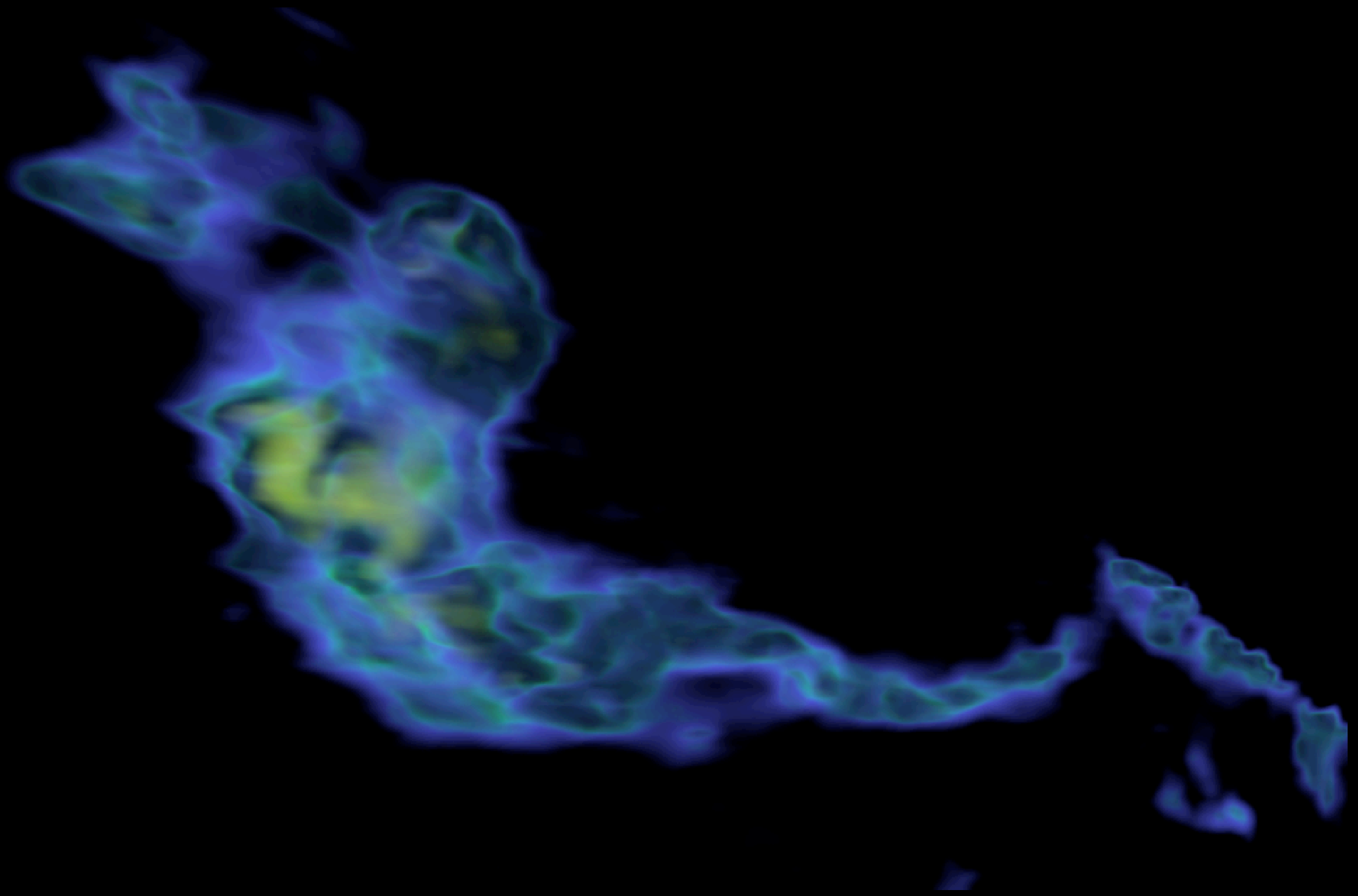
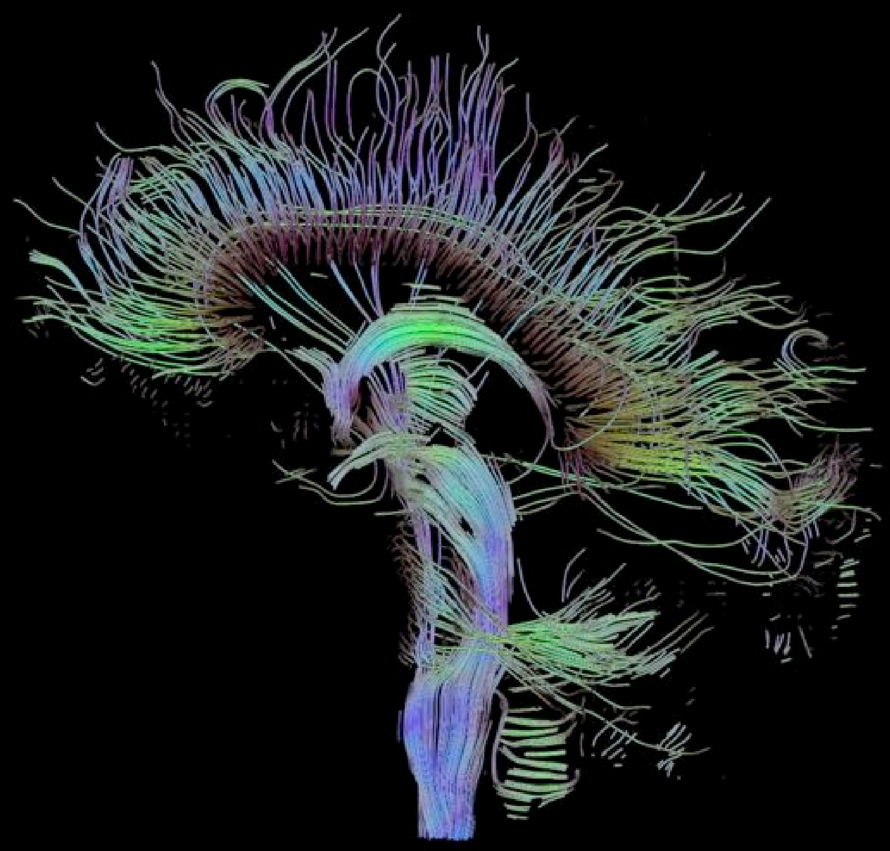
Astronomy + Medicine = Understanding





Alyssa A. Goodman
Initiative in Innovative Computing @ Harvard
and
Harvard-Smithsonian Center for Astrophysics

Special Thanks to...

COMPLETE

M. **Borkin** (IIC), J. **Foster** CfA), J. **Kauffmann** (CfA/IIC), J. **Pineda** (CfA) & E. **Rosolowsky** (CfA) + many COMPLETErs beyond Cambridge!

Astronomical Medicine

D. **Alan** (IIC), M. **Borkin** (IIC), M. **Halle** (IIC/BWH-SPL), N. **Holliman** (Durham, UK), J. **Kauffmann** (CfA/IIC), R. **Kikinis** (BWH-SPL)

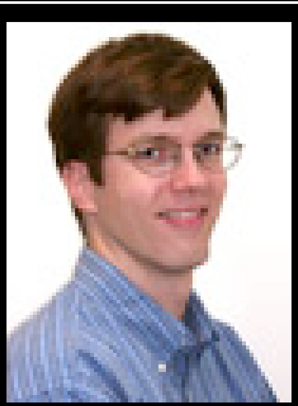
3D Software you will see...

3D Slicer, OsiriX, VolView

more at: http://astromed.iic.harvard.edu/

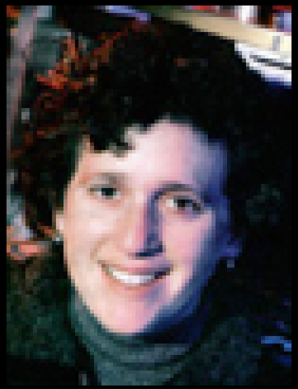
The Astronomical Medicine Story

Computer Scientist



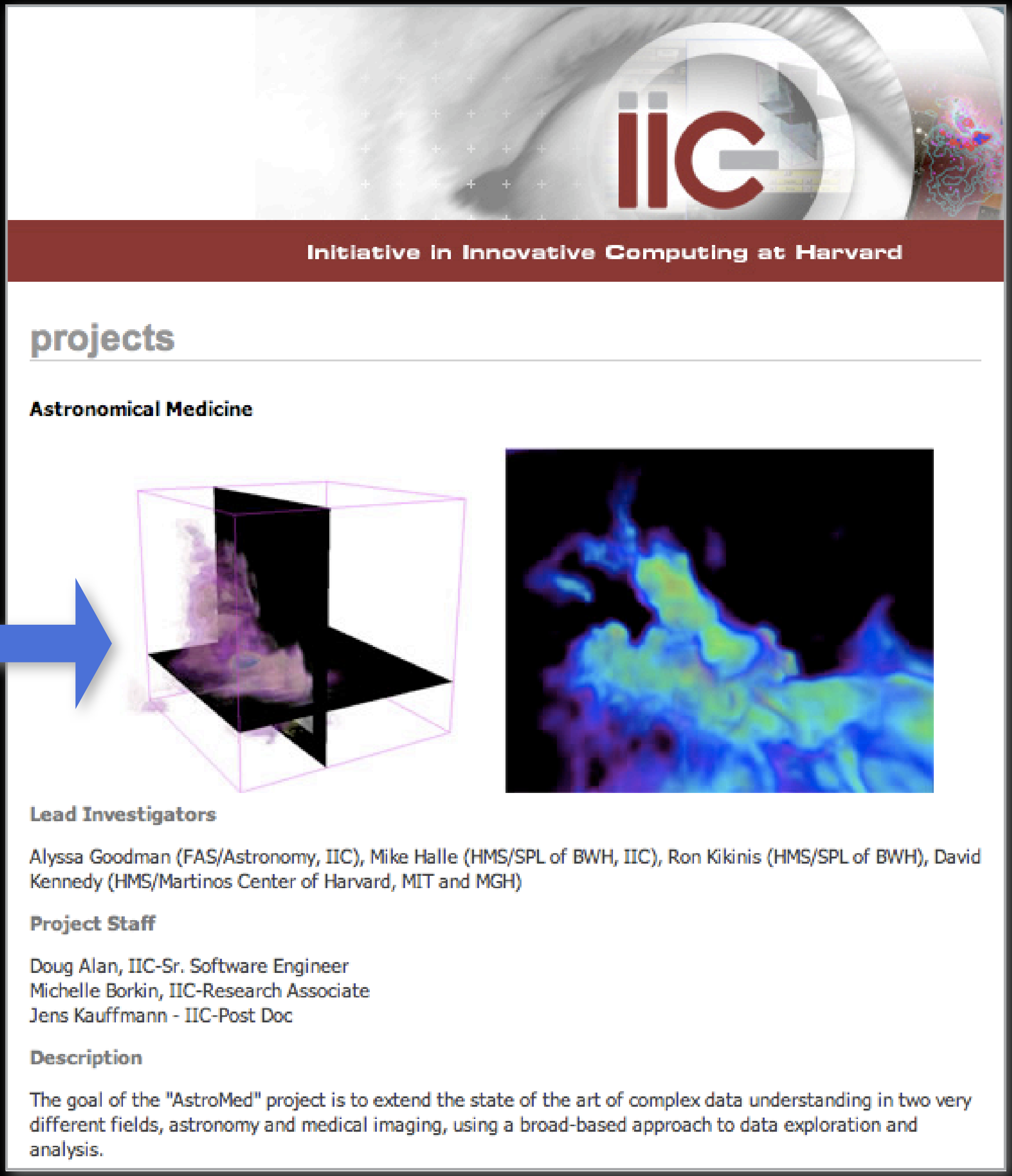
Computer Scientist

"Viz has failed the scientific community…"



Astronomer

Unsuspecting Undergrad



Initiative in Innovative Computing at Harvard

projects

Astronomical Medicine

Lead Investigators

Alyssa Goodman (FAS/Astronomy, IIC), Mike Halle (HMS/SPL of BWH, IIC), Ron Kikinis (HMS/SPL of BWH), David Kennedy (HMS/Martinos Center of Harvard, MIT and MGH)

Project Staff

Doug Alan, IIC-Sr. Software Engineer
Michelle Borkin, IIC-Research Associate
Jens Kauffmann - IIC-Post Doc

Description

The goal of the "AstroMed" project is to extend the state of the art of complex data understanding in two very different fields, astronomy and medical imaging, using a broad-based approach to data exploration and analysis.

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

Relative Strengths

Pattern Recognition

Creativity

Calculations

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.

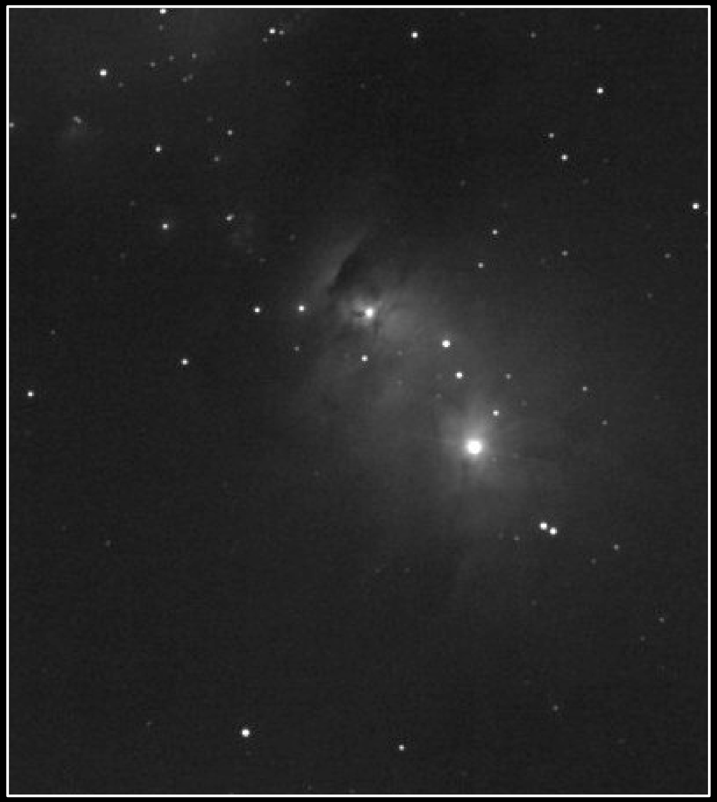
What can we observe?

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

Intensity

Spatial Position

$(x, y \quad)$



Optical Single-Band
Image of NGC1333

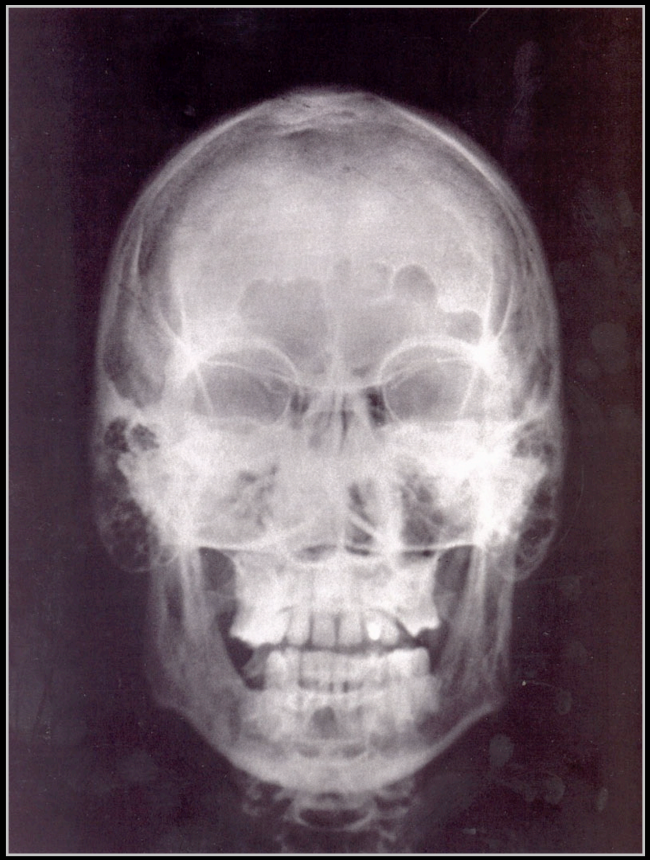
What can we observe?

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

Intensity

Spatial Position

$$(x, y \quad)$$



X-Ray of Human Skull, c. 1920

What can we observe?

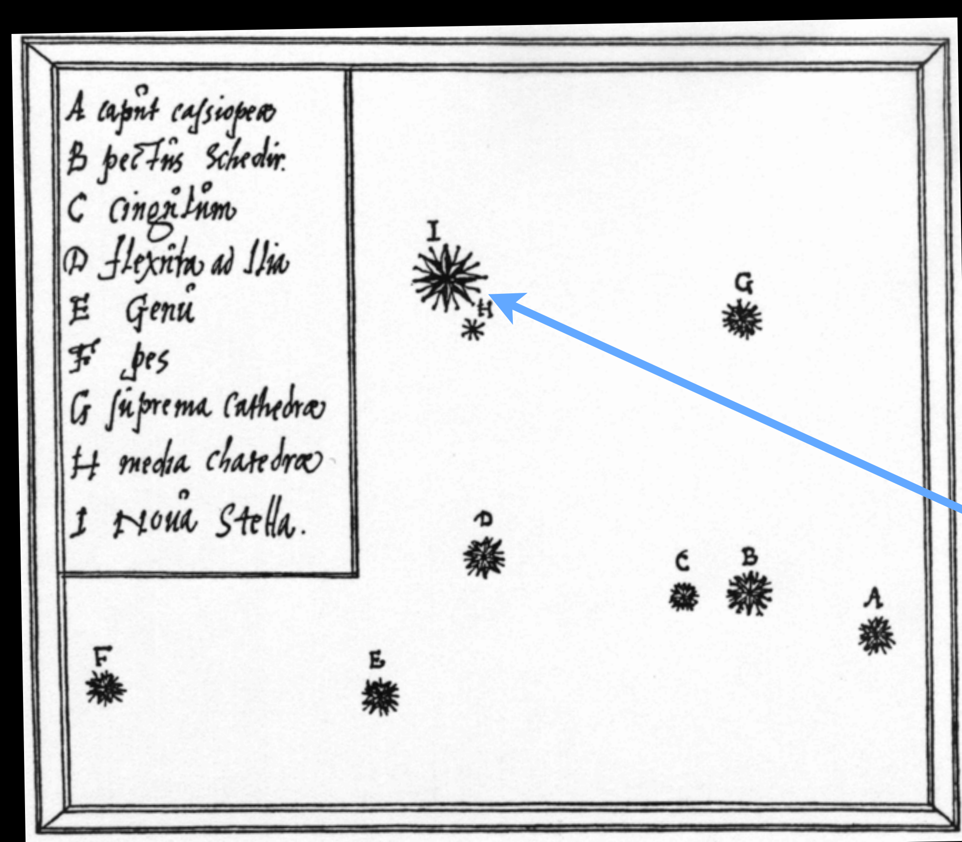
$$I(\vec{x}, t)$$

Intensity

Spatial Position

(x, y, z)

Time



"Nova Stella" of Tycho, 1572

What can we observe?

