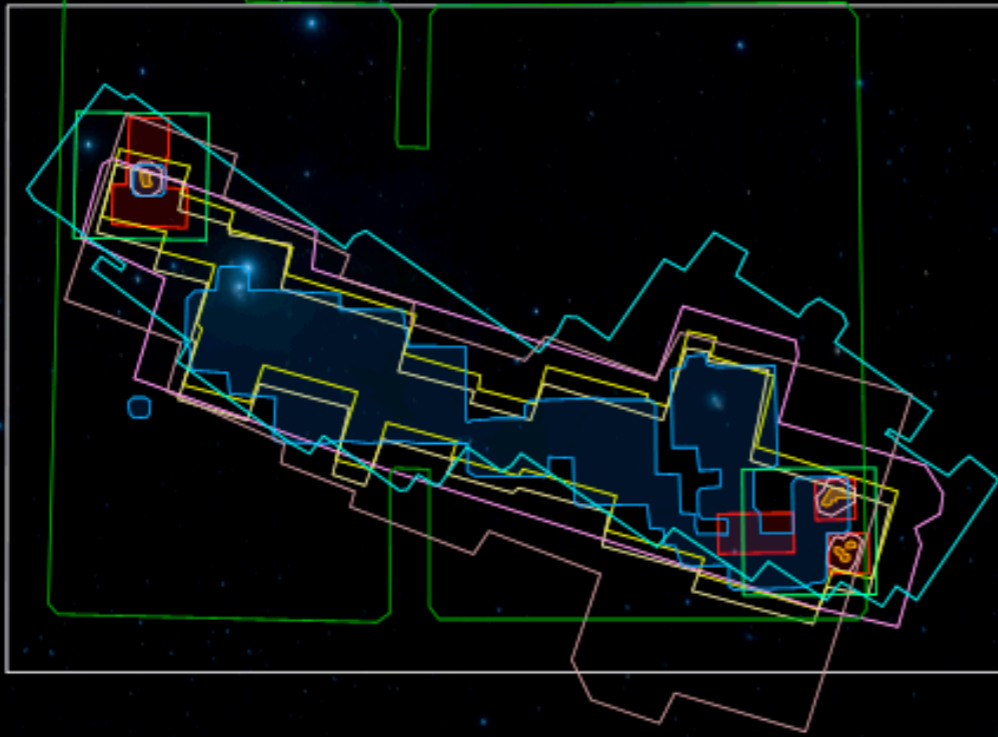
| Dataset | Show | Perseus | Ophiuchus | Serpens | Link |
|------------------------------------|-------------------------------------|---------|-----------|---------|----------------------|
| GBT: HI Data Cube | <input checked="" type="checkbox"/> | ✓ | ✓ | ∅ | Data |
| IRAS: Av/Temp Maps | <input checked="" type="checkbox"/> | ✓ | ✓ | ✓ | Data |
| FCRAO: 12CO | <input checked="" type="checkbox"/> | ✓ | ✓ | ✓ | Data |
| FCRAO: 13CO | <input checked="" type="checkbox"/> | ✓ | ✓ | ✓ | Data |
| JCMT: 850 microns | <input checked="" type="checkbox"/> | ✓ | ✓ | ∅ | Data |
| Spitzer c2d: IRAC 1,3 (3.6,5.8 μm) | <input checked="" type="checkbox"/> | ✓ | ✓ | ✓ | Data |
| Spitzer c2d: IRAC 2,4 (4.5,8 μm) | <input checked="" type="checkbox"/> | ✓ | ✓ | ✓ | Data |
| CSO/Bolocam: 1.2-mm | <input checked="" type="checkbox"/> | ✓ | ∅ | ∅ | Data |
| Spitzer MIPS: Derived Dust Map | <input checked="" type="checkbox"/> | ✓ | ∅ | ∅ | Data |

Targeted Regions (Phase II, Some Data Not Yet Available)

