Astronomy Pizza @ Harvard, 11.17.11

Alyssa A. Goodman

Professor of Astronomy

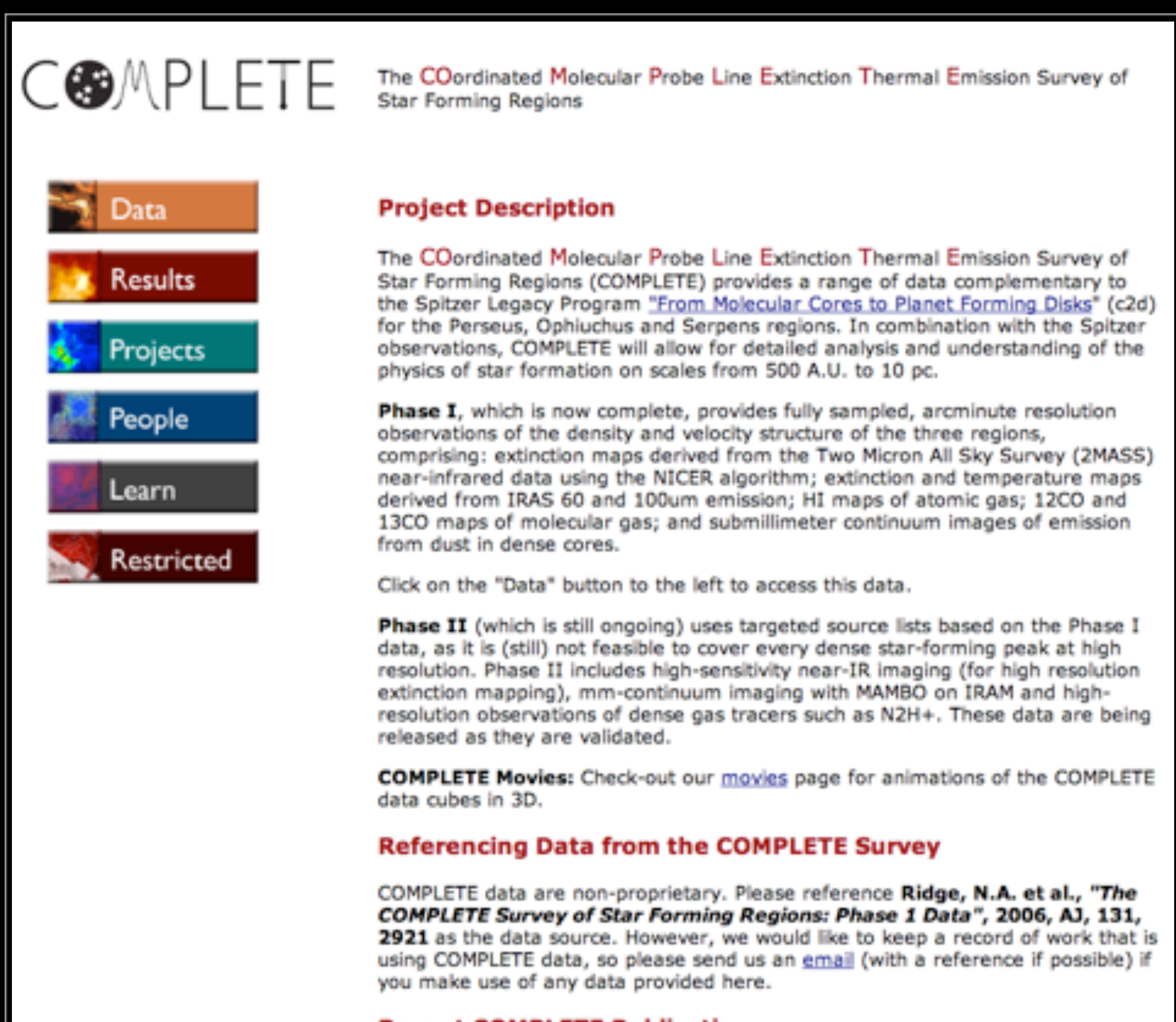
www.cfa.harvard.edu/~agoodman

Image credit: Astronomy Picture of the Day, 11.17.11, Pleiades to Hyades by Rogelio Bernal Andreo

“Astronomy IN the Cloud(s)”

Star Formation in the Interstellar Medium

"e-Science" (and Data Visualization)



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.

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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 Movies: Check-out our movies page for animations of the COMPLETE data cubes in 3D.

Referencing Data from the COMPLETE Survey

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Linking scientific data, publications, and communities

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The **Seamless Astronomy Group** at the **Harvard-Smithsonian Center for Astrophysics** brings together astronomers, computer scientists, information scientists, librarians and visualization experts involved in the development of tools and systems to study and enable the next generation of **online astronomical research**.

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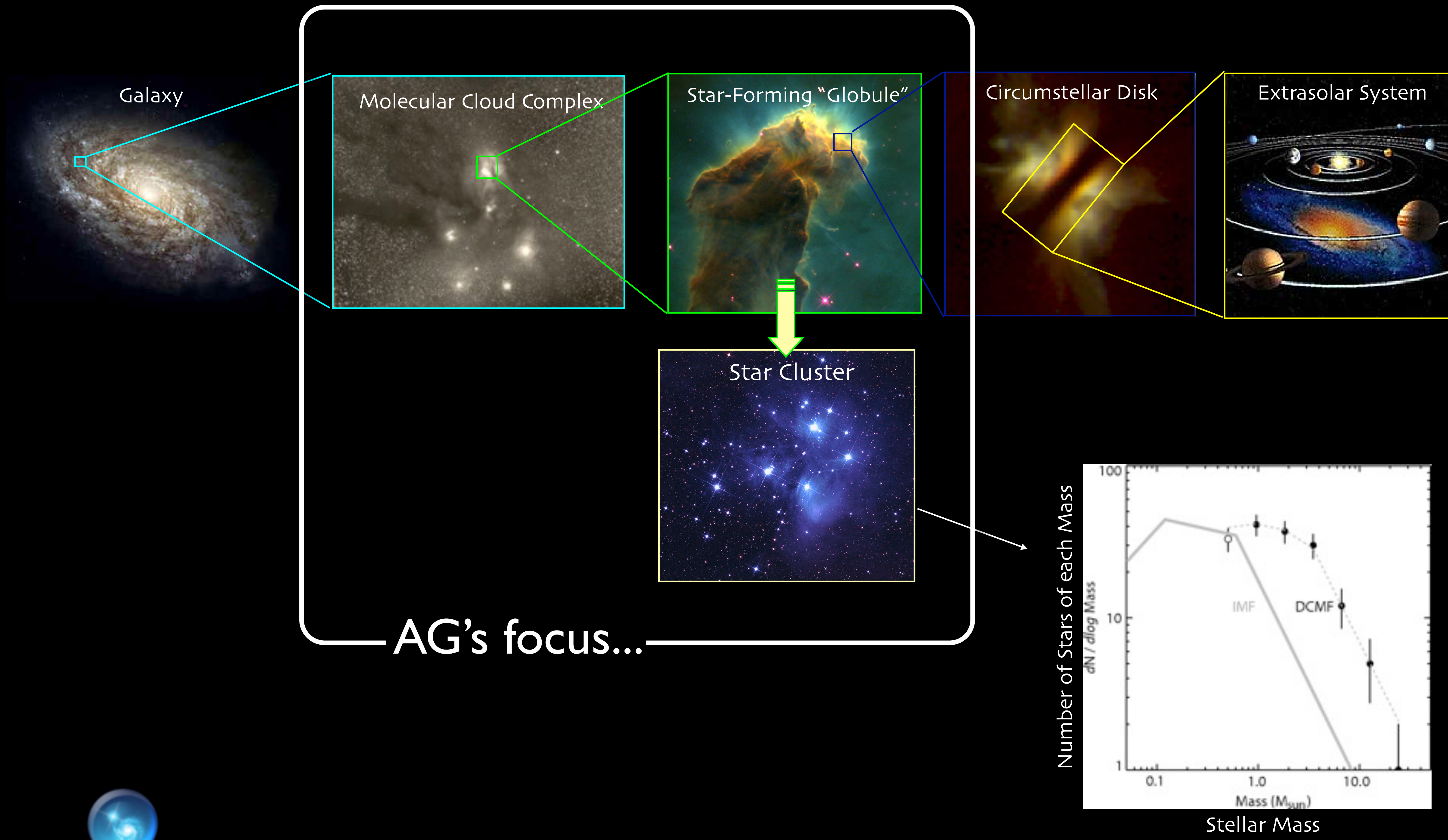
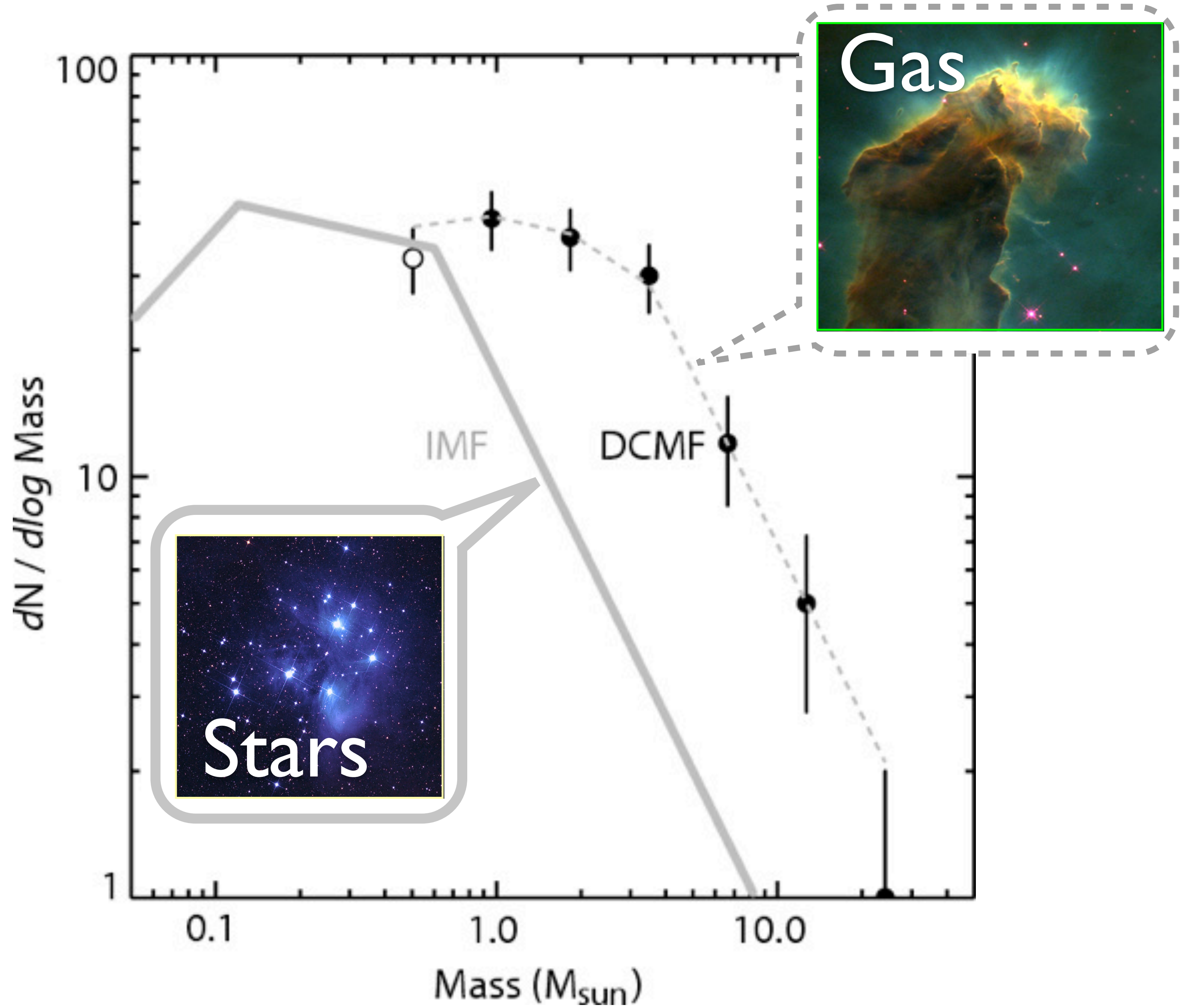
Star (and Planet, and Moon) Formation 101