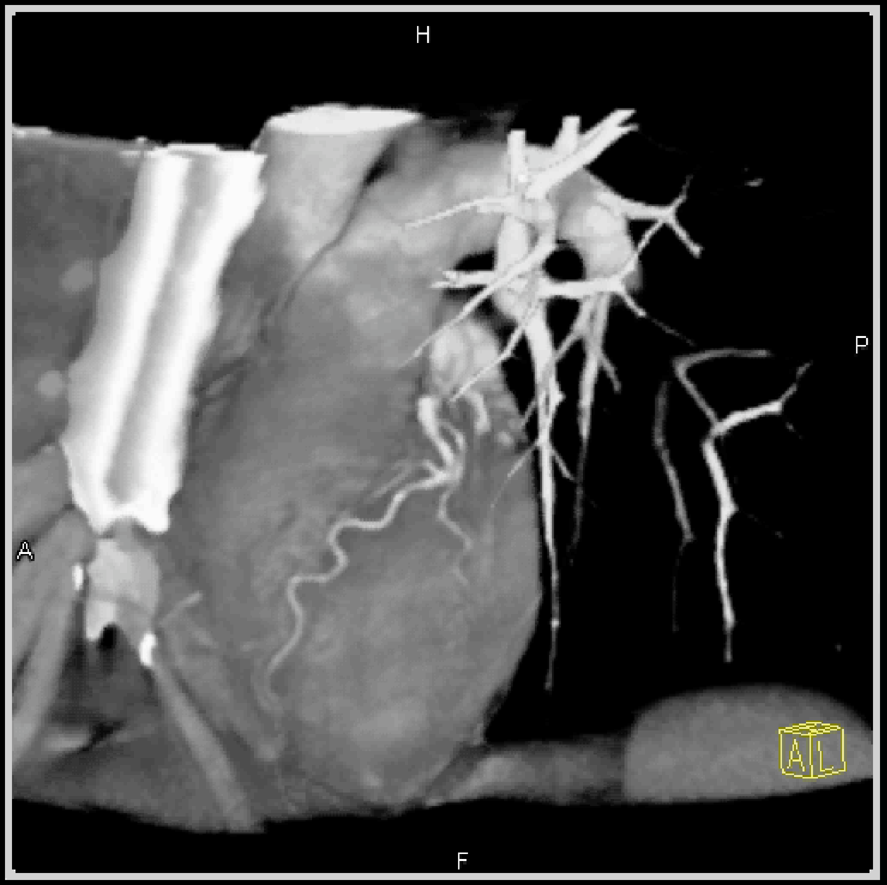
$$I(\vec{x}, t)$$

Intensity

Spatial Position

(x, y, z)

Time



Cardiac Motion

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

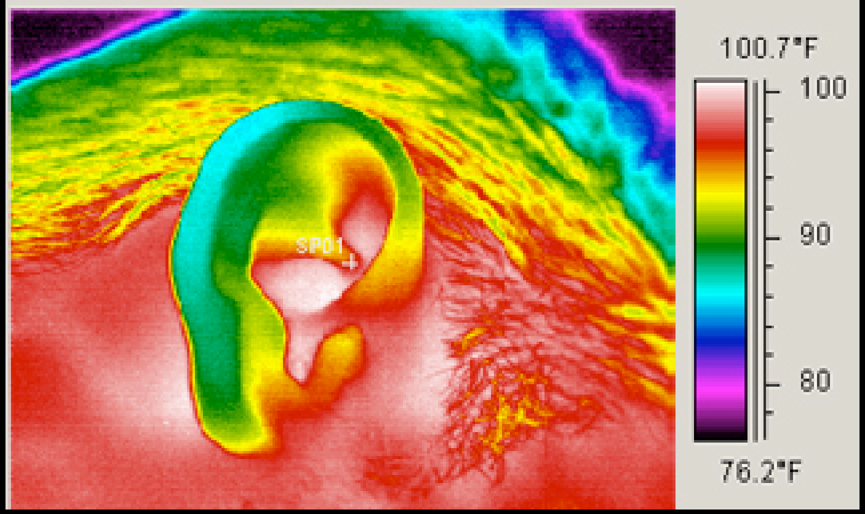
What can we observe?

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

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
$(x, y \quad)$

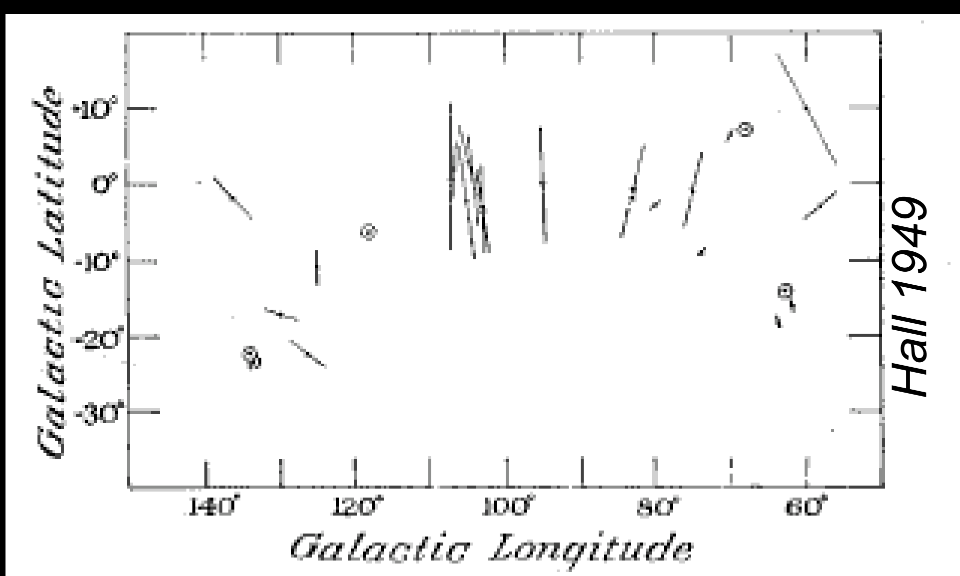


FIG. 4. Observational evidence that there is no one preferential orientation of the plane of polarization. Stars showing no polarization are represented by circles.

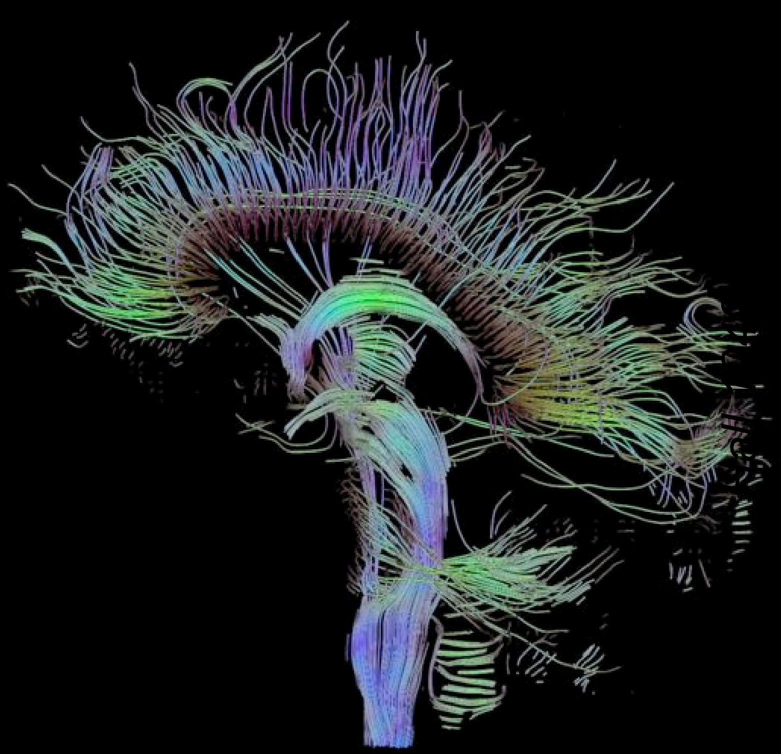
What can we observe?

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

Intensity

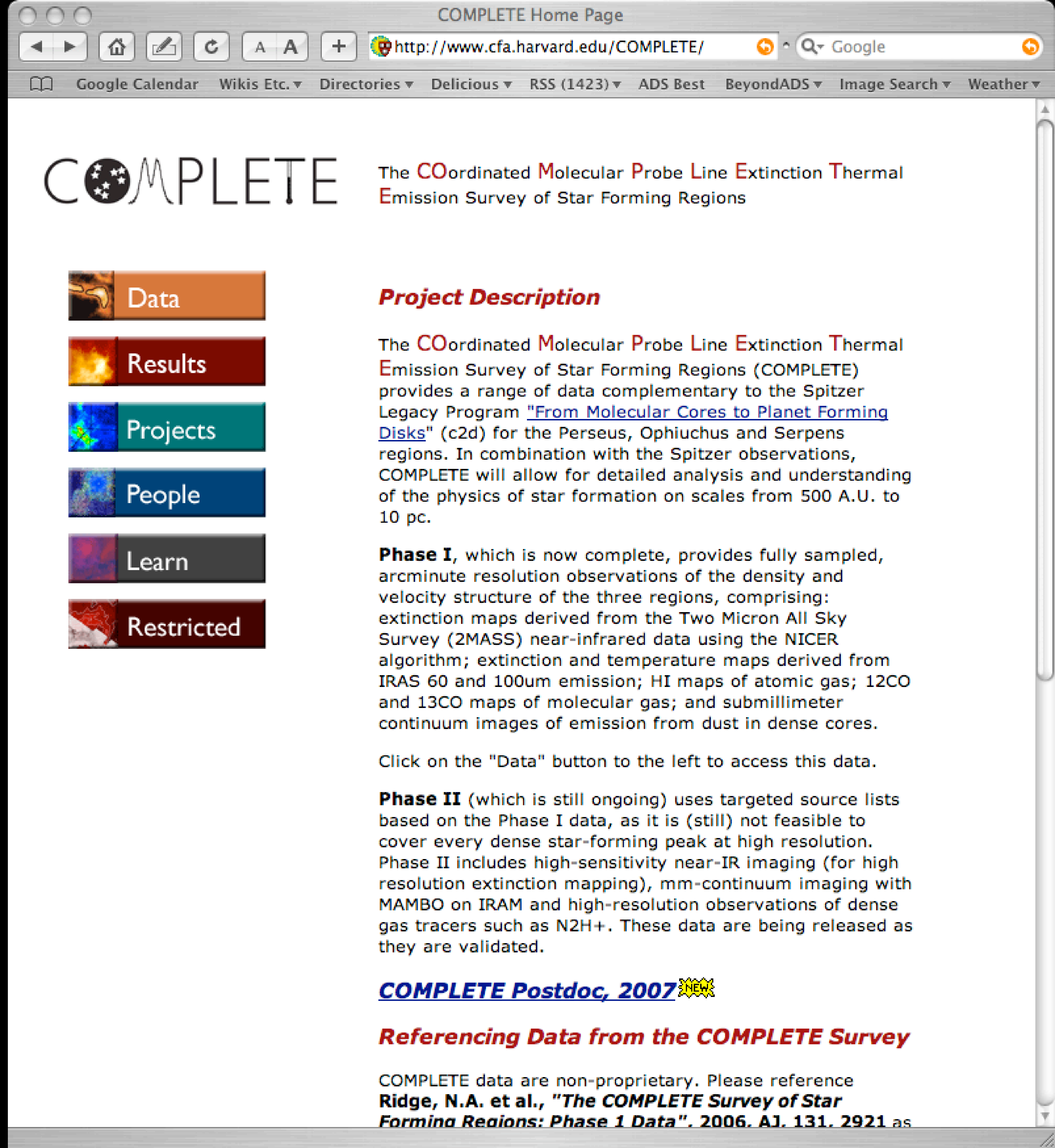
"State"
(~diffusivity)

Spatial Position
(x, y, z)



Our current interest in

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



COMPLETE Home Page

http://www.cfa.harvard.edu/COMPLETE/

Google Calendar | Wikis Etc. | Directories | Delicious | RSS (1423) | ADS Best | BeyondADS | Image Search | Weather

COMPLETE

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

Data

Results

Projects

People

Learn

Restricted

Project Description

The COordinated Molecular Probe Line Extinction Thermal Emission Survey of Star Forming Regions (COMPLETE) provides a range of data complementary to the Spitzer Legacy Program "From Molecular Cores to Planet Forming Disks" (c2d) for the Perseus, Ophiuchus and Serpens regions. In combination with the Spitzer observations, COMPLETE will allow for detailed analysis and understanding of the physics of star formation on scales from 500 A.U. to 10 pc.

Phase I, which is now complete, provides fully sampled, arcminute resolution observations of the density and velocity structure of the three regions, comprising: extinction maps derived from the Two Micron All Sky Survey (2MASS) near-infrared data using the NICER algorithm; extinction and temperature maps derived from IRAS 60 and 100um emission; HI maps of atomic gas; 12CO and 13CO maps of molecular gas; and submillimeter continuum images of emission from dust in dense cores.

Click on the "Data" button to the left to access this data.

Phase II (which is still ongoing) uses targeted source lists based on the Phase I data, as it is (still) not feasible to cover every dense star-forming peak at high resolution. Phase II includes high-sensitivity near-IR imaging (for high resolution extinction mapping), mm-continuum imaging with MAMBO on IRAM and high-resolution observations of dense gas tracers such as N2H+. These data are being released as they are validated.

COMPLETE Postdoc, 2007 NEW

Referencing Data from the COMPLETE Survey

COMPLETE data are non-proprietary. Please reference **Ridge, N.A. et al., *"The COMPLETE Survey of Star Forming Regions: Phase 1 Data"*, 2006, AJ, 131, 2921** as