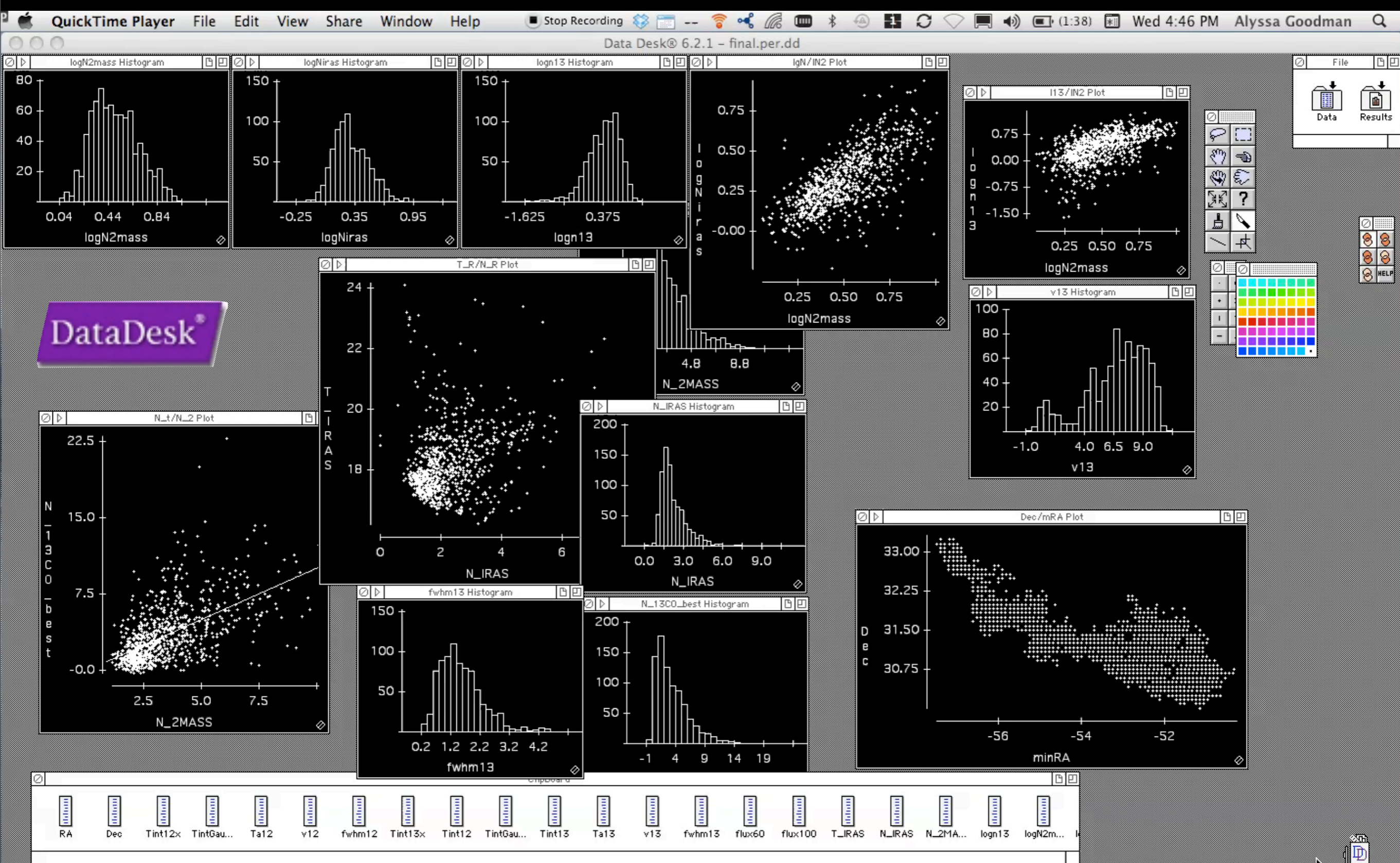
| | | | | | |
|-------------------------------|-------------------------------------|---|---|---|----------------------|
| CTIO/Calar Alto: NIR (J,H,Ks) | <input checked="" type="checkbox"/> | ✓ | ✓ | ∅ | Data |
| IRAM 30-m: N2H+ and C18O | <input checked="" type="checkbox"/> | ✓ | ∅ | ∅ | Data |
| IRAM 30-m: 1.1-mm continuum | <input checked="" type="checkbox"/> | ✓ | ∅ | ∅ | Data |
| Megacam/MMT: r,i,z images | <input checked="" type="checkbox"/> | ✓ | ∅ | ∅ | Data |

Catalogs & Pointed Surveys

| | | | | | |
|--------------------------|-------------------------------------|---|---|---|----------------------|
| NH3 Pointed Survey | <input checked="" type="checkbox"/> | ✓ | ∅ | ∅ | Data |
| YSO Candidate list (c2d) | <input checked="" type="checkbox"/> | ✓ | ✓ | ✓ | 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)

