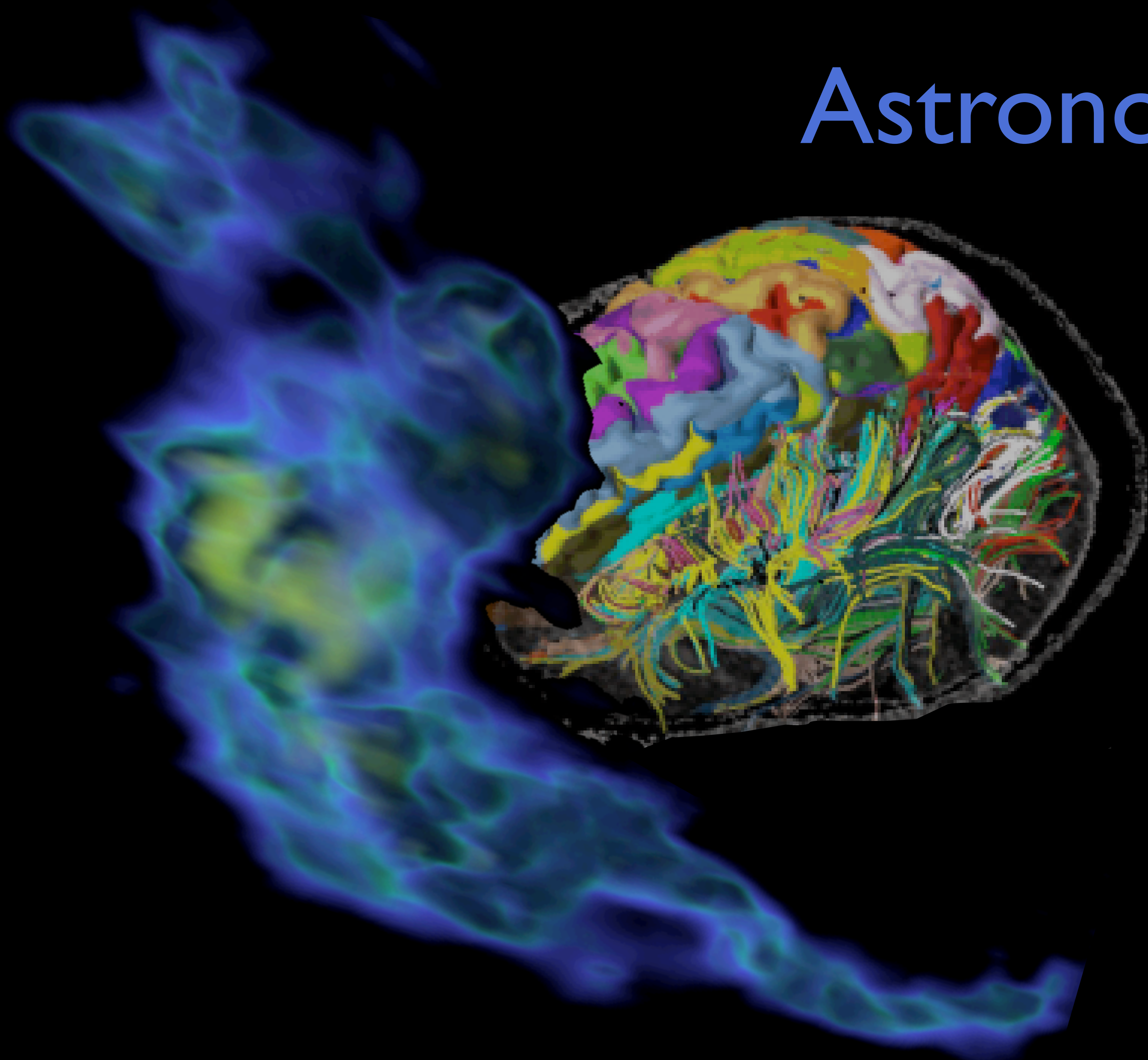


Astronomical Medicine and the IIC

Alyssa A. Goodman

Professor of Astronomy & Founding Director of the Initiative in Innovative Computing, Harvard University

Scholar-in-Residence, WGBH Boston

Friday, January 15, 2010

Abstract

I will consider the similarities between the imaging modalities and data visualization techniques used in Astronomy and in Medicine. Both fields inherently produce "cubes" or "hyper-cubes" of data where some dimensions are spatial. And, in both fields, tremendous extra value can be derived from visualizing "all" of the data represented in its natural number of dimensions. I will focus on the specific case study where we have used medical imaging software (e.g. 3D Slicer, Osirix) on astronomical observations of star-forming regions to look for the "tumors" (called "dense cores") destined to form new stars like our Sun, and then published our results in *Nature* as that journal's first interactive "3D PDF" interactive paper. I will conclude with a demonstration of the "WorldWide Telescope" program and explain how the natural, "seamless," model of data-literature connections it offers can be extended to other fields.

Astromedical Mathematics

Über das farbige Licht der Doppelsterne und einiger anderer Gestirne des Himmels

From Wikipedia, the free encyclopedia

Über das farbige Licht der Doppelsterne und einiger anderer Gestirne des Himmels is a treatise by Christian Doppler (1842)[1] in which he postulated his principle that the observed frequency changes if either the source or the observer is moving, which later has been coined the Doppler effect. The original German text can be found in wikisource. The following annotated summary serves as a companion to that original.

Summary

[edit]

The **title** "Über das farbige Licht der Doppelsterne und einiger anderer Gestirne des Himmels - Versuch einer das Bradley'sche Aberrations-Theorem als integrirenden Theil in sich schliessenden allgemeineren Theorie" *(On the coloured light of the binary stars and some other stars of the heavens - Attempt at a general theory including Bradley's theorem as an integral part)* specifies the purpose: describe the hypothesis of the Doppler effect, use it to explain the colours of binary stars, and establish a relation with Bradley's stellar aberration.[2]

Doppler effect

From Wikipedia, the free encyclopedia

Contents [hide]

WIKIPEDIA
The Free Encyclopedia

Fourier transform

From Wikipedia, the free encyclopedia

In mathematics, the **Fourier transform** (often abbreviated **FT**) is an operation that tra
variable into another. In such applications as signal processing, the domain of the orig
called the *time domain*. That of the new function is frequency, and so the Fourier trans
representation of the original function. It describes which frequencies are present in th
way that a chord of music can be described by notes that are being played. In effect,
oscillatory functions. The term Fourier transform refers both to the frequency domain r
formula that "transforms" one function into the other.

The Fourier transform and its generalizations are the subject of Fourier analysis. In thi
domains are unbounded linear continua. It is possible to define the Fourier transform c
for instance ii
such as finite

Phase-resolved Doppler Fourier Domain Optical Coherence Tomography in the *in vivo* mouse model

J. Walther[1], G. Mueller[2], M. Cuevas[1], H. Morawietz[2] and E. Koch[1]

Astromedical Mathematics (classic connections)

Astromedical Visualization (today)

Astromedical Informatics (Wednesday)

All within the purview of the IIC

Where did IIC come from?

Short Version

Response to Harvard's "expansion" in Science, and into Allston.

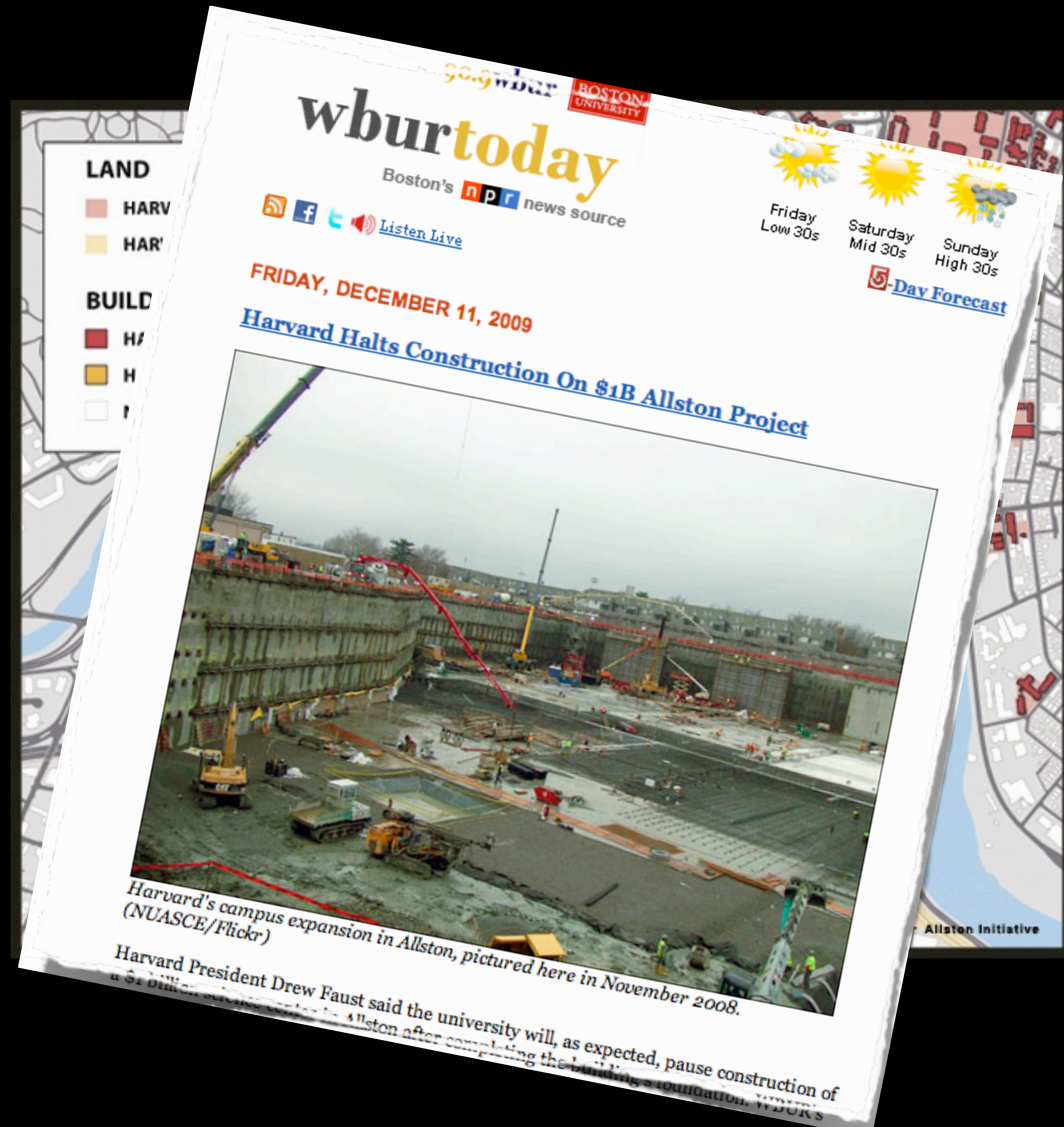
See IIC Whitepaper (2004) & Task Force on Science & Technology report (2005) for more.

Long Version

(see the News on Allston & Harvard)

Current Status

Part of Harvard's New School of Engineering and Applied Science



Filling the "Gap" between Science and Computer Science

Scientific disciplines

Computer Science departments

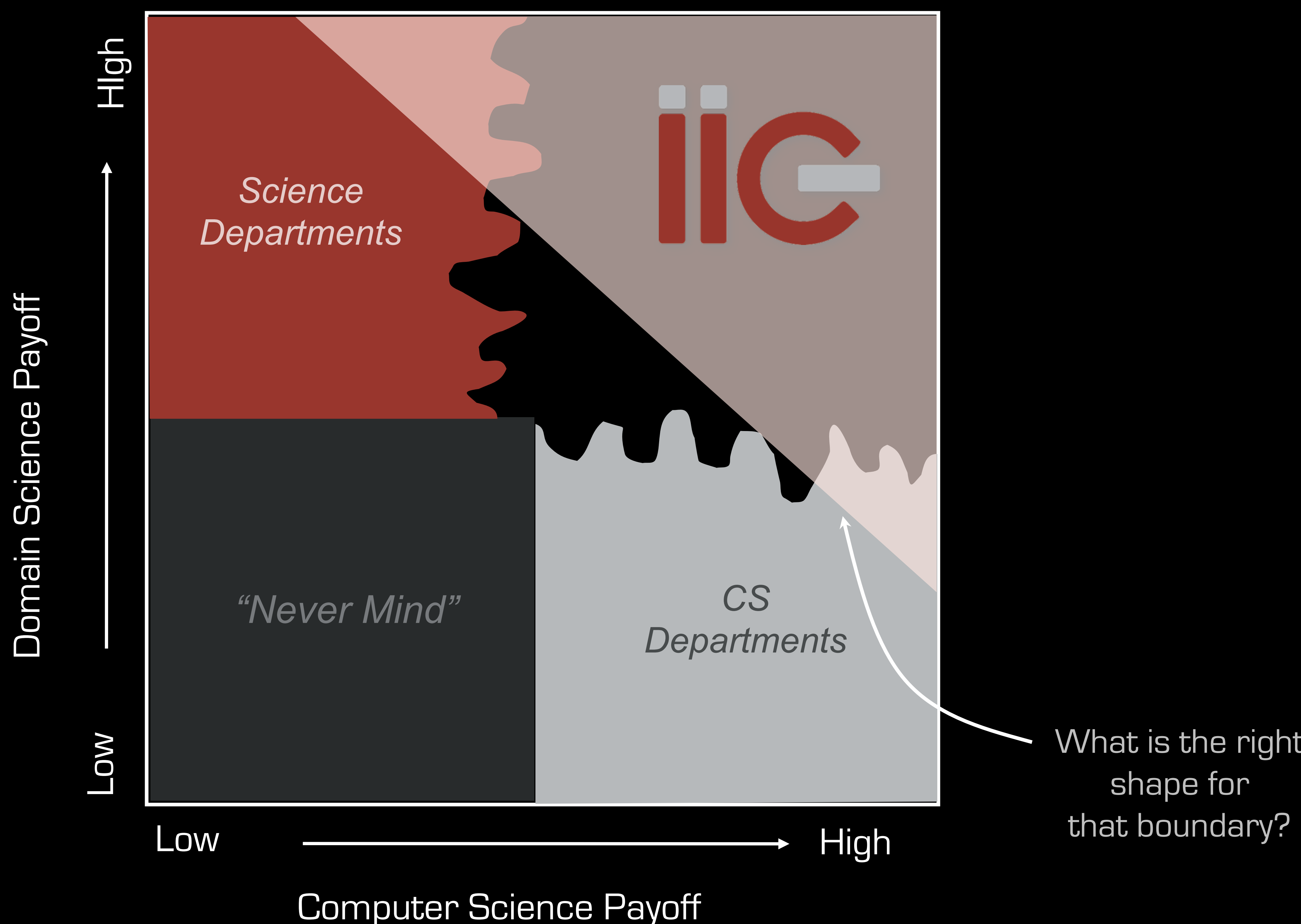
Increasingly, core problems in science require computational solution

Typically hire/"home grow" computationalists, but often lack the expertise or funding to go beyond the immediate pressing need

Focused on finding elegant solutions to basic computer science challenges

Often see specific, "applied" problems as outside their interests

Where are the optimal “IIC” problems?



IIC "Whitepaper" 2004

THE HARVARD INSTITUTE FOR INNOVATIVE COMPUTING
NOVEMBER 22, 2004

Principal Authors: Timothy Clark (HMS), Alyssa Goodman (FAS) & Christopher Stubbs (FAS)

Principal Editors: Felice Frankel (MIT), John Huth (FAS), Hanspeter Pfister (Mitsubishi Electric Research Laboratory), Joy Sircar (DEAS)[1]

TA

PARSING, DISPLAYING, AND SERVING THE COMPLETE DATABASE ON THE WEB: A STEPPING STONE TO THE VIRTUAL OBSERVATORY

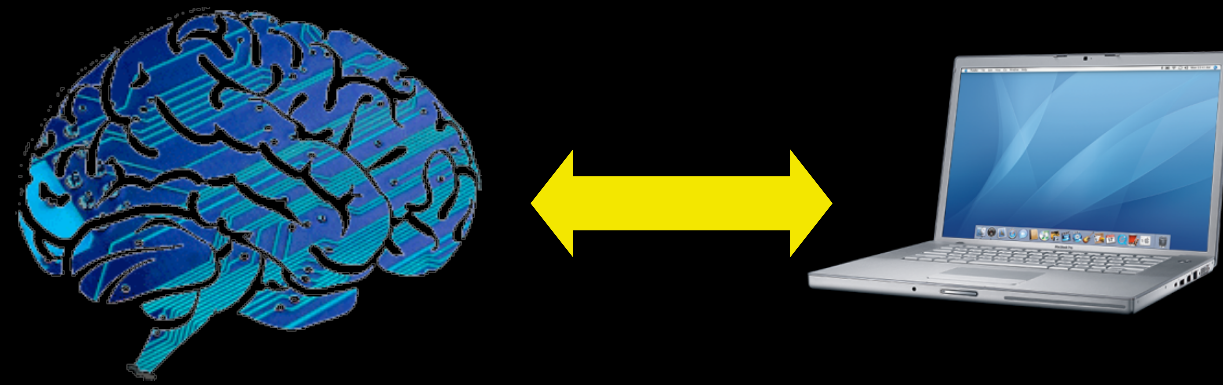
Alyssa A. Goodman
Department of Astronomy, Faculty of Arts & Sciences, Harvard University

The COMPLETE Survey (cfa-www.harvard.edu/COMPLETE) currently underway is the largest, most diverse, systematic, multi-wavelength study of star-forming regions ever undertaken. Star formation, in spite of its central role in the evolution of the Universe, is currently very poorly understood, and the COMPLETE database will be used to answer a tremendous variety of physical questions, including ones like "How did the Sun form?". Without systematic surveys like COMPLETE, the data available are just too statistically sparse and poorly archived to make headway on these questions.

The COMPLETE data set includes maps made at wavelengths from optical through radio, some of which have an added "velocity" dimension beyond the three dimensions (position-position-intensity) astronomical images usually contain. Each of the mapping techniques employed produces a unique "kind" of data that is ordinarily dealt with almost exclusively by experts on that "type" of data, and very few researchers are expert in all the techniques. The tools for displaying and interpreting these kinds of data are, at this point in time, technique-specific. Trying to retrieve, use, and display COMPLETE and other similarly diverse astronomical data now is akin to trying to assemble a car from all of the one-thousand needed parts, but using directions partially in Chinese, partially in English, and partially in French, with some illustrations that can only be viewed on Windows PCs, others only on Macs, and some others only with the right brand of 3D glasses. Making all of COMPLETE's data readily searchable and accessible to astronomers worldwide, regardless of their expertise or computing platform, is an unprecedented—but definitely achievable—challenge in both database design and visualization.

We envision two potential members of the IIC who would work together in making the COMPLETE dataset accessible to all on the Web. One IIC collaborator would be expert in the design and searching of large multi-dimensional databases, and the other would be more focused on designing tools to use existing and new visual interfaces to access and analyze the database. We expect that a total of four person-years (two years per participant, in parallel) would be needed to create a streamlined working system.

The result of this IIC work would be a new data retrieval/display system that would be the first to handle what is known as "velocity resolved" or "spectral line data cube" data sets that intrinsically have four dimensions. This system would be incorporated into all of the Virtual Observatory interfaces now being developed (see http://www.us-vo.org/) to provide this kind of access to multi-wavelength, multi-dimensional data sets across astronomy.