3D Simulation of a Star-Forming Cluster

HD turbulence gives "t=0" conditions; Jeans mass=1 M_{sun}

*50 M_{sun}, **0.38 pc**, n_{avg}=3 x 10^5 ptcls/cc*

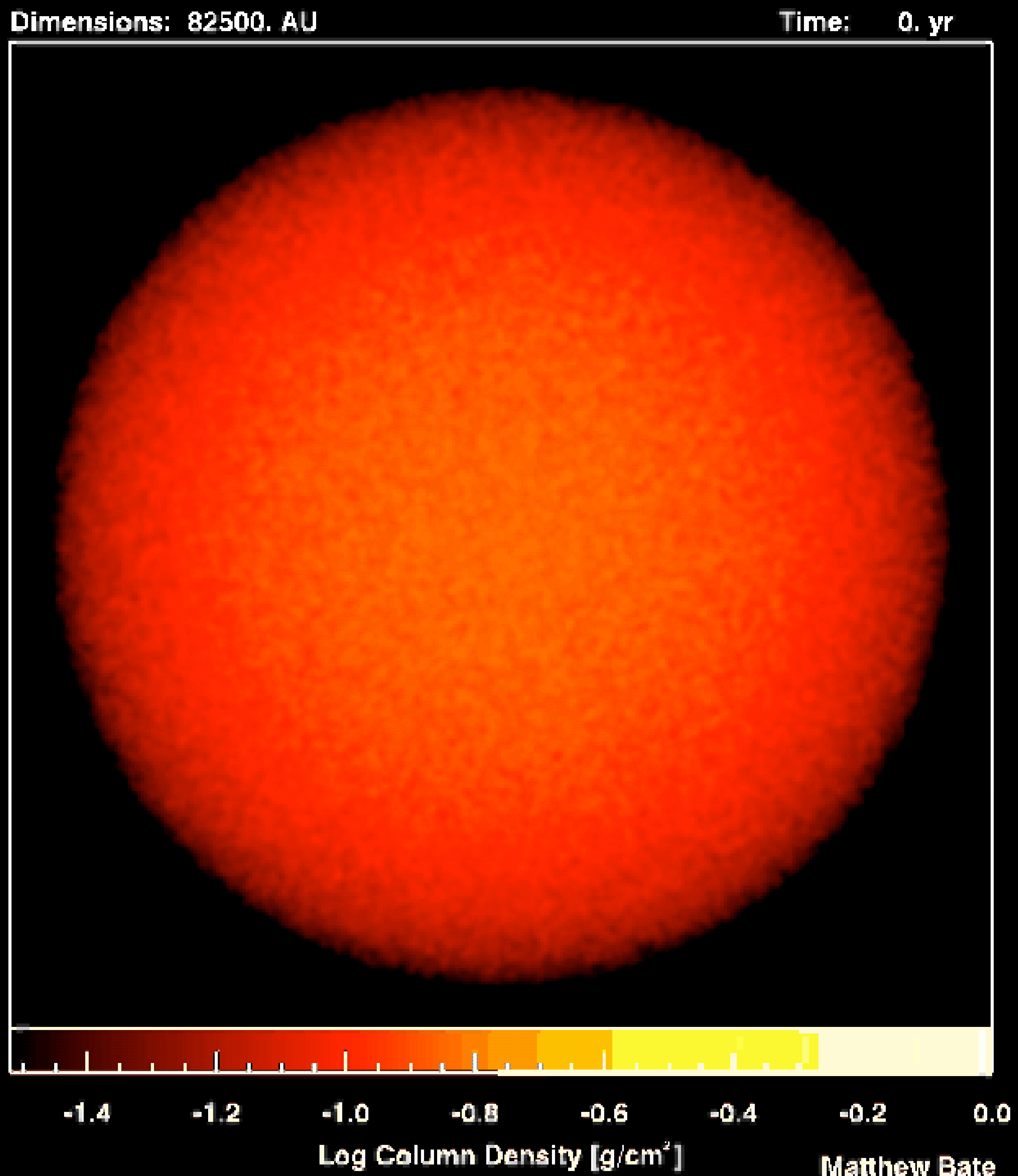
forms ~50 objects

T=10 K

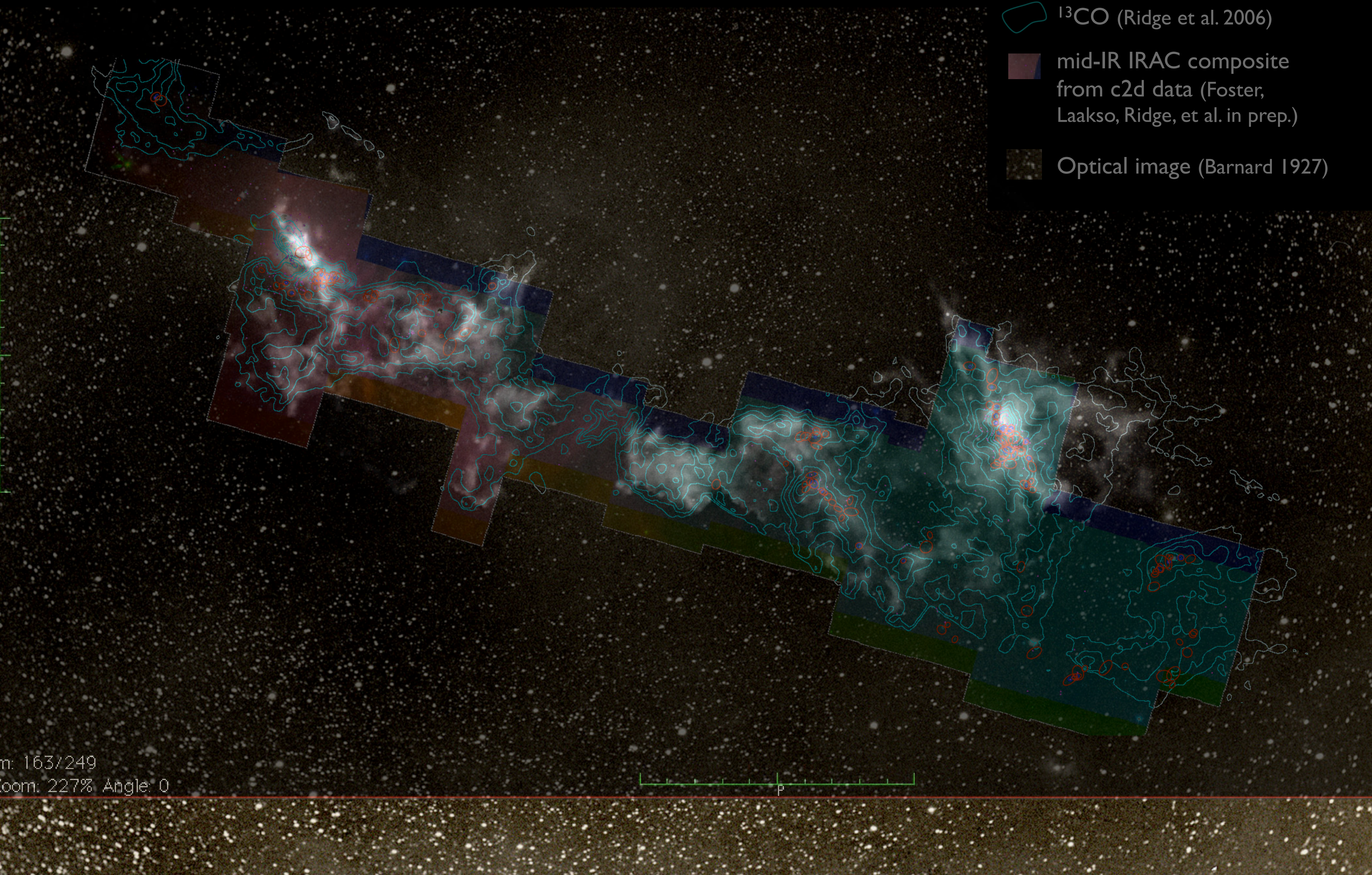
SPH, no B or Λ, Γ

movie=1.4 free-fall times

Bate, Bonnell & Bromm 2002



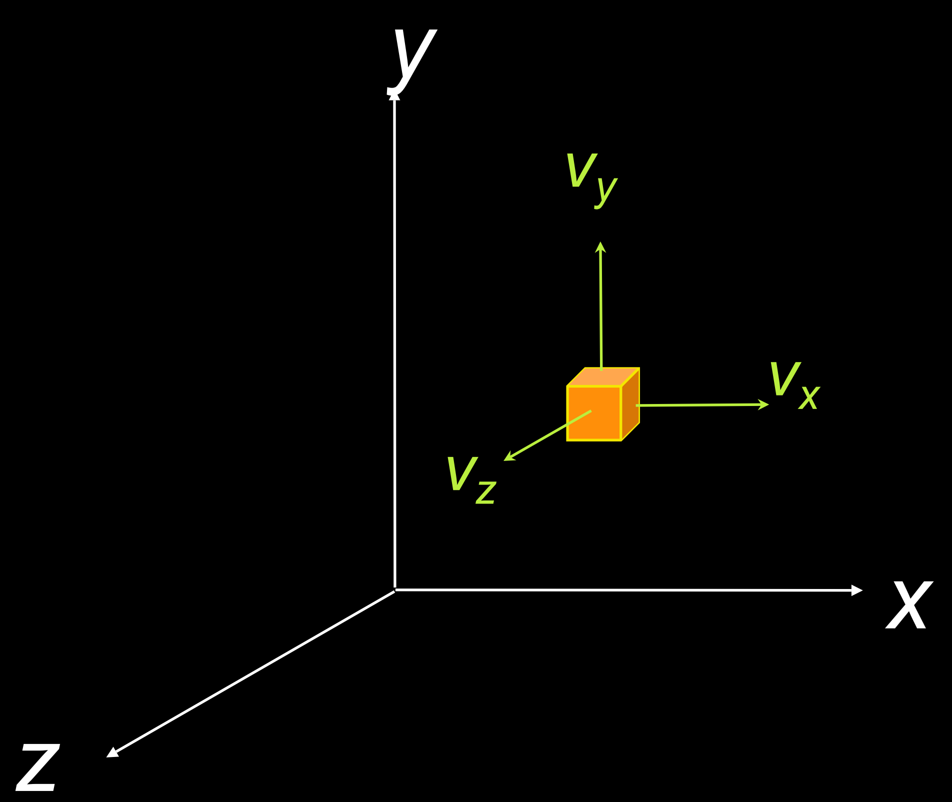
COMPLETE =COordinated Molecular Probe Line Exinction Thermal Emission



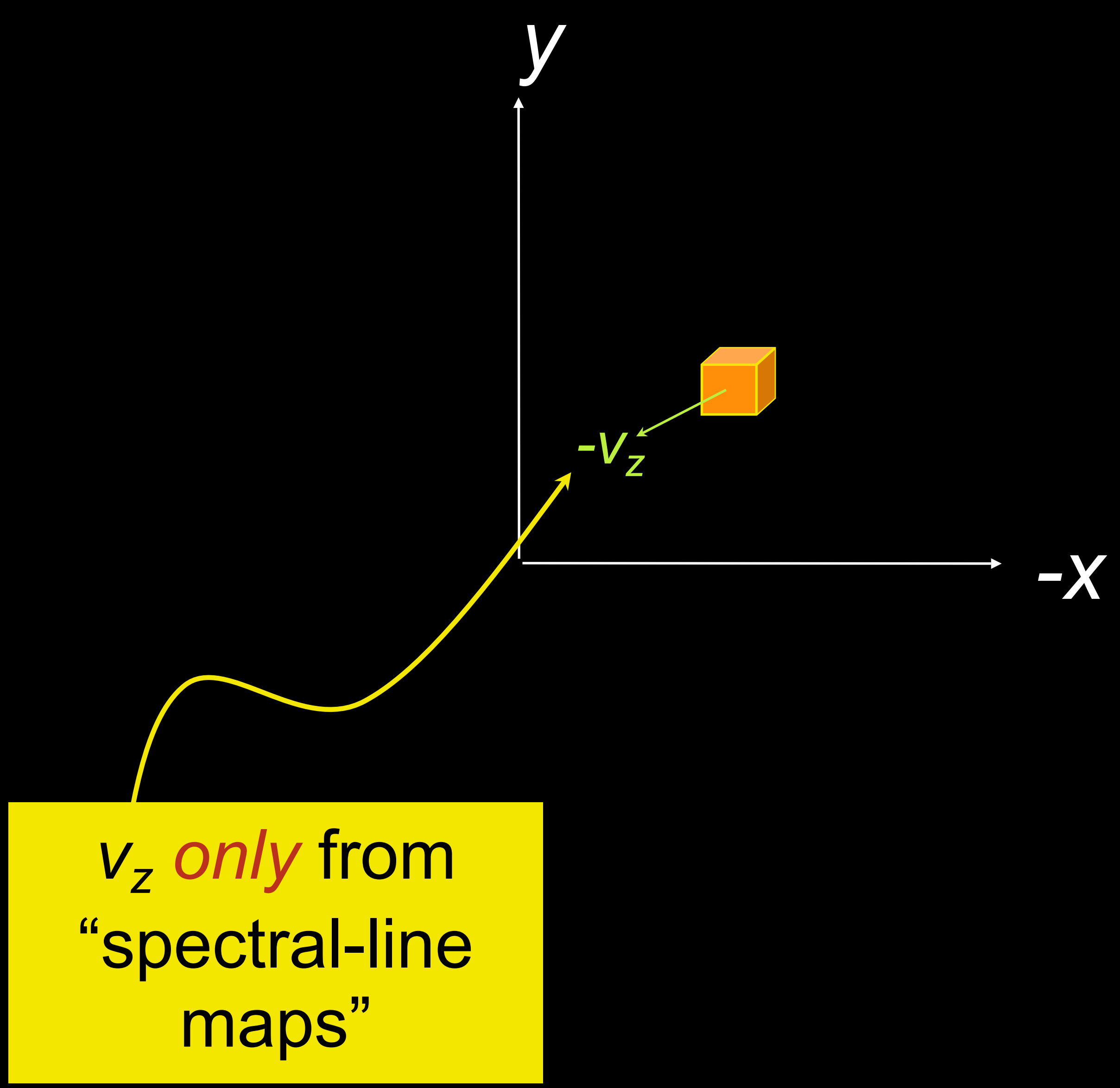
- mm peak (Enoch et al. 2006)
- sub-mm peak (Hatchell et al. 2005, Kirk et al. 2006)
- ^{13}CO (Ridge et al. 2006)
- mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al. in prep.)
- Optical image (Barnard 1927)