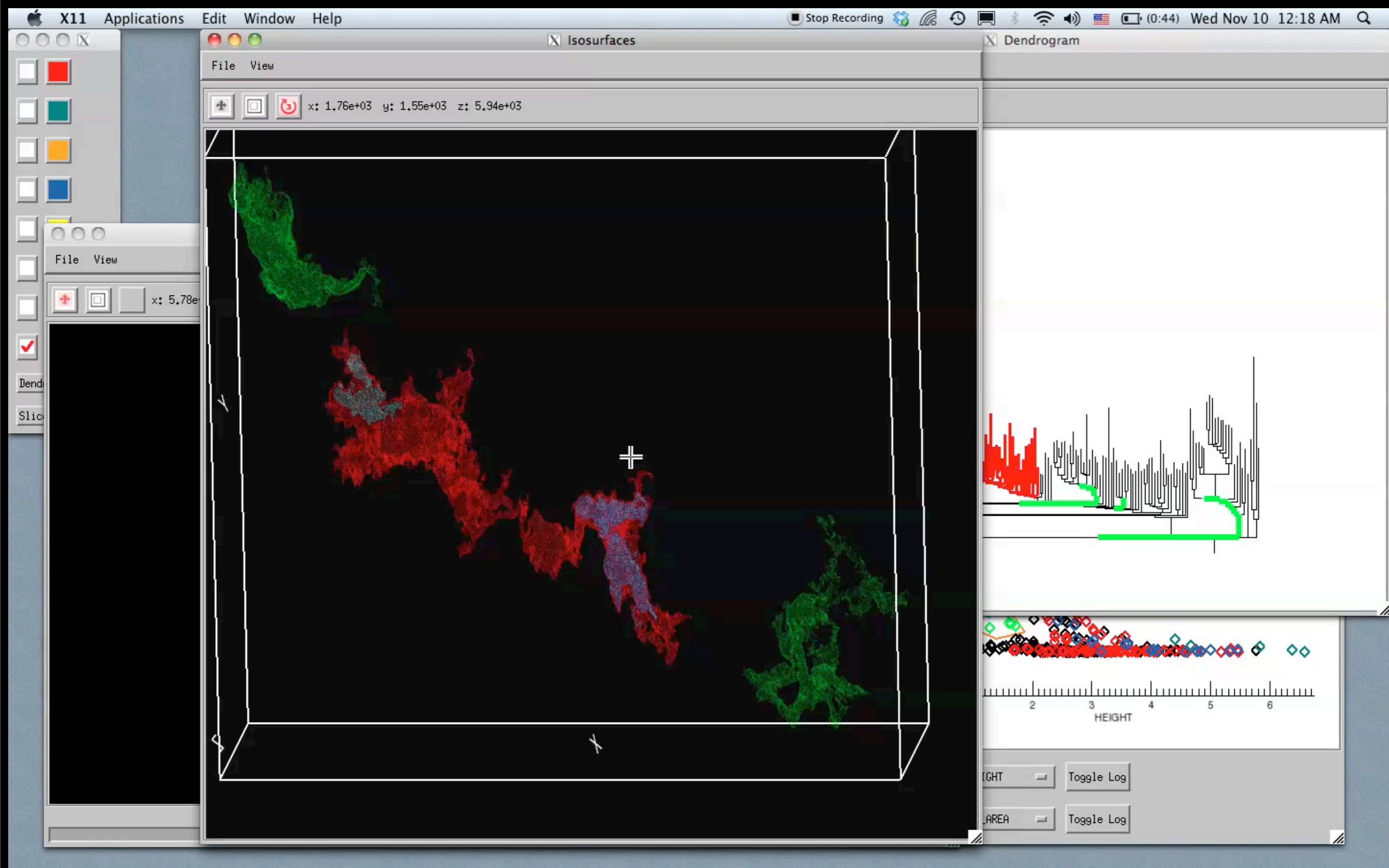
Warning

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

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



Exemplar: Linked Dendrogram Views in IDL

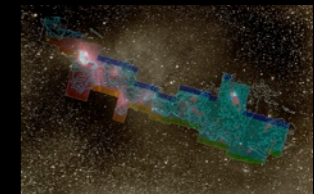
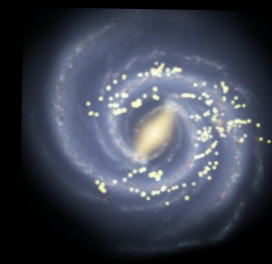
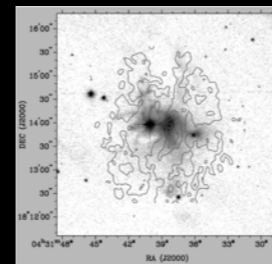


*Video & implementation: Christopher Beaumont, CfA/UHawaii;
inspired by AstroMed work of Douglas Alan, Michelle Borkin, AG, Michael Halle, Erik Rosolowsky*