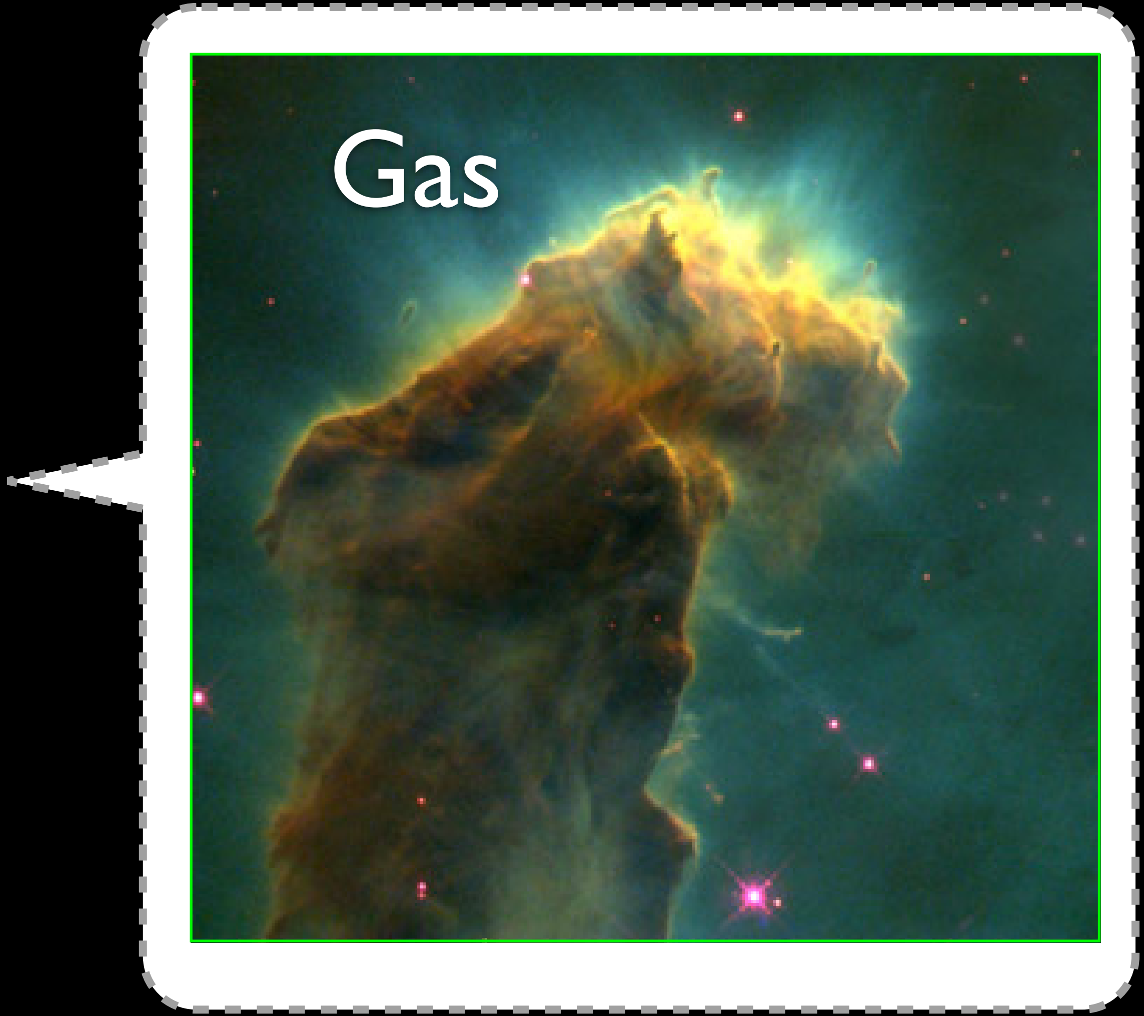


"IMF"? "CMF"?

Note: IMF= "Initial Mass Funciton" of Stars, not "International Monetary Fund."

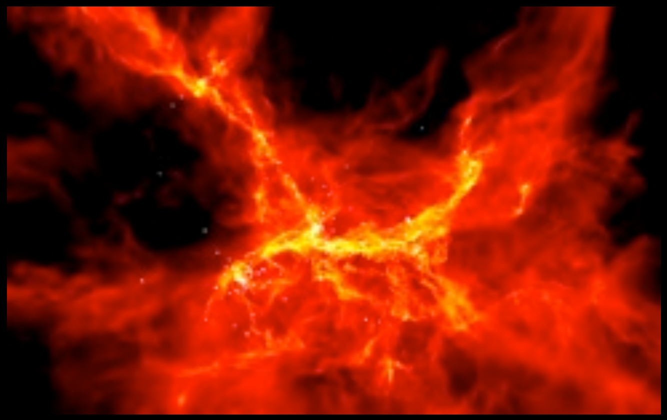


Alves, Lombardi & Lada 2007

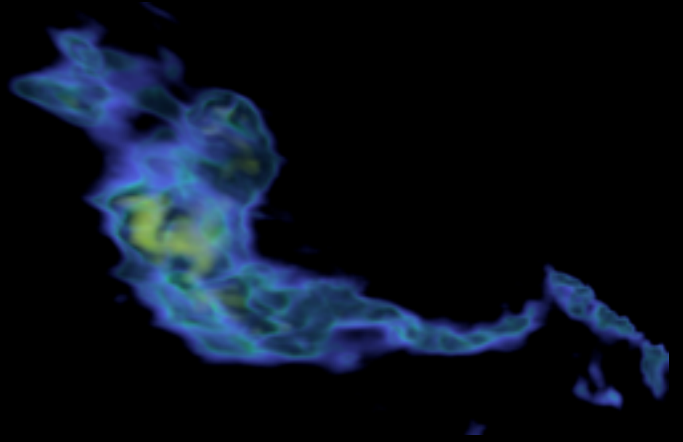


BUT: Beautiful images like this do not reveal *internal* structure directly...

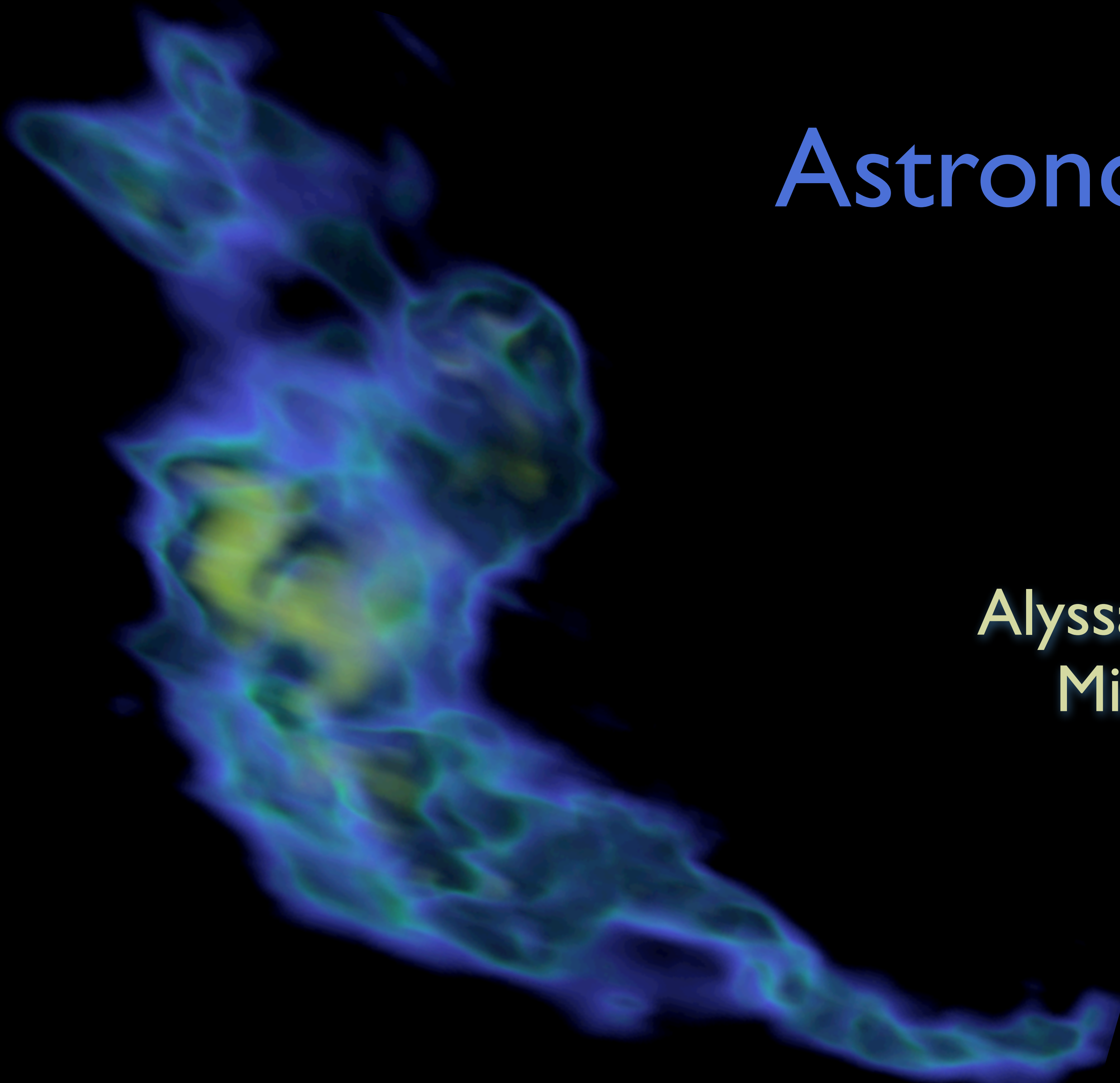
simulations



>2D observations



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

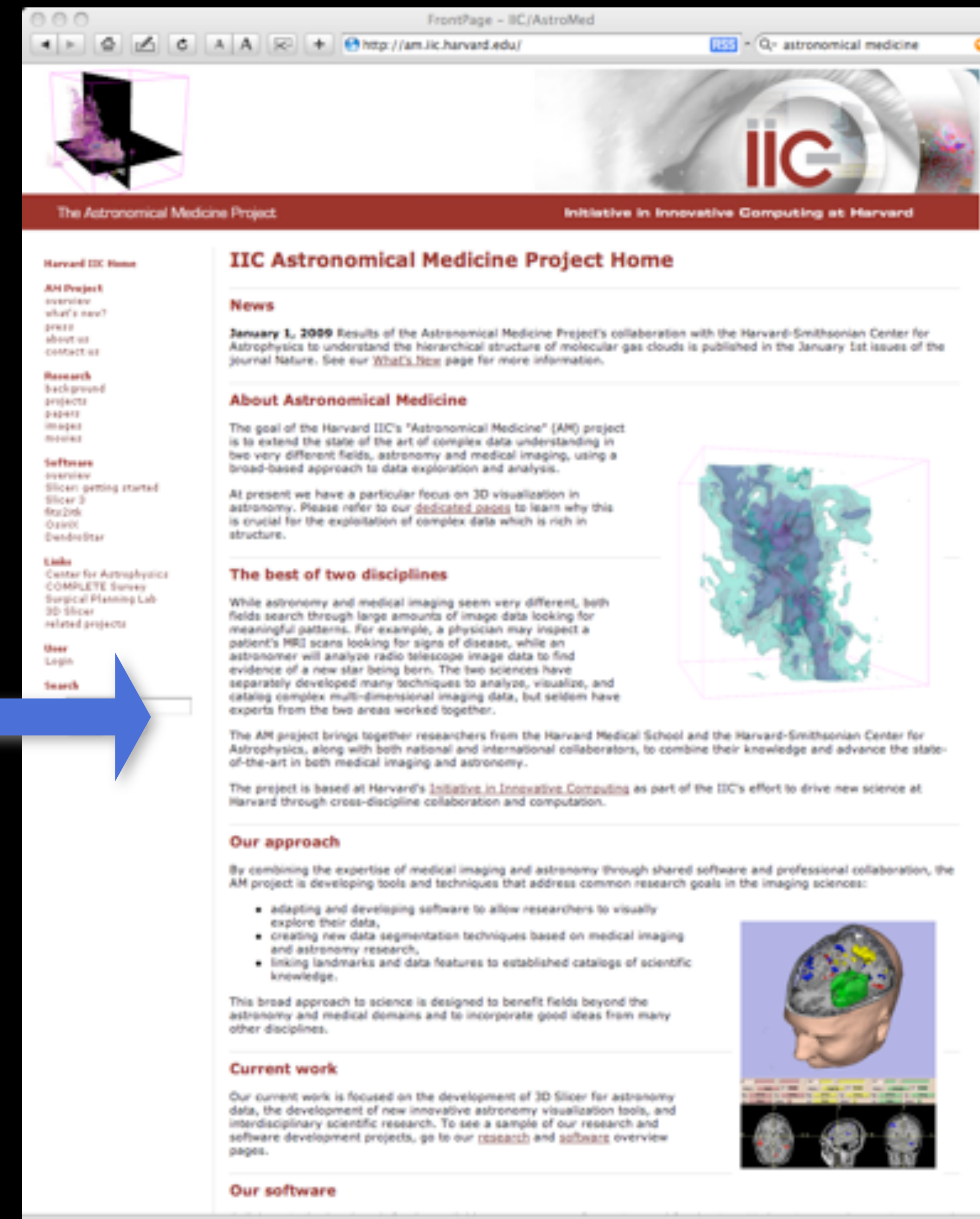
Computer Scientist

Computer Scientist

"Viz has failed the scientific community…"