“Three” Dimensions: Spectral-Line Mapping

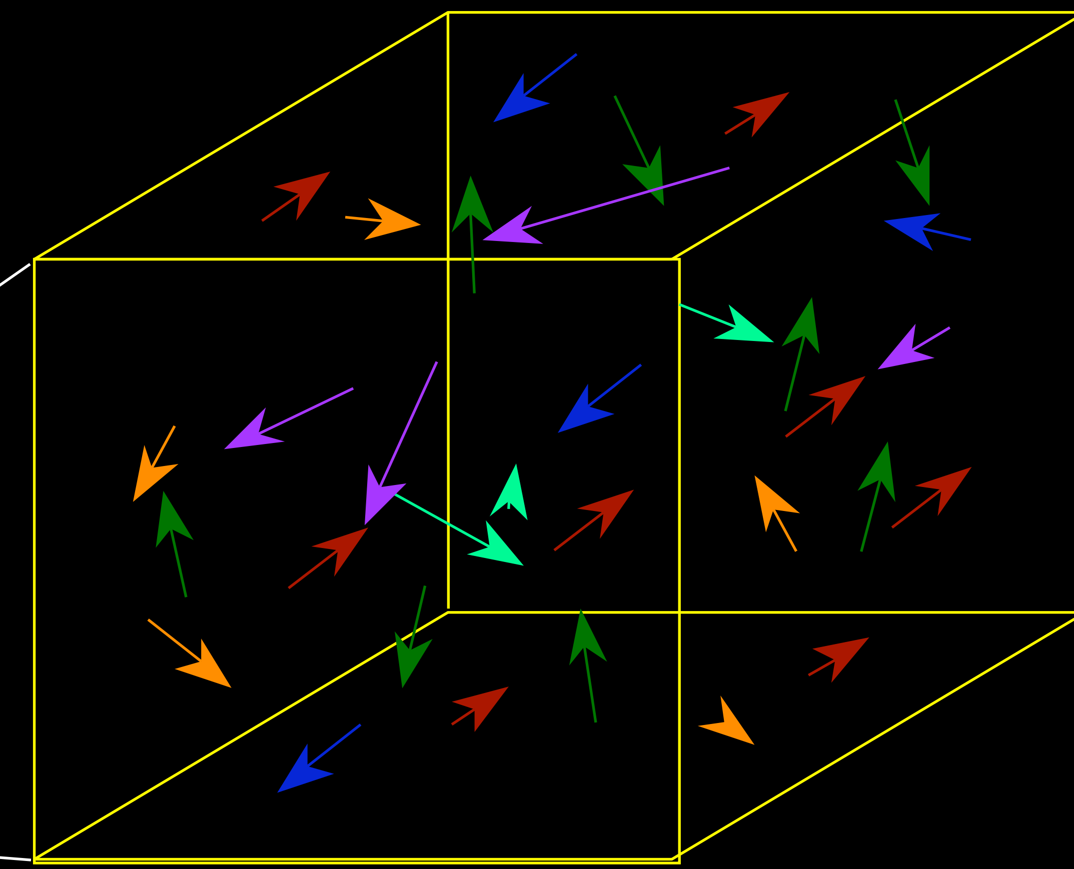
We wish we could measure…

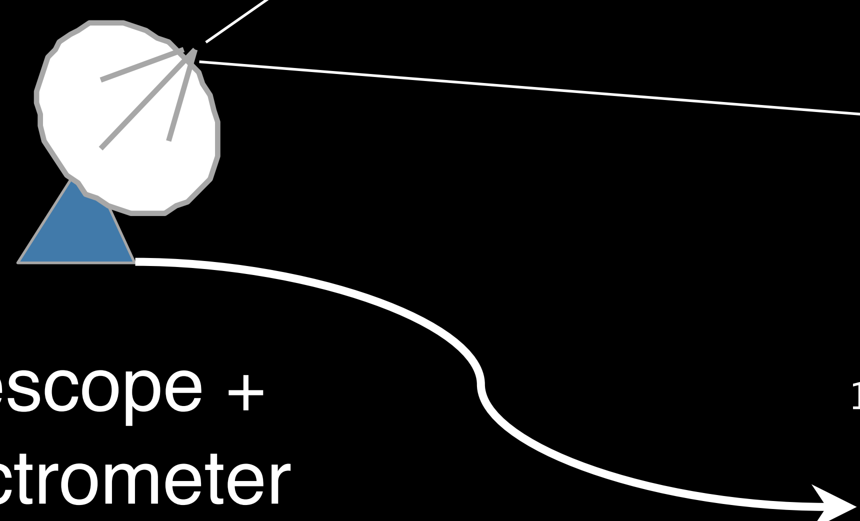


But we can measure…

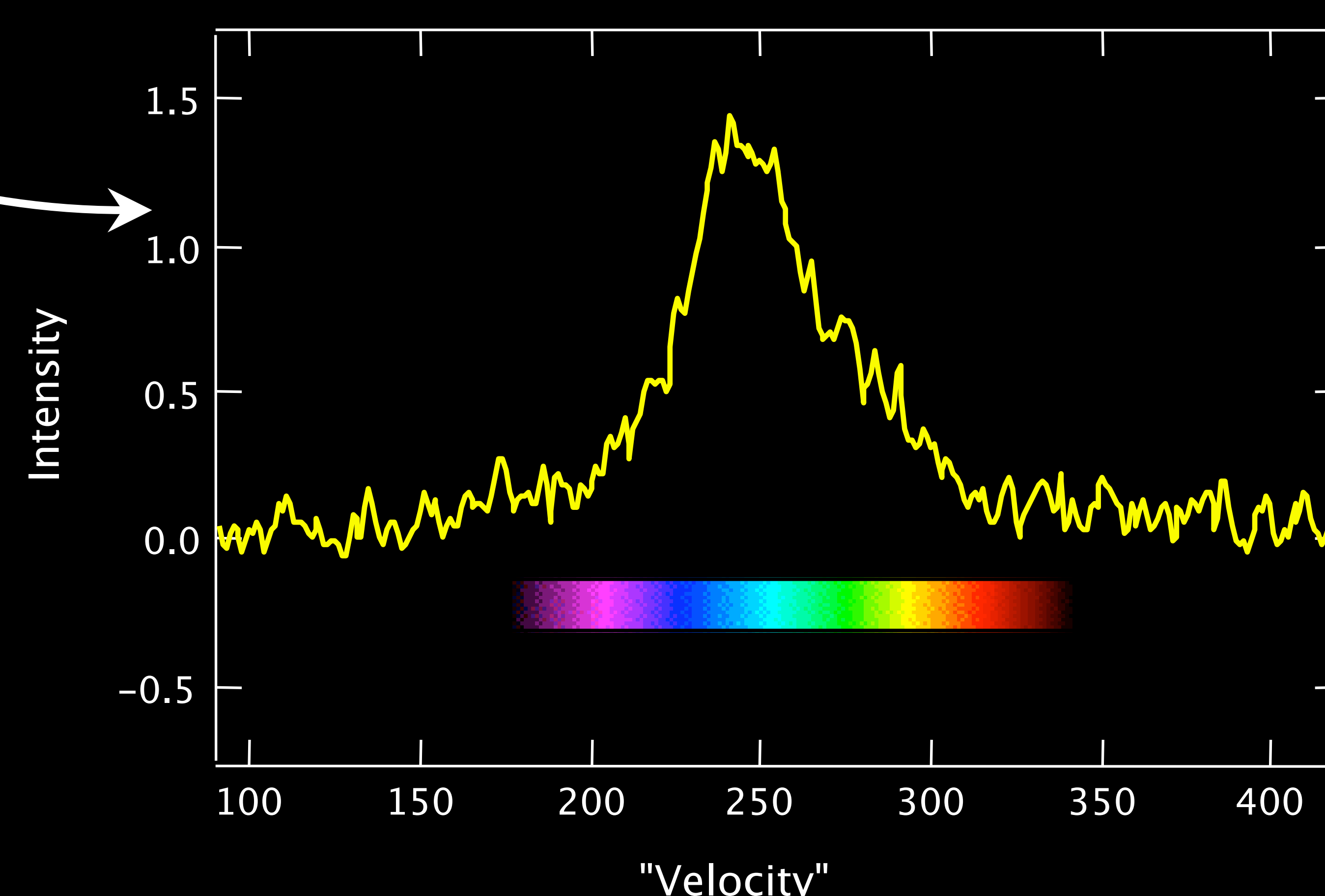


Velocity from Spectroscopy



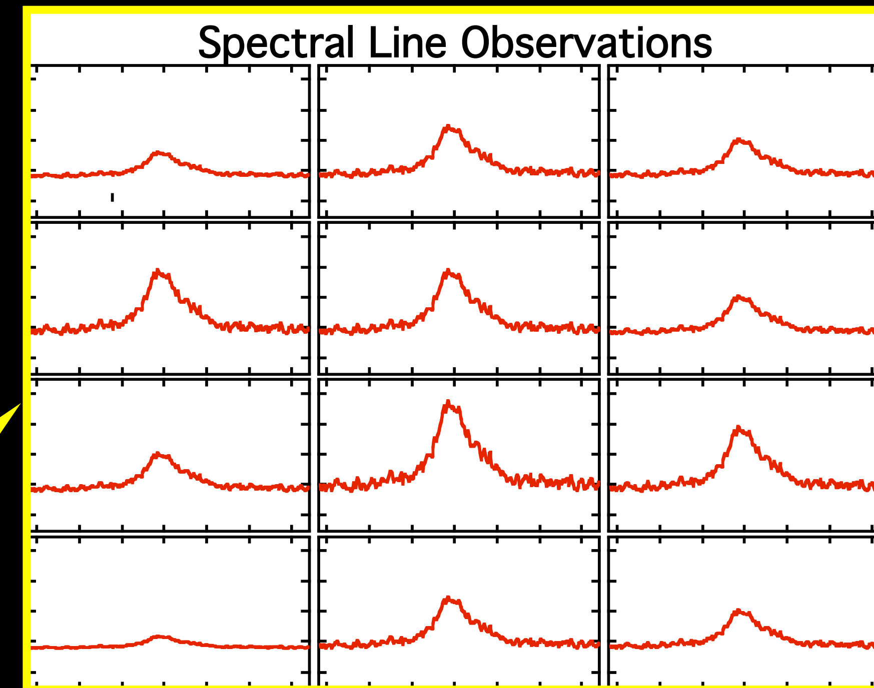


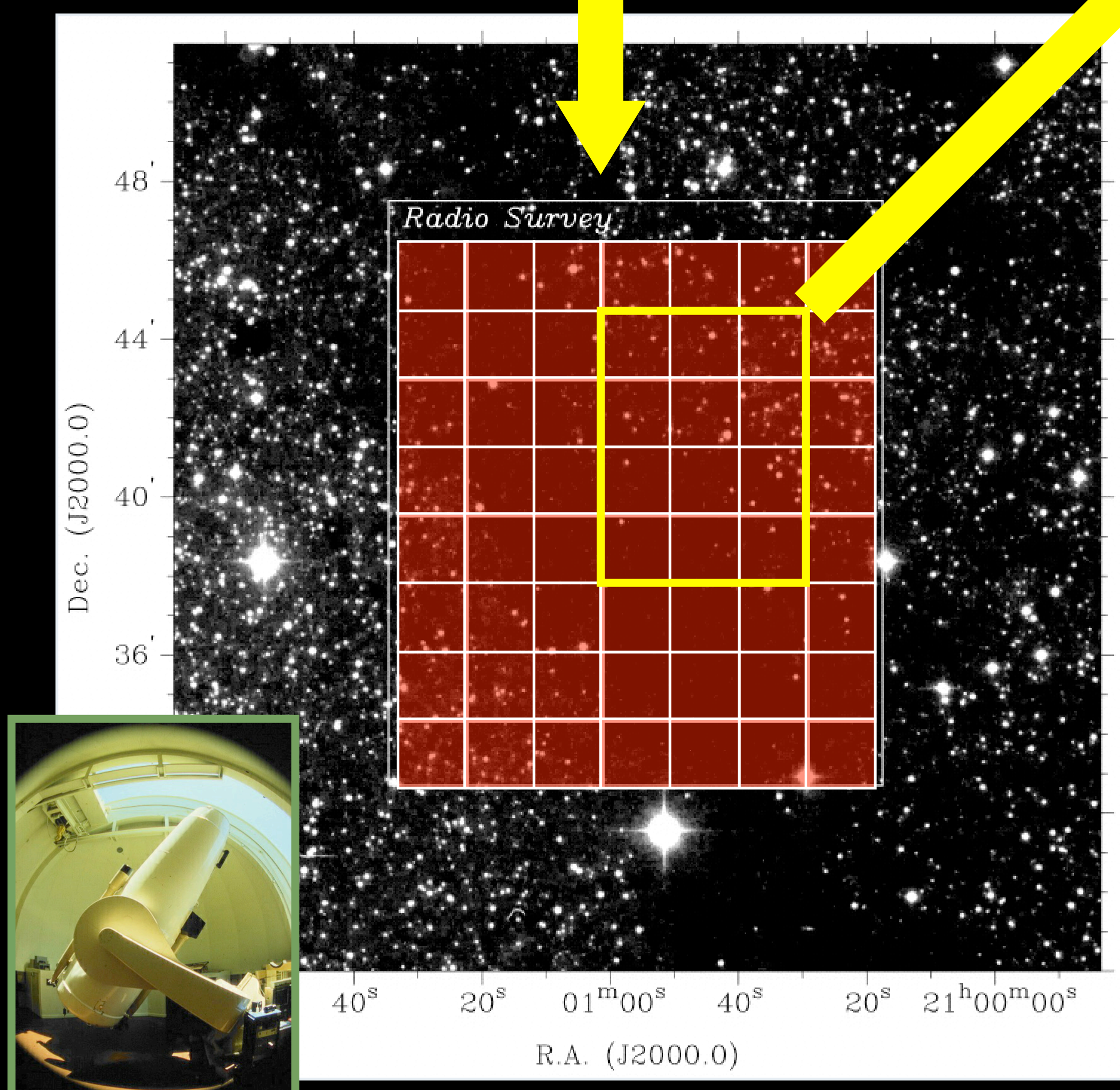
Telescope +
Spectrometer

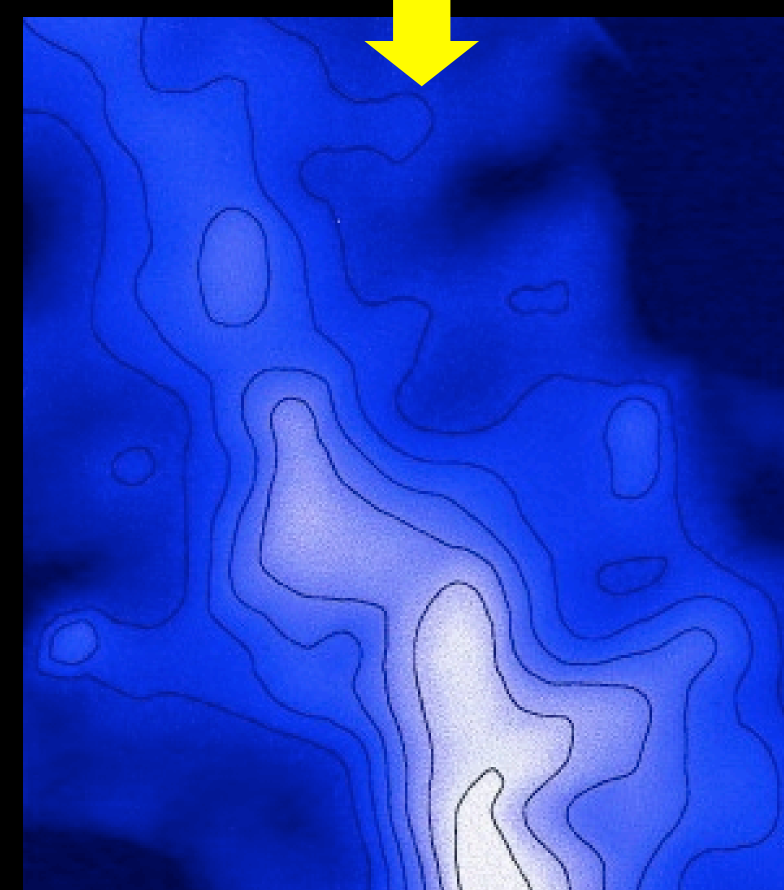


All thanks to Doppler

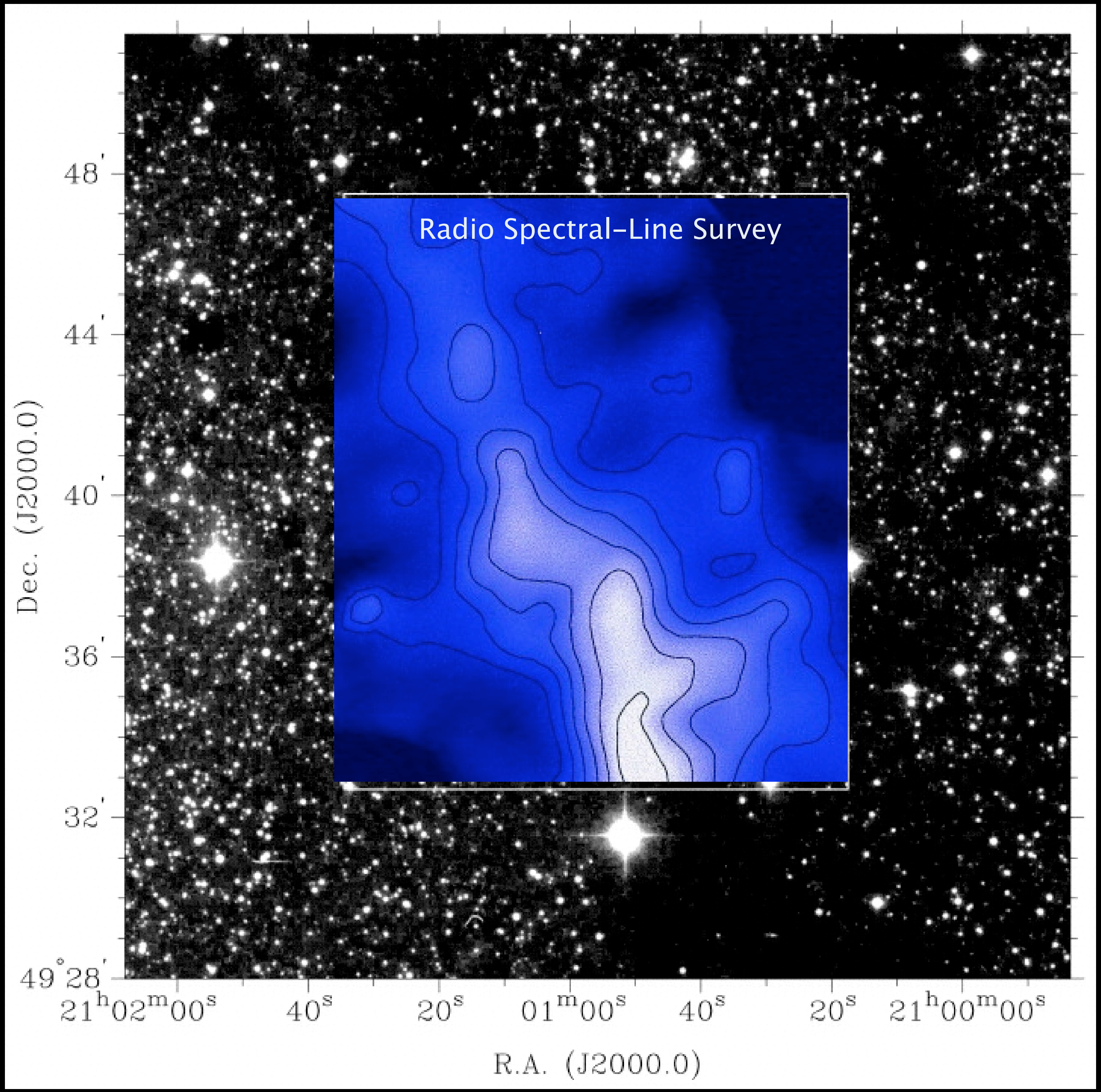
Radio Spectral-line Observations of Interstellar Clouds





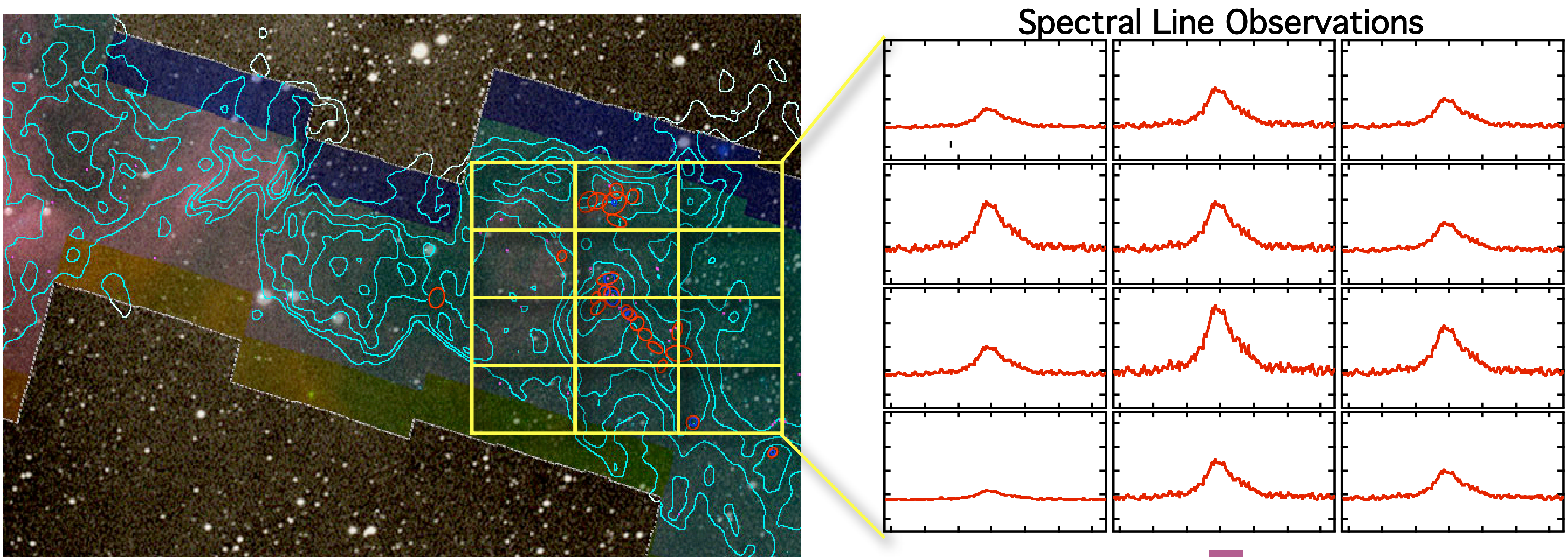


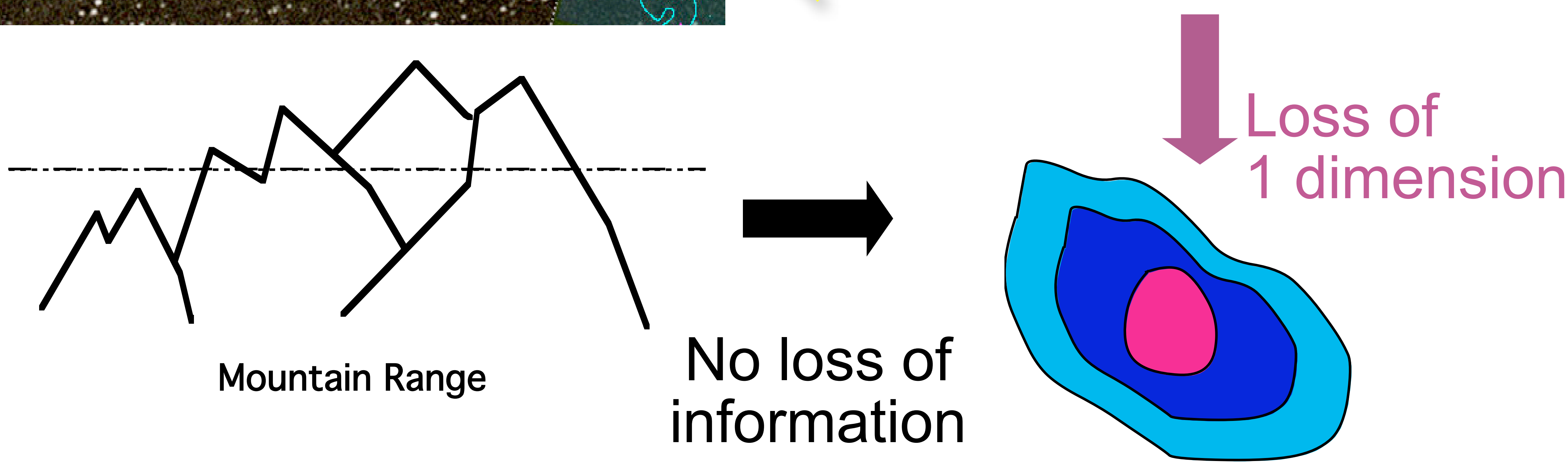
Radio Spectral-line Observations of Interstellar Clouds