Value: *Compared to what?*

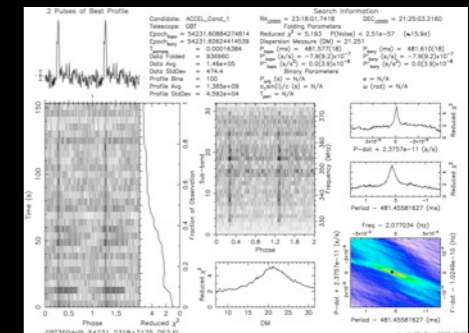
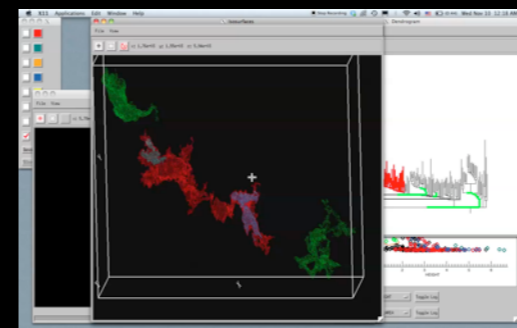
Validation & Discovery

The Value of Context in Astronomy

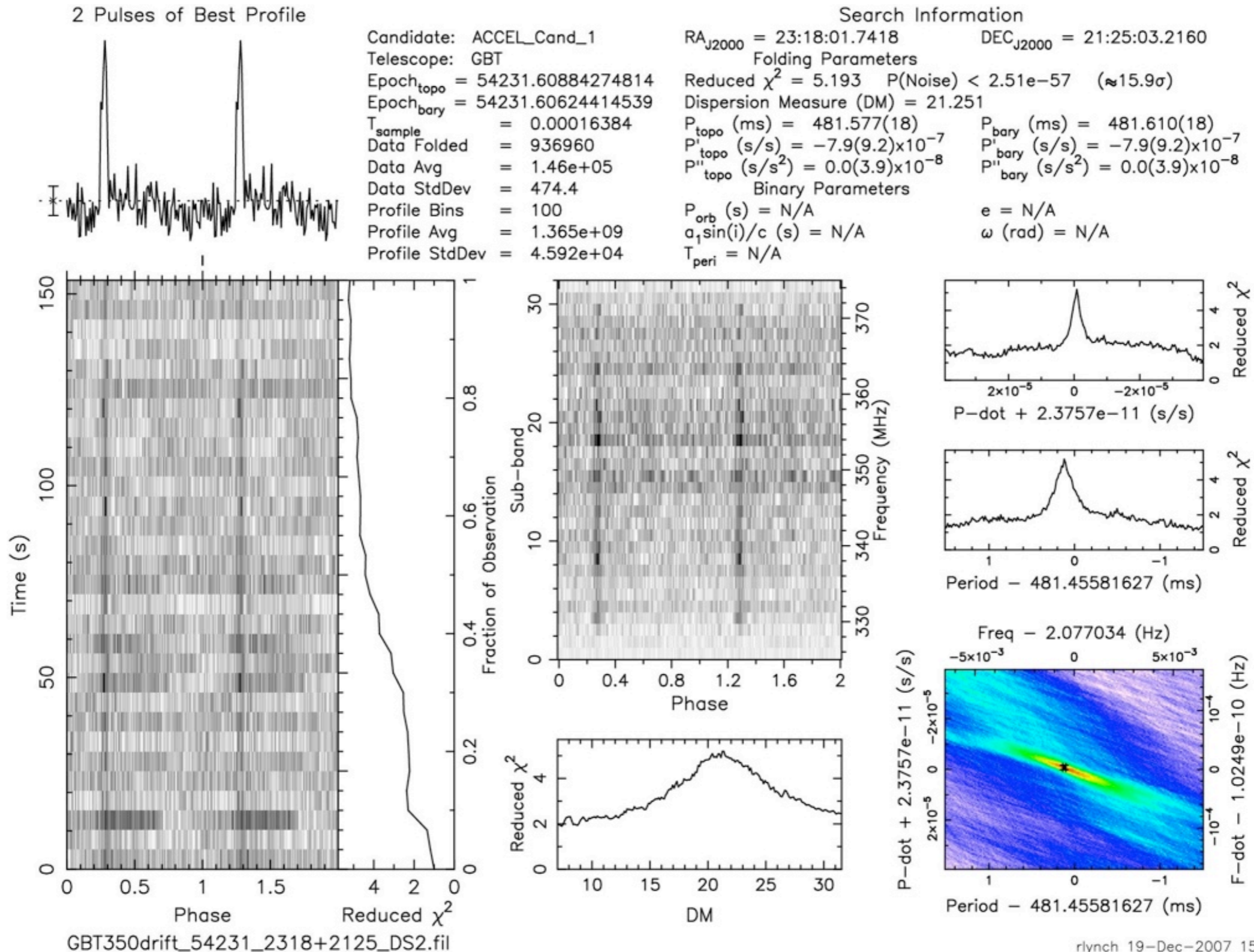


Context

Spatial & Abstract