Data Reduction

Data Display

Astromedical Visualization (today)

Context (e.g. journals + online data)

Simulation Design

Statistics Design

Data Exploration (Visualization)

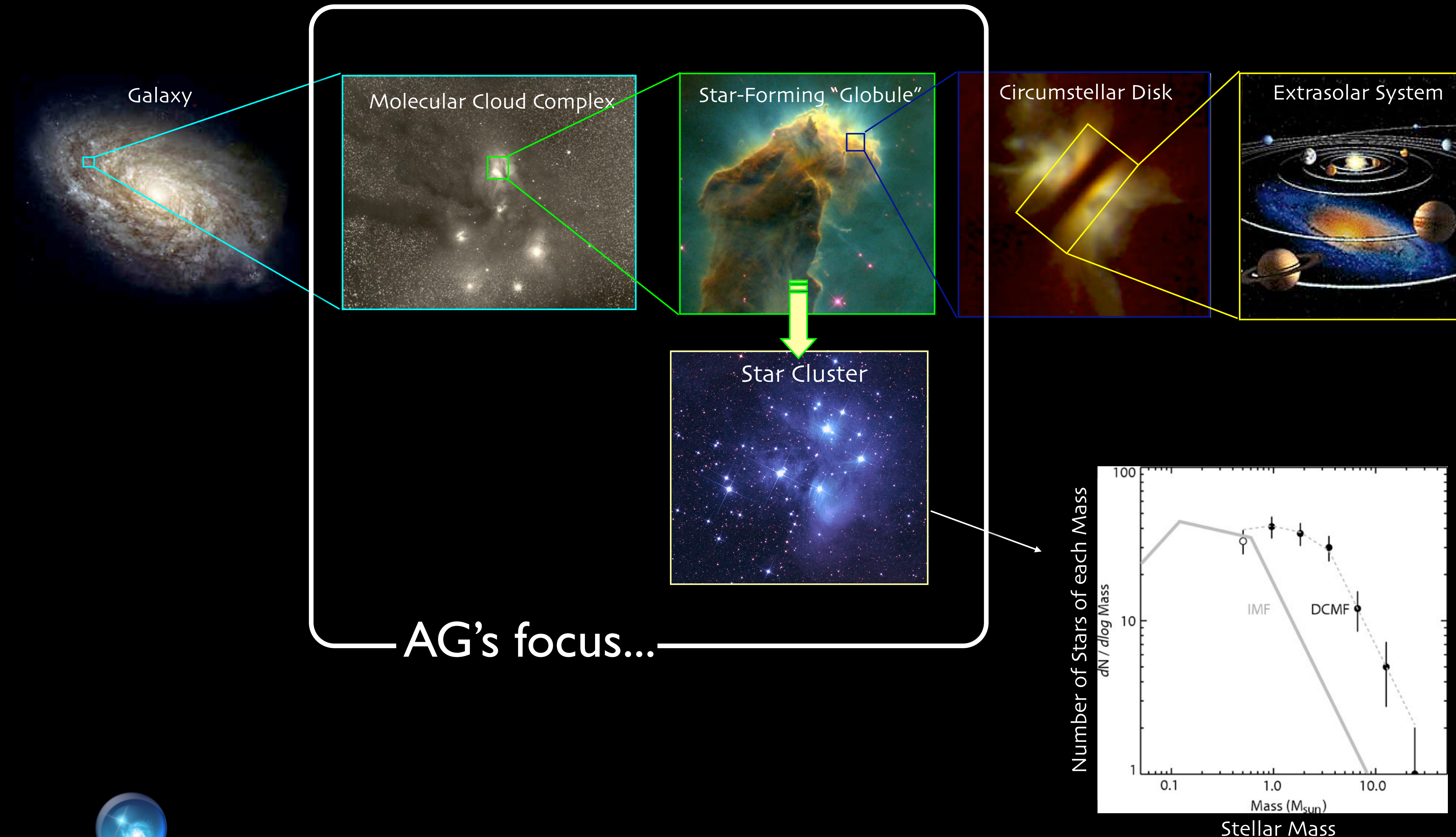
Seamless Astronomy (Wednesday)

COMPLETE

The COordinated Molecular Probe Line Extinction Thermal Emission Survey of Star-Forming Regions

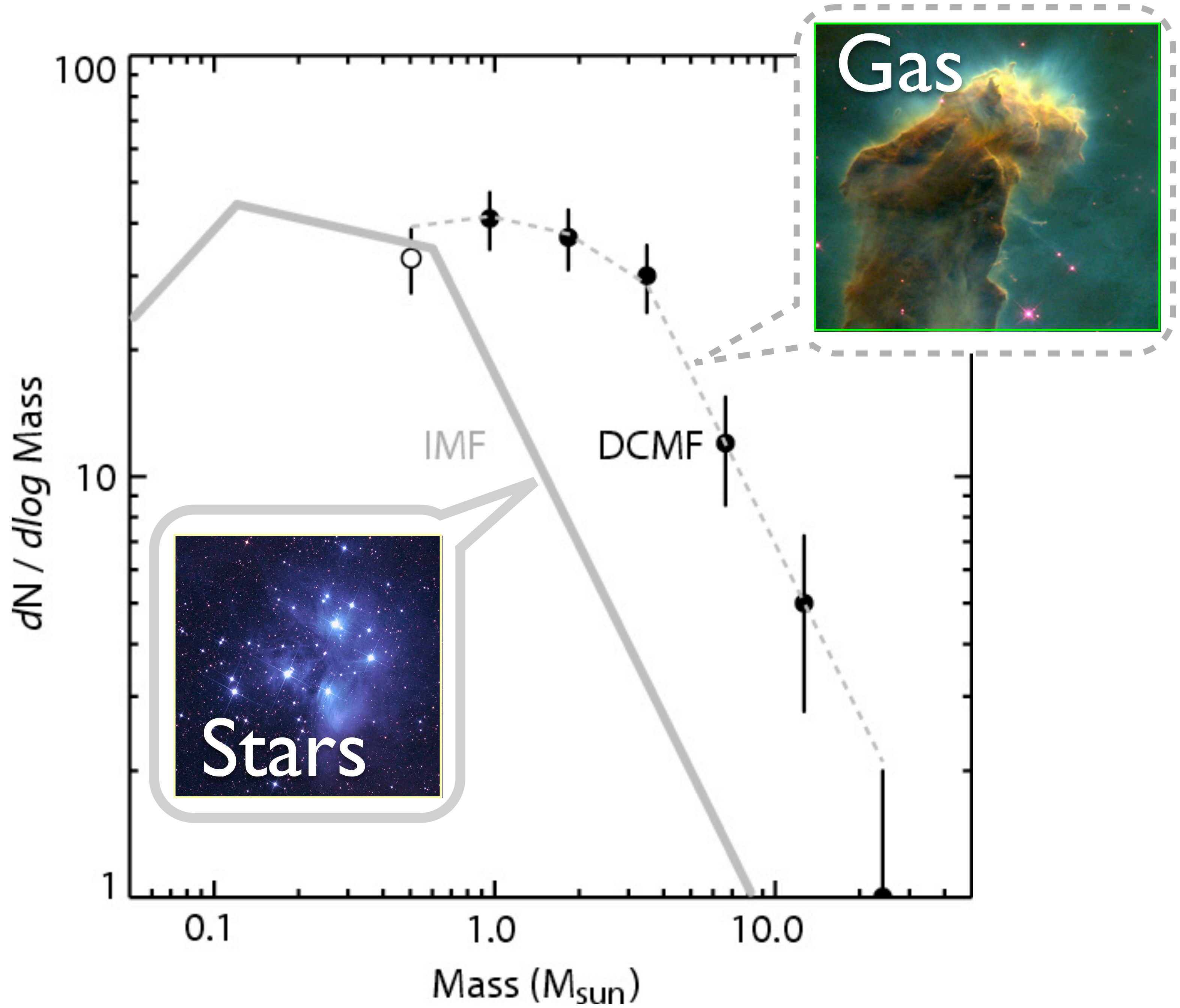
www.cfa.harvard.edu/COMPLETE
(and more on Wednesday!)

Star (and Planet, and Moon) Formation 101

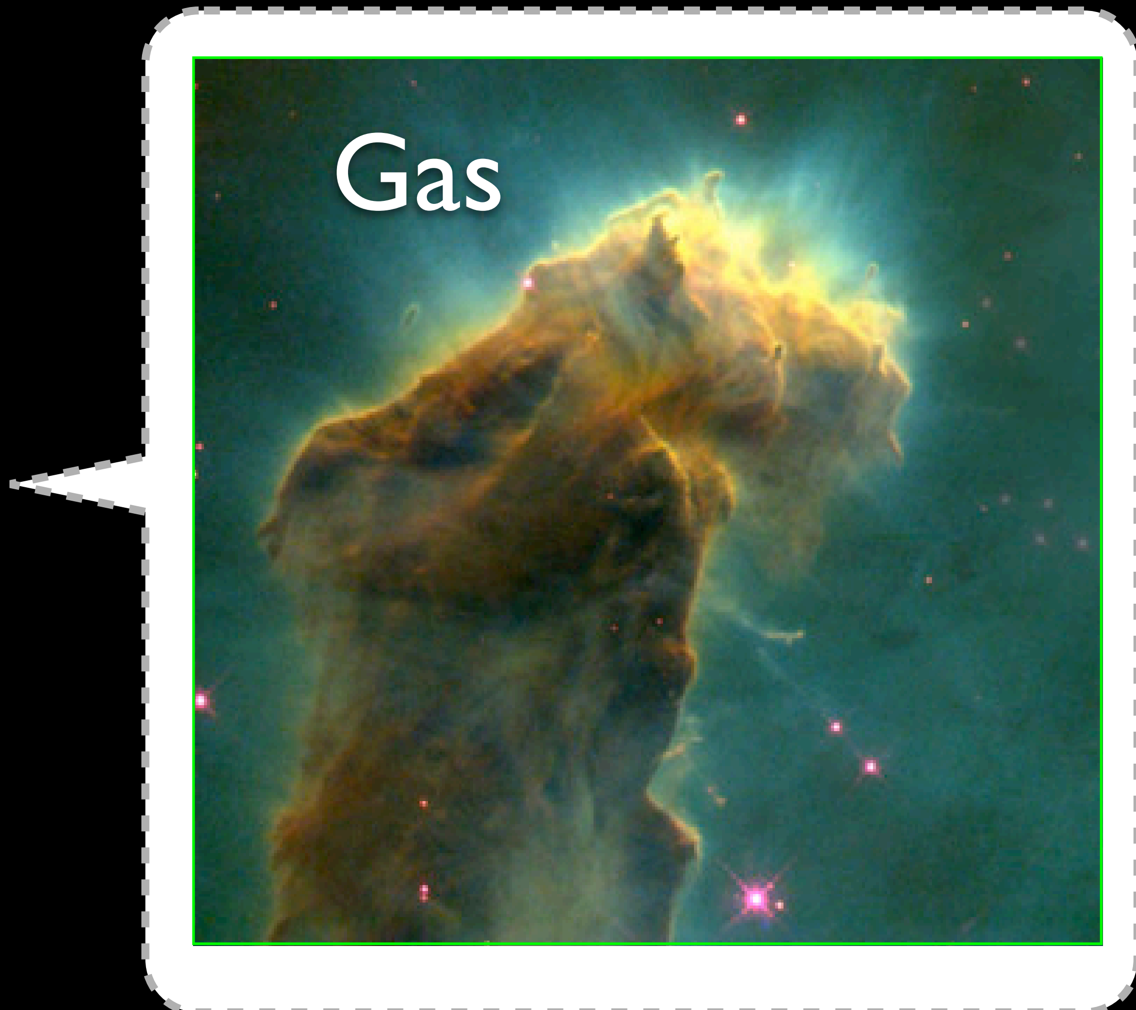


“IMF”? “CMF”?

Note: IMF= “Initial Mass Function” of Stars, not “International Monetary Fund.”



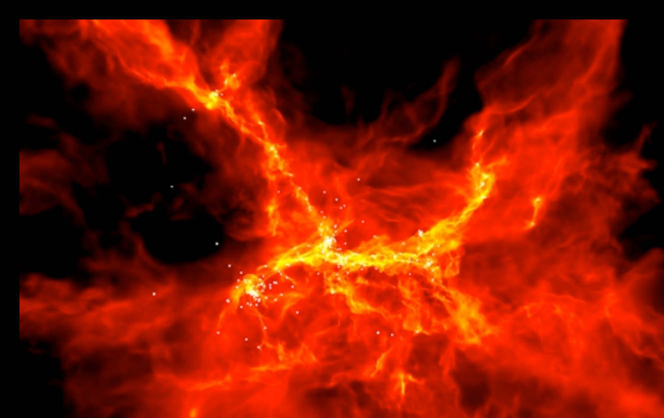
Alves, Lombardi & Lada 2007

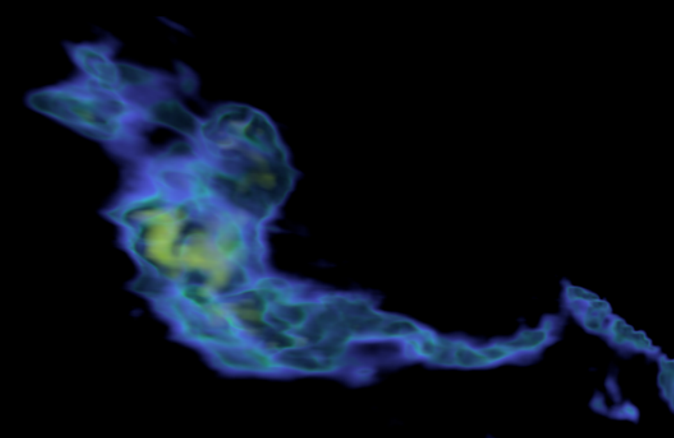


BUT: Beautiful images like this do not reveal *internal* structure directly...

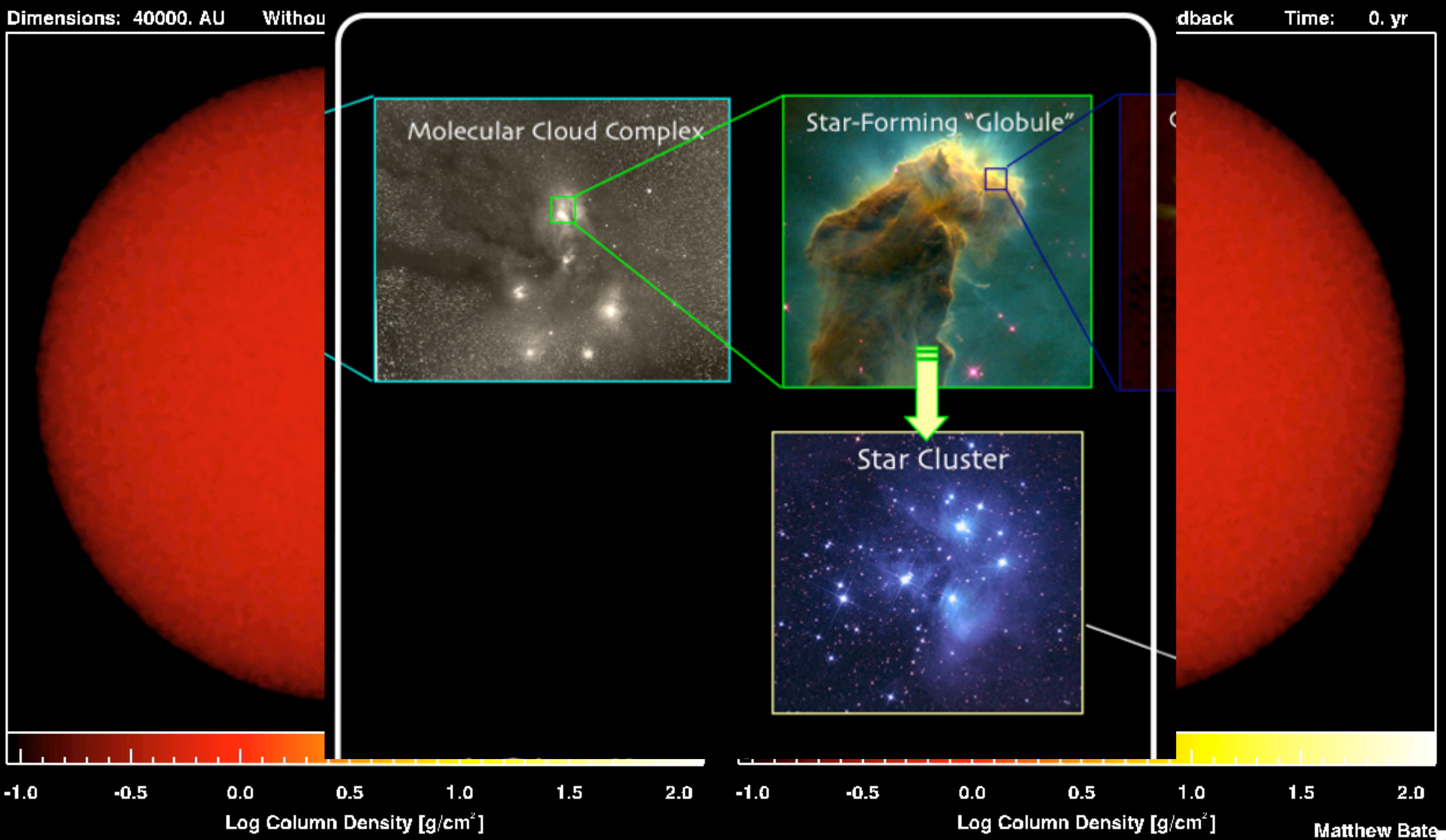
simulations

>2D observations

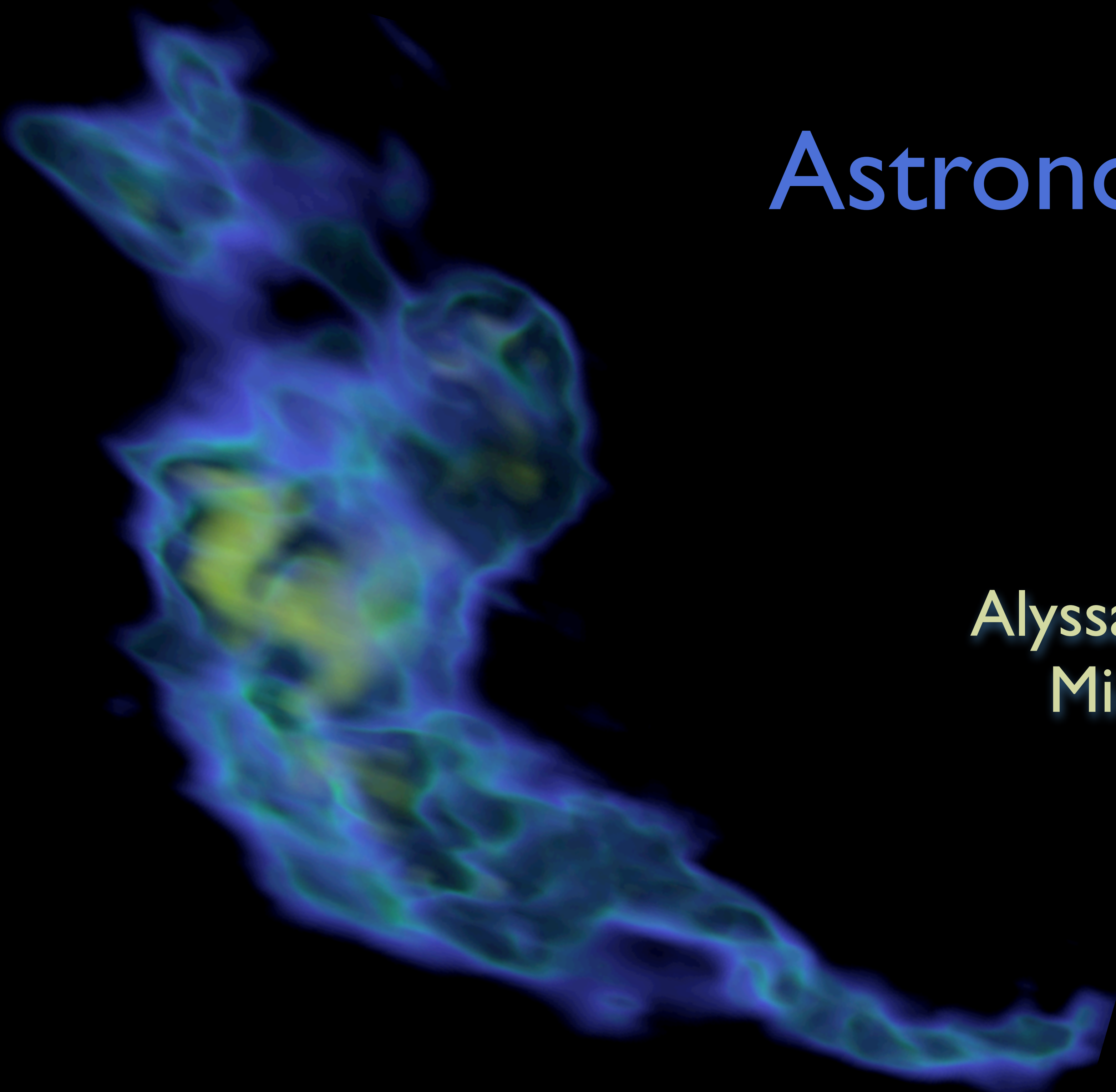




Our Goal is to "Taste" Star Formation



Simulations of Bate 2009



Astronomical Medicine

Alyssa Goodman (IIC/CfA/FAS)
Michael Halle (IIC/SPL/HMS)
Ron Kikinis (SPL/HMS)
Douglas Alan (IIC)
Michelle Borkin (FAS/IIC)
Jens Kauffmann (CfA/IIC)
Erik Rosolowsky (CfA/UBC Okanagan)
Nick Holliman (U. Durham)