Alves, Lada & Lada 1999

Velocity as a "Fourth" Dimension





Astronomical Visualization Tools are Traditionally 2D

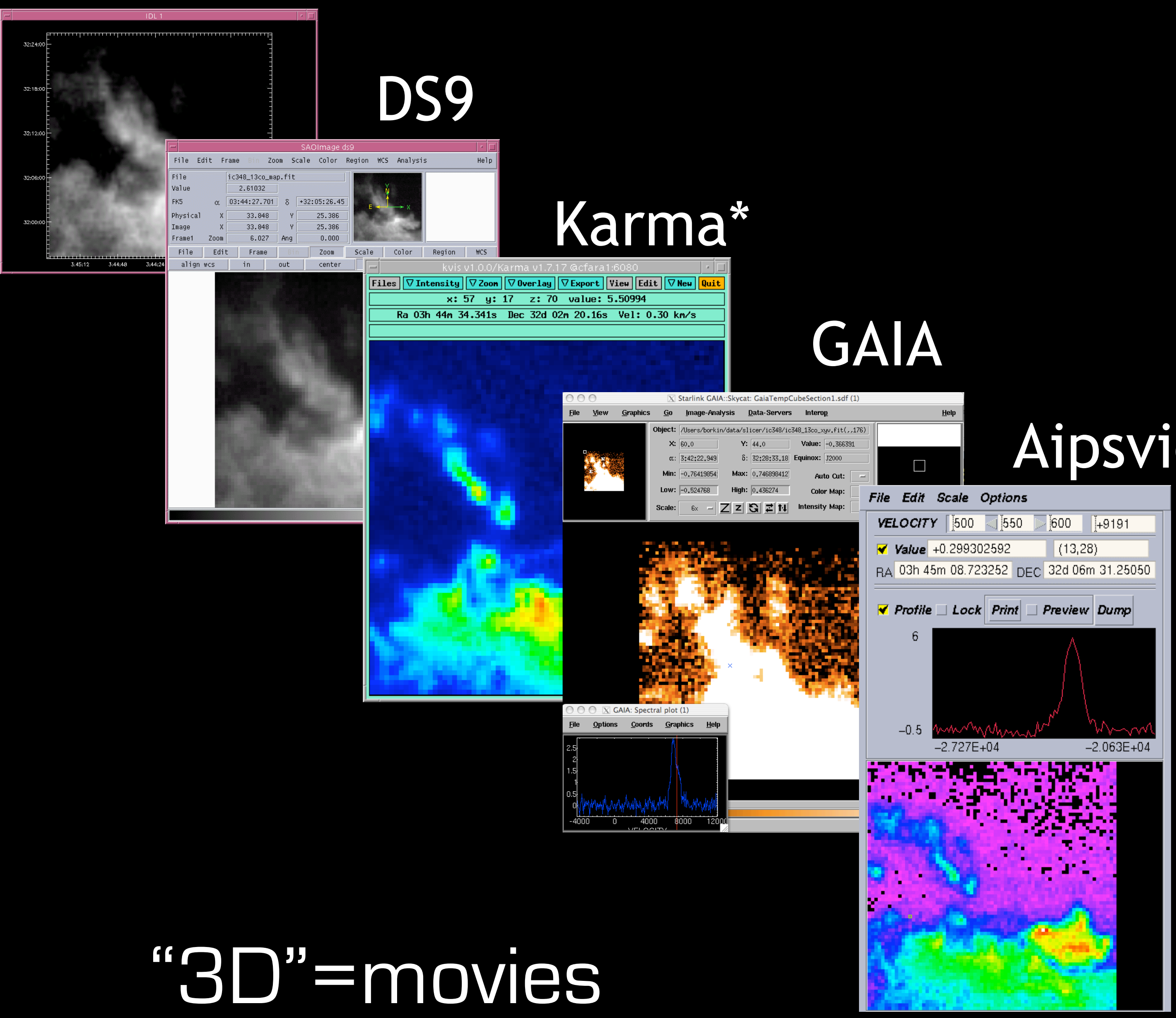
IDL

DS9

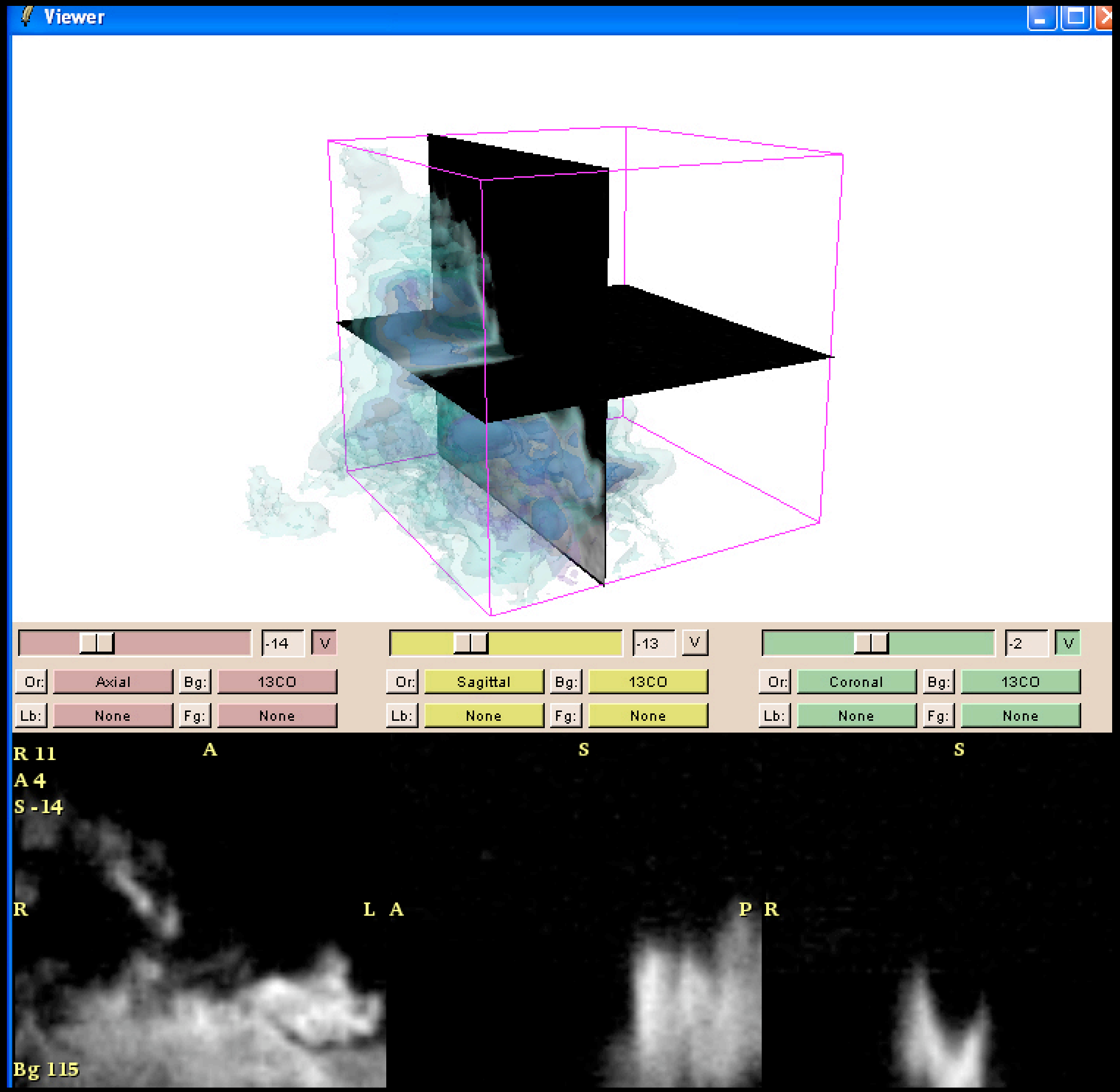
Karma*

GAIA

Aipsview



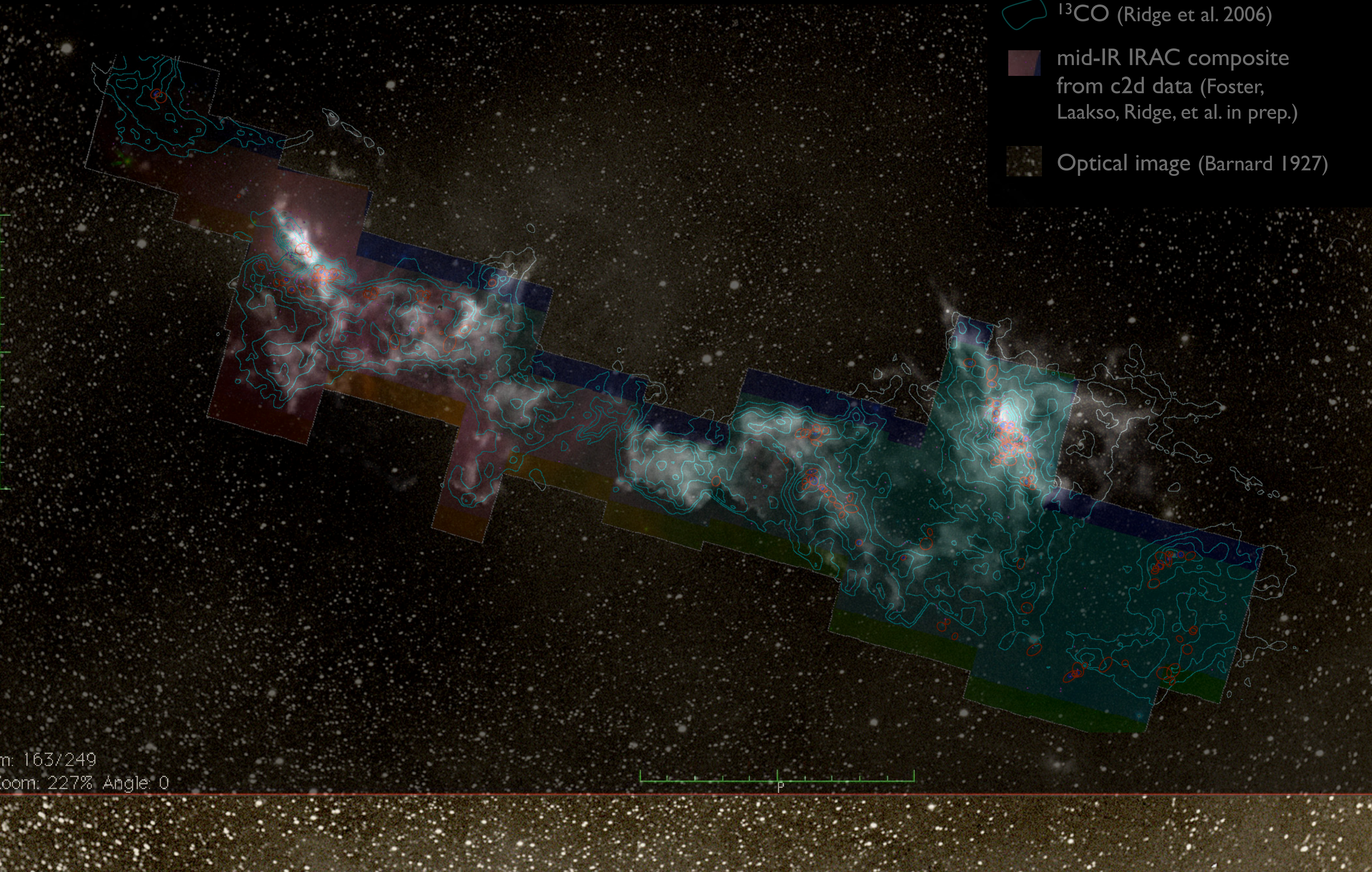
3D Slicer



"3D"=movies

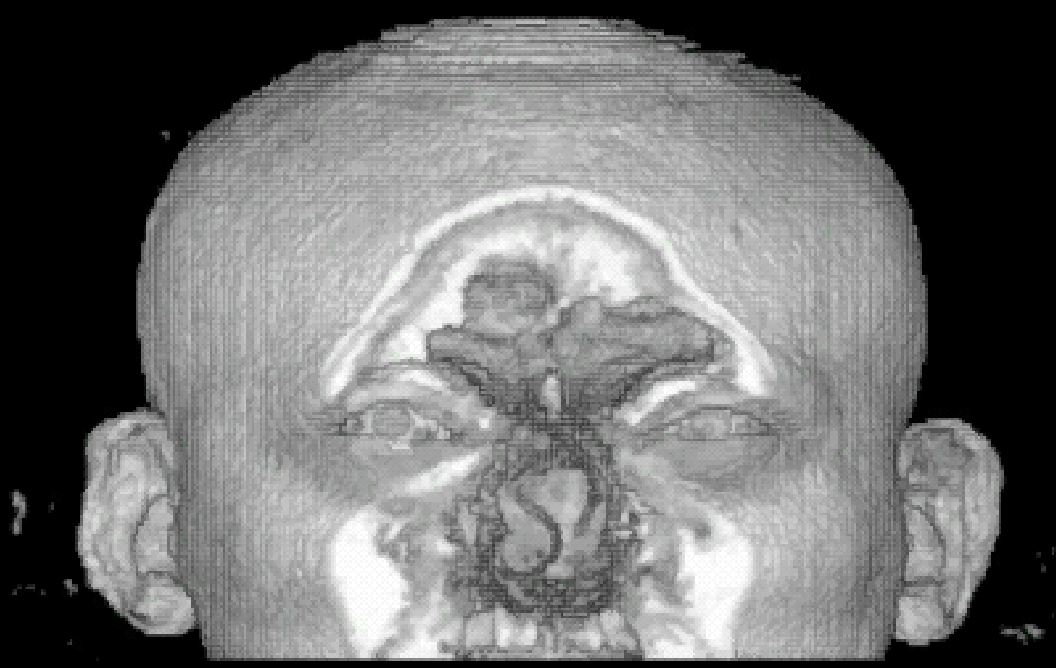
COMPLETE =COordinated Molecular Probe Line Exinction Thermal Emission

- 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. in prep.)
- Optical image (Barnard 1927)

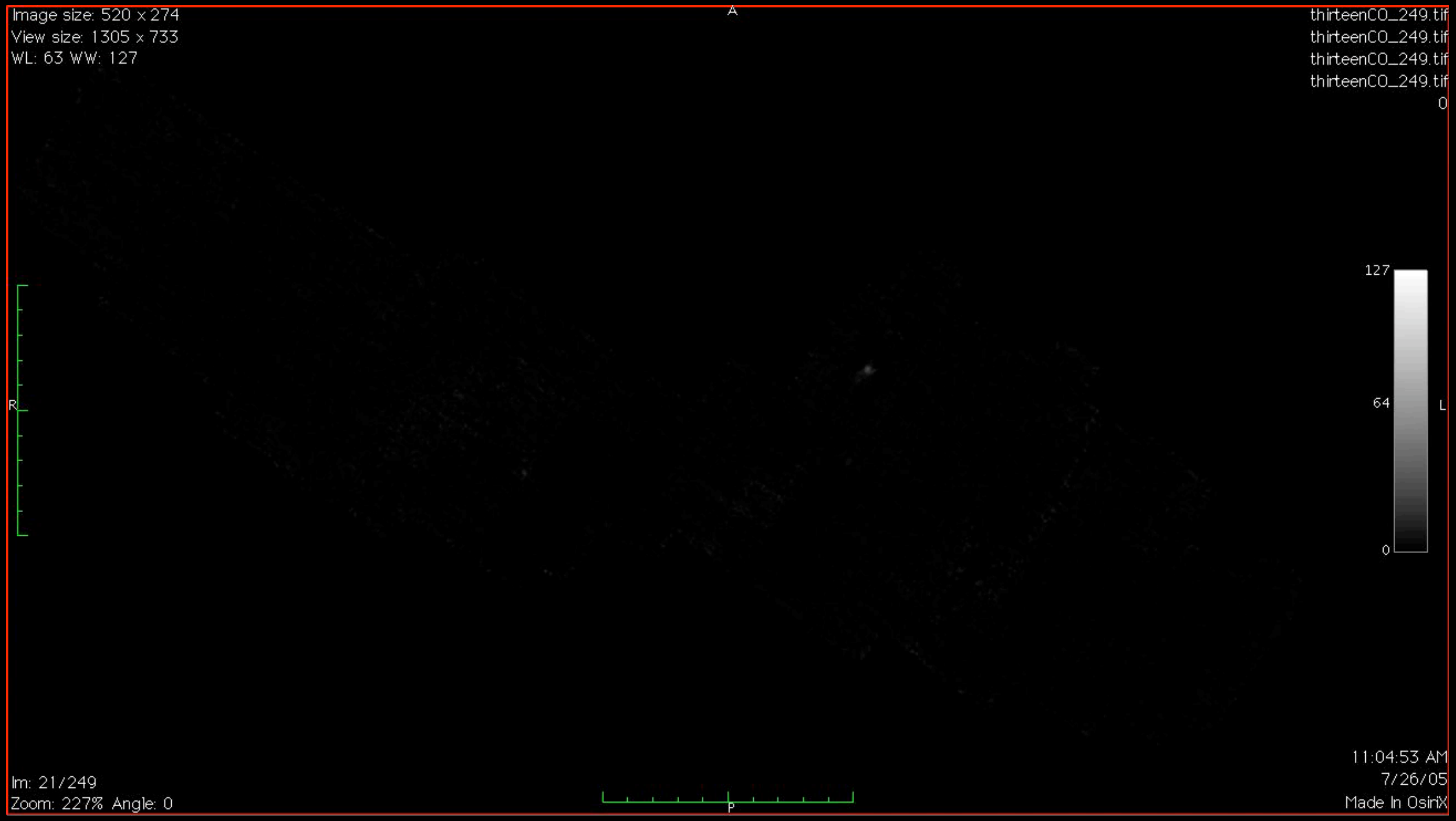


“Slices”

“KEITH”



“PERSEUS”