Abstract Context + Data, Dimensions, Display

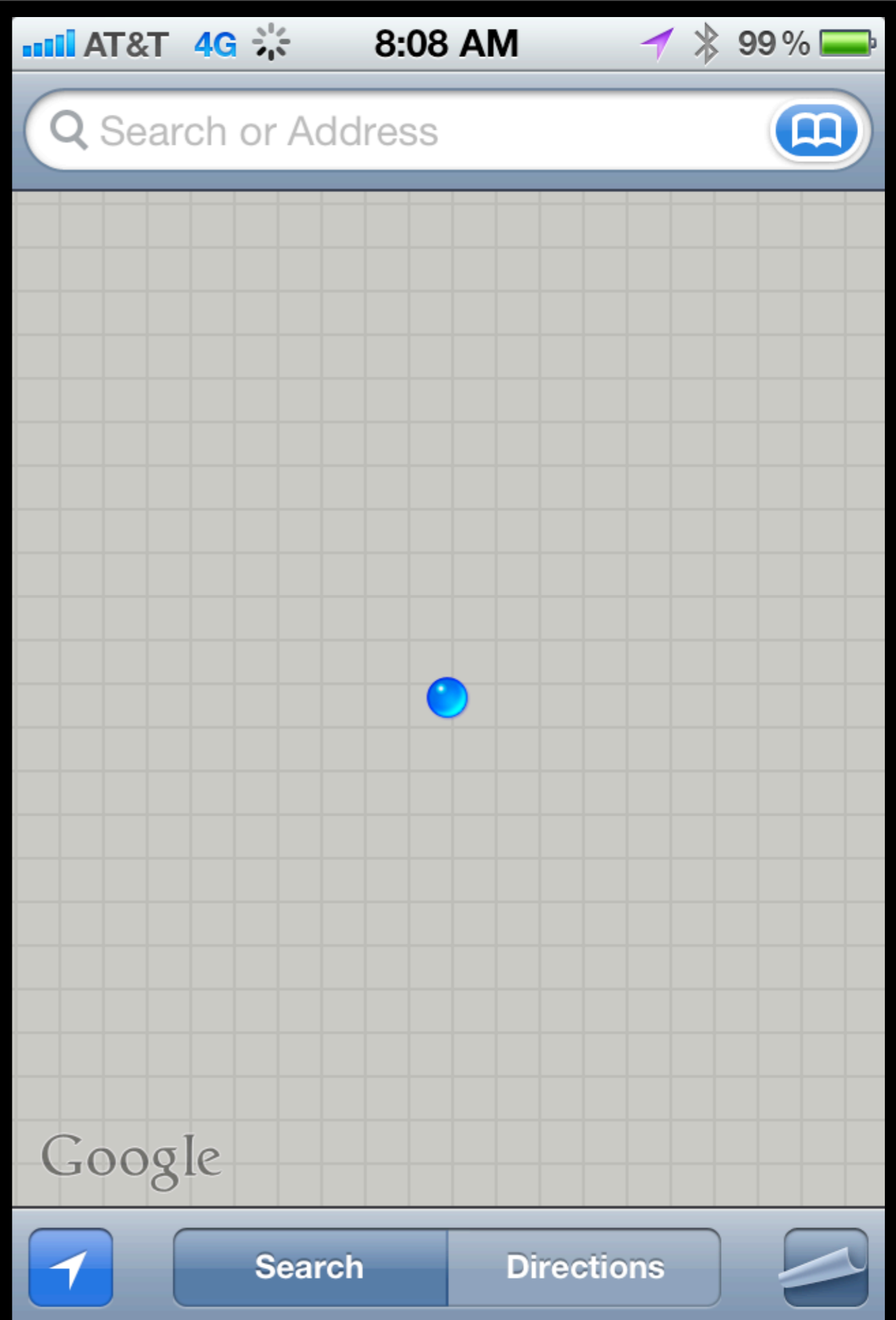


rlync 19-Dec-2007 15:59

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*



EMR 19/12

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