The Astronomical Medicine Story

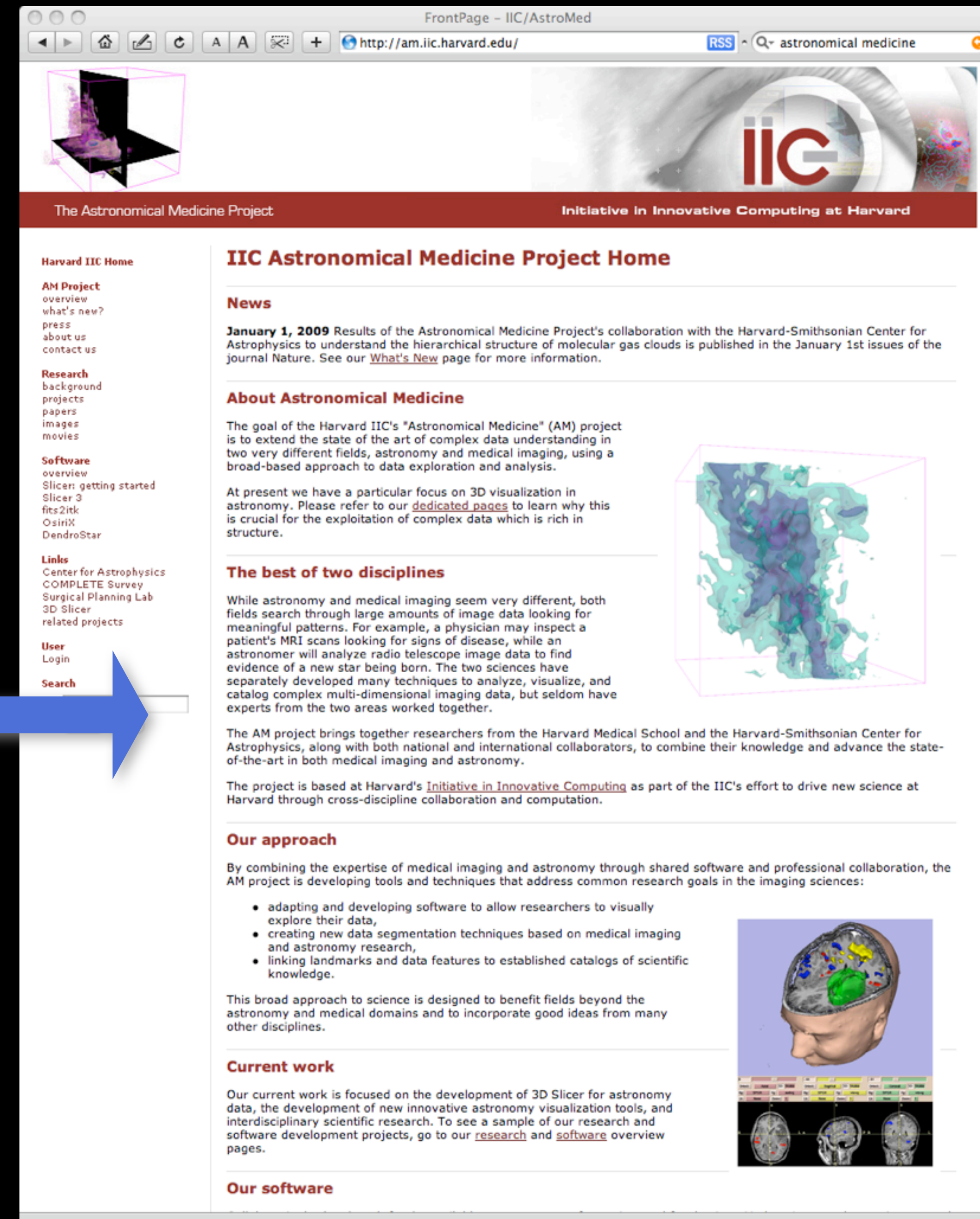
Computer Scientist

"Viz has failed the scientific community…"

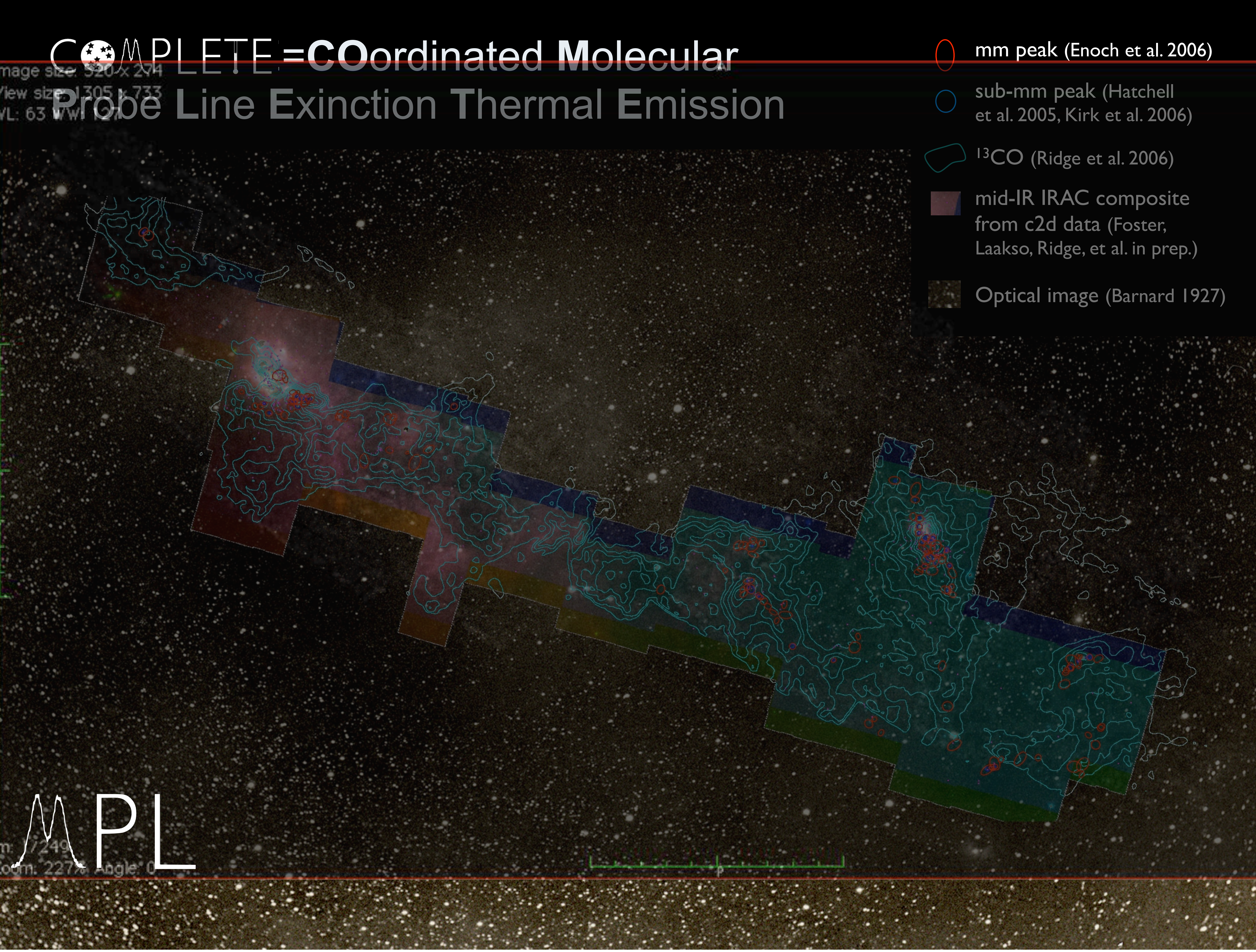
Computer Scientist

Astronomer

Unsuspecting Undergrad



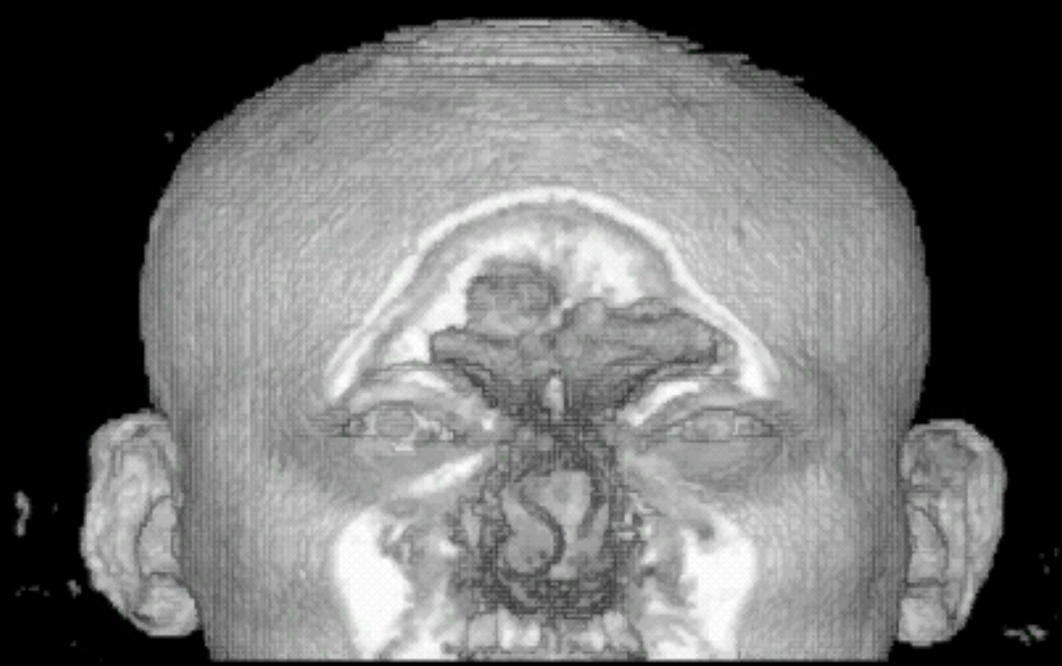
+Nick Holliman (CS, 3D expert)
+Doug Alan (S/W Engineer)
+Jens Kauffmann (postdoc)
+Erik Rosolowsky (postdoc) + ...



Friday, January 15, 2010

“Astronomical Medicine”

“KEITH”



“z” is depth into head

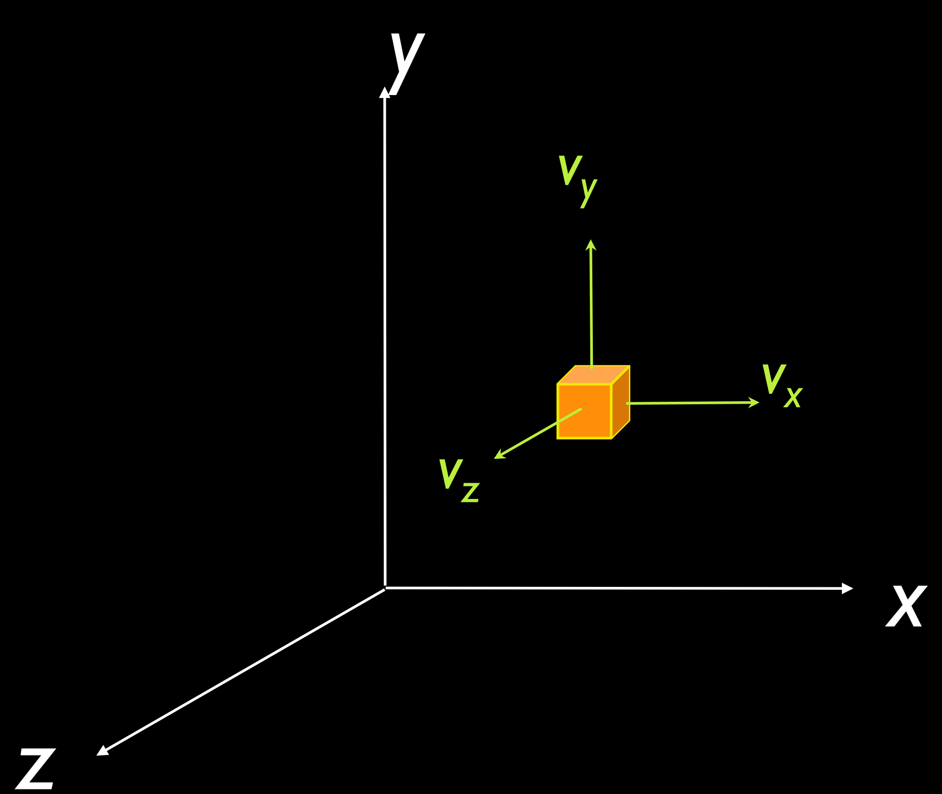
“PERSEUS”

“z” is line-of-sight velocity

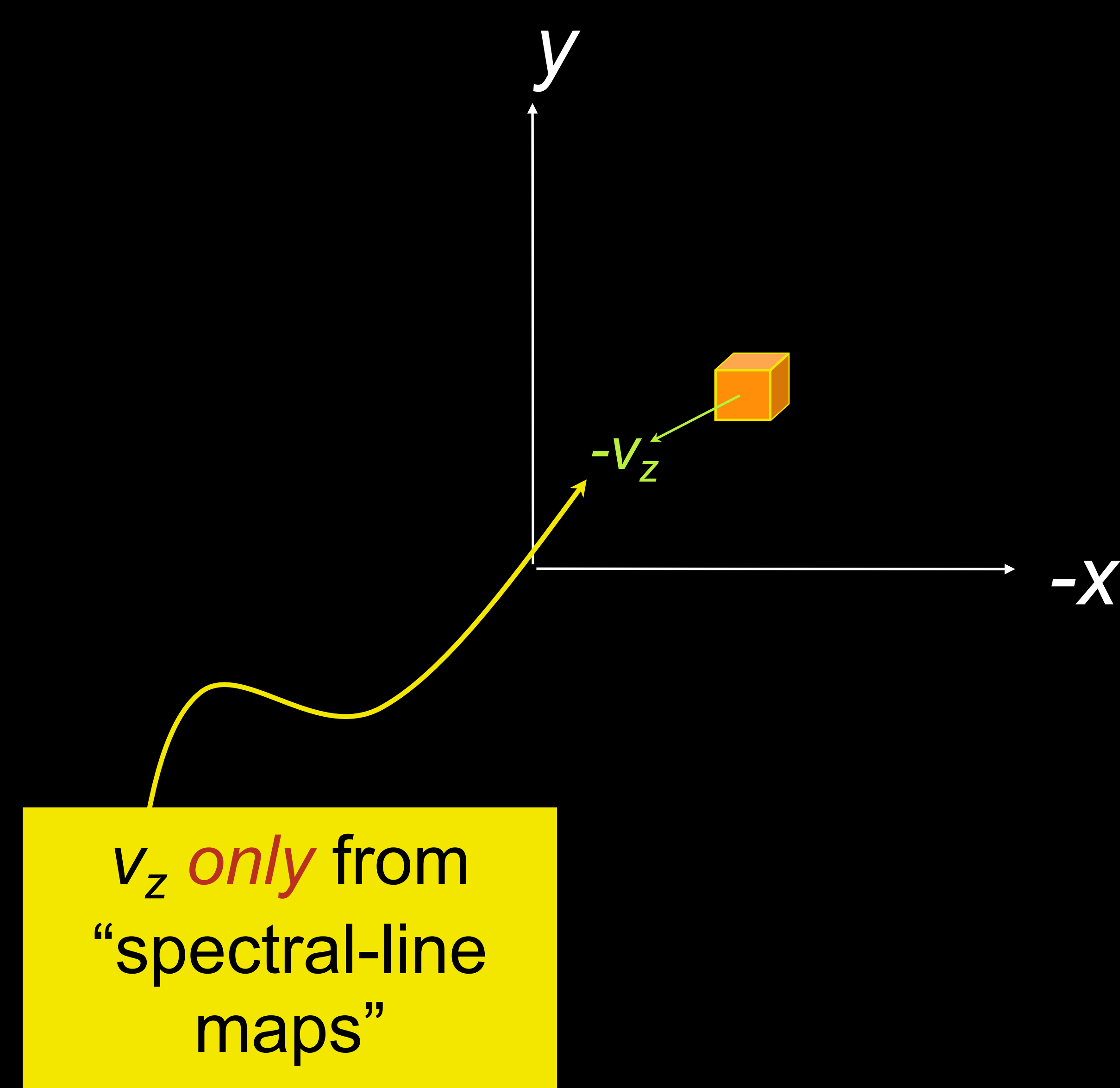
(This kind of “series of 2D slices view” is known in the Viz as “the grand tour”)