“z” is depth into head

“z” is line-of-sight velocity

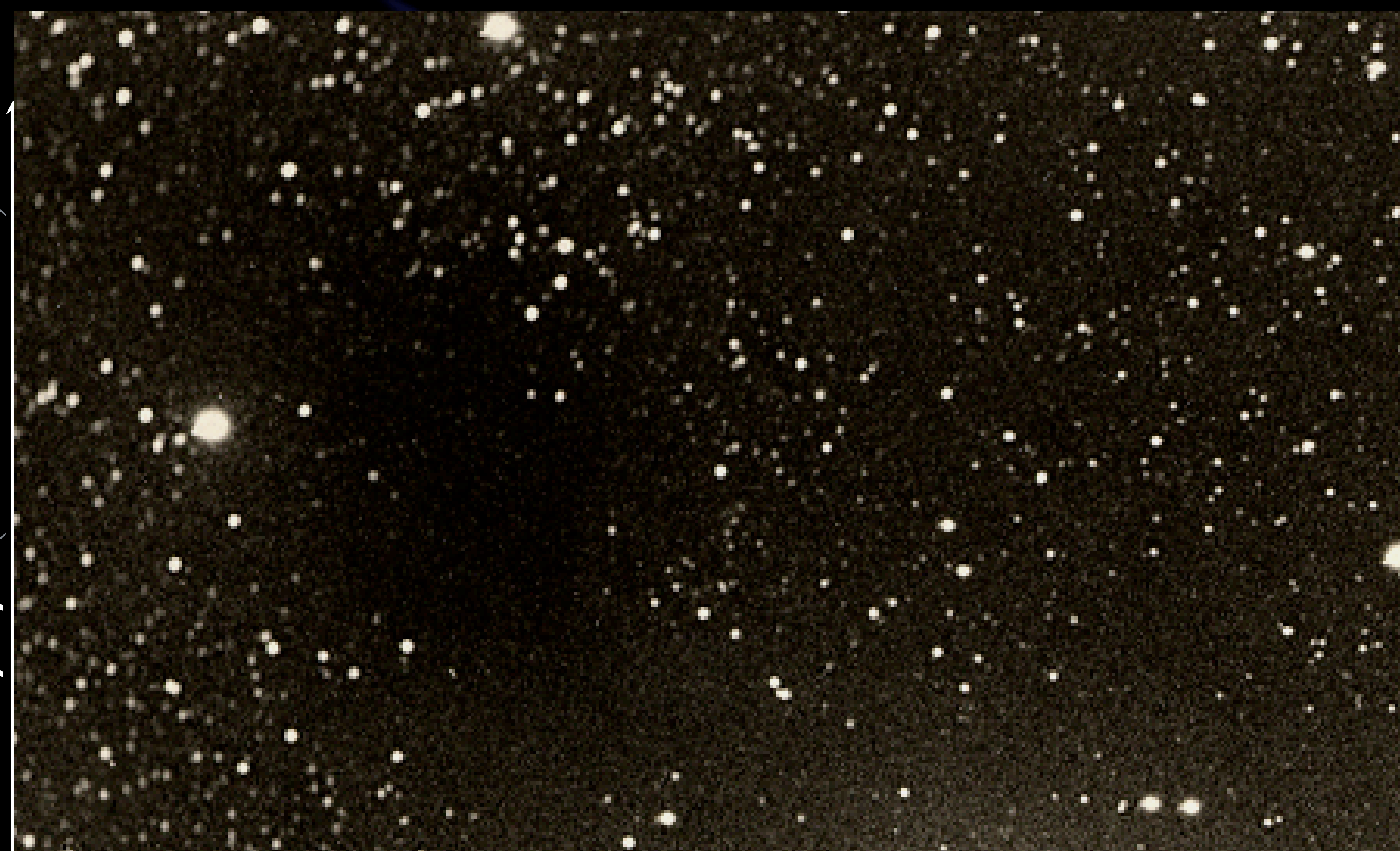
Real 3D space

Head "y"

Head "x"

3D rendering: [GE Healthcare]

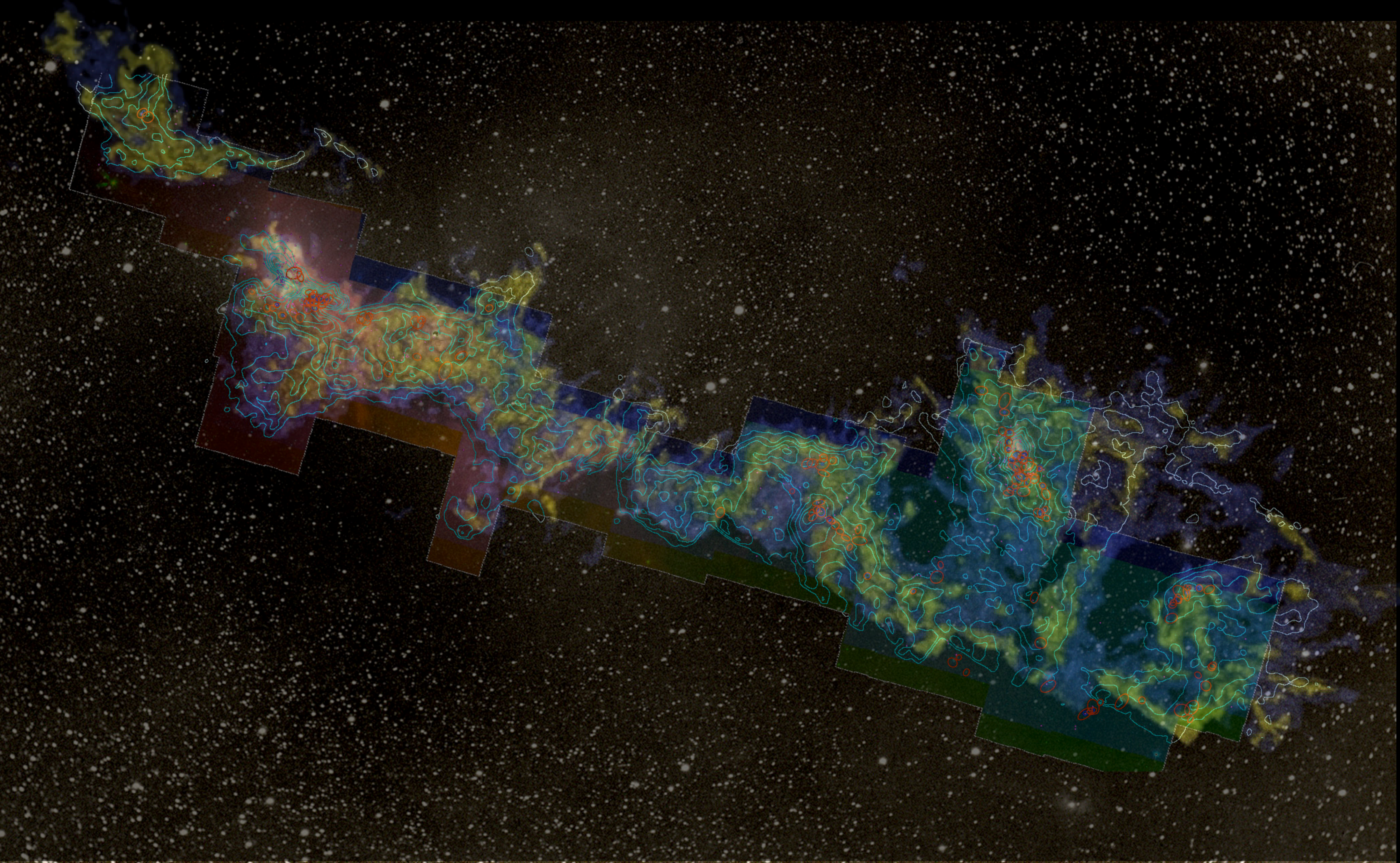
"Position-Position-Velocity" Space



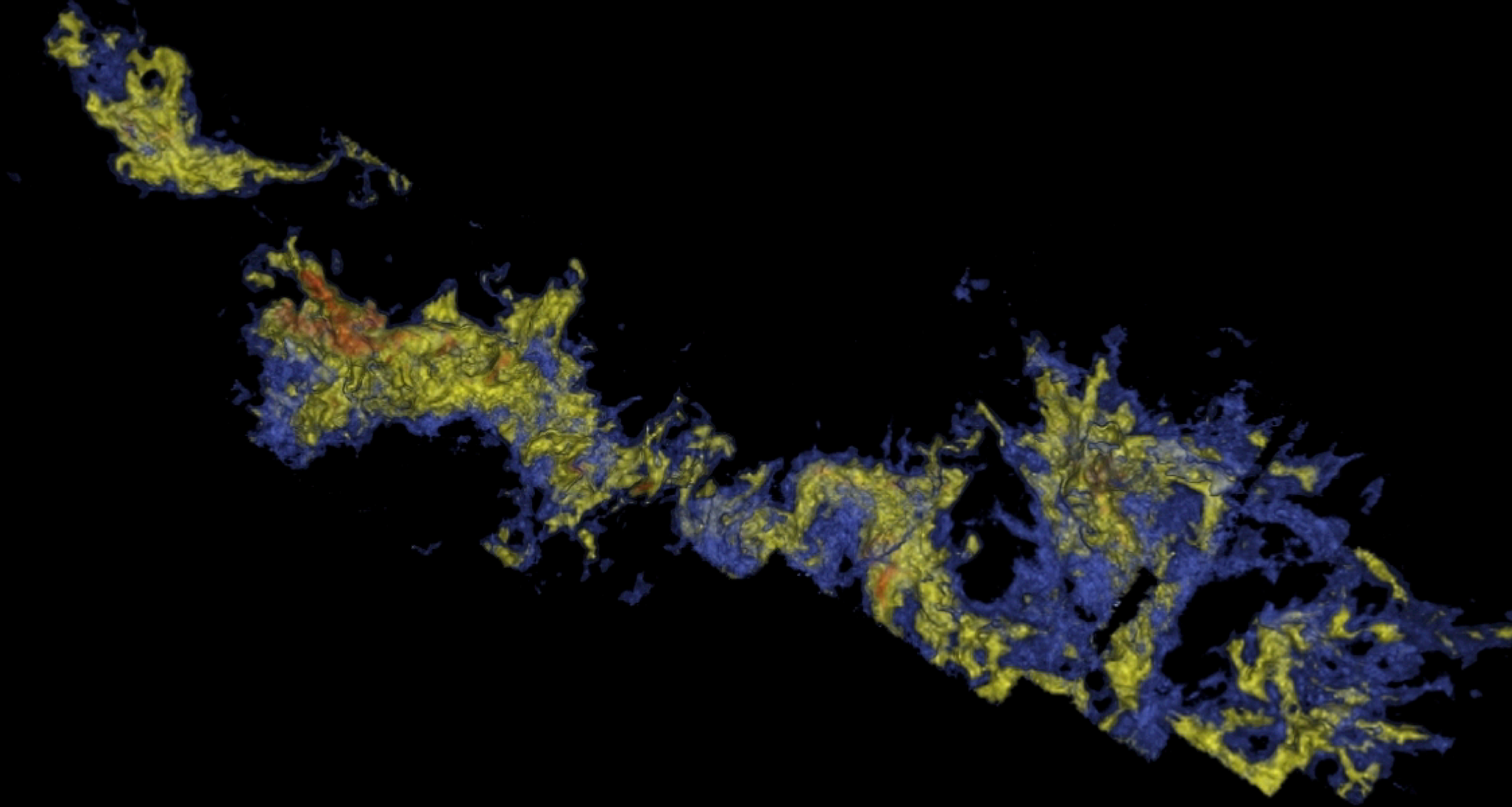
Sky "y" (Declination)

Sky "x" (Right Ascension)

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



3D Viz made with VolView



3D Viz made with VolView

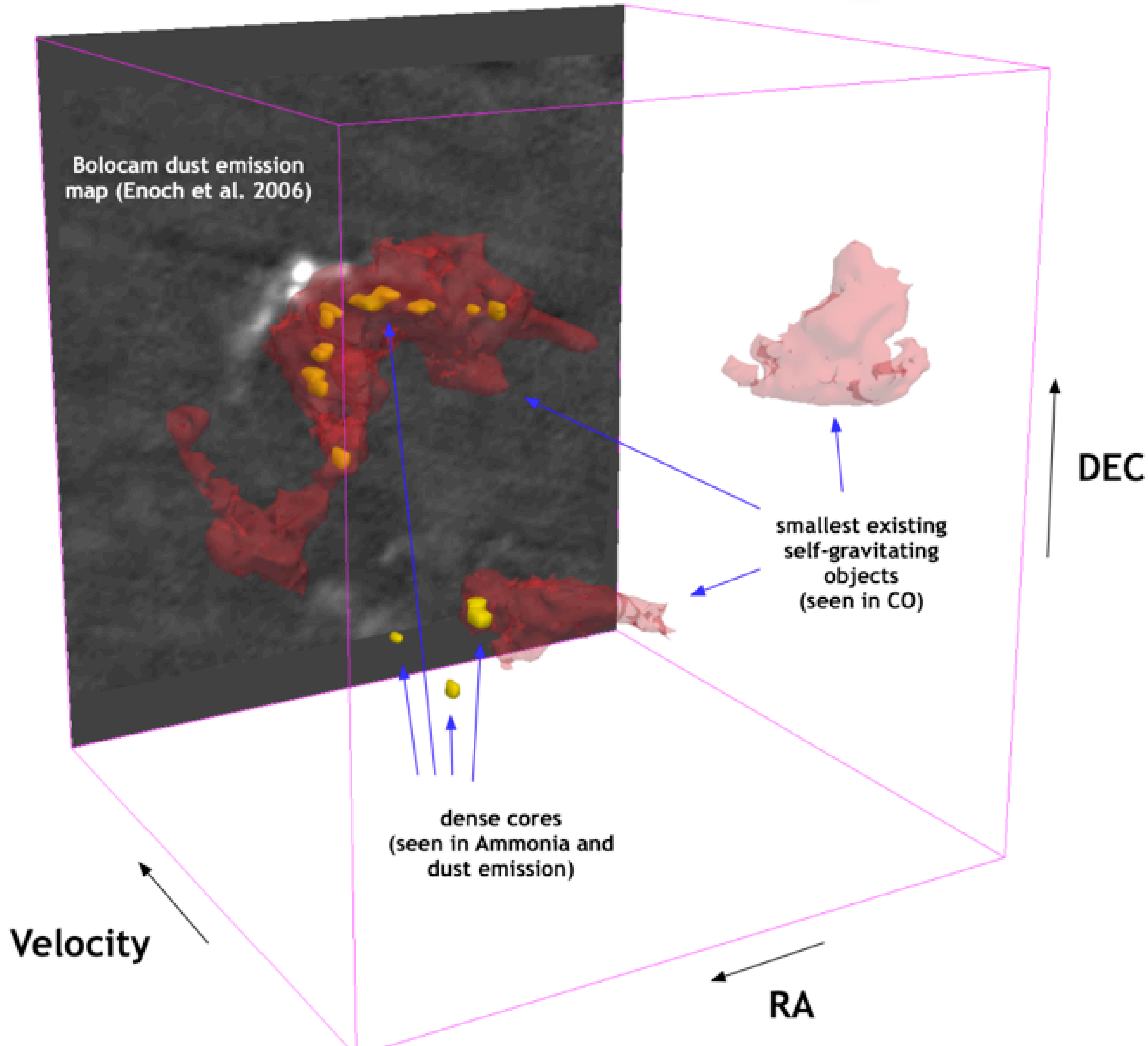
AstroMed@IIC

COMPLETE

Astronomy + Medicine = Understanding

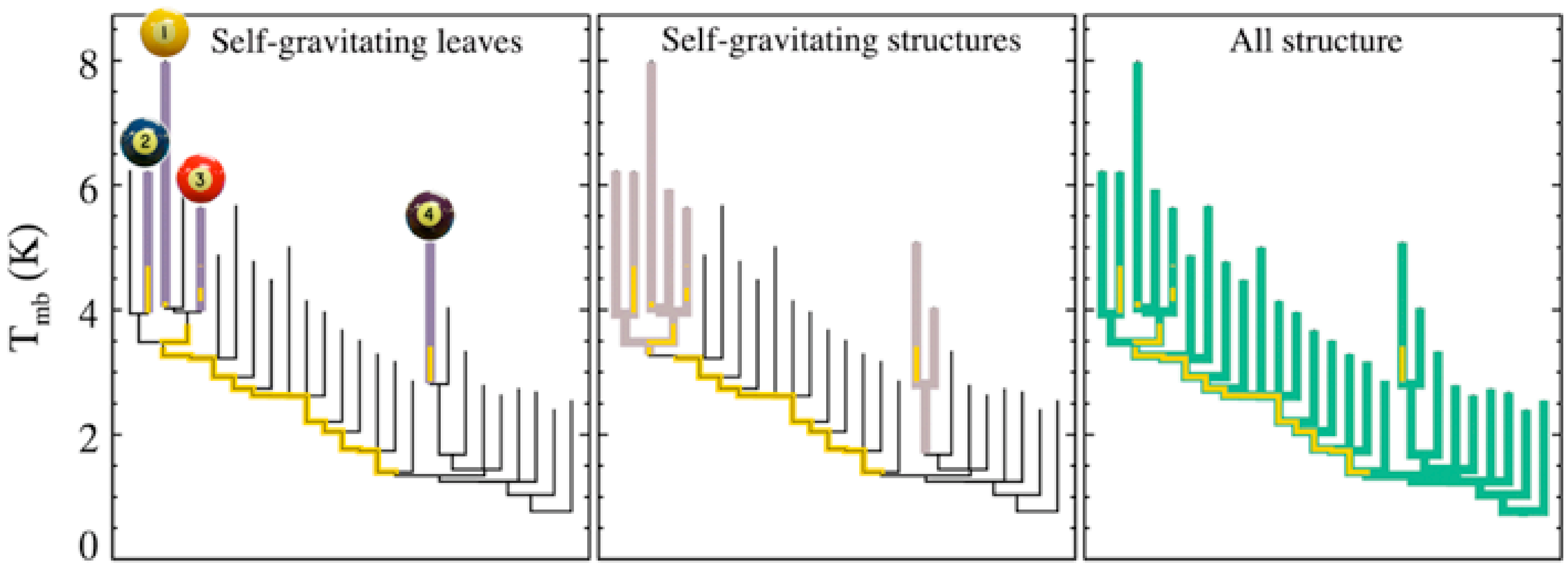
What have we learned, so far?

(see Michelle Borkin's talk next, and our demo table--in 3D!--too!)