Unsuspecting Undergrad

Astronomer



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

COMPLETE =COordinated Molecular Probe Line Exinction Thermal Emission

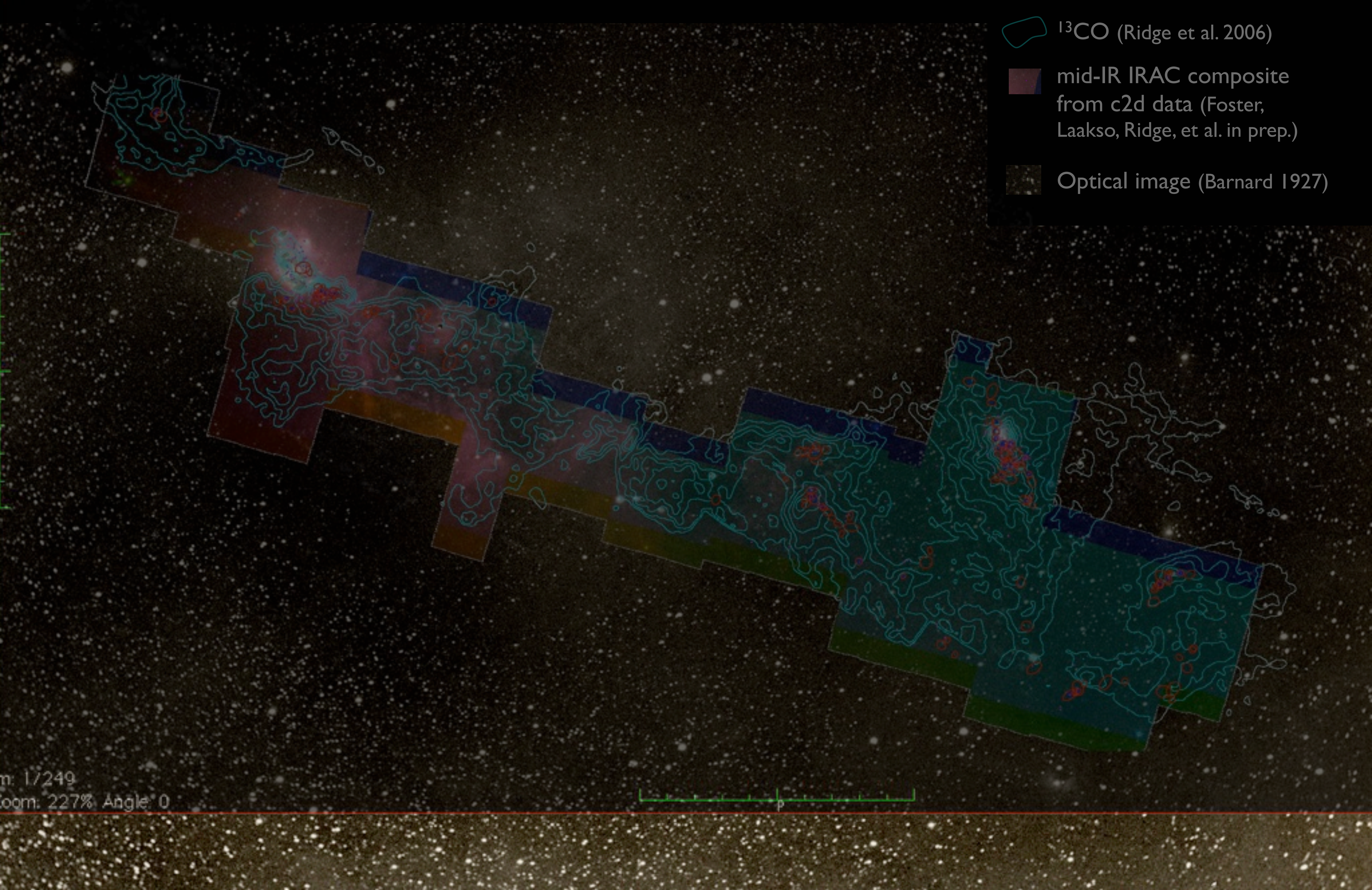
mm peak (Enoch et al. 2006)

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

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

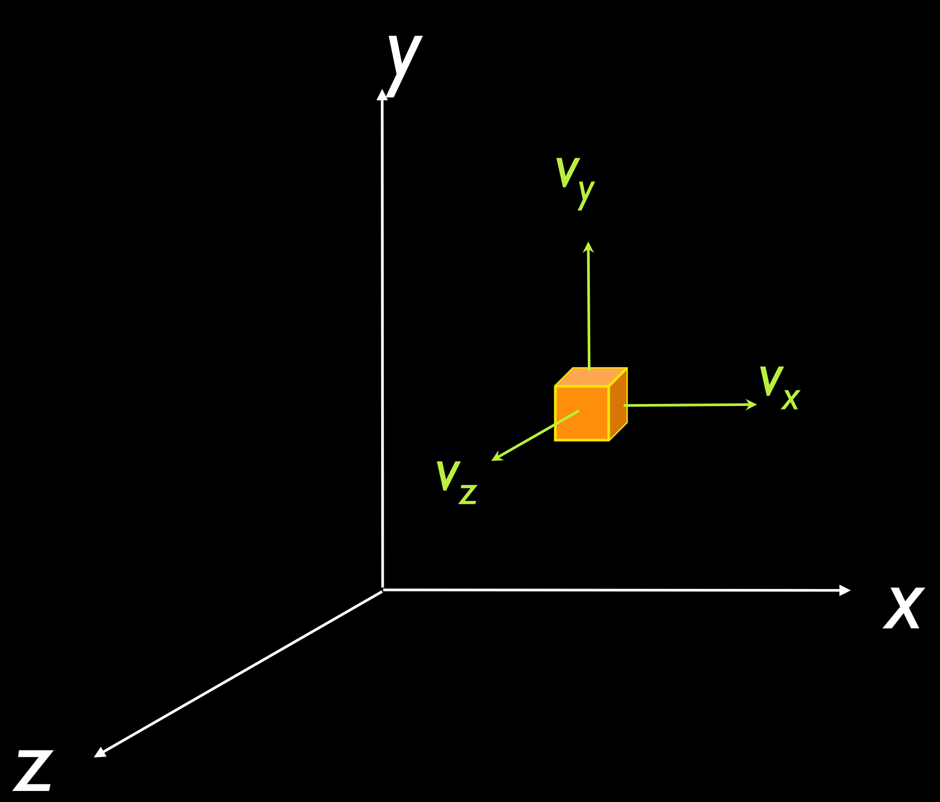
mid-IR IRAC composite from c2d data (Foster, Laakso, Ridge, et al. in prep.)

Optical image (Barnard 1927)