“Three” Dimensions: Spectral-Line Mapping

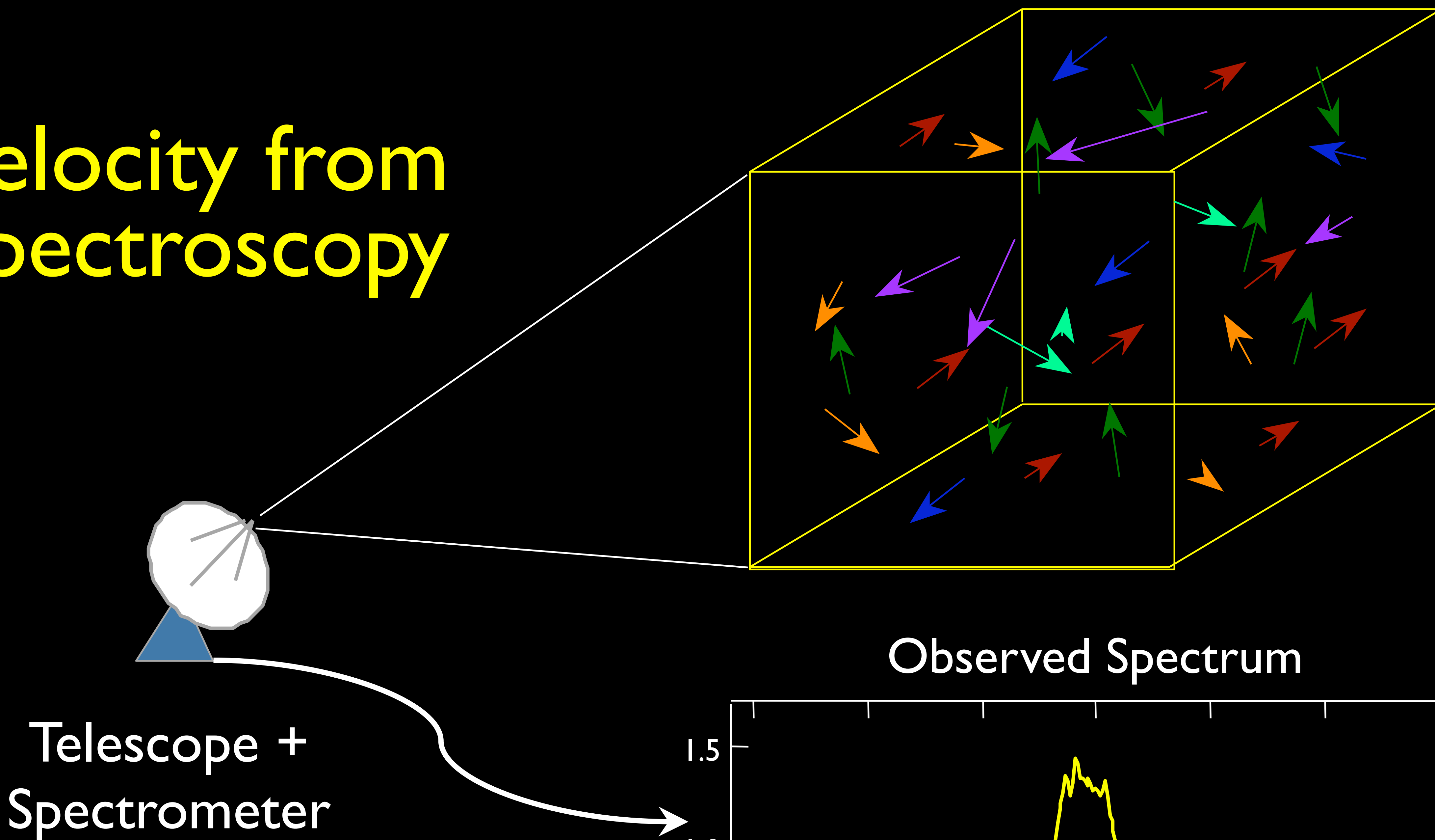
We wish we could measure…

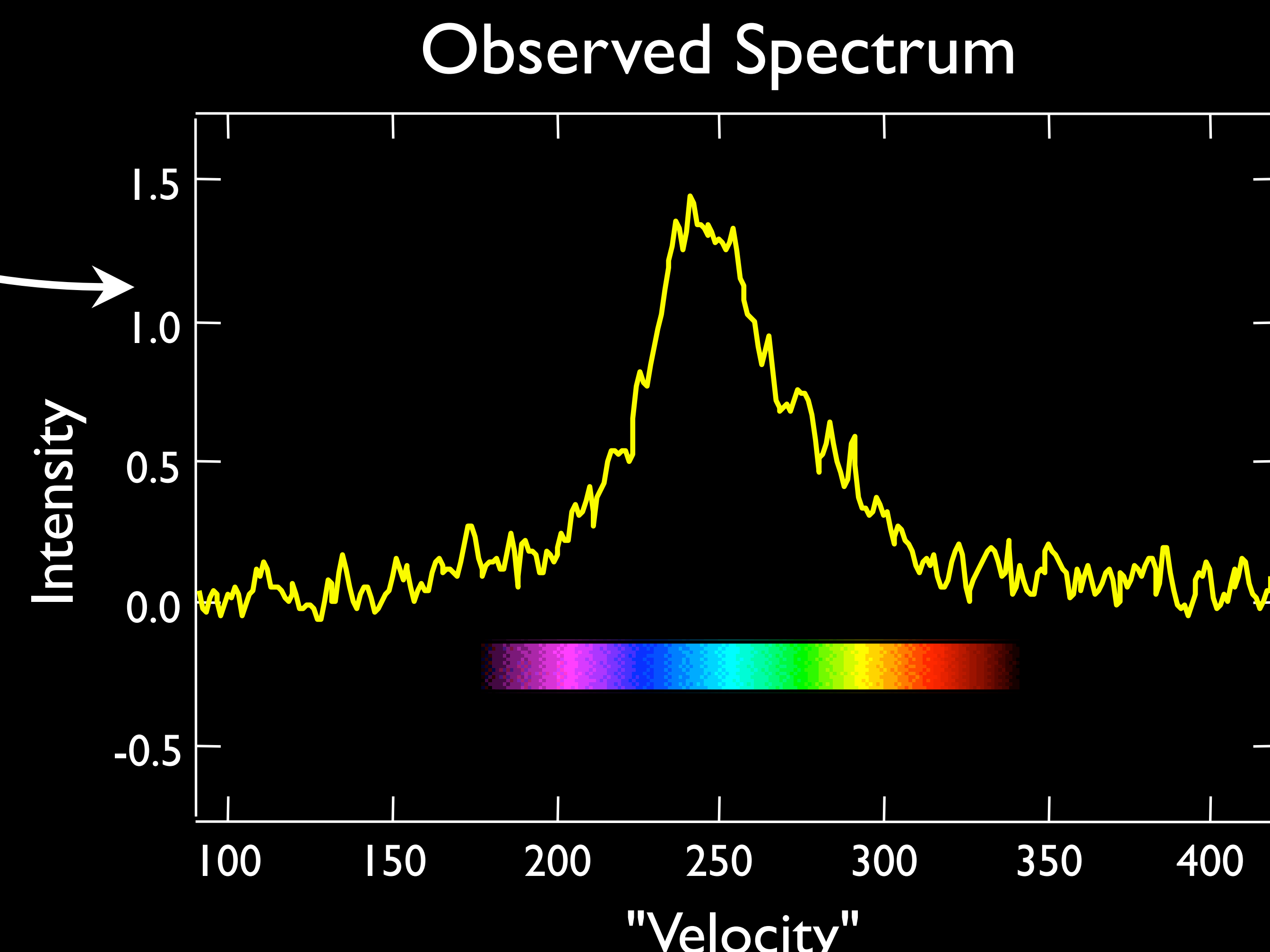


But we can measure…



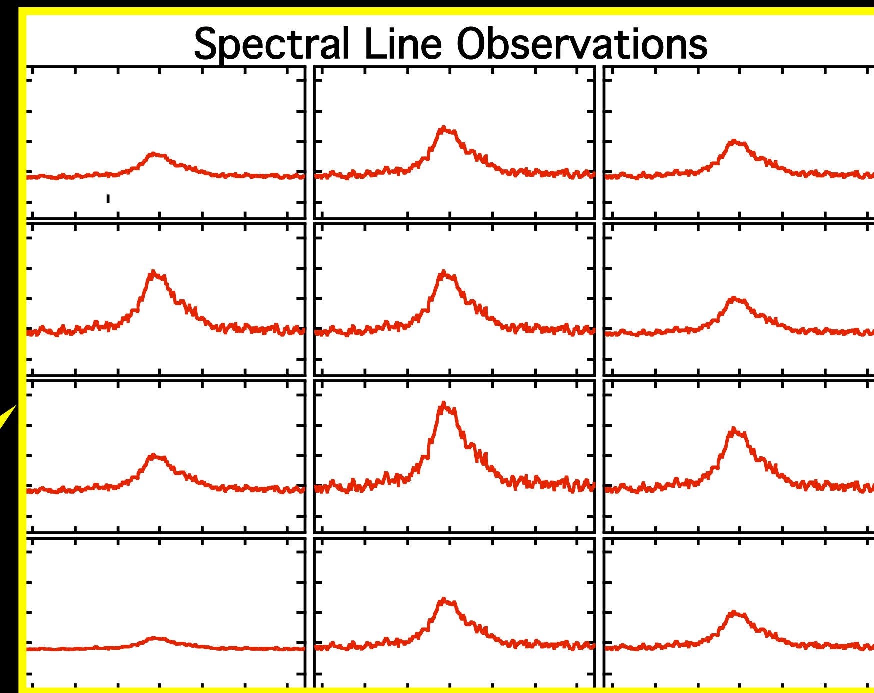
Velocity from Spectroscopy

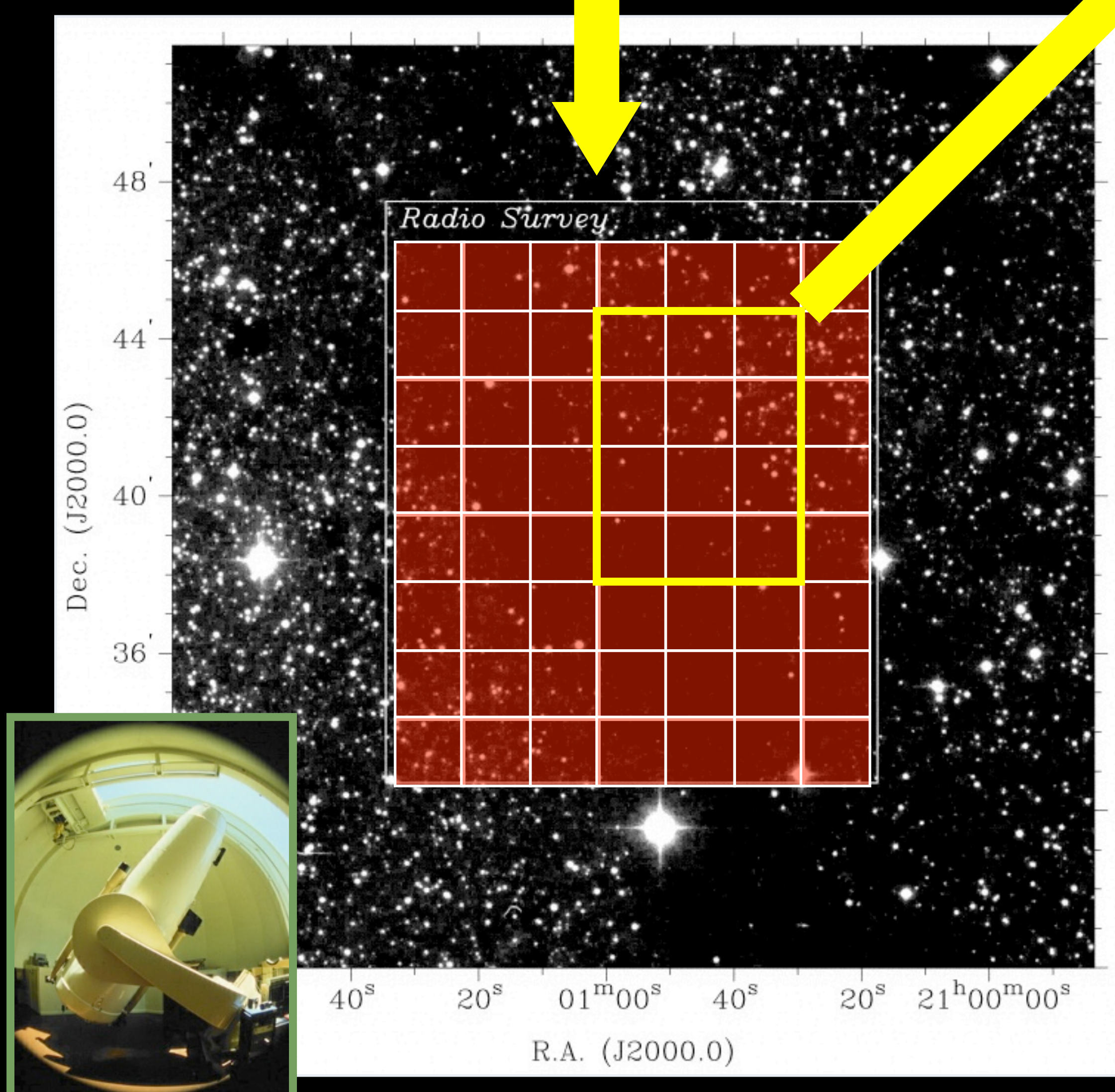


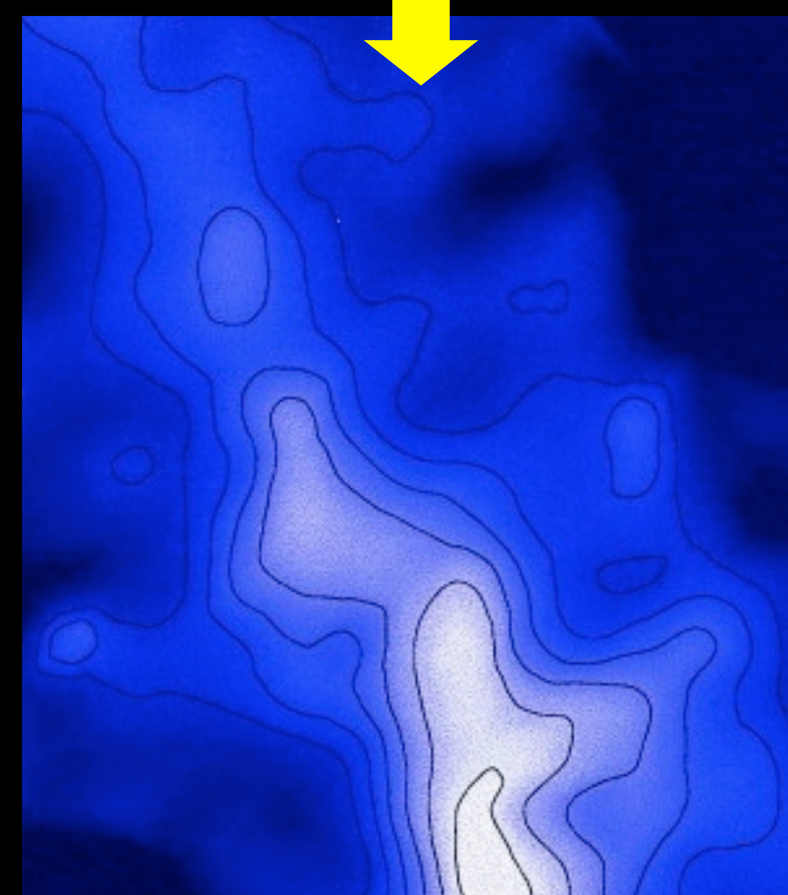


All thanks to Doppler

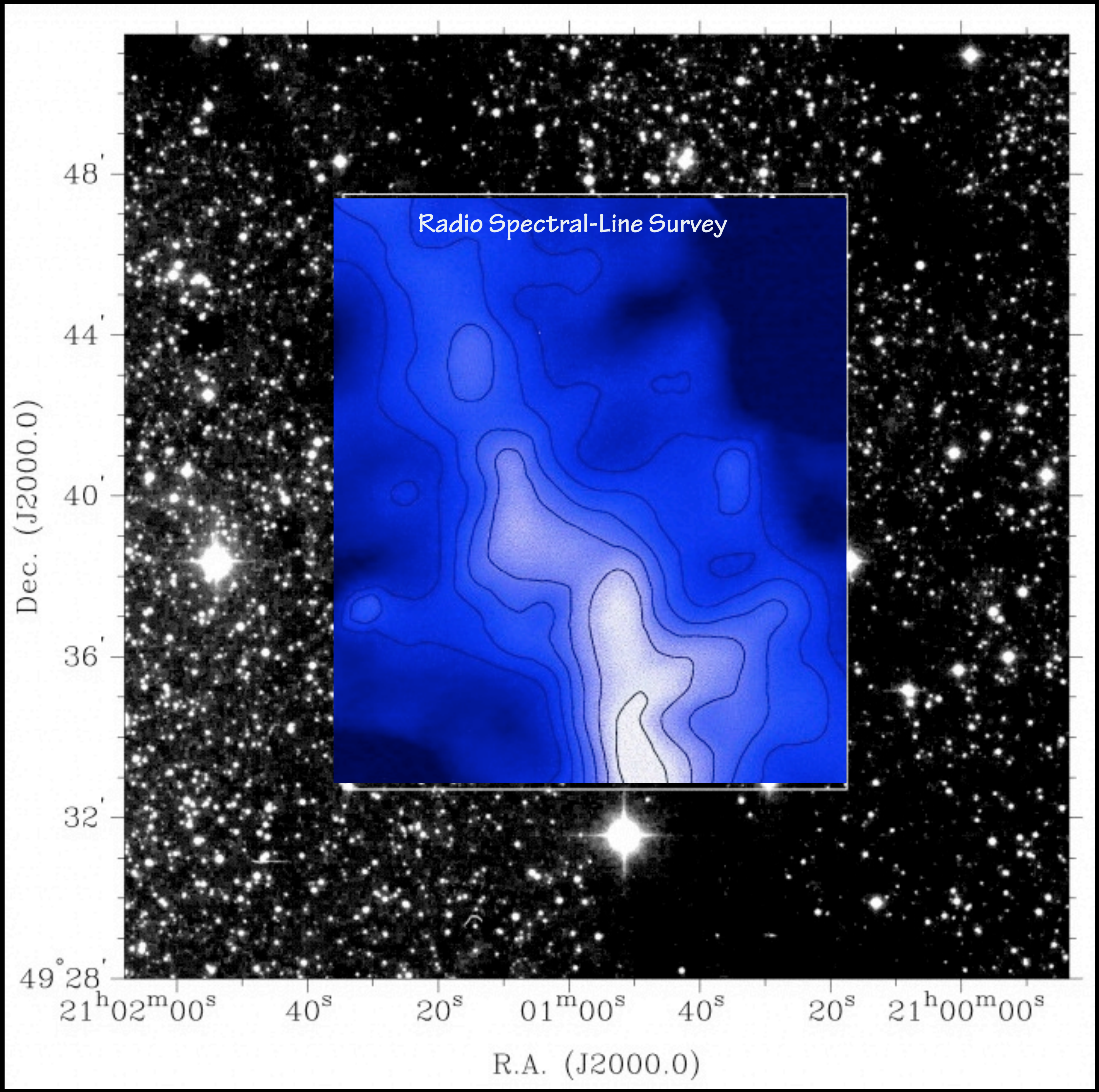
Radio Spectral-line Observations of Interstellar Clouds





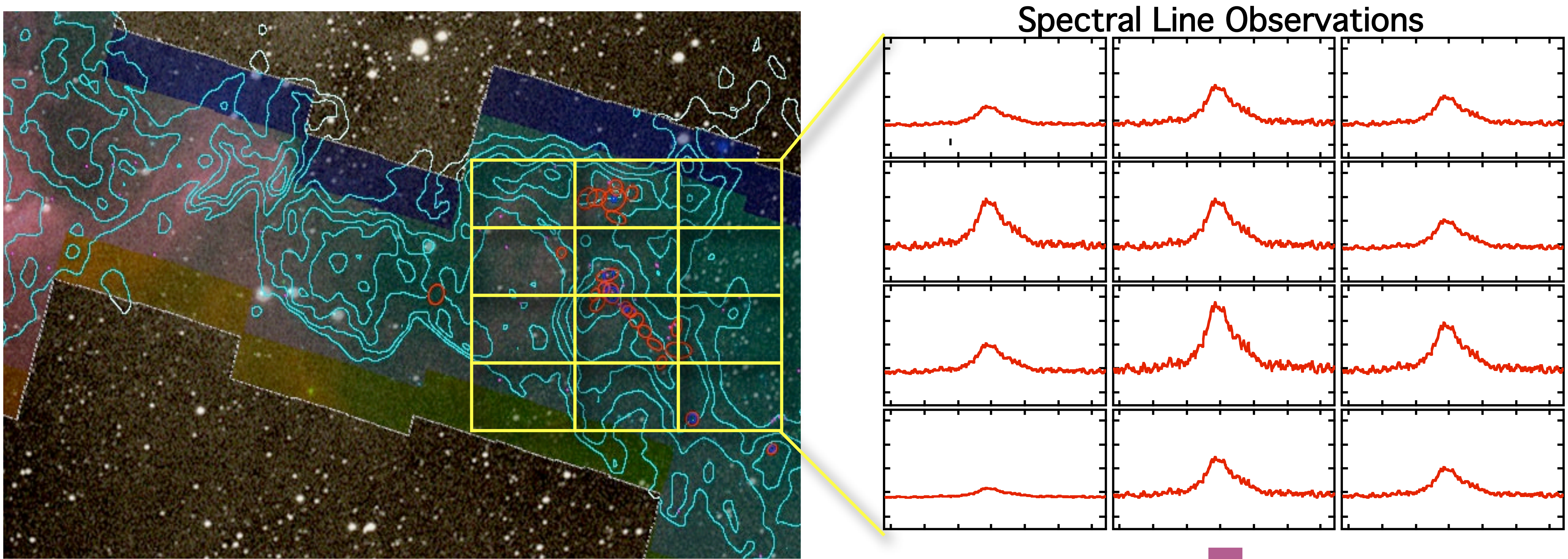


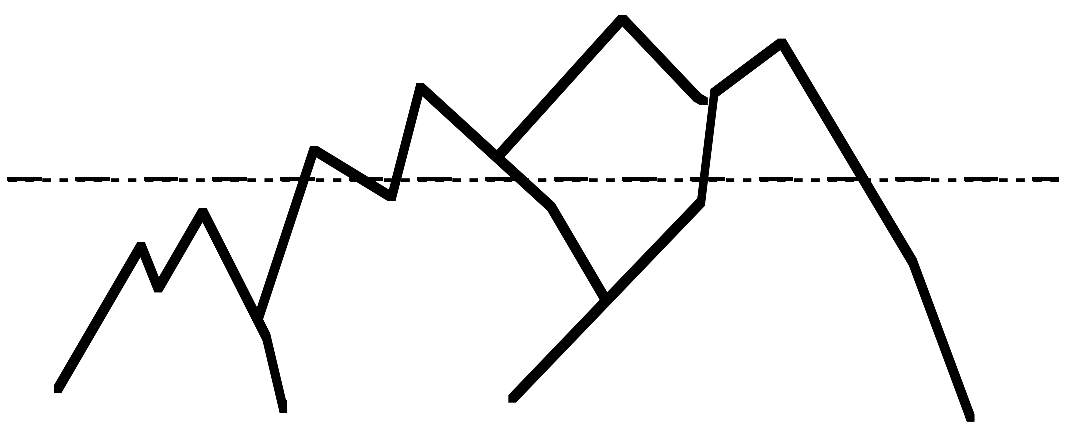
Radio Spectral-line Observations of Interstellar Clouds



Alves, Lada & Lada 1999

Velocity as a "Fourth" Dimension



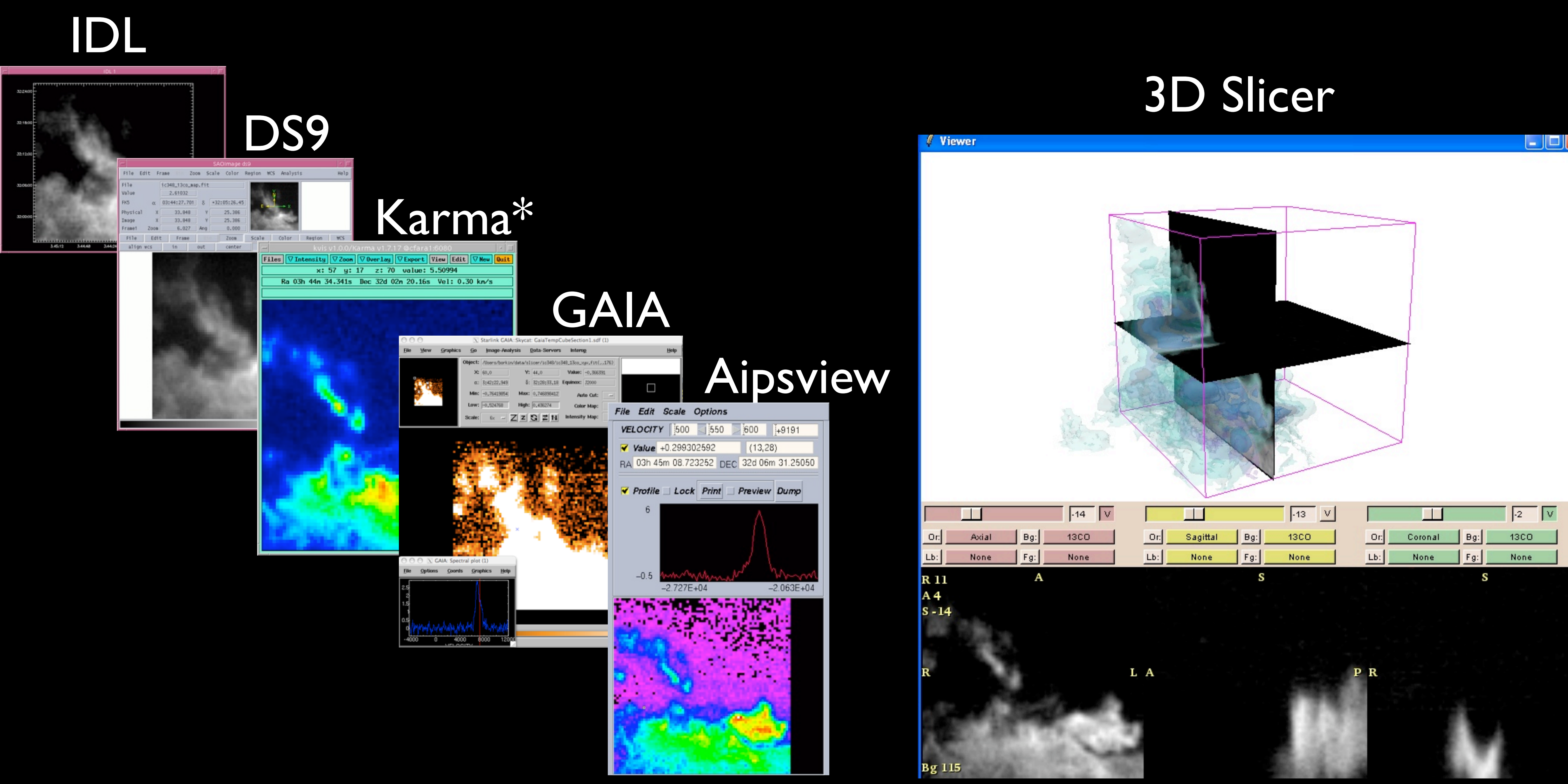


Mountain Range

No loss of information

Loss of 1 dimension

Astronomical Visualization Tools are Traditionally 2D



“3D”=movies

Friday, January 15, 2010

Challenge in displaying spectral line data cubes.