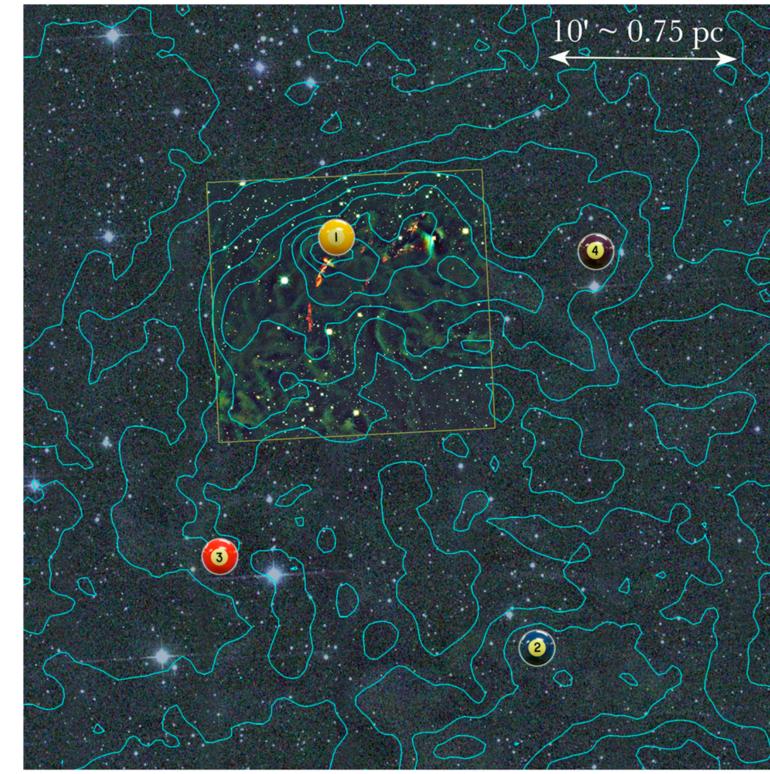


Visualization created by Jens Kauffmann (CfA/IIC) using 3D Slicer

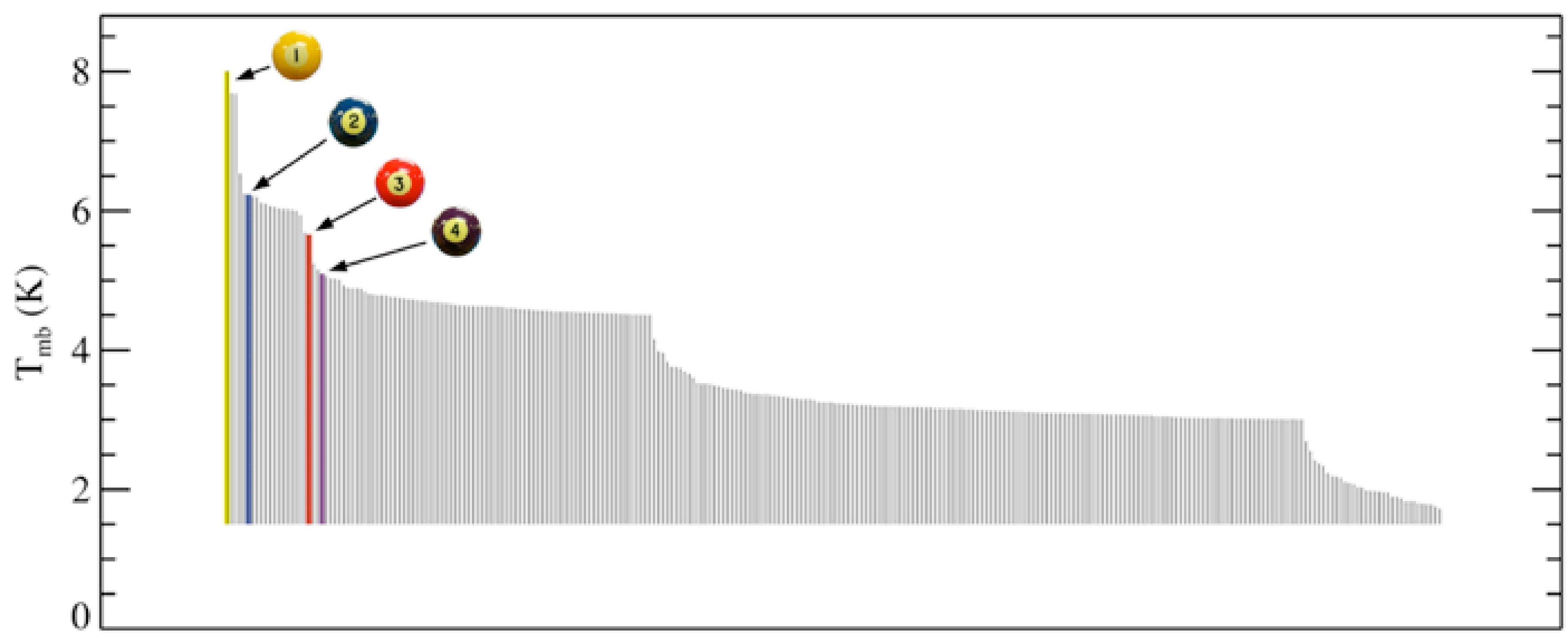
Dendrograms (Hierarchical) vs. CLUMPFIND (Non-hierarchical)

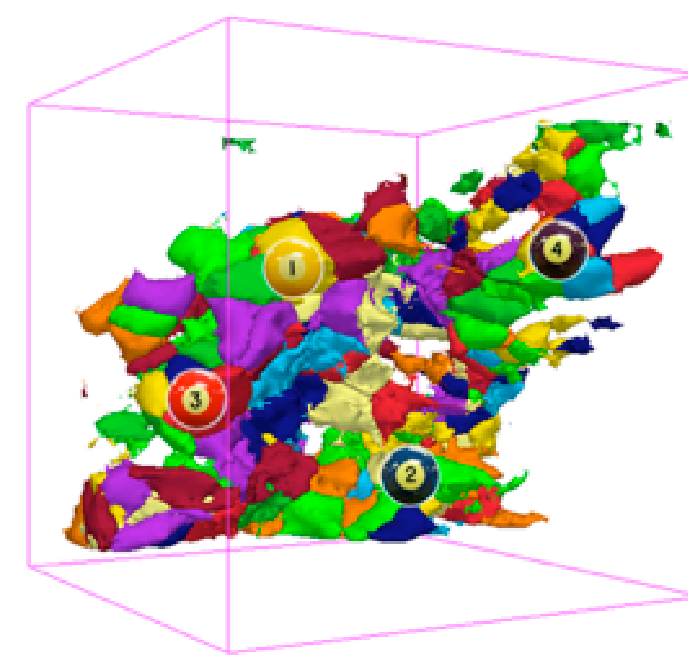


(Yellow = self-gravitating components)



The online PDFs of these insets are interactive, and can be rotated and manipulated by the viewer.





Goodman, Rosolowsky, Borkin, Foster, Halle, Kauffmann & Pineda, 2007, *Nature*, submitted.

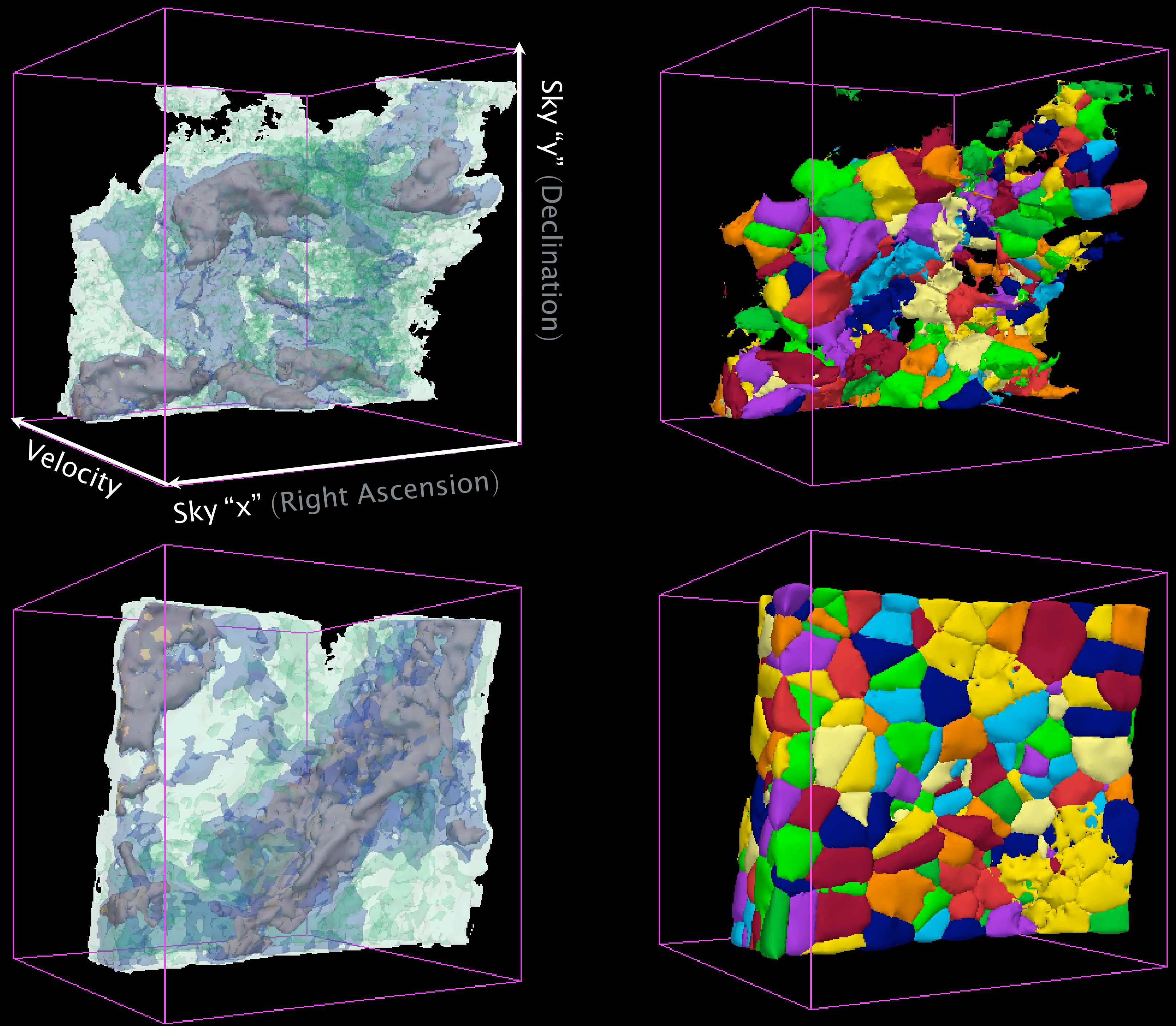
“Reality” and “Unreality”?

(Dendro)Surfaces

“CLUMPFIND”

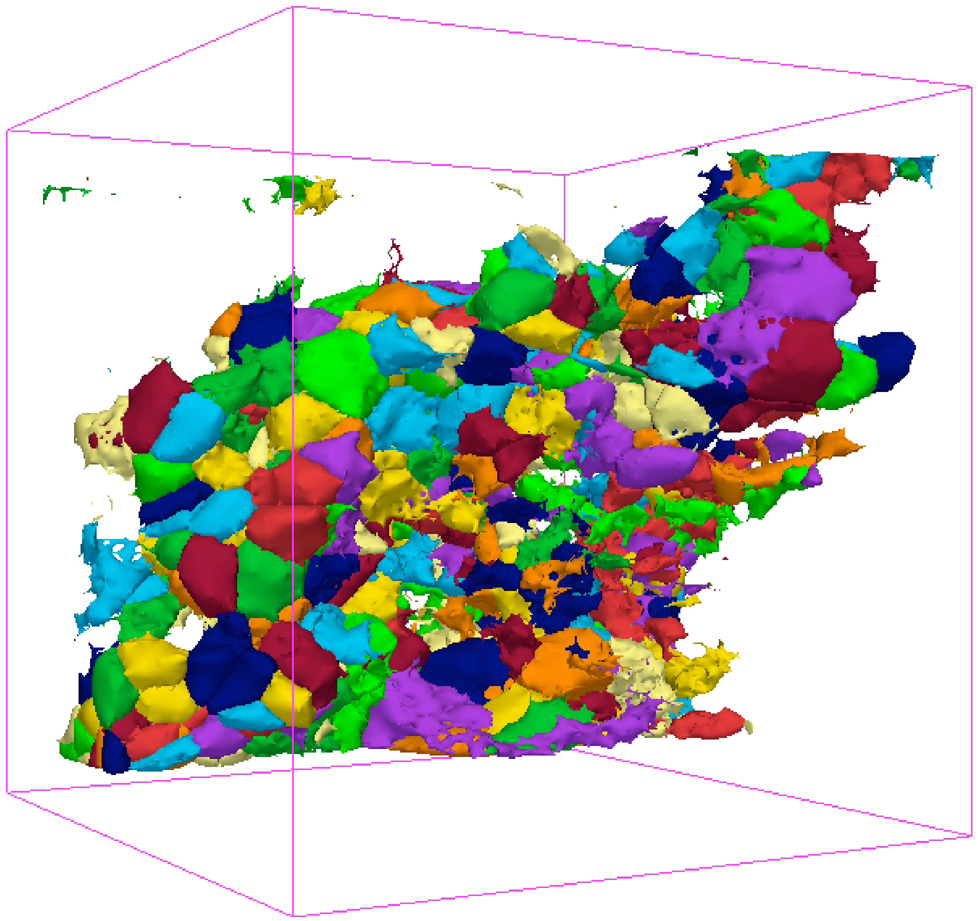
Observed Reality

“Observed” Simulations



work of Rosolowsky, Pineda, Kauffmann, Borkin,Padoan, Halle & Goodman;
figure from Goodman & Rosolowsky NSF “Star Formation Taste Tests” Proposal, Fall 2006

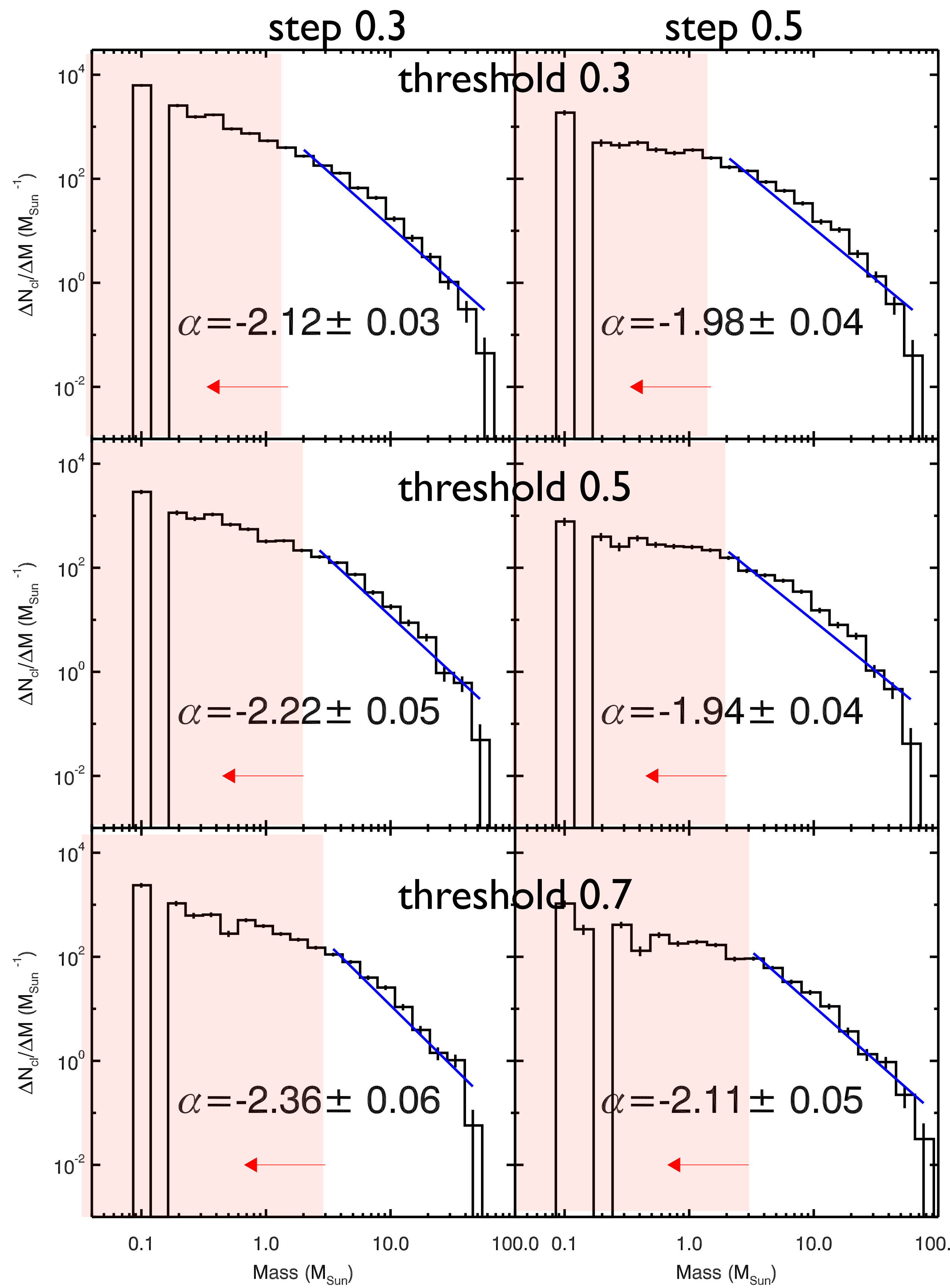
Is CLUMPFIND OK as a Statistic?



CLUMPFIND output for L1448
(1.2K step & threshold; lower values give too many clumps to show!)