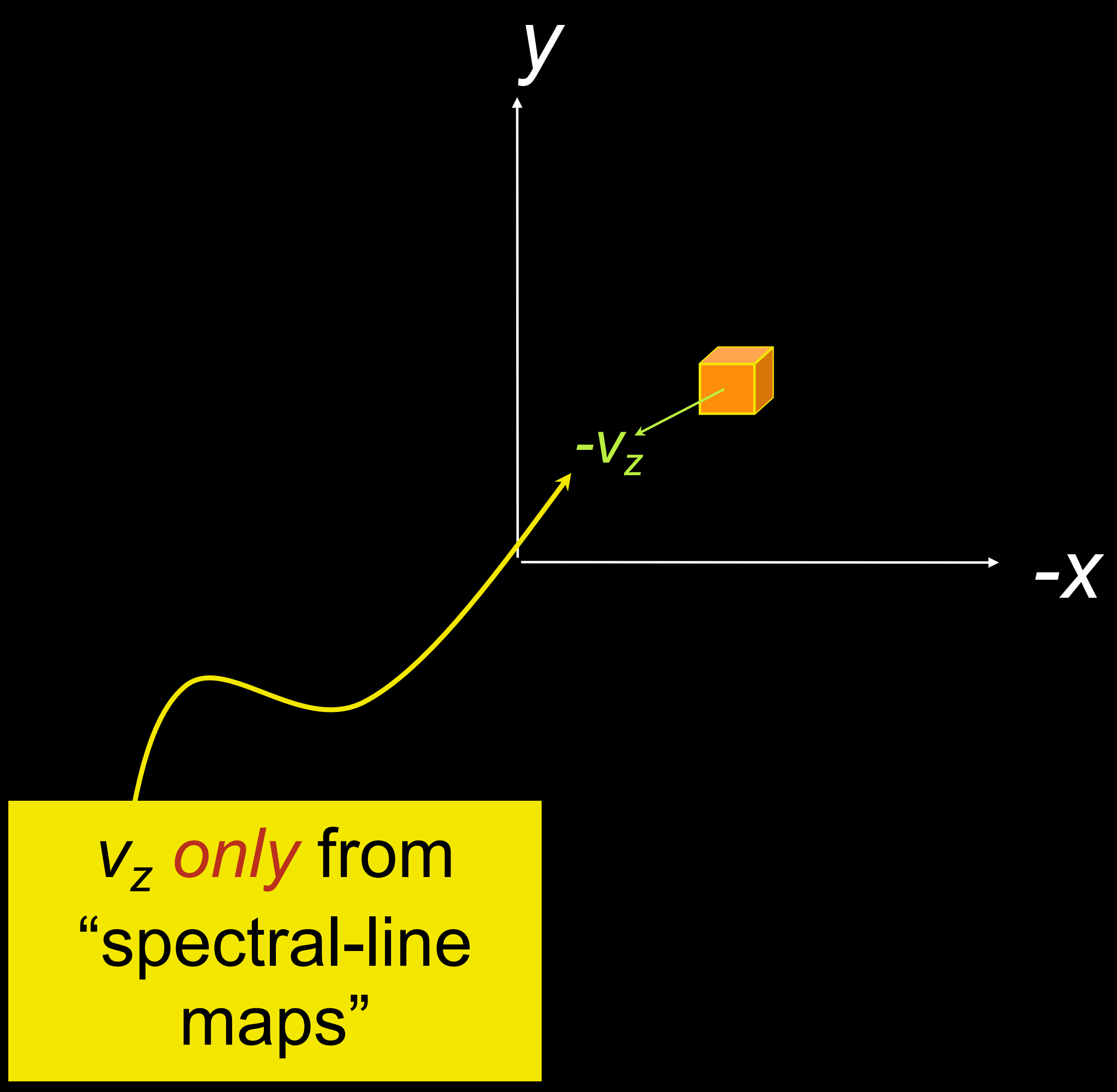


“Three” Dimensions: Spectral-Line Mapping

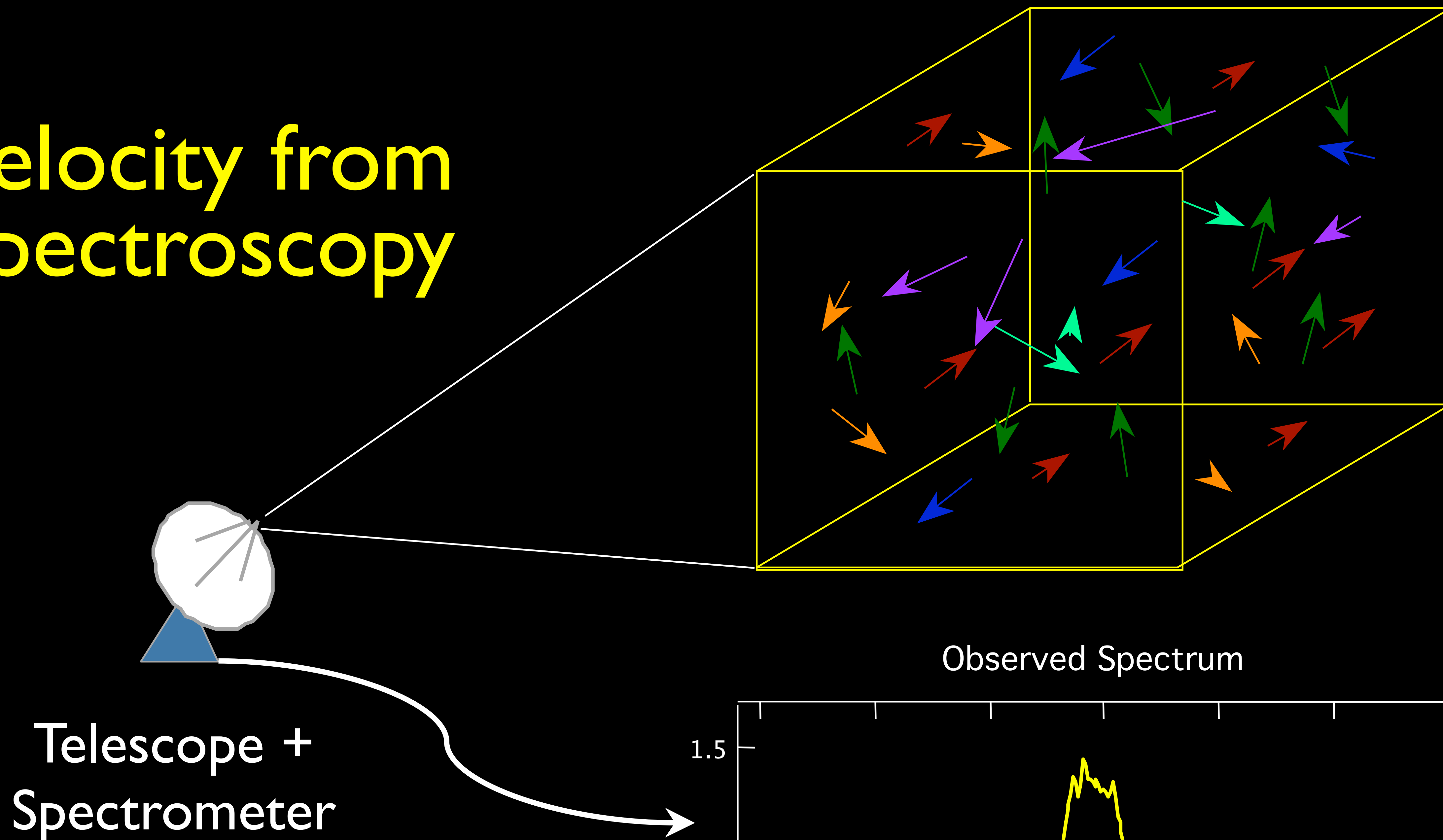
We wish we could measure…

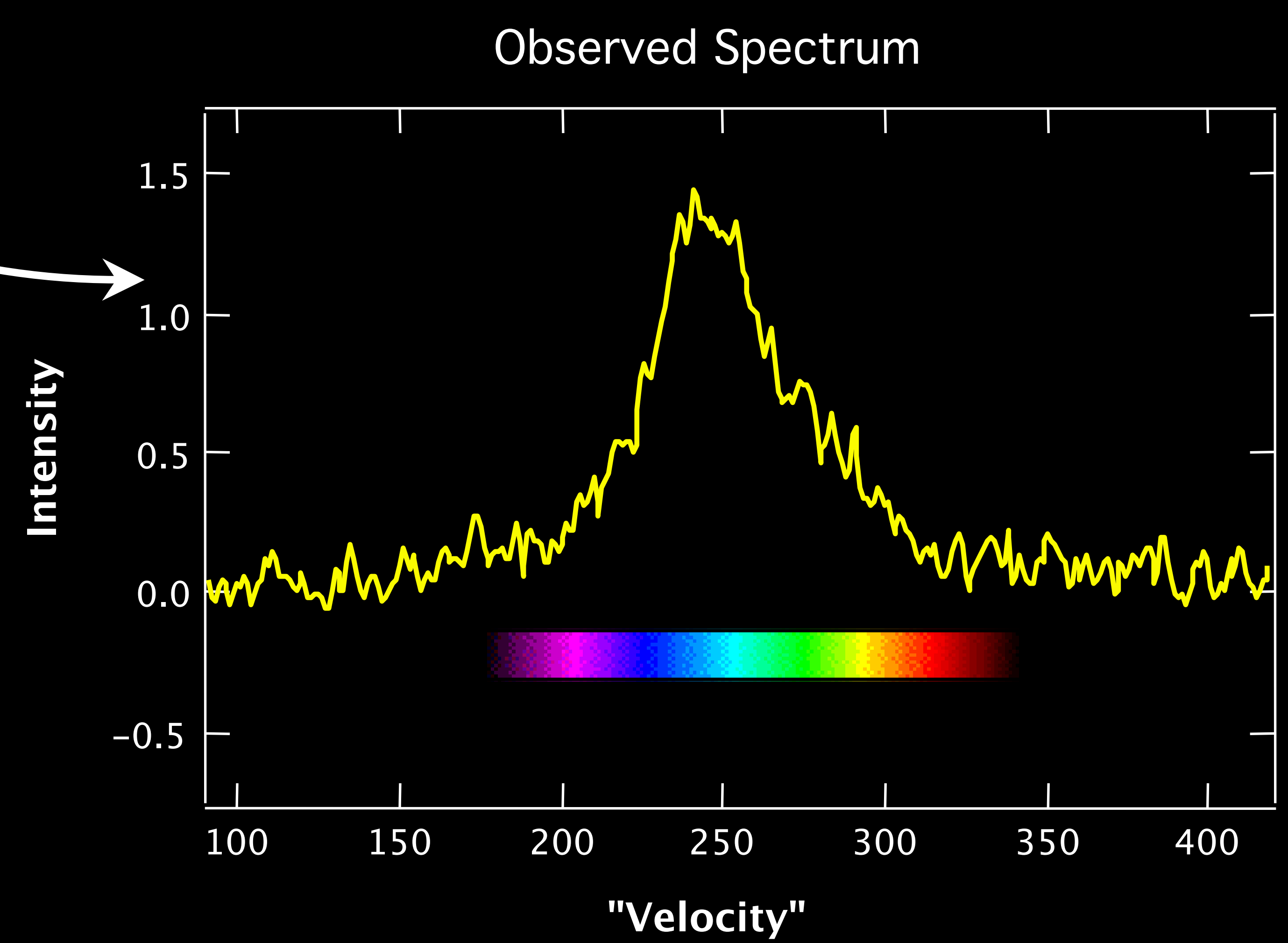


But we can measure…



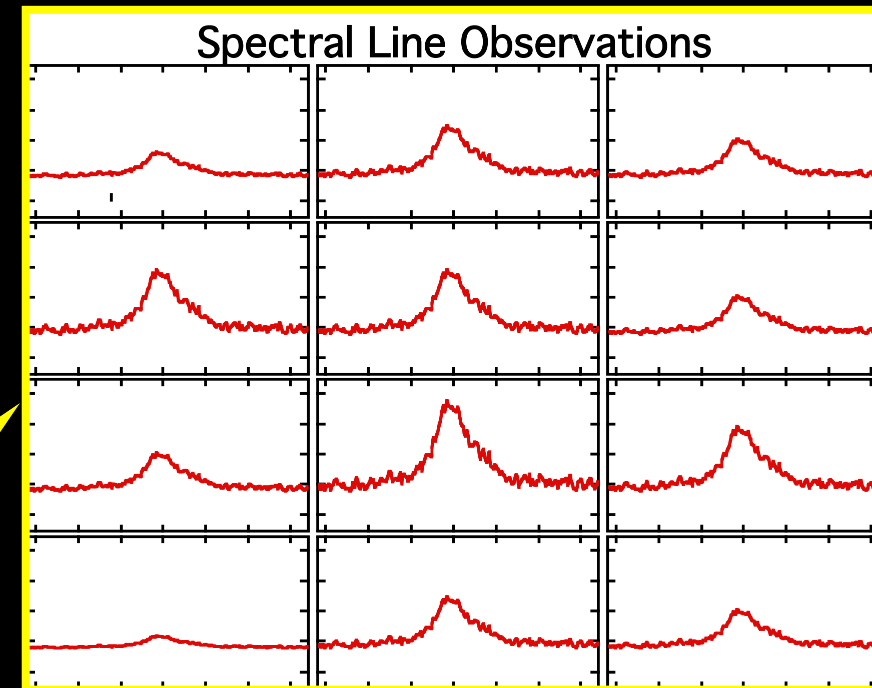