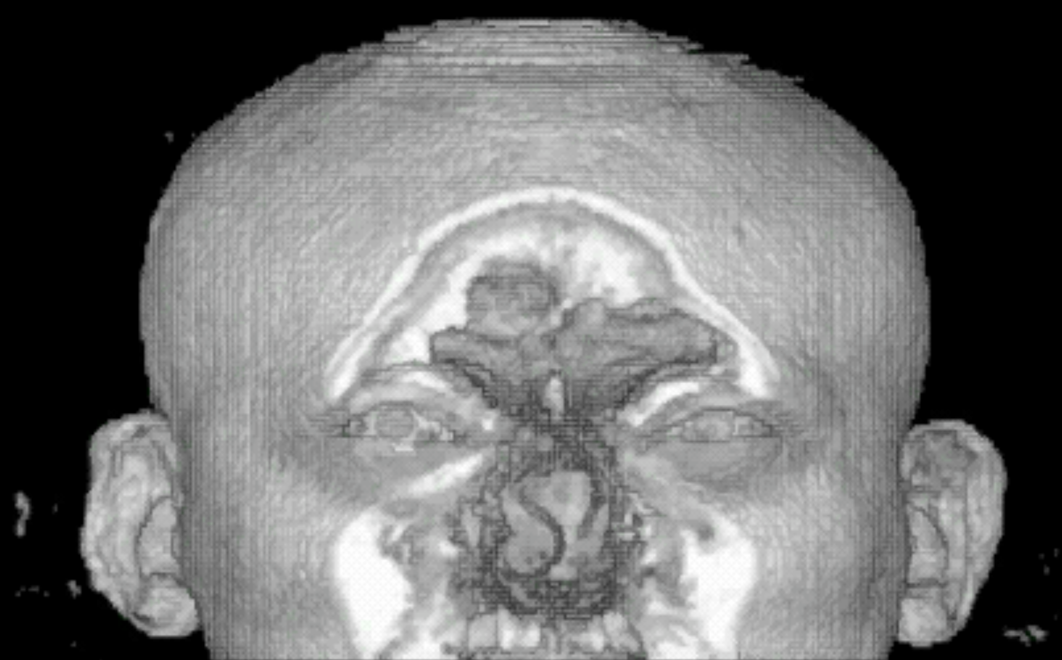
Hard to address all three dimensions at once, but made compact with 3D Slicer.

3D Slicer is a visualization tool taking fundamentally different approach.

3D Slicer built and designed for 3D viewing; others come from 2D approach.

"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")

What can we observe?

$$I(E, s, \vec{x}, t)$$

Intensity

Energy (wavelength)

"State" (e.g. polarization)

Spatial Position (x, y, z)

Time

...and the science is in the interpretation of these measurements into physical quantities & processes.

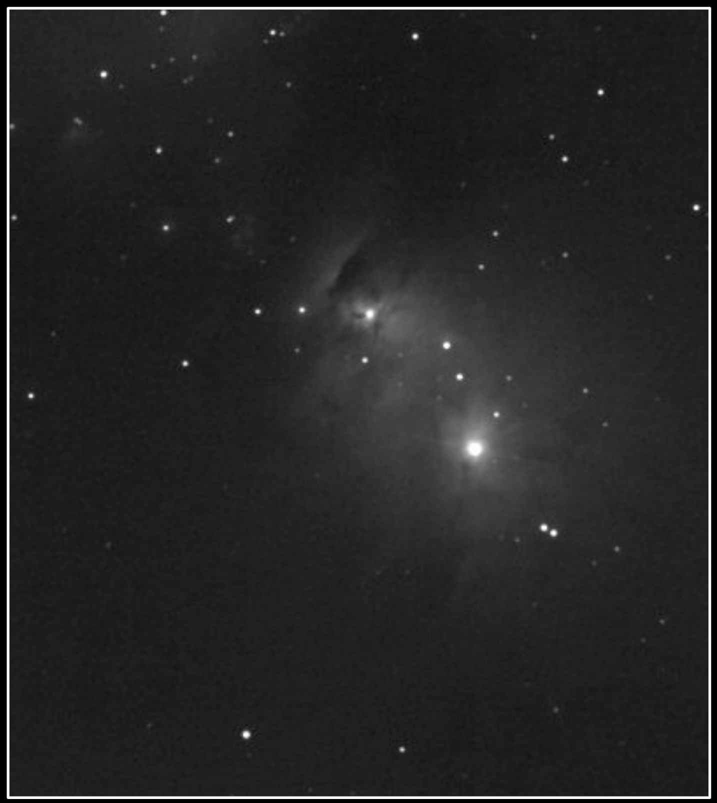
What can we observe?

$$I(\quad \vec{x} \quad)$$

Intensity

Spatial Position

$(x, y \quad)$



Optical Single-Band
Image of NGC1333

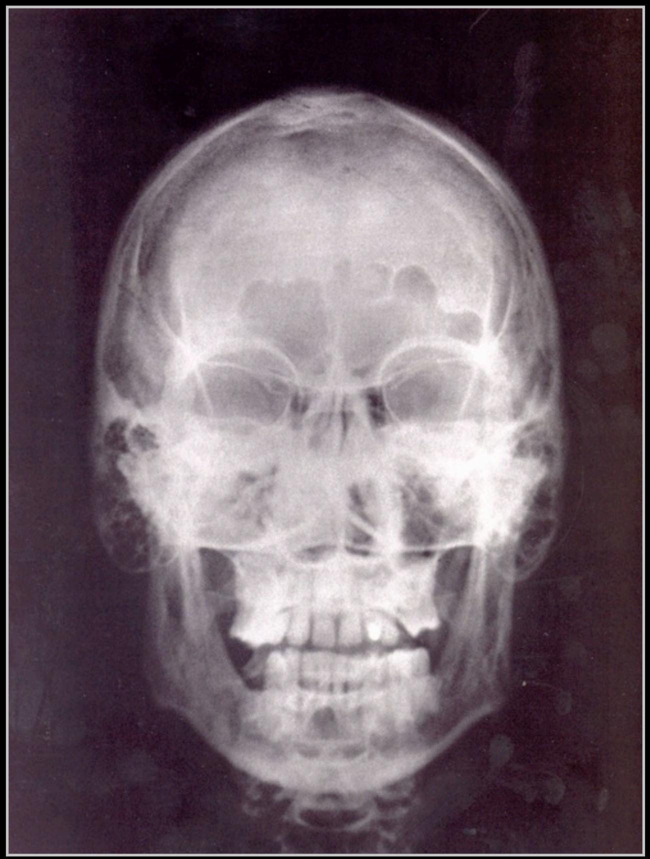
What can we observe?

$$I(\vec{x})$$

Intensity

Spatial Position

$$(x, y)$$



X-Ray of Human Skull, c. 1920

What can we observe?

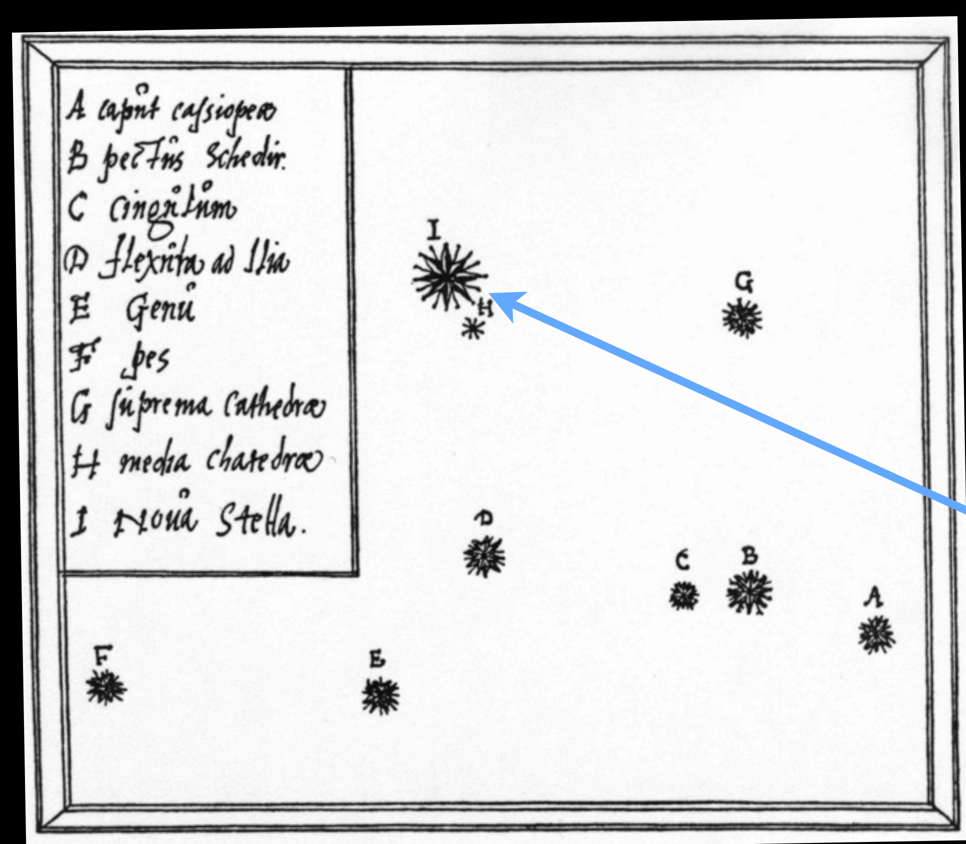
$$I(\vec{x}, t)$$

Intensity

Spatial Position

(x, y, z)

Time



"Nova Stella" of Tycho, 1572

What can we observe?

$$I(\quad \vec{x}, t)$$

Intensity

Spatial Position (x, y, z)

Time

Cardiac Motion

Friday, January 15, 2010

Cardiac Motion: This is an excellent demonstration of why we need to reconstruct at various sequences in the cardiac cycle. You will note how depending on the contracting heart, the right coronary artery is either absolutely normal or evaluation might be considered limited by motion related artifact. This is why we reconstruct all cases at 10% intervals. From: http://www.ctisus.org/rsna_2006/cardiac_cta/videos.html

What can we observe?

$$I(E, \quad \vec{x} \quad)$$

Intensity

Energy
(wavelength)

Spatial Position
$(x, y \quad)$

Optical (B,V,R) image
of NGC1333

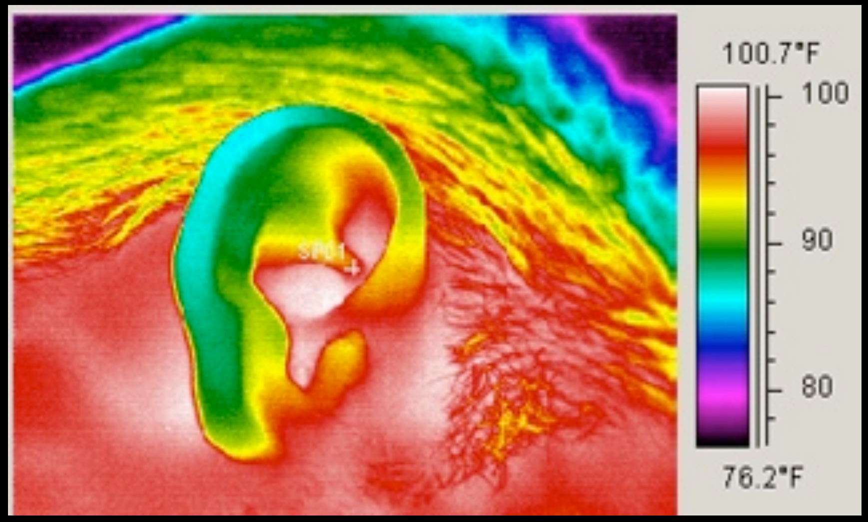
What can we observe?

$$I(E, \quad \vec{x} \quad)$$

Intensity

Energy
(wavelength)

Spatial Position
$(x, y \quad)$



Human Ear,
Thermal Infrared

What can we observe?

$$I(\quad s, \vec{x} \quad)$$

Intensity

"State"
(e.g. polarization)

Spatial Position
$(x, y \quad)$

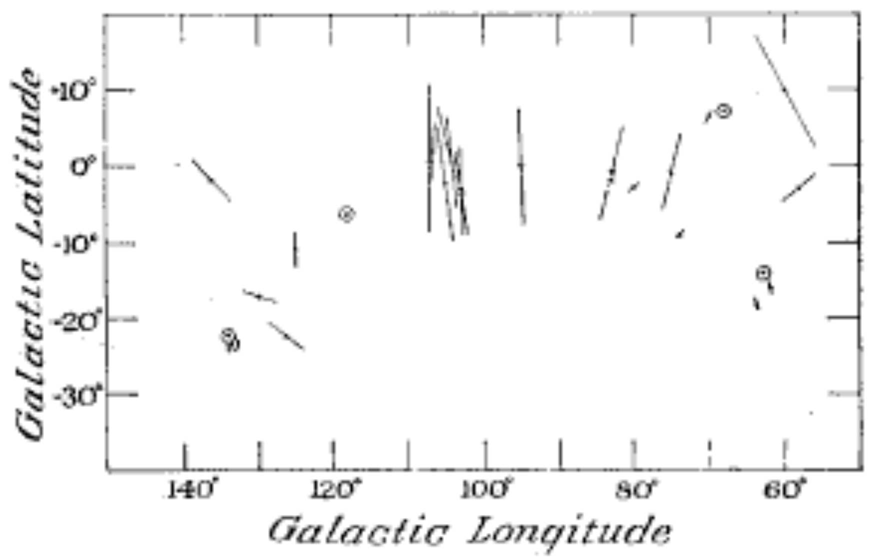


FIG. 4. Observational evidence that there is no one preferential orientation of the plane of polarization. Stars showing no polarization are represented by circles.

Hall 1949

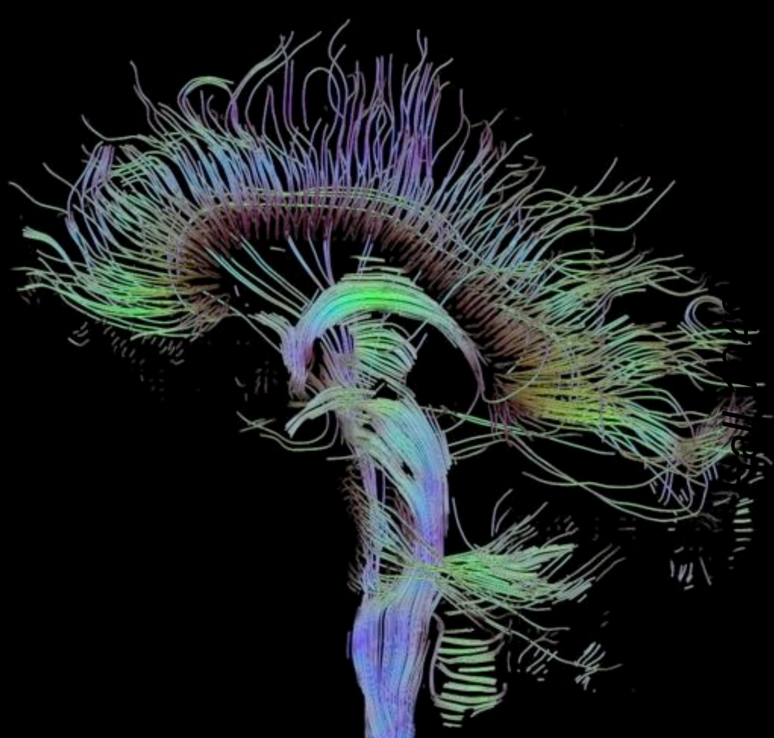
What can we observe?

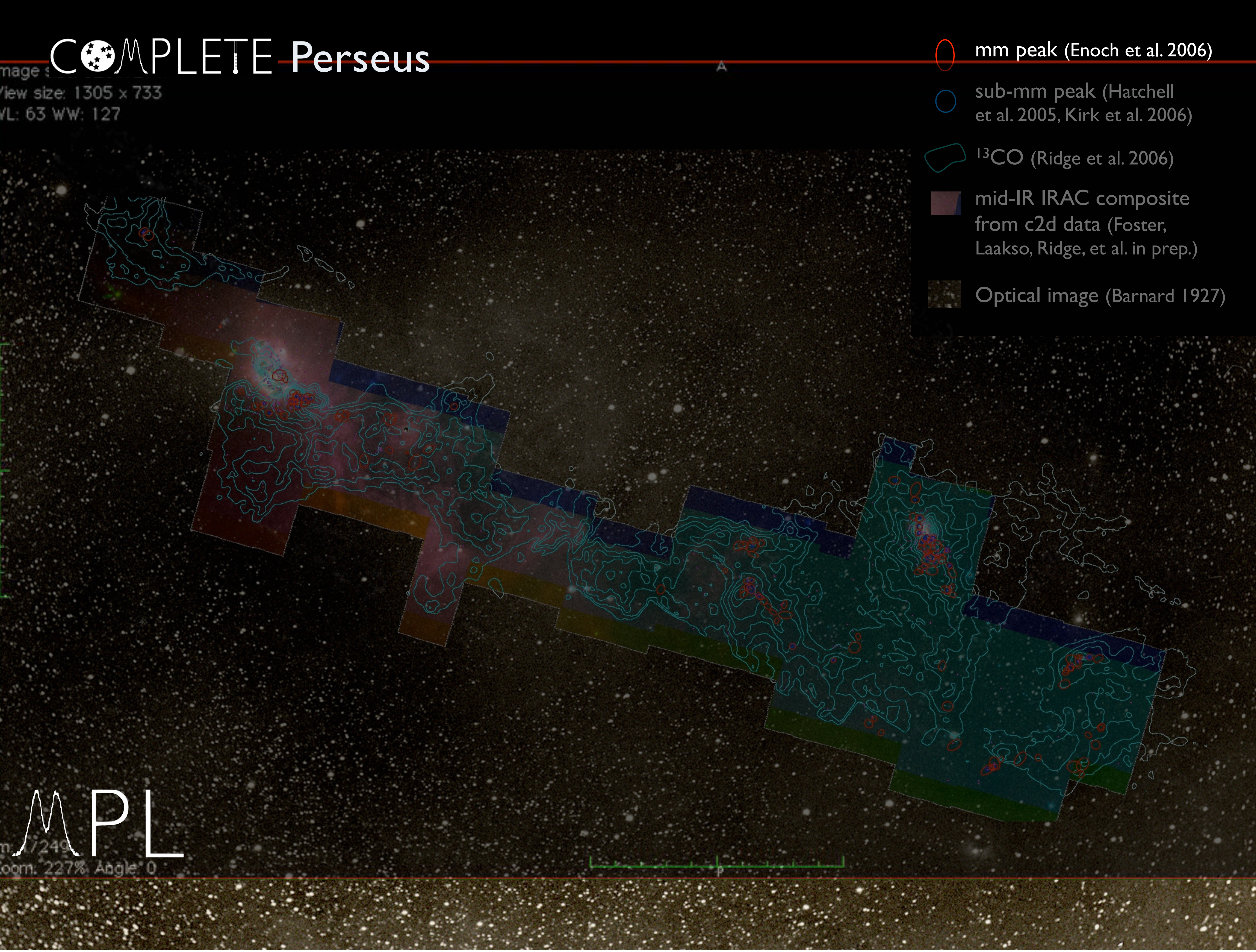
$$I(\quad s, \vec{x} \quad)$$

Intensity

"State"
(~diffusivity)