Results for full Perseus Map

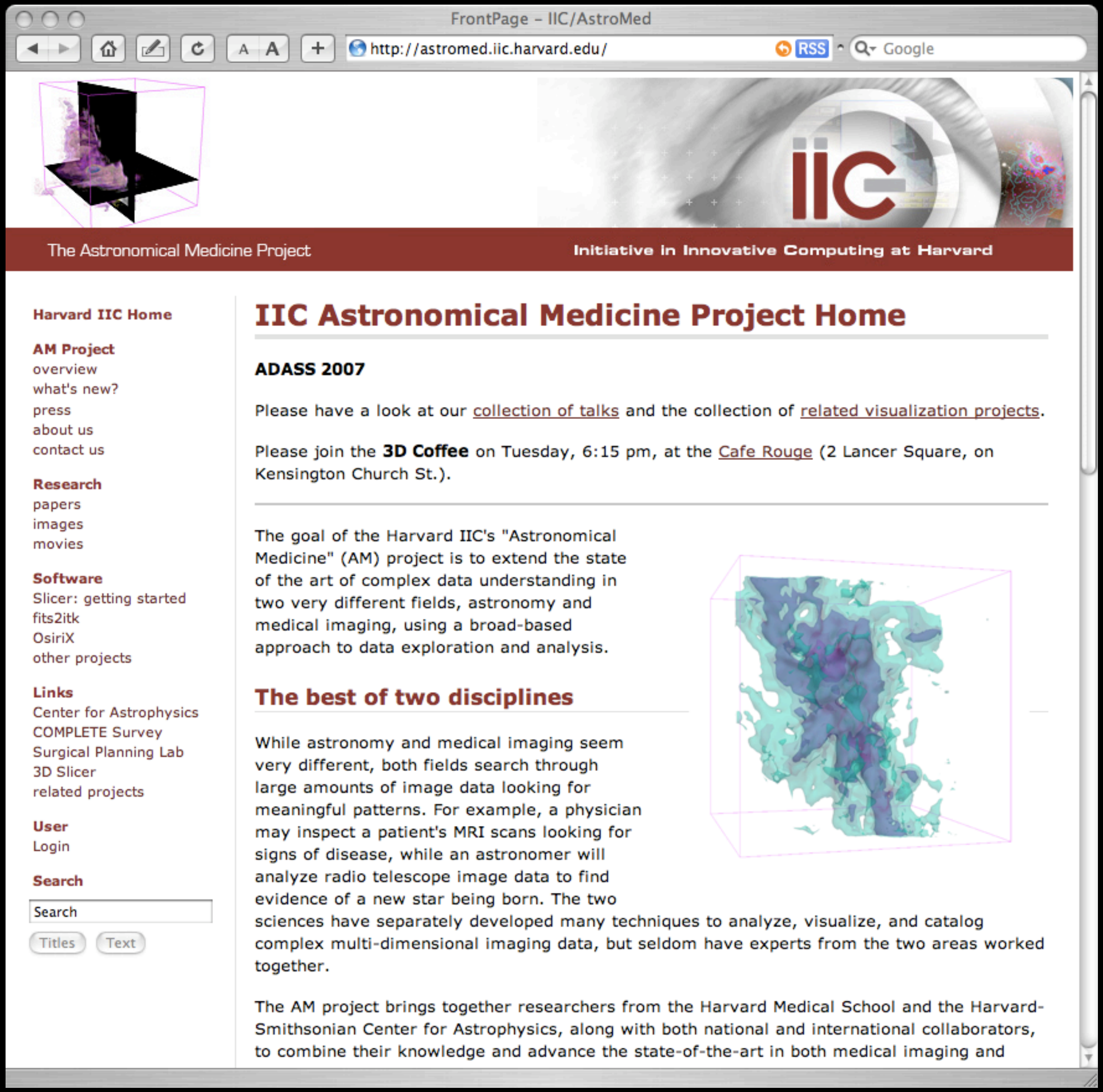
Threshold	Step size	total number of Clump	% above sensitivity limit Mass v/s Radius	% above sensitivity limit FWHM v/s Radius	% above both curves
0.3	0.3	5199	47.32%	58.03%	46.59%
0.3	0.5	3844	40.74%	46.96%	40.30%
0.5	0.3	2141	79.12%	89.72%	78.14%
0.5	0.5	1420	86.83%	89.01%	86.20%
0.7	0.3	1748	79.06%	90.79%	78.60%
0.7	0.5	1168	87.07%	90.58%	86.73%



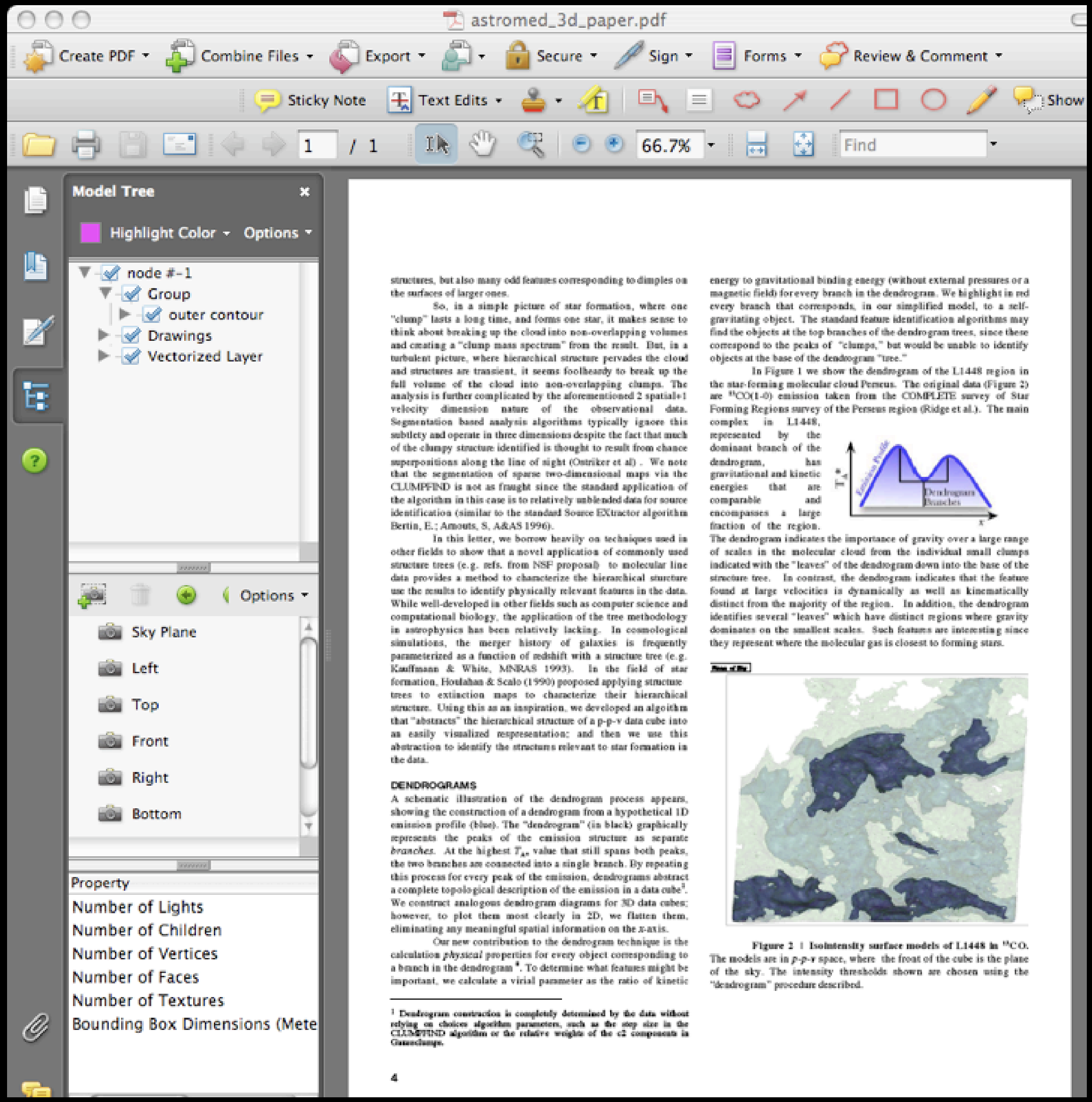
Pineda, Goodman & Rosolowsky 2007

Generalizing & Sharing

Open-Source code released, and explained, as it is developed.



Changing the future of scientific publishing.



Goodman et al., *Nature*, submitted June 2007; see also Barnes & Fluke 2007 arXiv:0709.2734

Scalability

10^6 pixels	this projector
10^7 voxels	an MRI of your brain, at 0.5 mm resolution
10^8 voxels	**Perseus COMPLETE data cube**
10^{14} voxels	the **Connectome**, 0.5 mm^3 of brain tissue
10^{16} pixels	Google Earth Imagery at 1 foot resolution
10^{18} voxels	200 nights LSST data, at 6 wavelengths (x,y,t)
10^{19} voxels	Google Earth 3D, ±1000 feet of elevation, 1ft. res.
10^{22} voxels	the Connectome, full human brain

SCIENTIFIC DISCIPLINES

COMPUTER SCIENCE

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

Academic researchers often focused on finding elegant solutions to basic computer science challenges

Often see specific, “applied” problems as outside their interests

Higher-dimensional visualization and analysis is a generic problem.

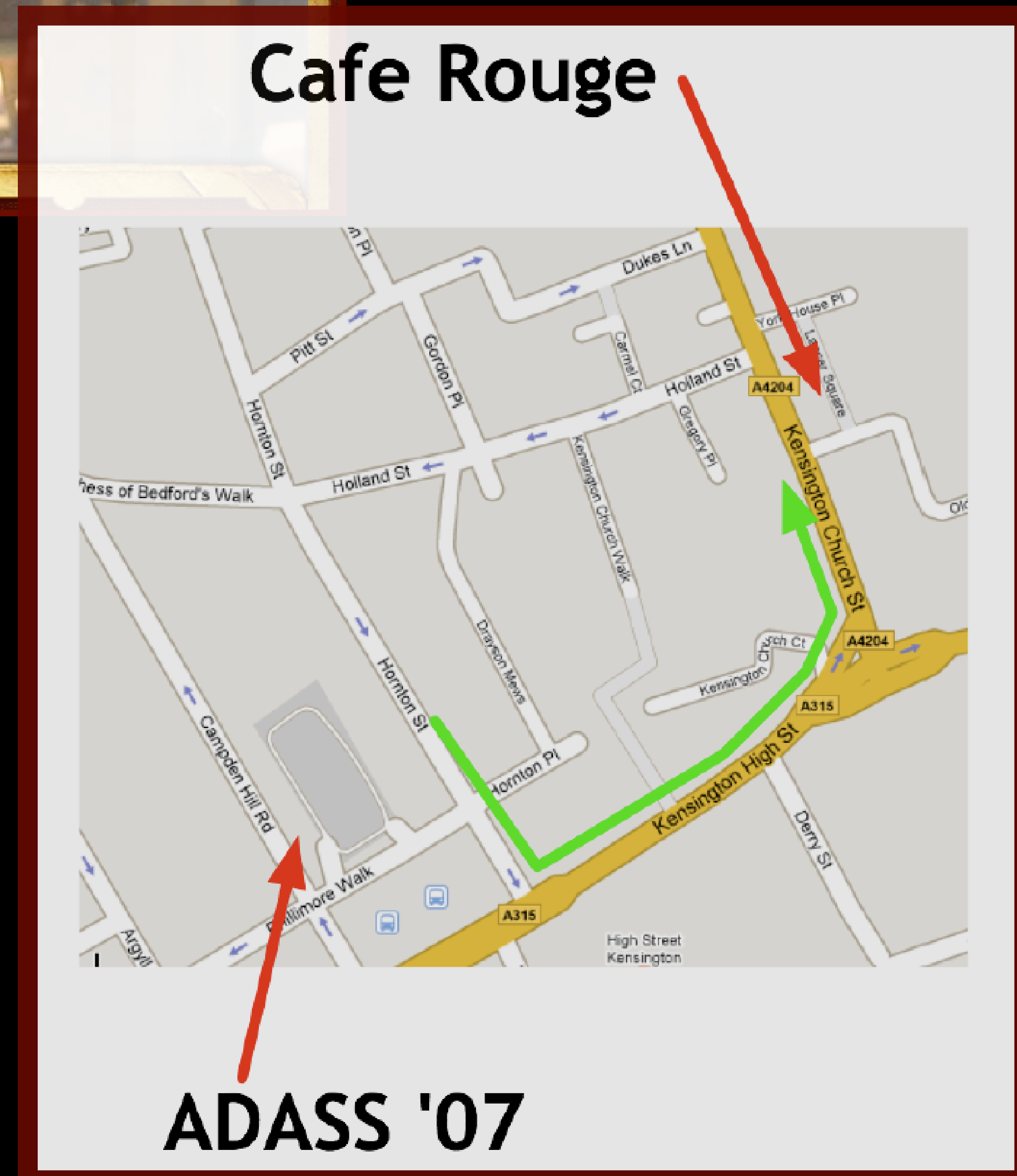
Solutions:

Think Web 2.0, think PLASTIC. Think "my 2-D grapher is yours" ... "my renderer is yours" ..."my spectral analysis tools are yours" ... "my bookmarks are your bookmarks" ... "my library is your library" ... etc.

So, we need **both**:

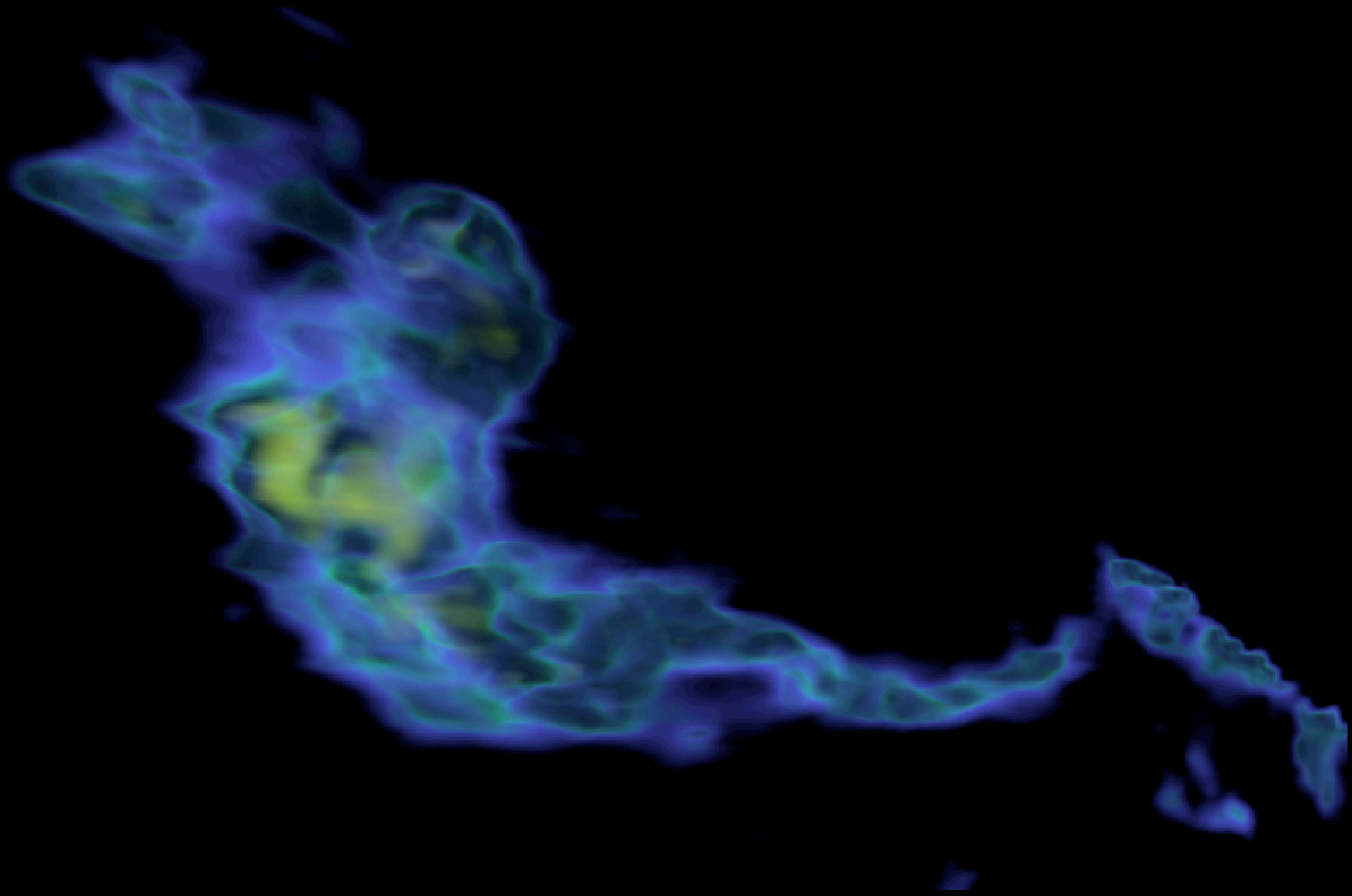
parts to share

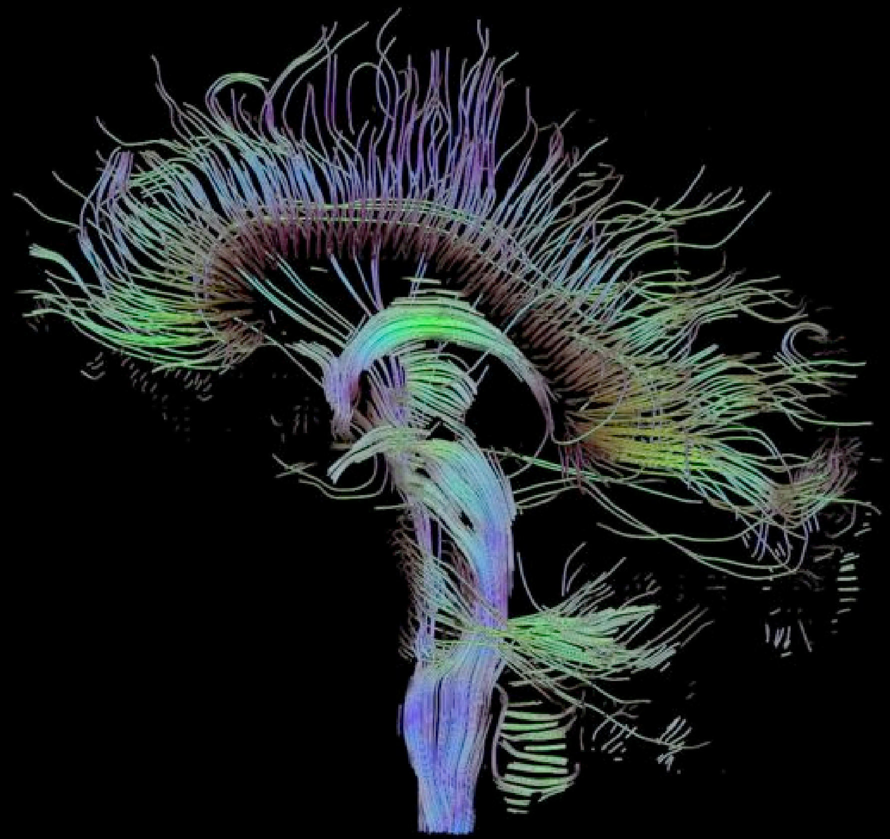
& (easier!) ways to share them.



More 3D, later...6:15 meet outside of this building, see J. Kauffmann

Astronomy + Medicine = Understanding





Alyssa A. Goodman
Initiative in Innovative Computing @ Harvard
and
Harvard-Smithsonian Center for Astrophysics

Official Abstract

(O7.1) Astronomy + Medicine = Understanding

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Astronomy and medicine are two fields that rely heavily on imaging for insight. The "Astonomical Medicine" project, based at Harvard's new "Initiative in Innovative Computing," seeks to combine the best advances in both medical and astronomical image display, manipulation, and analysis techniques, in order to create tools that are better for everyone. To date, our focus has been on three-dimensional data, such as the position-position-velocity data cubes typically produced by spectral-line observations. We have leveraged several existing medical imaging packages, all built upon ITK and VTK, in order to give astronomers easy access to views of their data as 3D surfaces and volumes.

The talk will focus both on the **general overlap of the astronomical and medical challenges** and solutions and on **specific examples of successes to date**. In one particularly noteworthy example, we have used the 3D Slicer package (see Note) to show that traditional **"segmentation" (a.k.a. "clumpfinding") techniques** used in the study of star formation need to be reconsidered, and that alternative "**tree-based" techniques** may prove superior.

Note: The "3D Slicer" package, developed for **surgical planning**, has proven especially useful in our work, and a tutorial featuring 3D Slicer will be offered before the ADASS meeting. For more information, please see http://astromed.iic.harvard.edu/.