Velocity from Spectroscopy

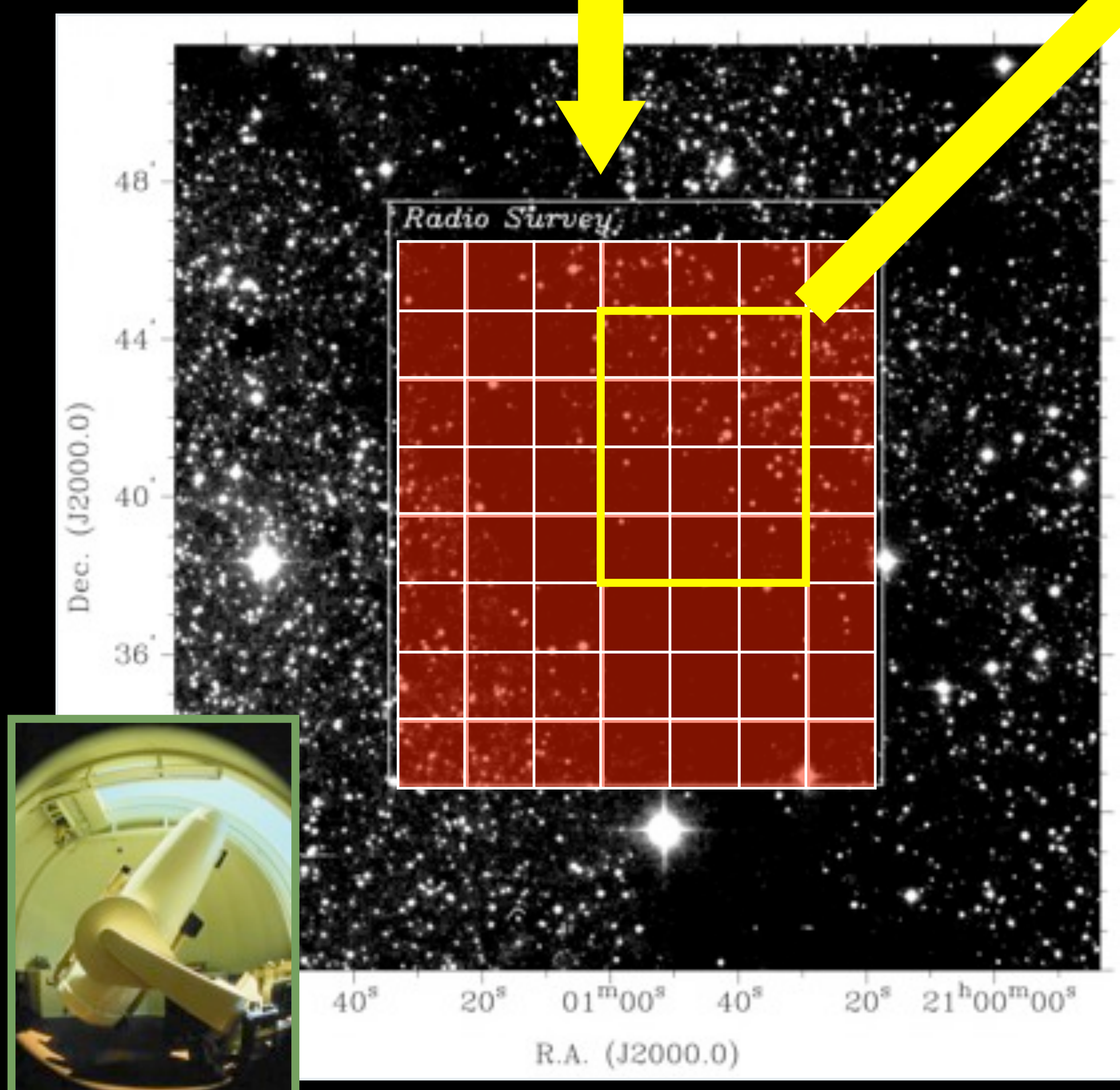


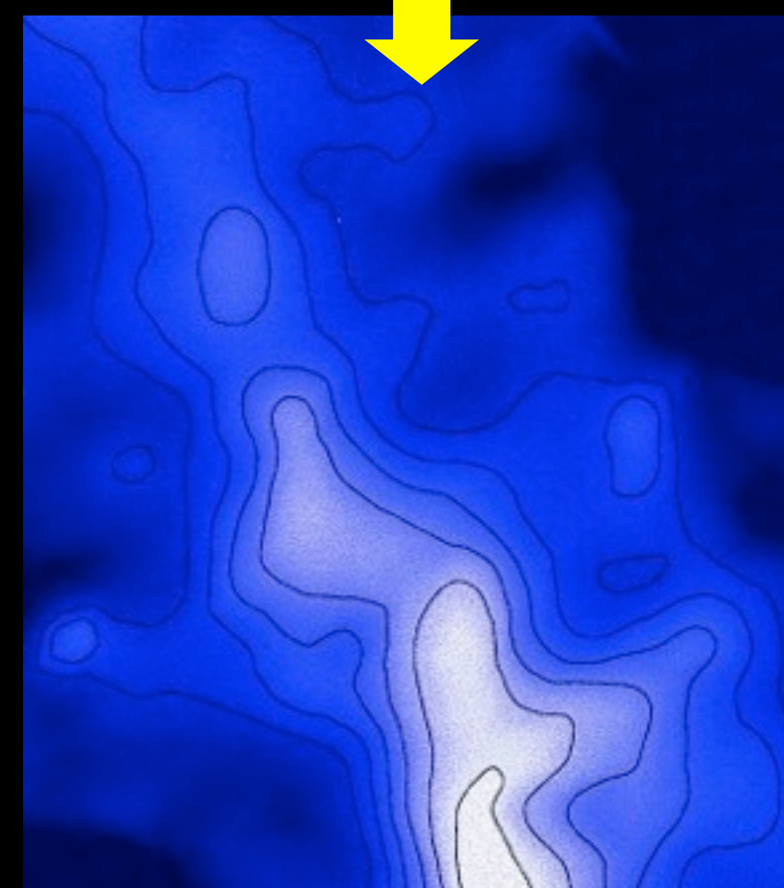


All thanks to Doppler

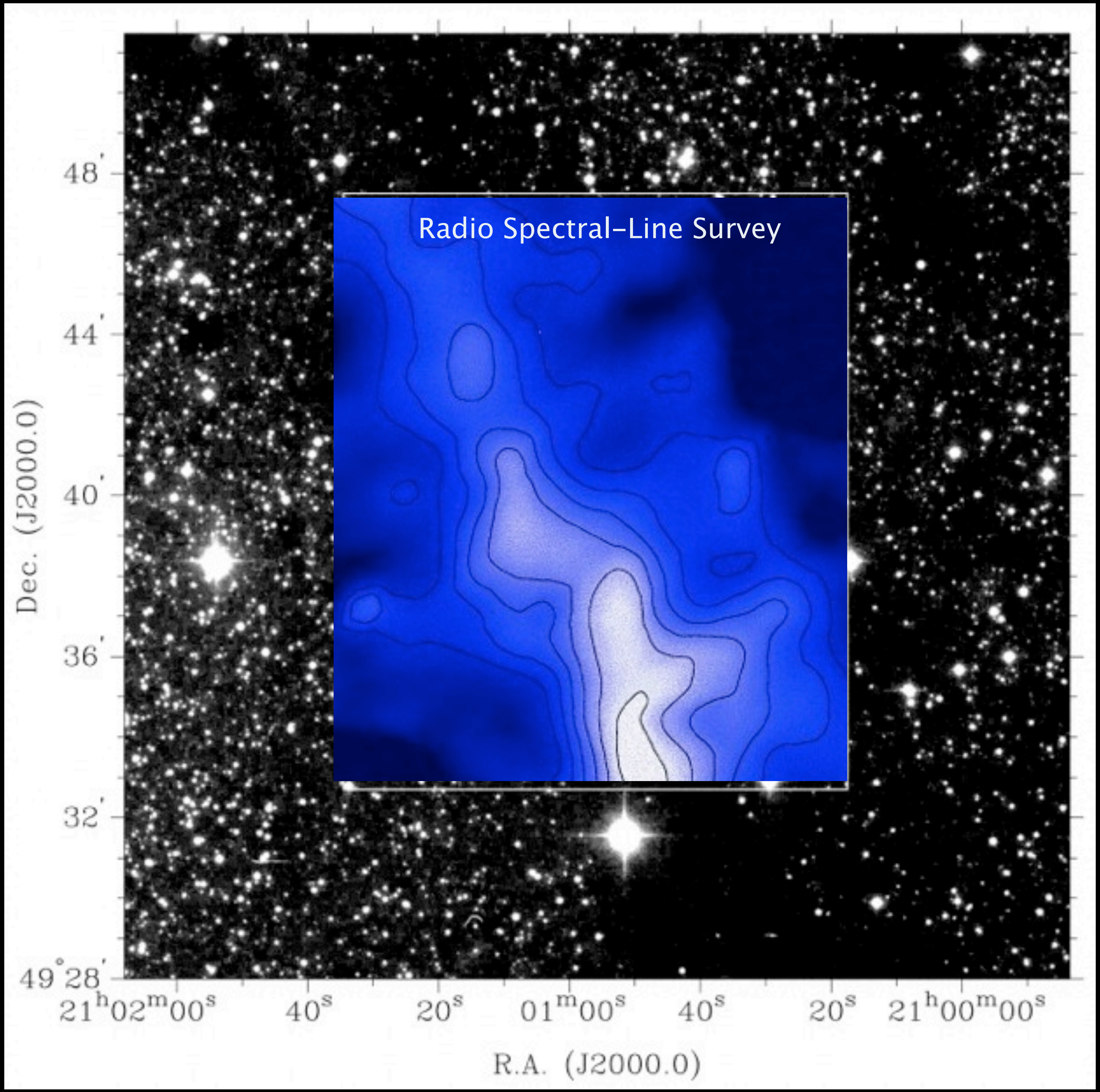
Radio Spectral-line Observations of Interstellar Clouds