Spatial Position
(x, y, z)





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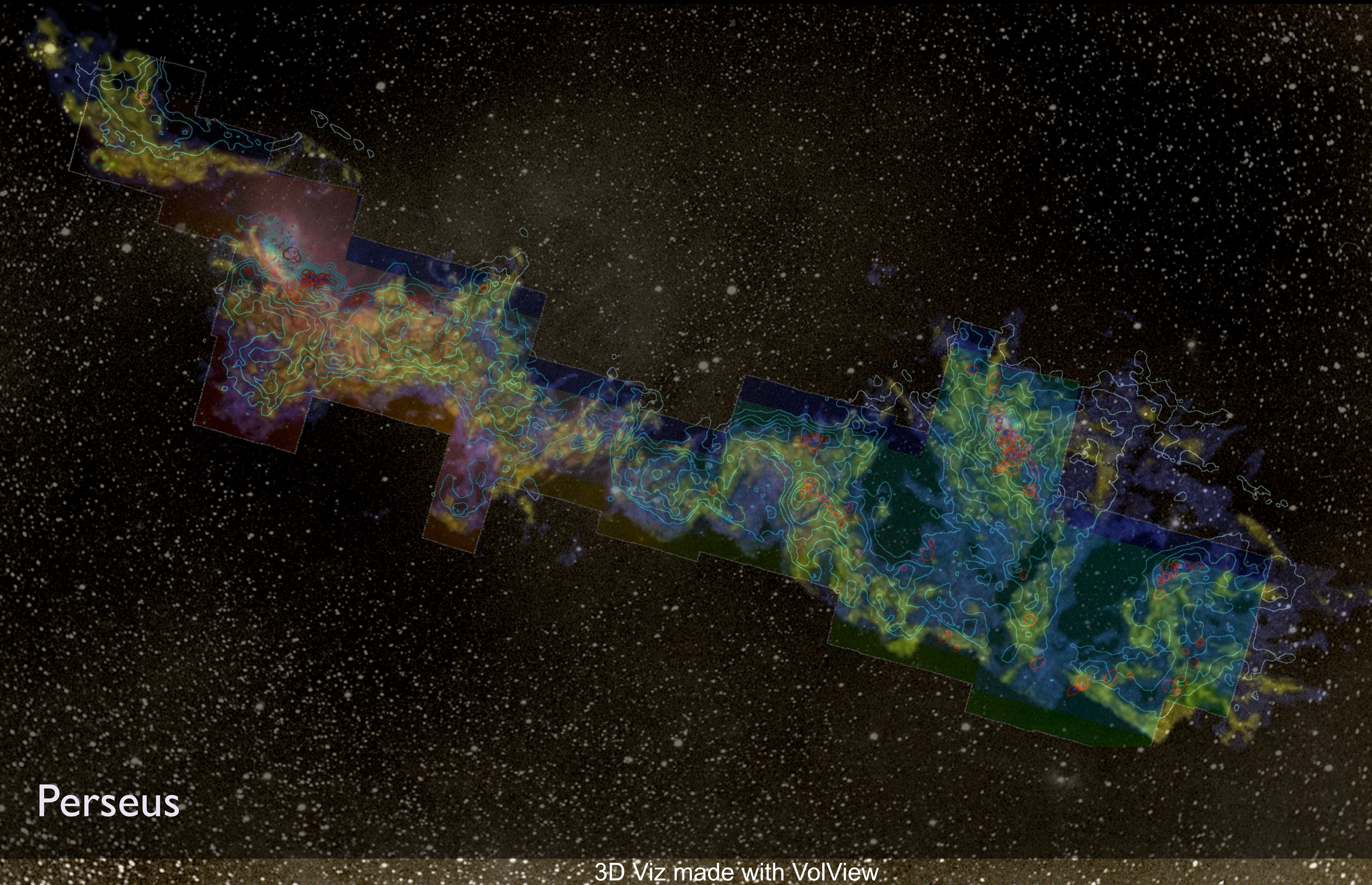


AstronomicalMedicine@IIC

COMPLETE

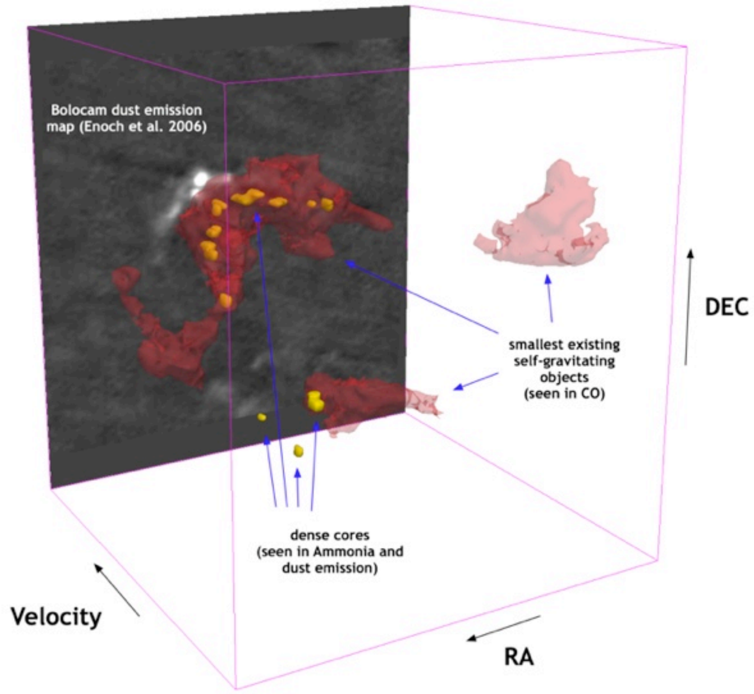
Real 3D space

3D rendering: GE Healthcare

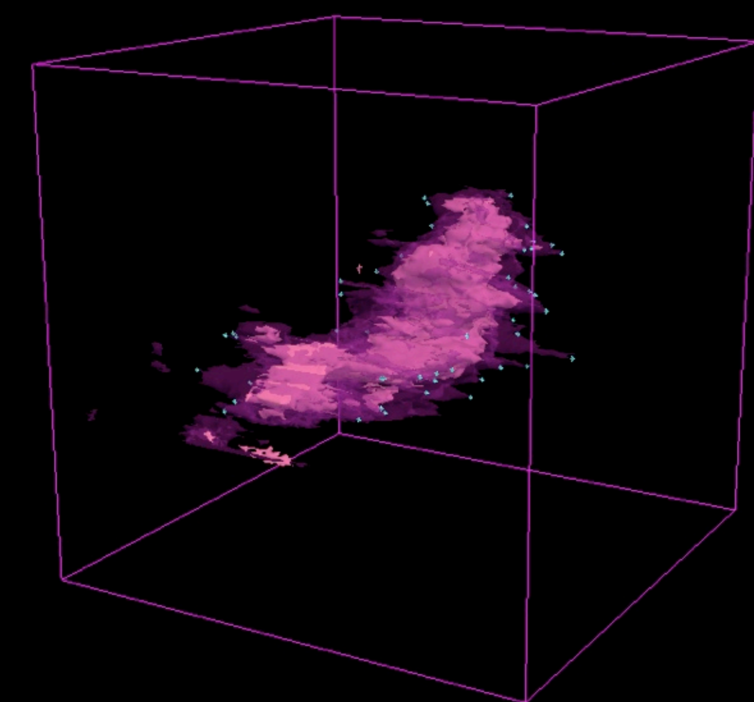
“Position-Position-Velocity” Space

3D rendering: AstroMed /N. Holliman (U. Durham), using VolView (ITK-based)

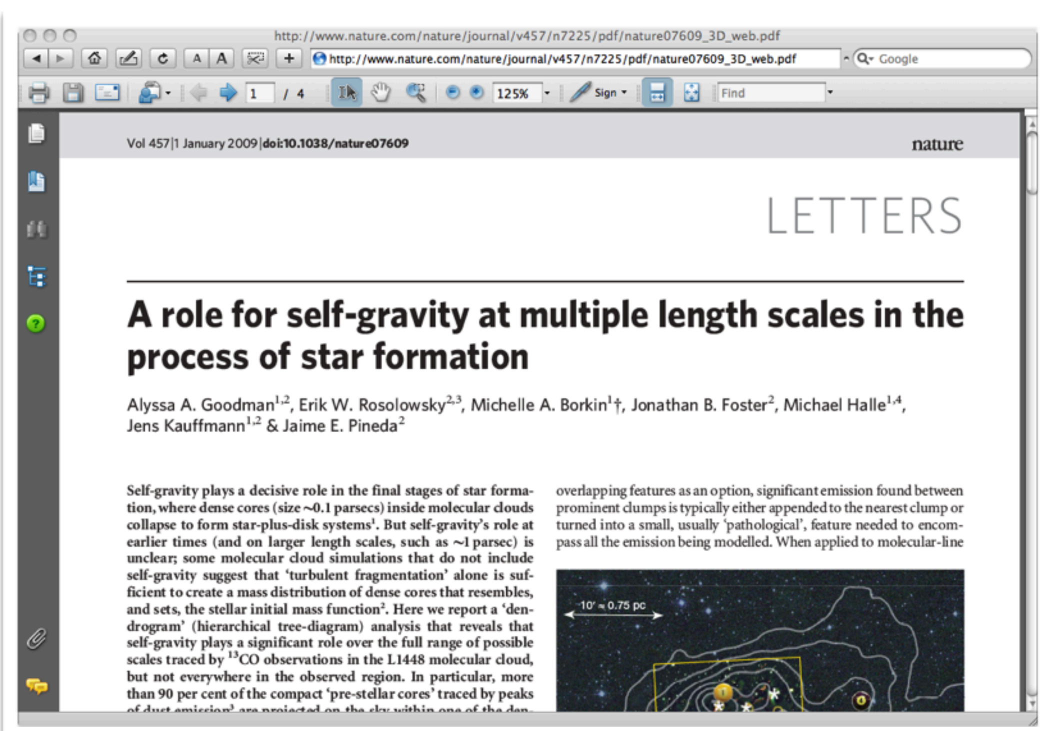
Some of What We've Learned...



Cores nest in coccoons
(Kauffmann et al. 2009)



Tripled Outflows
(Borkin et al. 2008,9)



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

LETTERS

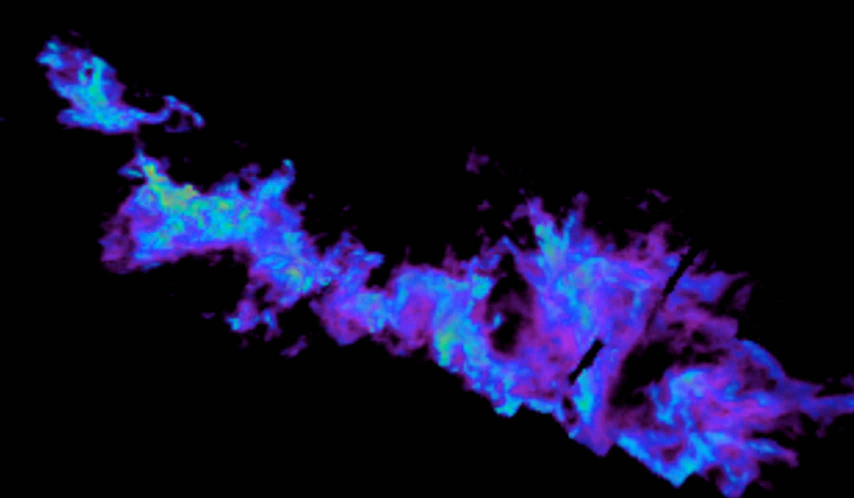
A role for self-gravity at multiple length scales in the process of star formation

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

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

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

Gravity Matters
(Goodman et al. 2009)



Shells Rule
(Arce et al. 2009)

Astronomical

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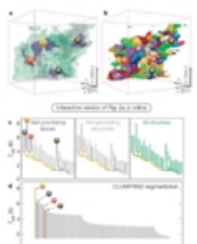
A role for self-gravity at multiple length scales in the process of star formation



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

Institution: [1]Initiative in Innovative Computing at Harvard, Cambridge, Massachusetts 02138, USA. agoodman@cfa.harvard.edu
[2]Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts 02138, USA.

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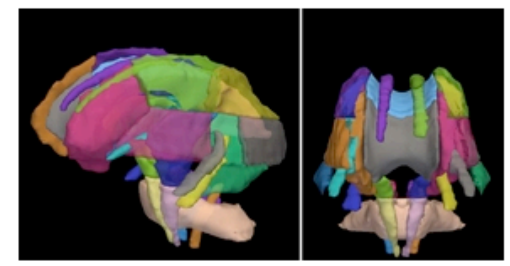
A Mathematical Framework for Incorporating Anatomical Knowledge in DT-MRI Analysis



[1]Mahnaz Maddah, [1]Lilla Zollei, [1]W E L Grimson, [2]C-F Westin, [3]William M Wells III

Institution: [1]Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Cambridge, MA, USA.
[2]Laboratory of Mathematics in Imaging, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA.
[3] Surgical Planning Lab, Department of Radiology, Brigham and Women's Hospital, Boston, MA, USA.

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Sharing Insight

“3D PDF”

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Incorporating interactive three-dimensional graphics in astronomy research papers ☆

David G. Barnes *, Christopher J. Fluke

Centre for Astrophysics and Supercomputing, Swinburne University of Technology, P.O. Box 218, Hawthorn, Victoria 3122, Australia

A R T I C L E   I N F O

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Galaxies: general
Stars: fundamental parameters

A B S T R A C T

Most research data collections created or used by astronomers are intrinsically multi-dimensional. In contrast, all visual representations of data presented within research papers are exclusively two-dimensional (2D). We present a resolution of this dichotomy that uses a novel technique for embedding three-dimensional (3D) visualisations of astronomy data sets in electronic-format research papers. Our technique uses the latest Adobe Portable Document Format extensions together with a new version of the S2PLOT programming library. The 3D models can be easily rotated and explored by the reader and, in some cases, modified. We demonstrate example applications of this technique including: 3D figures exhibiting subtle structure in redshift catalogues, colour-magnitude diagrams and halo merger trees; 3D isosurface and volume renderings of cosmological simulations; and 3D models of instructional diagrams and instrument designs.

Barnes & Fluke, *New Astronomy*, 2008

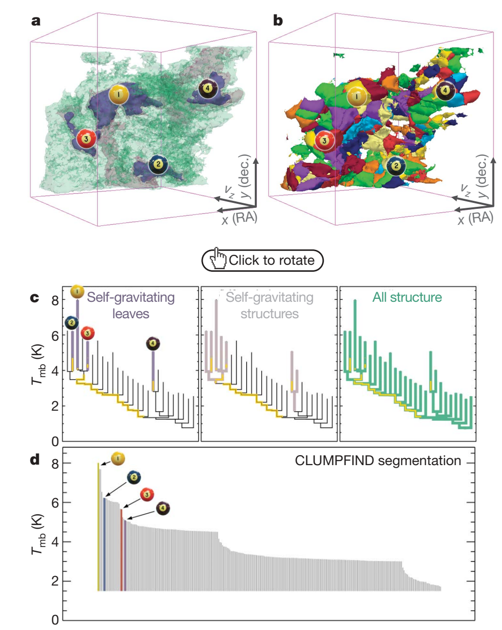


Figure 2 | Comparison of the ‘dendrogram’ and ‘CLUMPFIND’ feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. a, 3D visualization of the surfaces indicated by colours in the dendrogram shown in **c**. Purple illustrates the smallest scale self-gravitating 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.

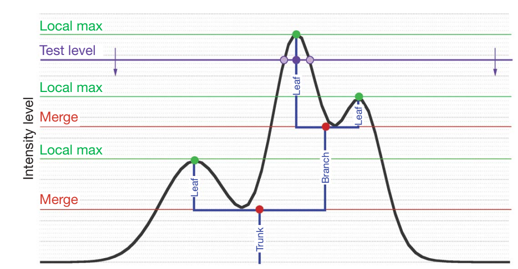
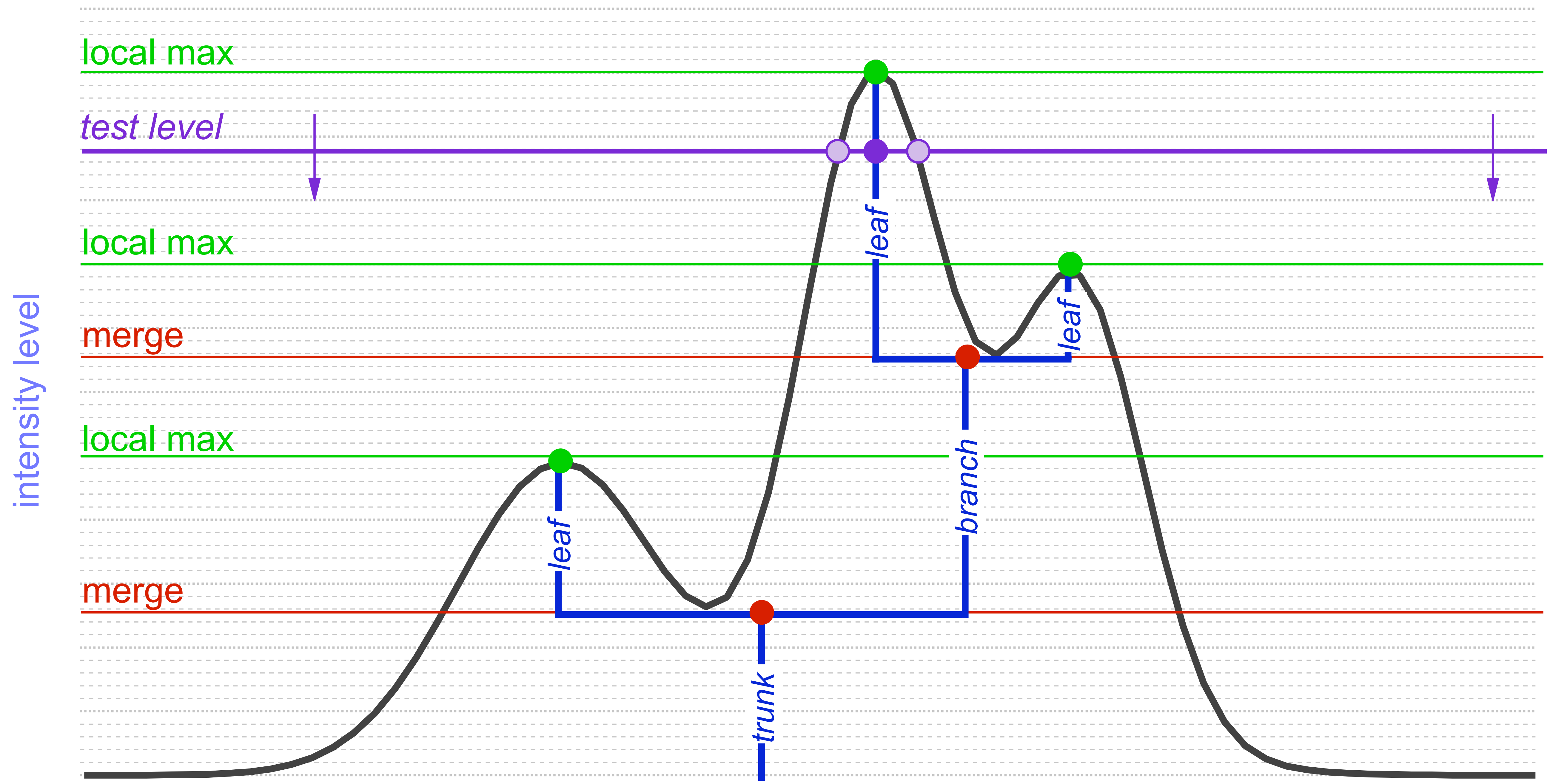


Figure 3 | Schematic illustration of the dendrogram process. Shown is the construction of a dendrogram from a hypothetical one-dimensional emission profile (black). The dendrogram (blue) can be constructed by ‘dropping’ a test constant emission level (purple) from above in tiny steps (exaggerated in 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.

Goodman et al. *Nature*, 2009

A few words on segmentation?
(or ask me later...)

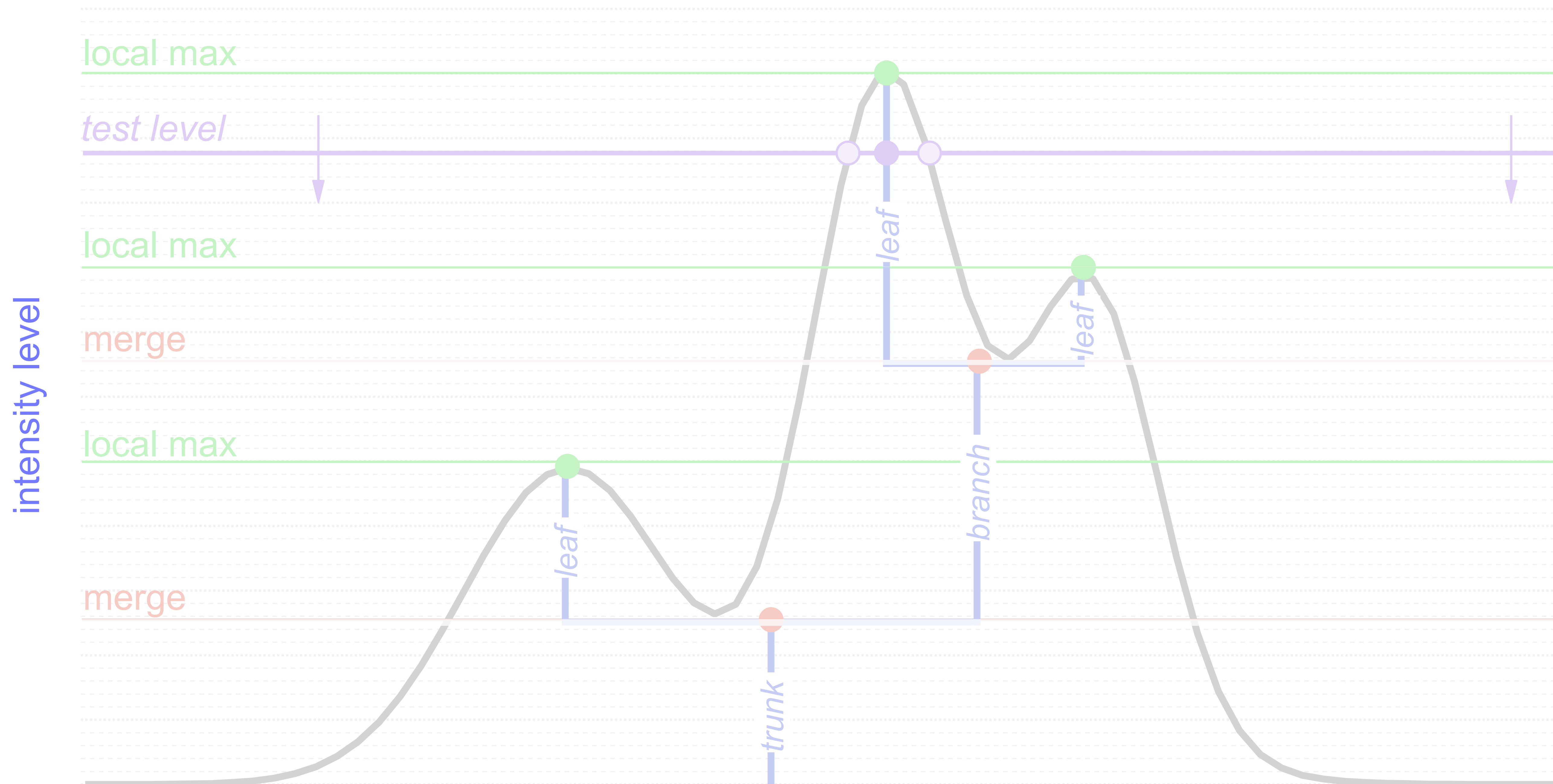
Dendrograms



Hierarchical "Segmentation"

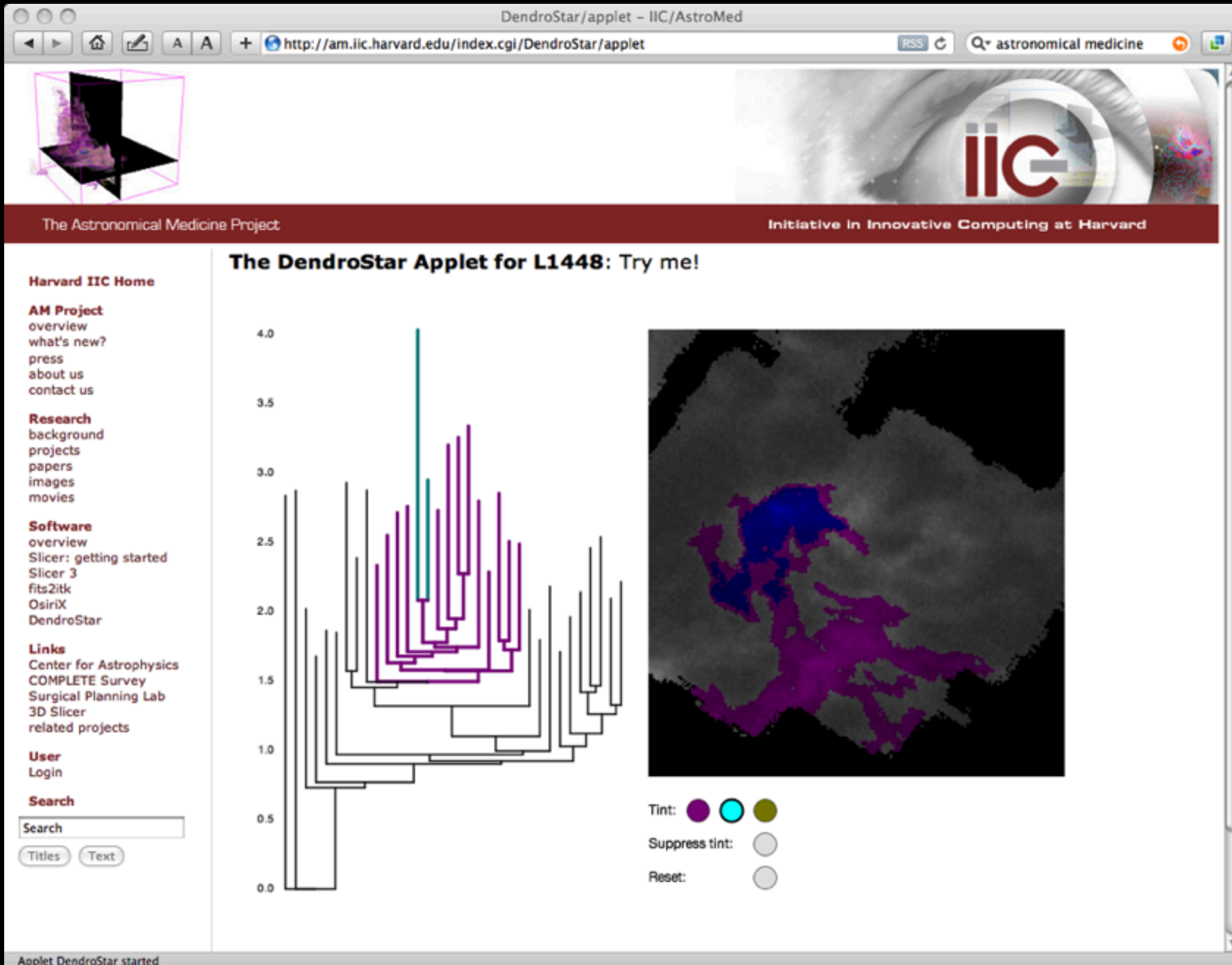
Rosolowsky, Pineda, Kauffmann & Goodman 2008

Dendrograms



1-D: points; 2-D closed curves (contours); 3-D surfaces enclosing volumes

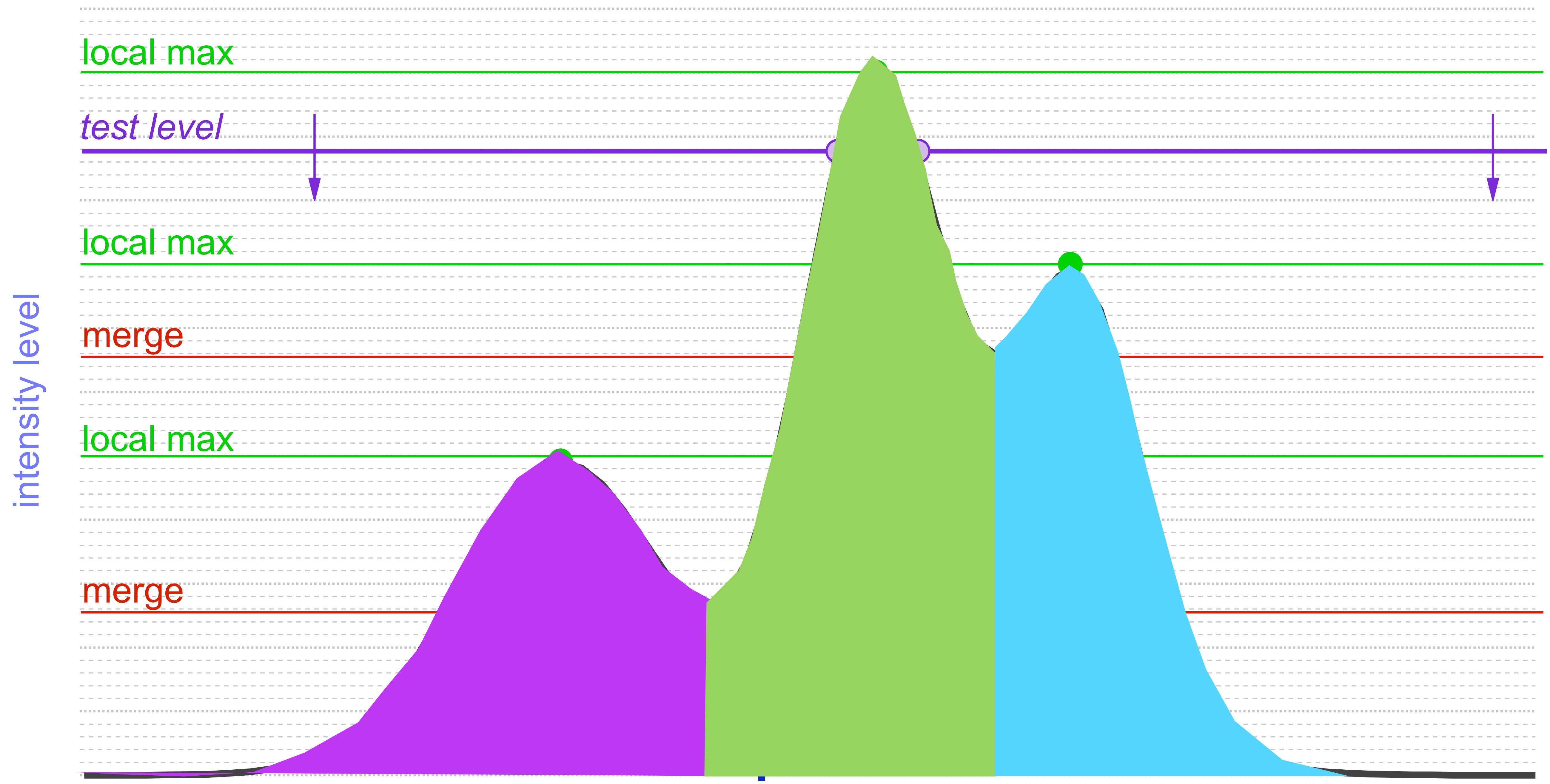
see 2D demo at *http://am.iic.harvard.edu/index.cgi/DendroStar/applet*



http://am.iic.harvard.edu/index.cgi/DendroStar/applet
Dendrogram Algorithm by Erik Rosolwosky; Applet by Douglas Alan

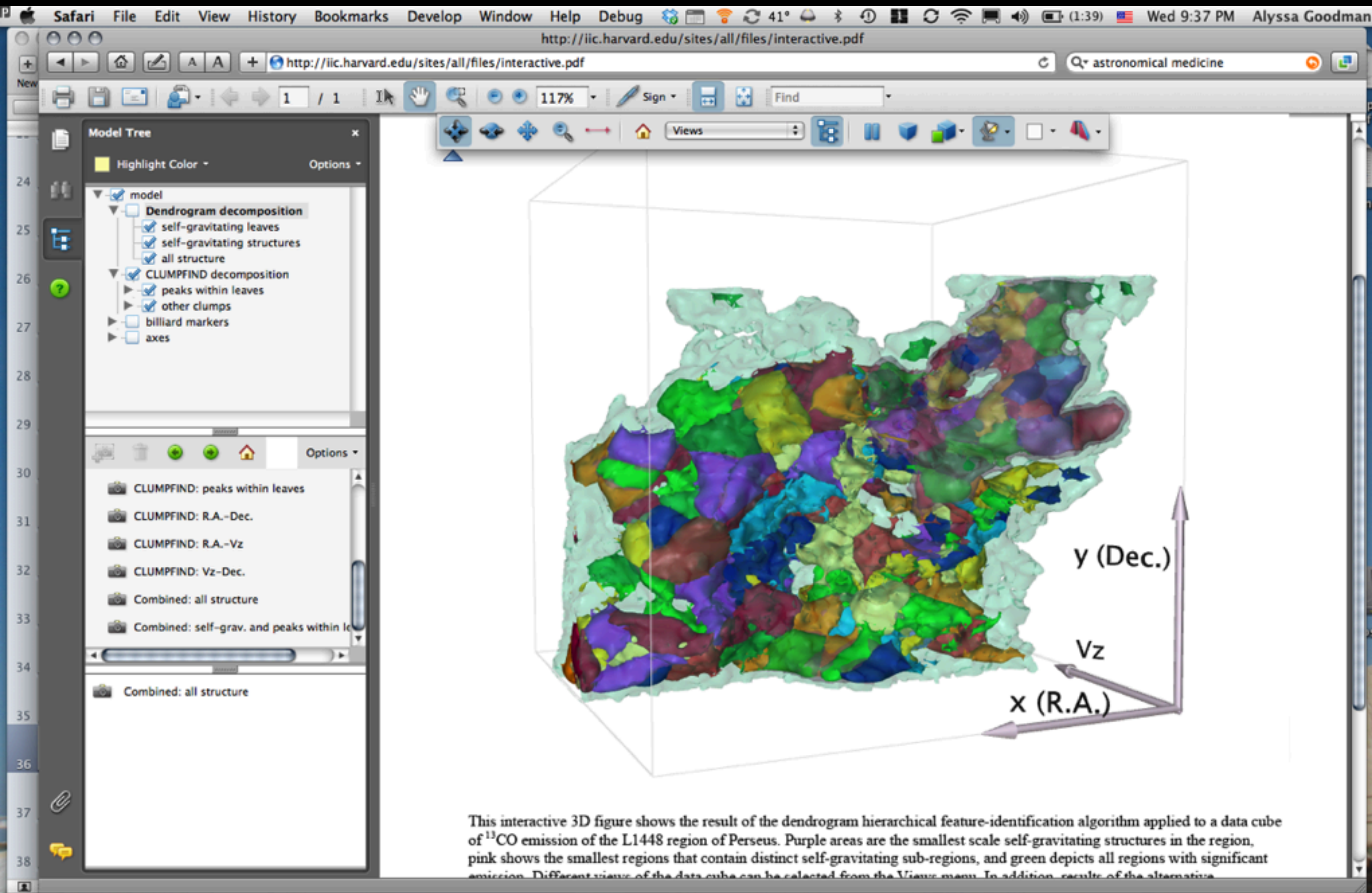
3D, see PDF...

What would *CLUMPFIND* do?



No hierarchy is allowed, all clumps go to the baseline.

(Williams, De Geus & Blitz 1994)



http://iic.harvard.edu/sites/all/files/interactive.pdf;

with many thanks to Mike Halle, Michelle Borkin, Jens Kauffmann & Douglas Alan

“Crowded” 3D data *(very dangerous)*

“Sparse” 2D data *(OK)*

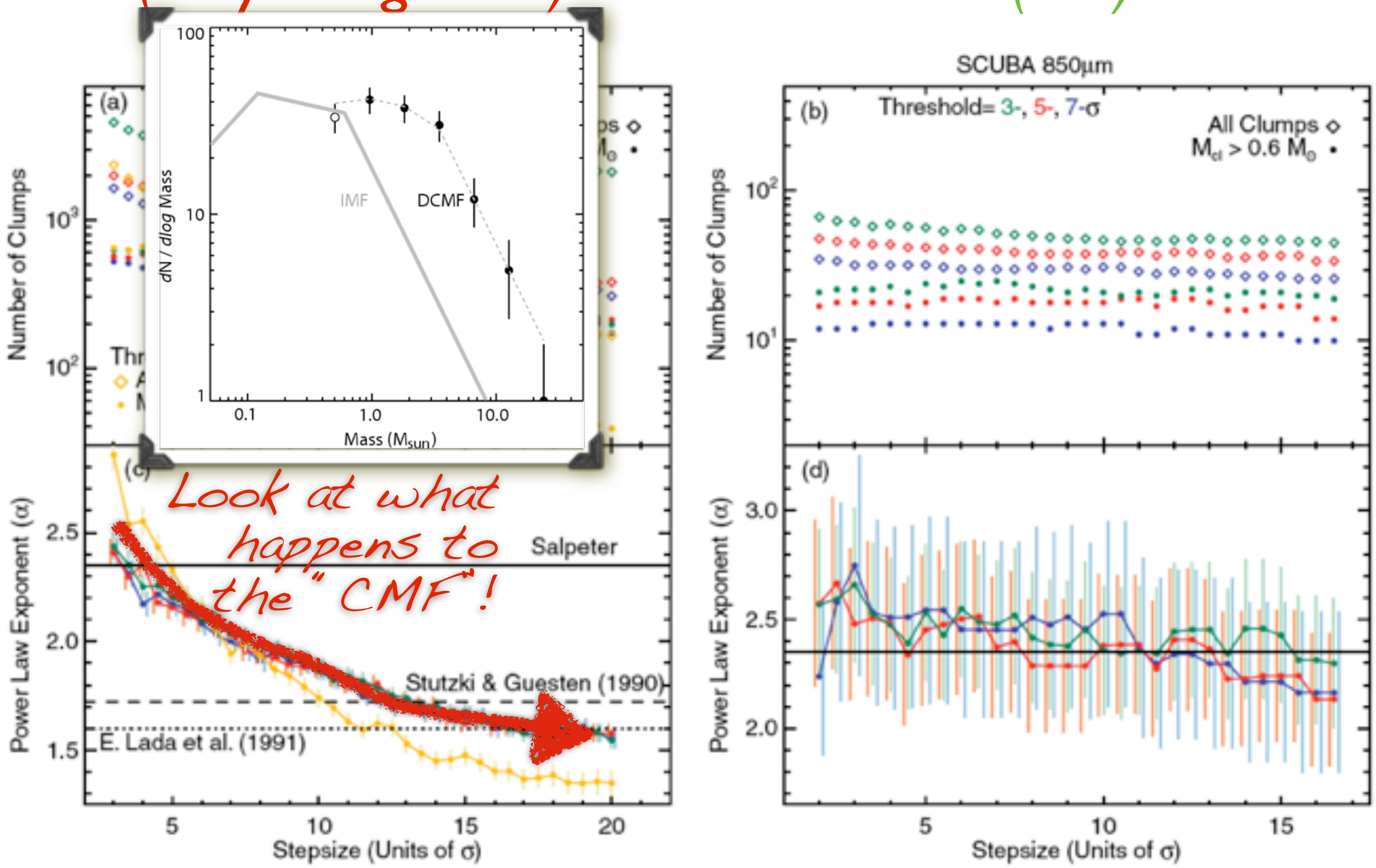


Figure 2. Summary of all Clumpfind runs as a function of stepsize. Color represent different thresholds: blue, red, and green for 3σ, 5σ, and 7σ, respectively; we also show in orange results with a threshold of 5σ for ^{13}CO data with added noise. Left and right columns show results for ^{13}CO and SCUBA data, respectively. Panels (a) and (b) show the number of clumps under a given category per model. Total number of clumps found, and total number of clumps with mass larger than the completeness limit are shown in open diamonds and filled circles, respectively. Panels (c) and (d) show the exponent of the fitted mass spectrum of clumps above the completeness limit, $dN/dM \propto M^{-\alpha}$, with error bars estimated from Equation (6). Horizontal black lines show some fiducial exponents for comparison. Average noise in ^{13}CO, ^{13}CO with added noise, and SCUBA data is 0.1 K, 0.2 K, and 0.06 Jy beam^{-1}, respectively. Completeness limit is estimated to be 4 $M_{\odot}$, 3 $M_{\odot}$, and 0.6 $M_{\odot}$ for ^{13}CO, ^{13}CO with added noise, and SCUBA data. Panel (c) also shows that for different noise level in the data, if a threshold of ~2 K (20σ and 10σ for original and noise-added data, respectively) is used, then the fitted power-law exponents are closer to previous works.