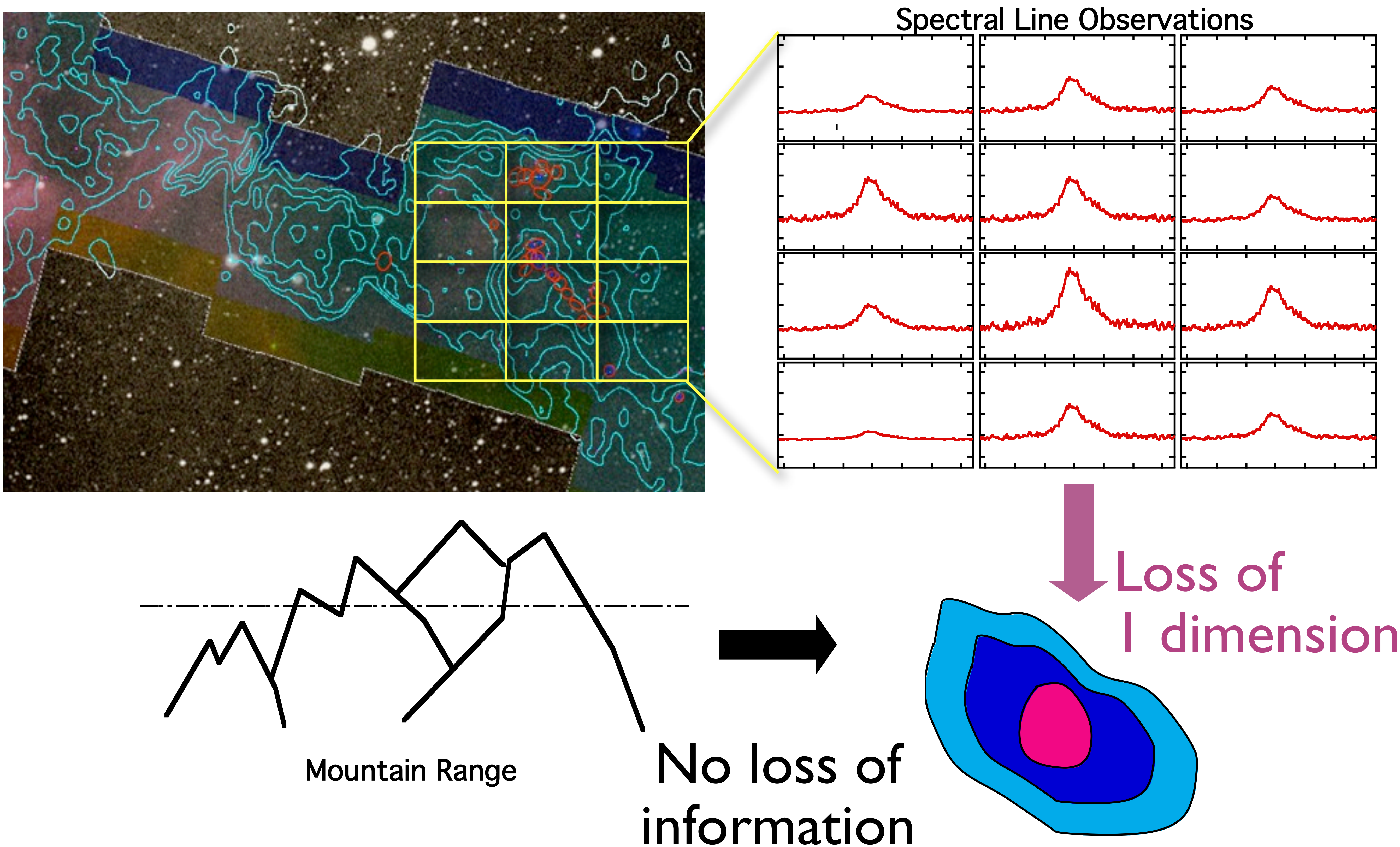


Radio Spectral-line Observations of Interstellar Clouds



Alves, Lada & Lada 1999

Velocity as a "Fourth" Dimension



Astronomical Visualization Tools are Traditionally 2D

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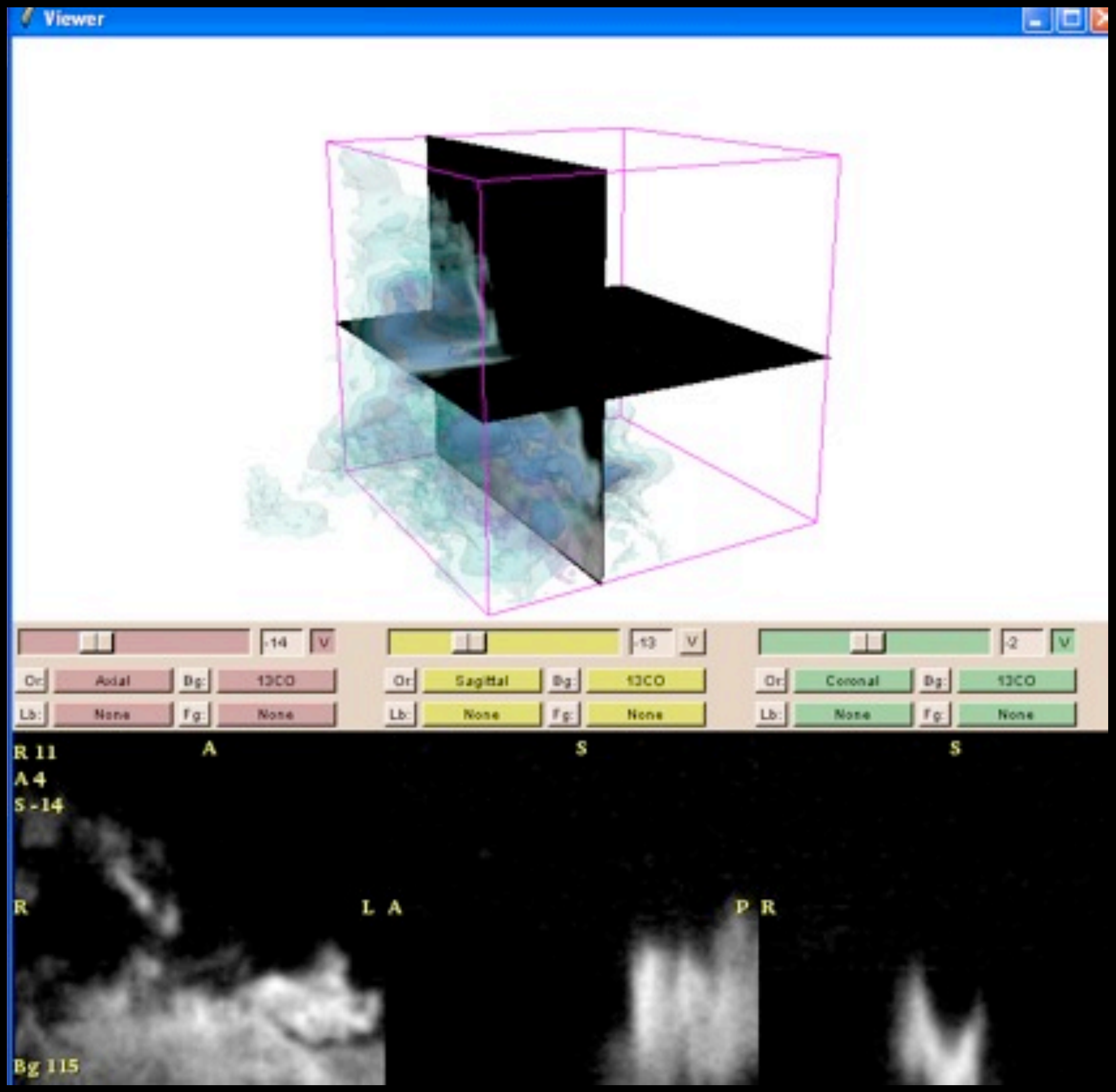
DS9

Karma*

GAIA

Aipsview

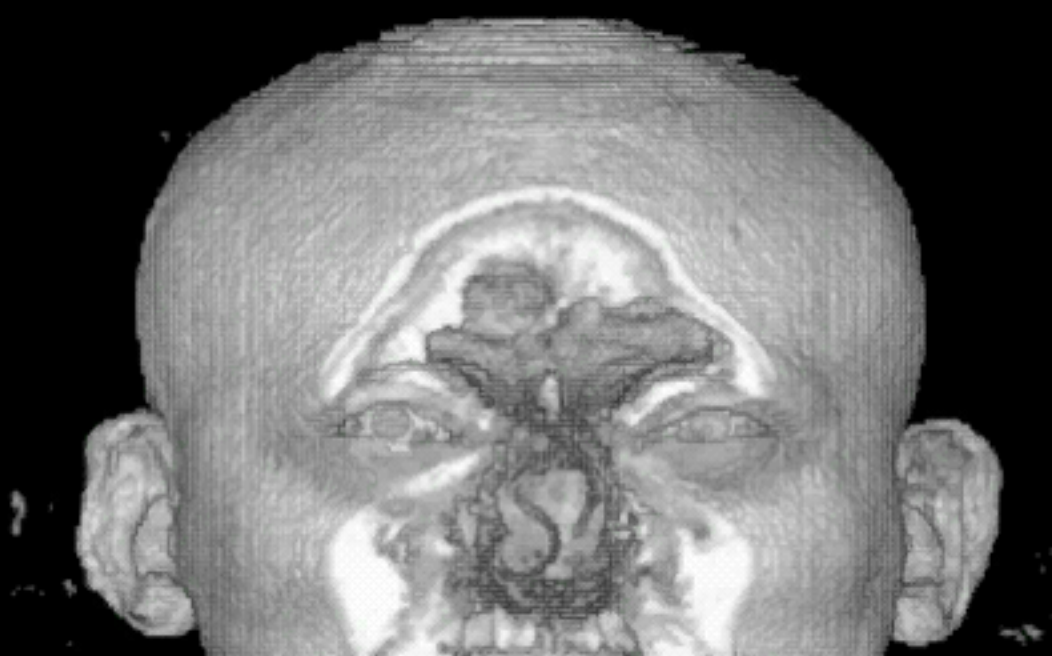
3D Slicer



“3D”=movies

"Astronomical Medicine"

"KEITH"



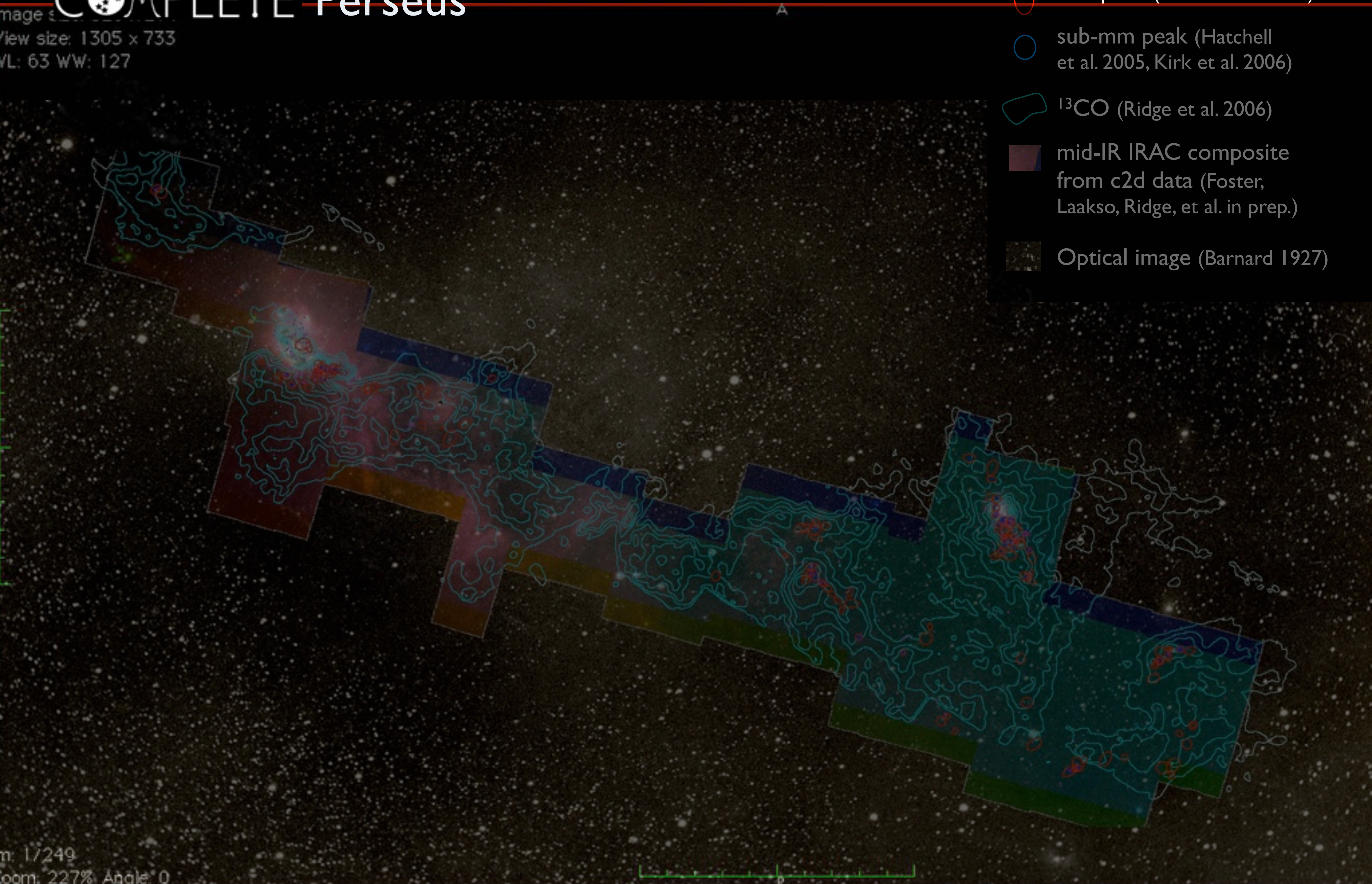
"z" is depth into head

"PERSEUS"