*from **“The Perils of CLUMPFIND”** by Pineda, Rosolowsky & Goodman 2009*

Touching Insight

The Scientists' Discovery Room

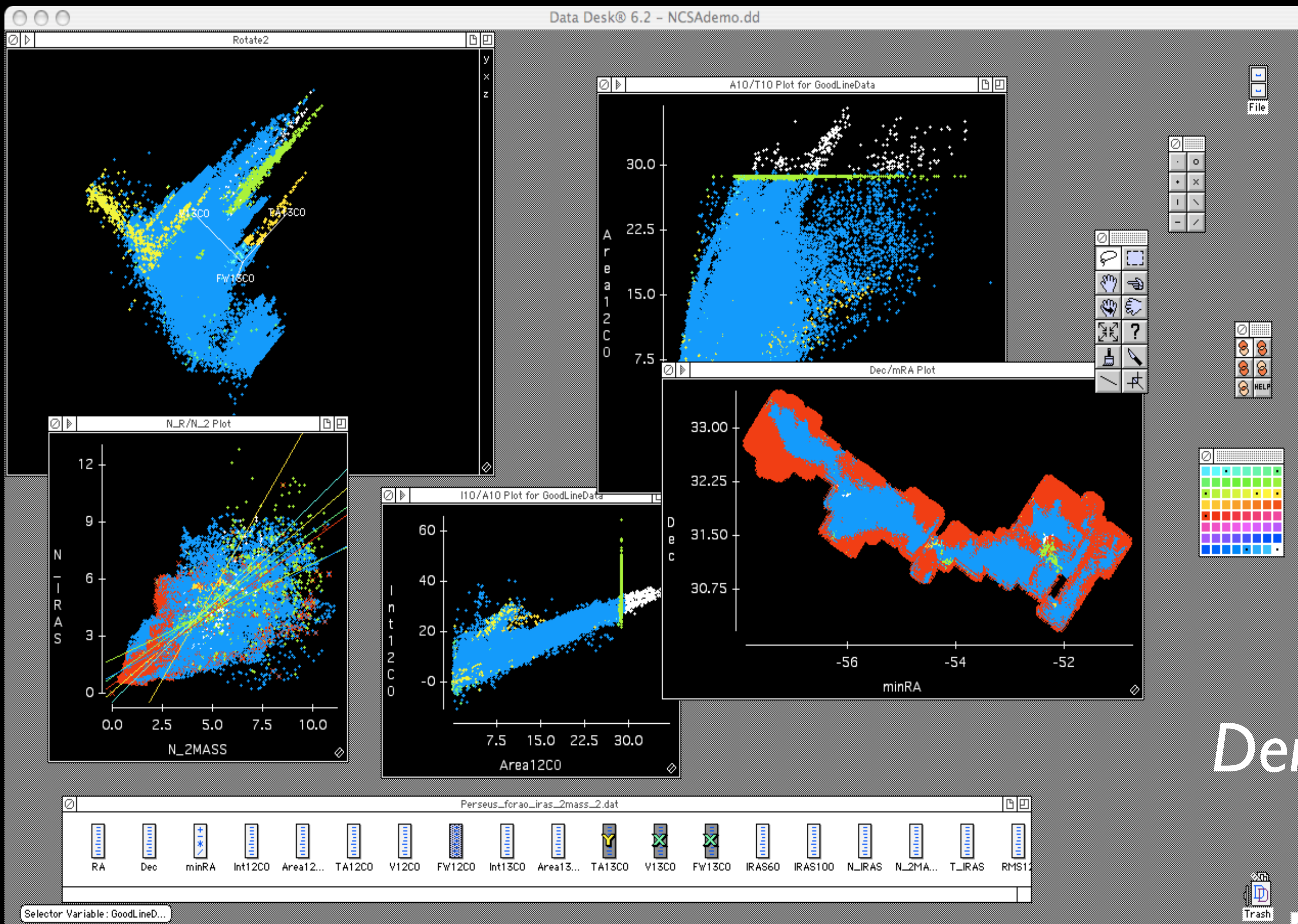
movie courtesy Daniel Wigdor, equipment now in Chia Shen's SDR lab at SEAS

What I learned from AstroMed at IIC, but never before have talked about publicly

1. The story about the hammer & the screw is a cliché, but it's true. Don't use "more" software than you must. (e.g. 3DSlicer/Osirix/VolView/AplPy/S2PLOT/custom apps)
2. Smart hackers rule. Software engineering is great when you have the money & time.
3. Distribution is key. There's too much great S/W no one knows about.

The App(s) of the Future

“Data Desk”

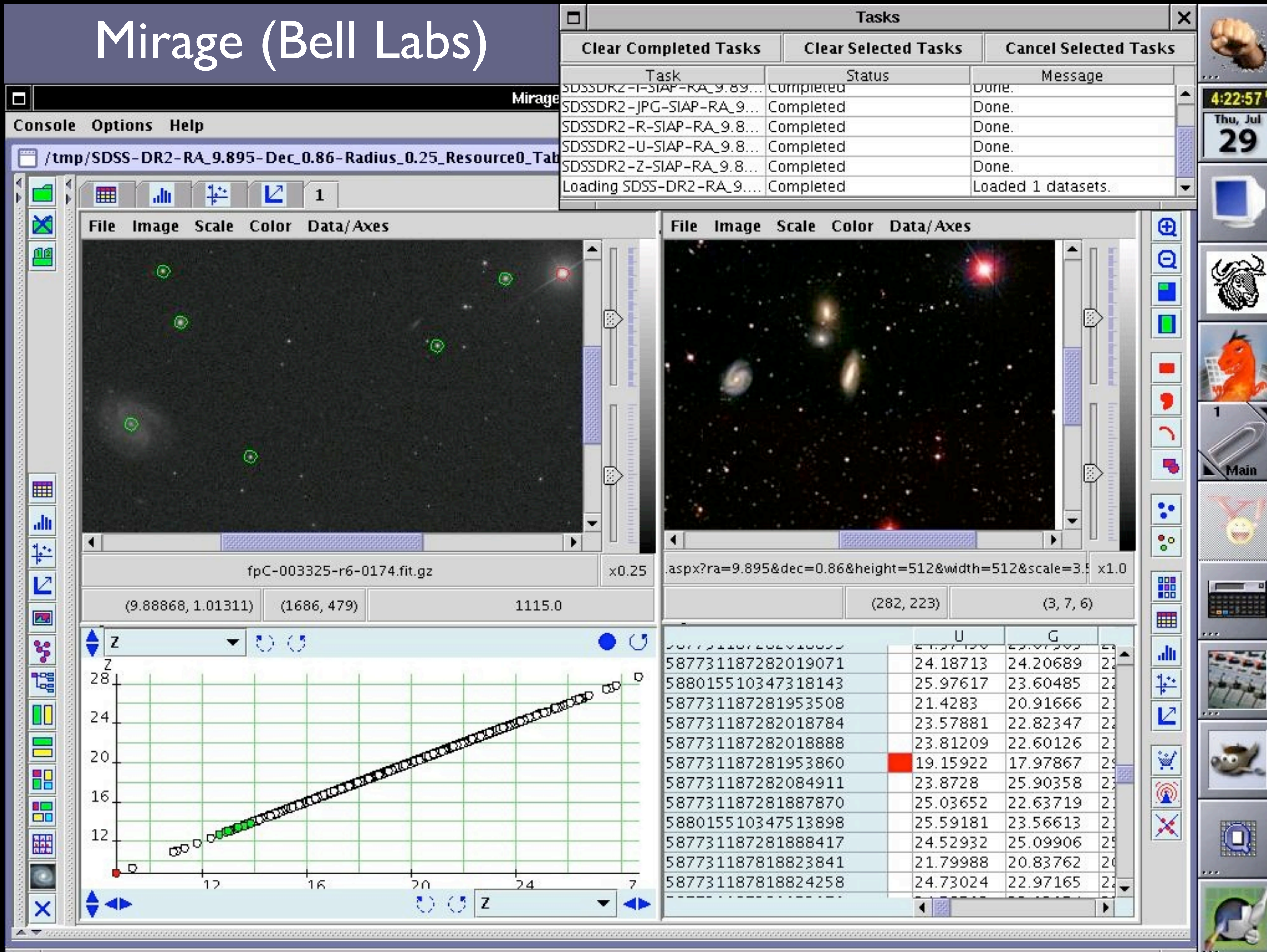


Demo?

If only DataDesk were >2D...??

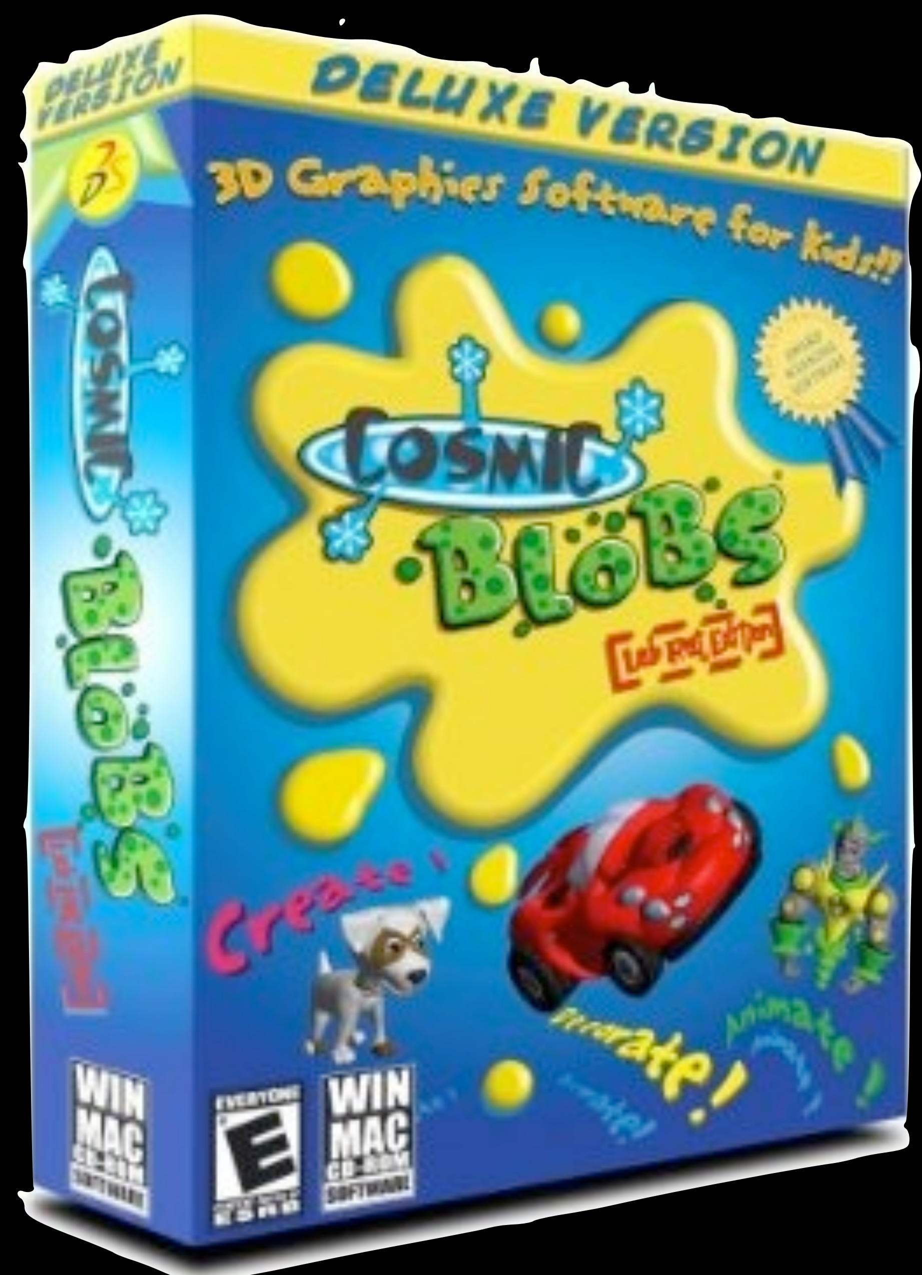
3D selction tools (& interaction) are challenging

Mirage (Bell Labs)

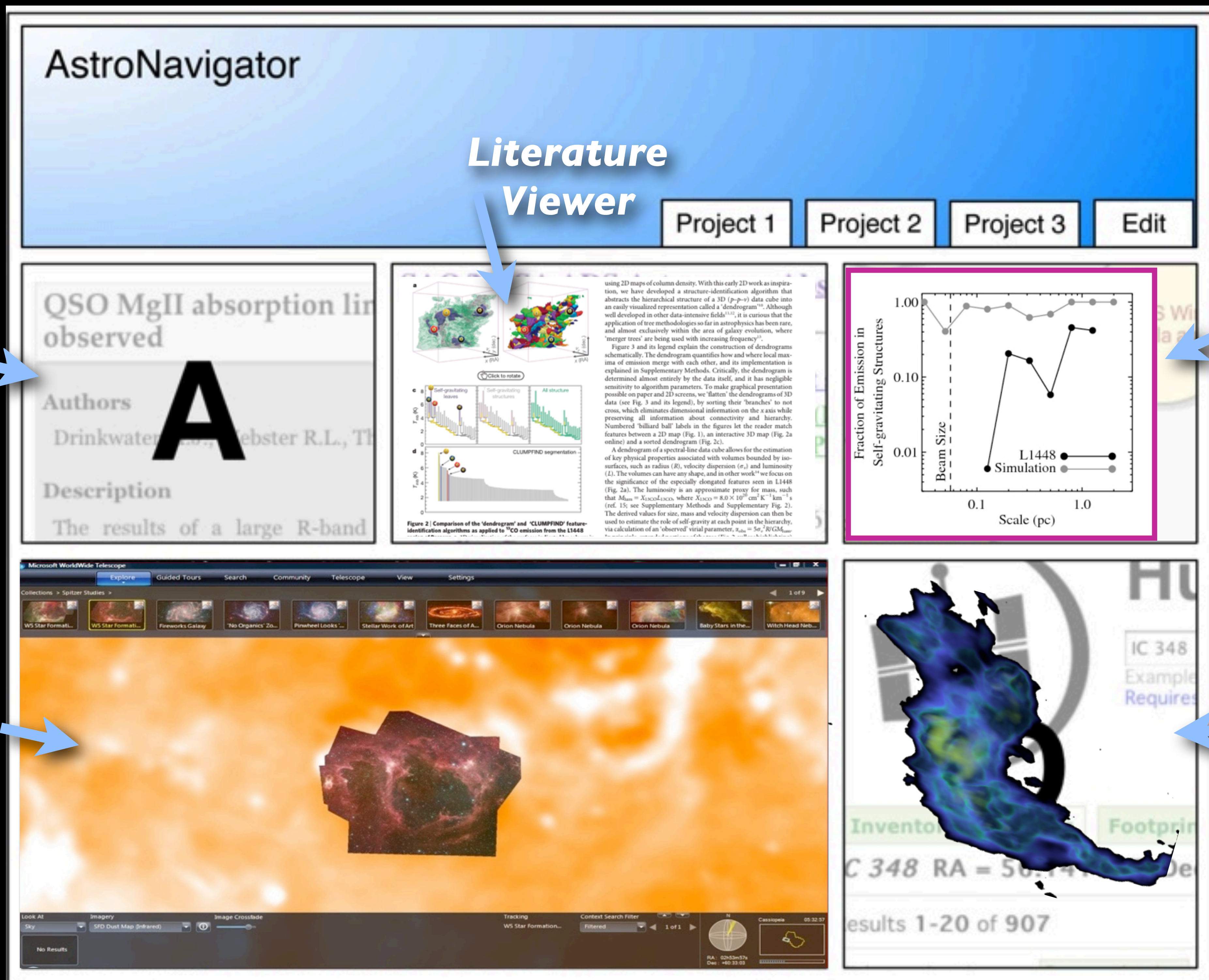


cf. Avizo (Mercury Systems); some aspects of GenePattern; Taverna...

The "Cosmic Blobs" Problem



"Seamless Astronomy"
(Wednesday)



Semantic Search

Data Viewer (e.g. WWT)

Info-Viz for Analytics

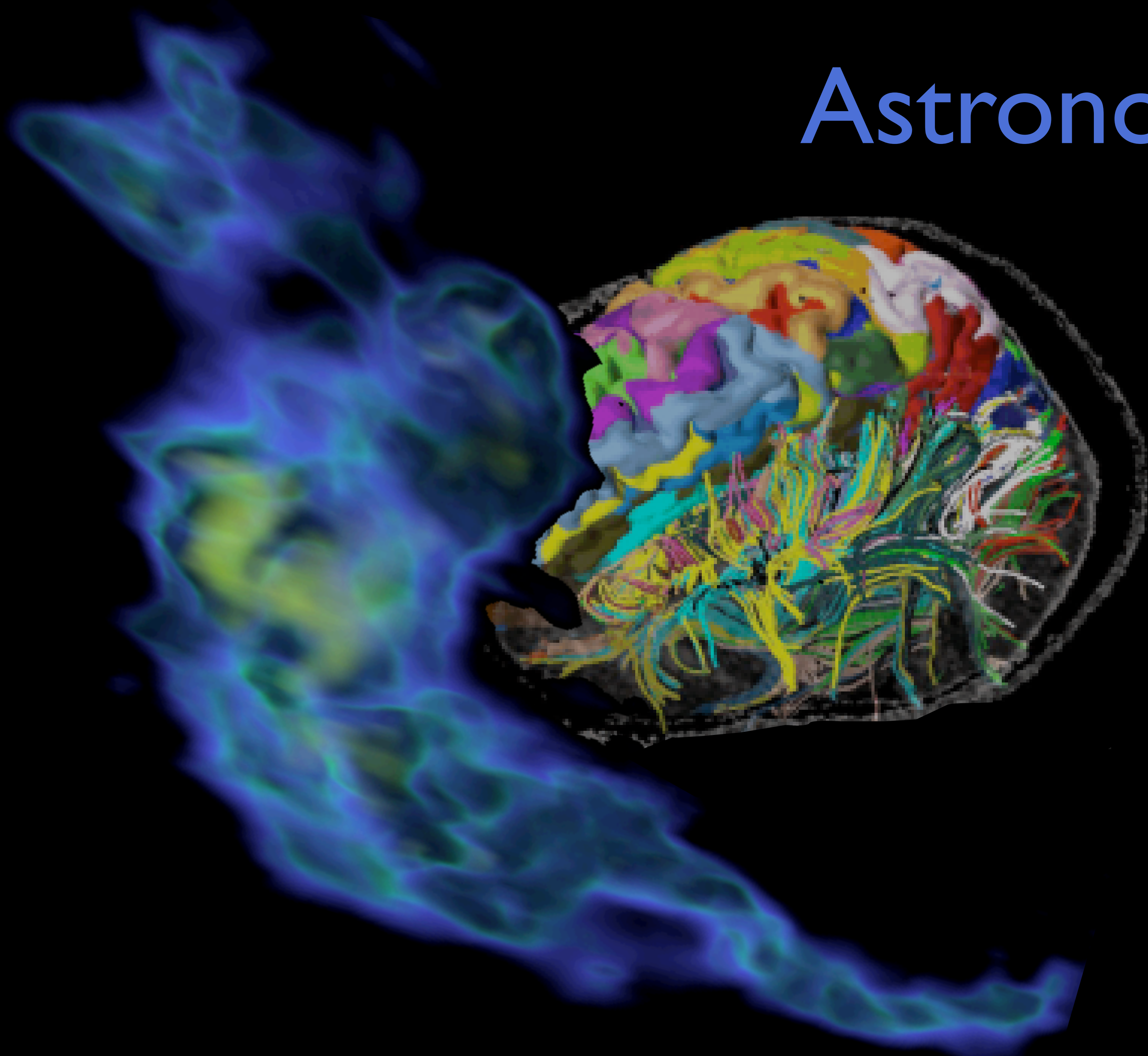
Site-based Search Results

3D Viewer

Archive Browser

Mockup based on work of Eli Bressert, excerpted from NASA AISRP proposal by Goodman, Muench, Christian, Conti, Kurtz, Burke, Accomazzi, McGuinness, Hendler & Wong, 2008

Astronomical Medicine and the IIC



Alyssa A. Goodman

Professor of Astronomy & Founding Director of the Initiative in Innovative Computing, Harvard University

Scholar-in-Residence, WGBH Boston

Friday, January 15, 2010

Abstract

I will consider the similarities between the imaging modalities and data visualization techniques used in Astronomy and in Medicine. Both fields inherently produce "cubes" or "hyper-cubes" of data where some dimensions are spatial. And, in both fields, tremendous extra value can be derived from visualizing "all" of the data represented in its natural number of dimensions. I will focus on the specific case study where we have used medical imaging software (e.g. 3D Slicer, Osirix) on astronomical observations of star-forming regions to look for the "tumors" (called "dense cores") destined to form new stars like our Sun, and then published our results in *Nature* as that journal's first interactive "3D PDF" interactive paper. I will conclude with a demonstration of the "WorldWide Telescope" program and explain how the natural, "seamless," model of data-literature connections it offers can be extended to other fields.