"z" is line-of-sight velocity

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

COMPLETE Perseus



- mm peak (Enoch et al. 2006)
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- ^{13}CO (Ridge et al. 2006)
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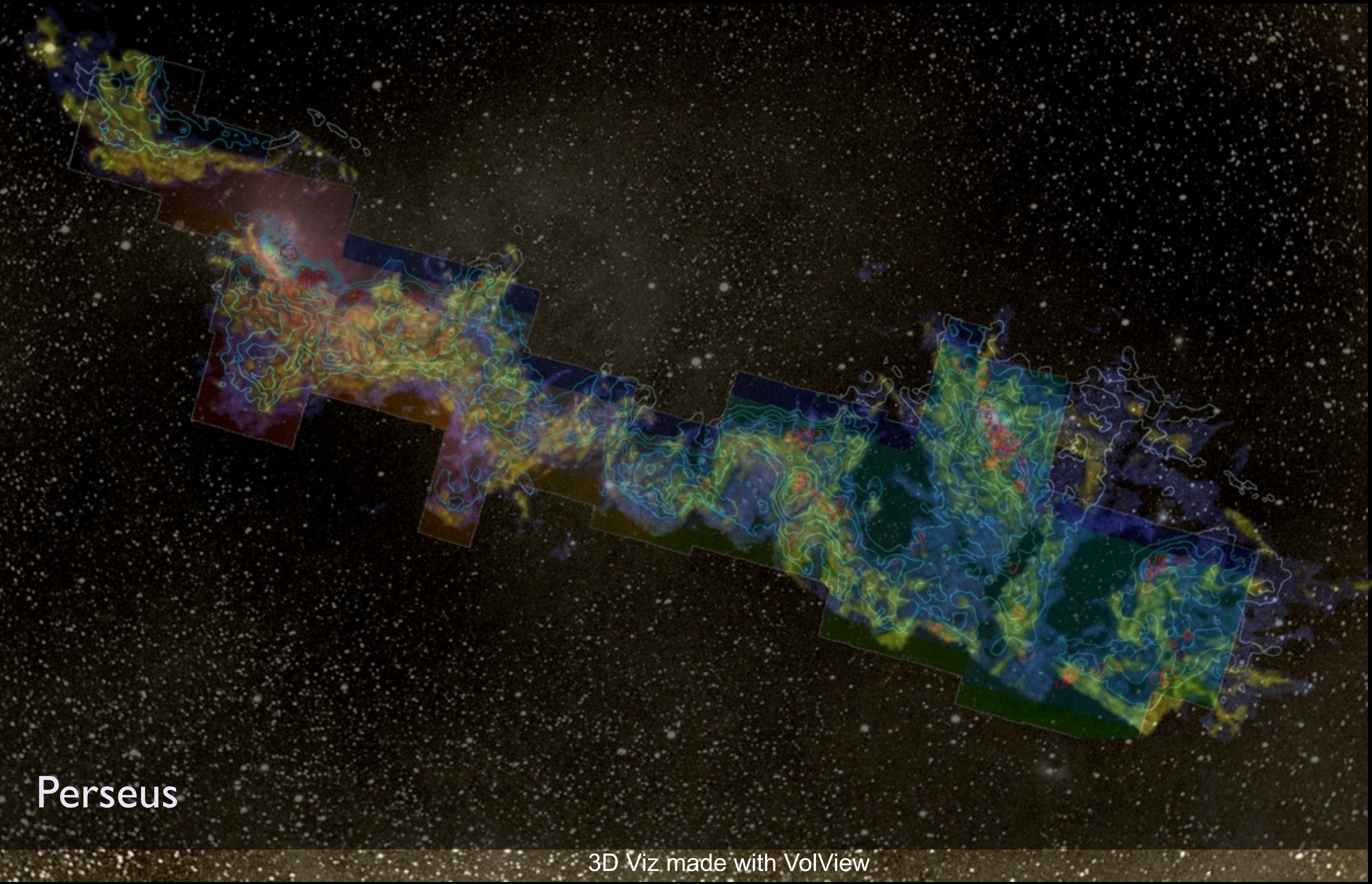
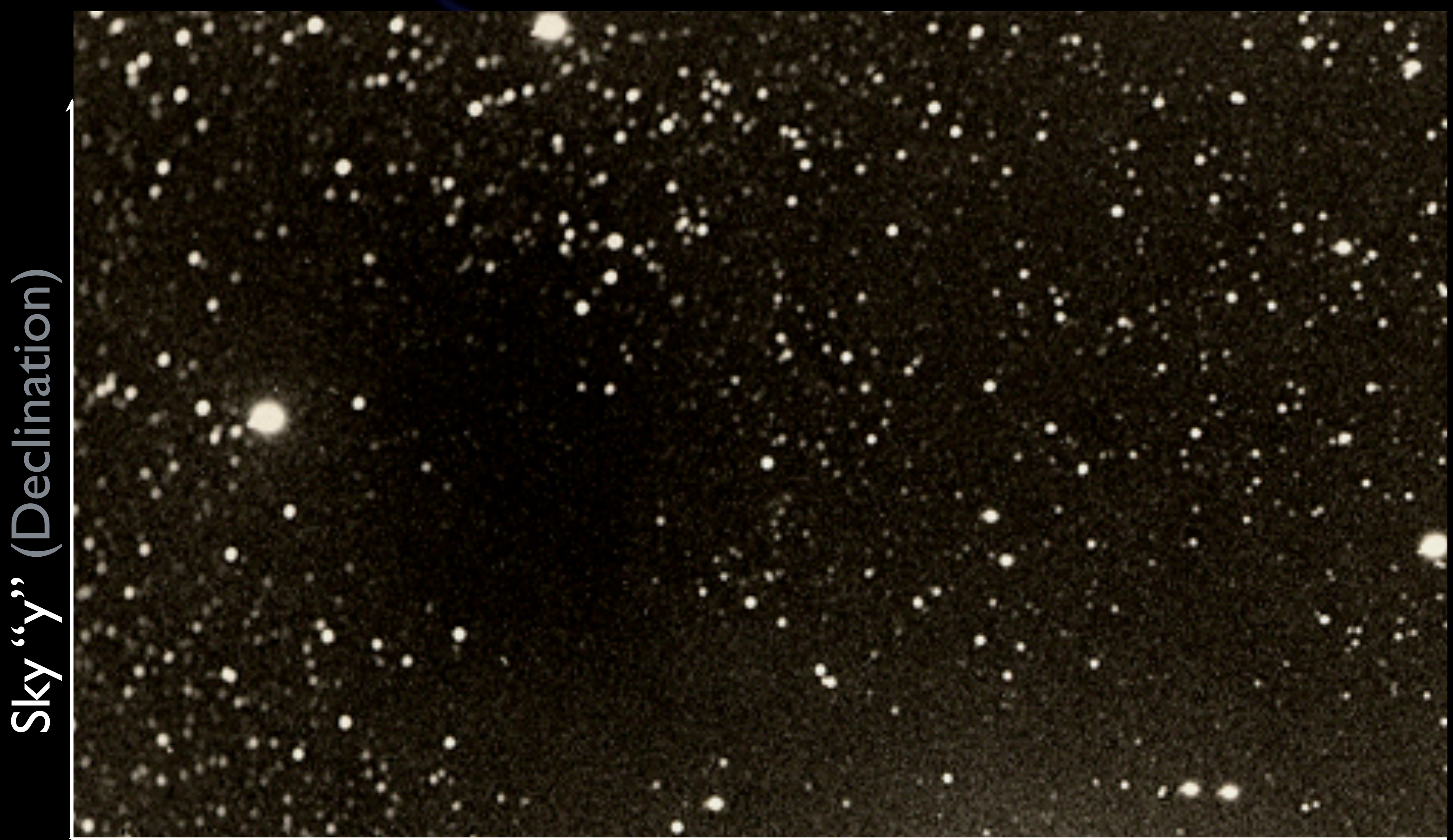
- Optical image (Barnard 1927)


Perseus
3D Viz made with VolView

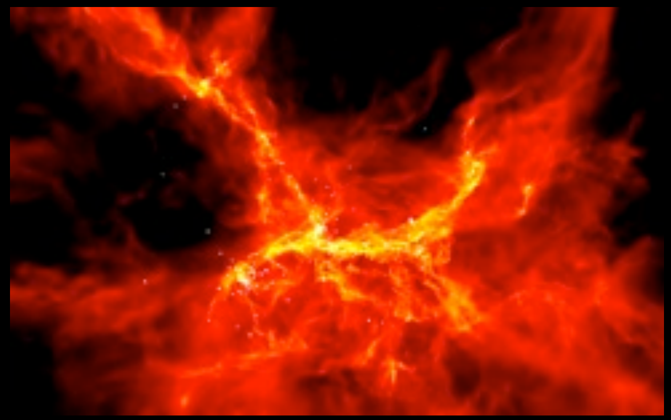
Real 3D space

3D rendering: [GE Healthcare]

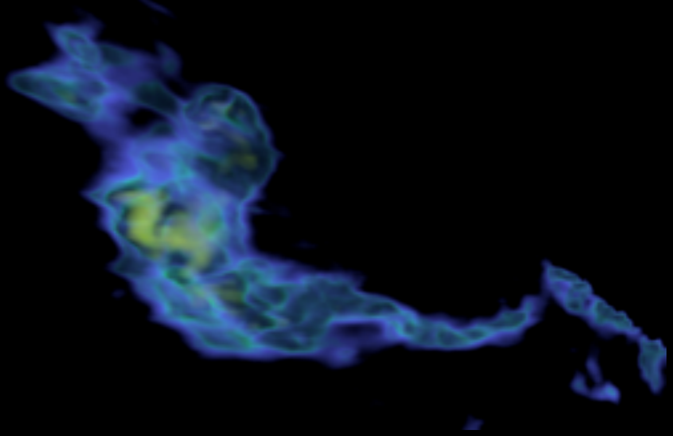
"Position-Position-Velocity" Space



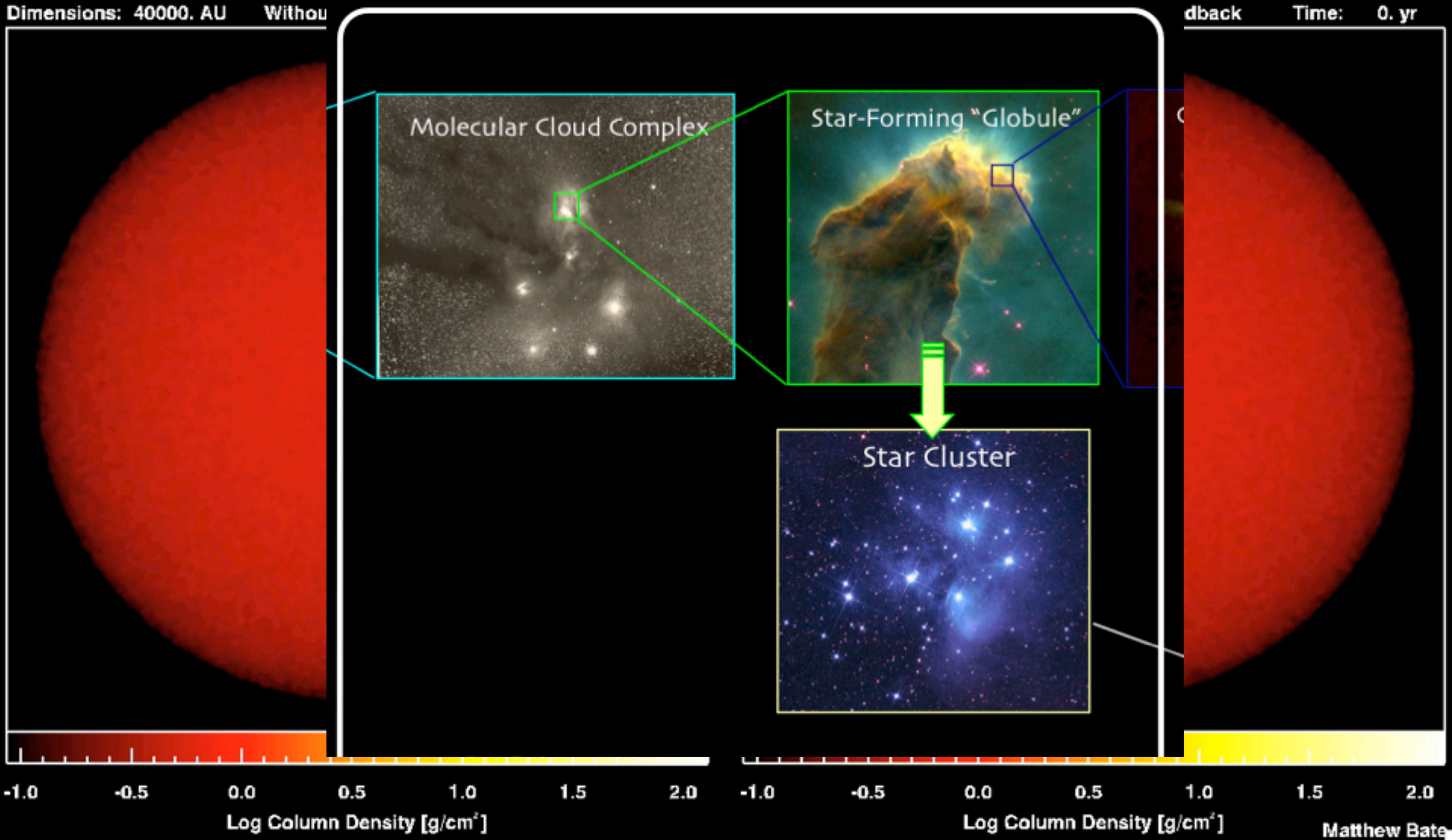
3D rendering: AstroMed / N. Holliman (U. Durham), using VolView (ITK-based) simulations



>2D observations

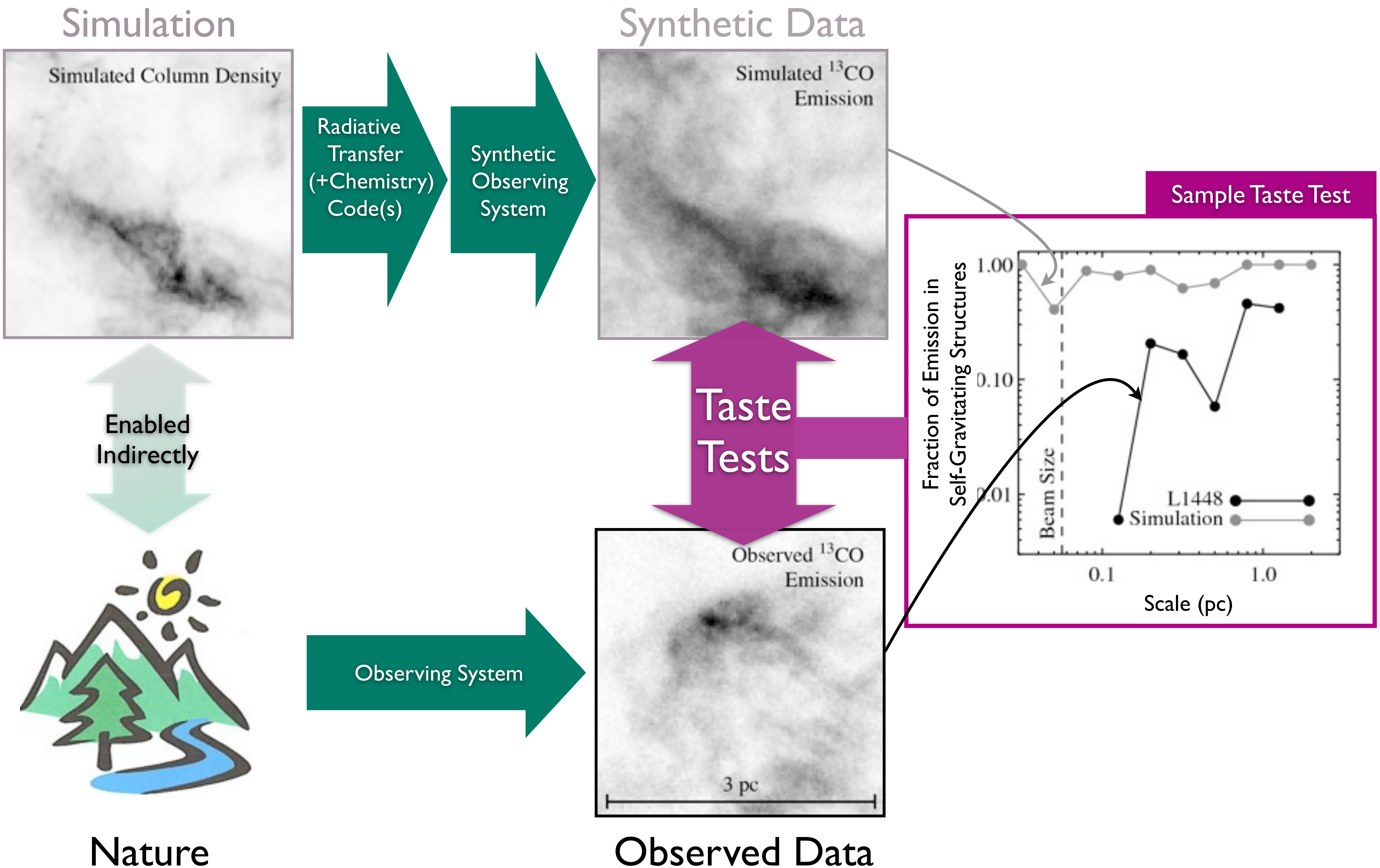


"Tasting" Magnetohydrodynamic Simulations



Simulations of Bate 2009

The Taste-Testing Process



"Seeing" and "Tasting"
The Role Self-Gravity in Star Formation

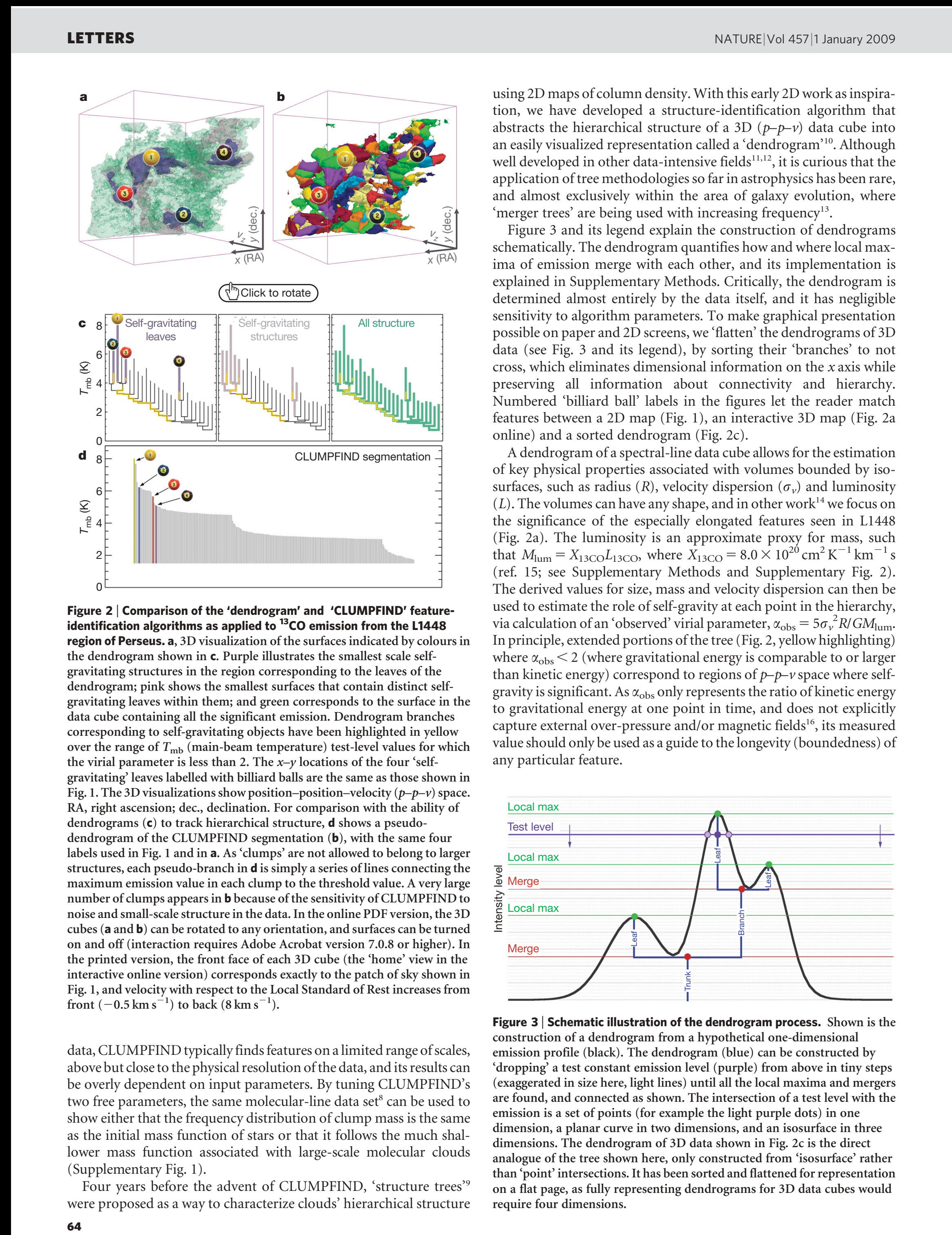


Figure 2 | **Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to ^{13}CO emission from the L1448 region of Perseus. a**, 3D visualization of the surfaces indicated by colours in the dendrogram shown in **c**. Purple illustrates the smallest scale self-gravitating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

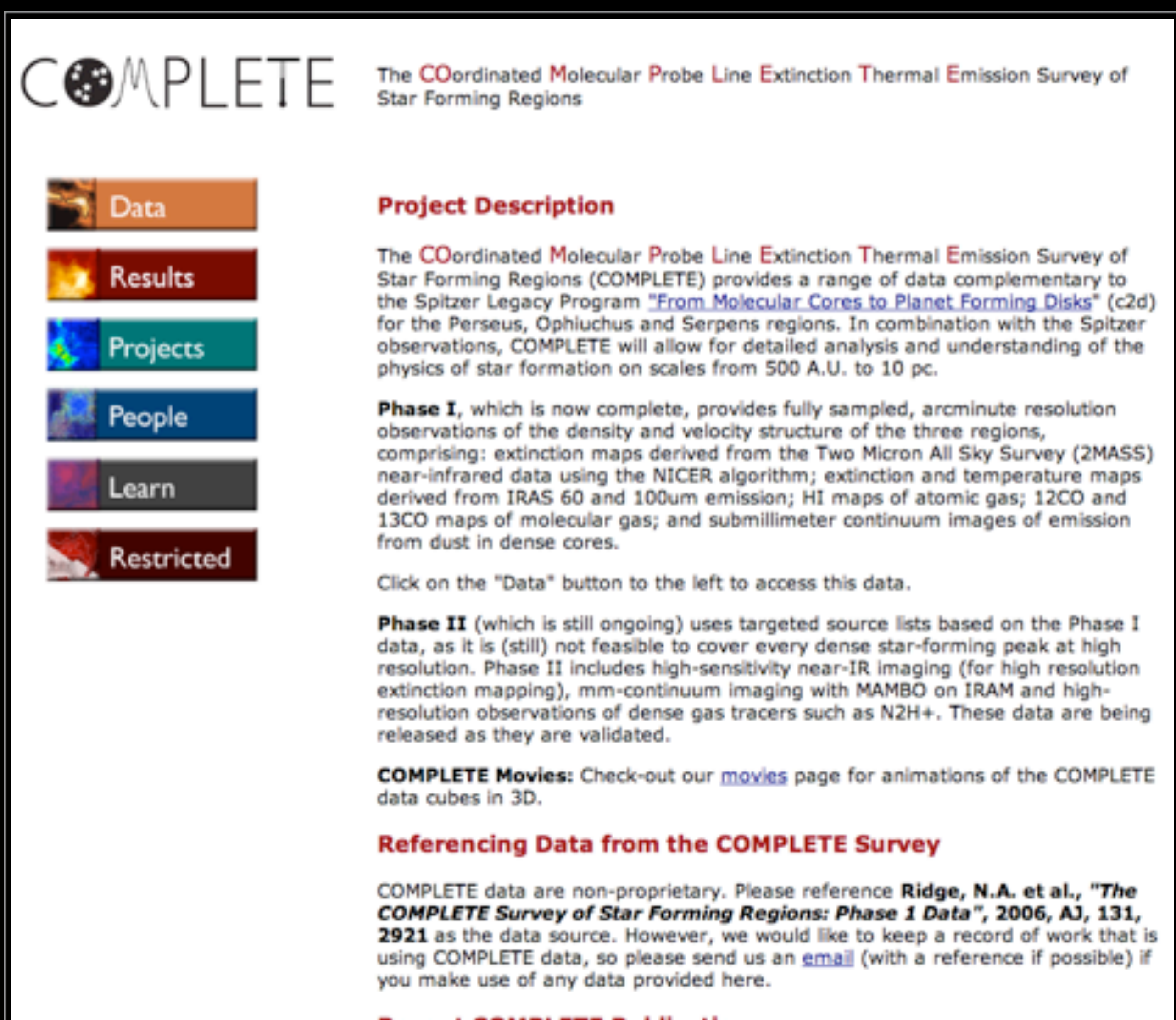
Goodman et al. *Nature*, 2009

The Scientists' Discovery Room
(now at SEAS)

movie courtesy Daniel Wigdor, equipment now in SDR lab at SEAS

Star Formation in the Interstellar Medium

"e-Science" (and Data Visualization)



COMPLETE

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Linking scientific data, publications, and communities

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SEAMLESS ASTRONOMY

About

The **Seamless Astronomy Group** at the **Harvard-Smithsonian Center for Astrophysics** brings together astronomers, computer scientists, information scientists, librarians and visualization experts involved in the development of tools and systems to study and enable the next generation of **online astronomical research**.

Current projects include research on the development of systems that seamlessly integrate scientific data and literature, the semantic interlinking and annotation of scientific resources, the study of the impact of social media and networking sites on scientific dissemination, and the analysis and visualization of astronomical research communities. Visit our project page to find out more.

Sponsors of Seamless Astronomy include NASA, NSF and Microsoft Research.

Contact us. For inquiries or questions, please email Sarah Block at sblock@cfa.harvard.edu. Alternatively

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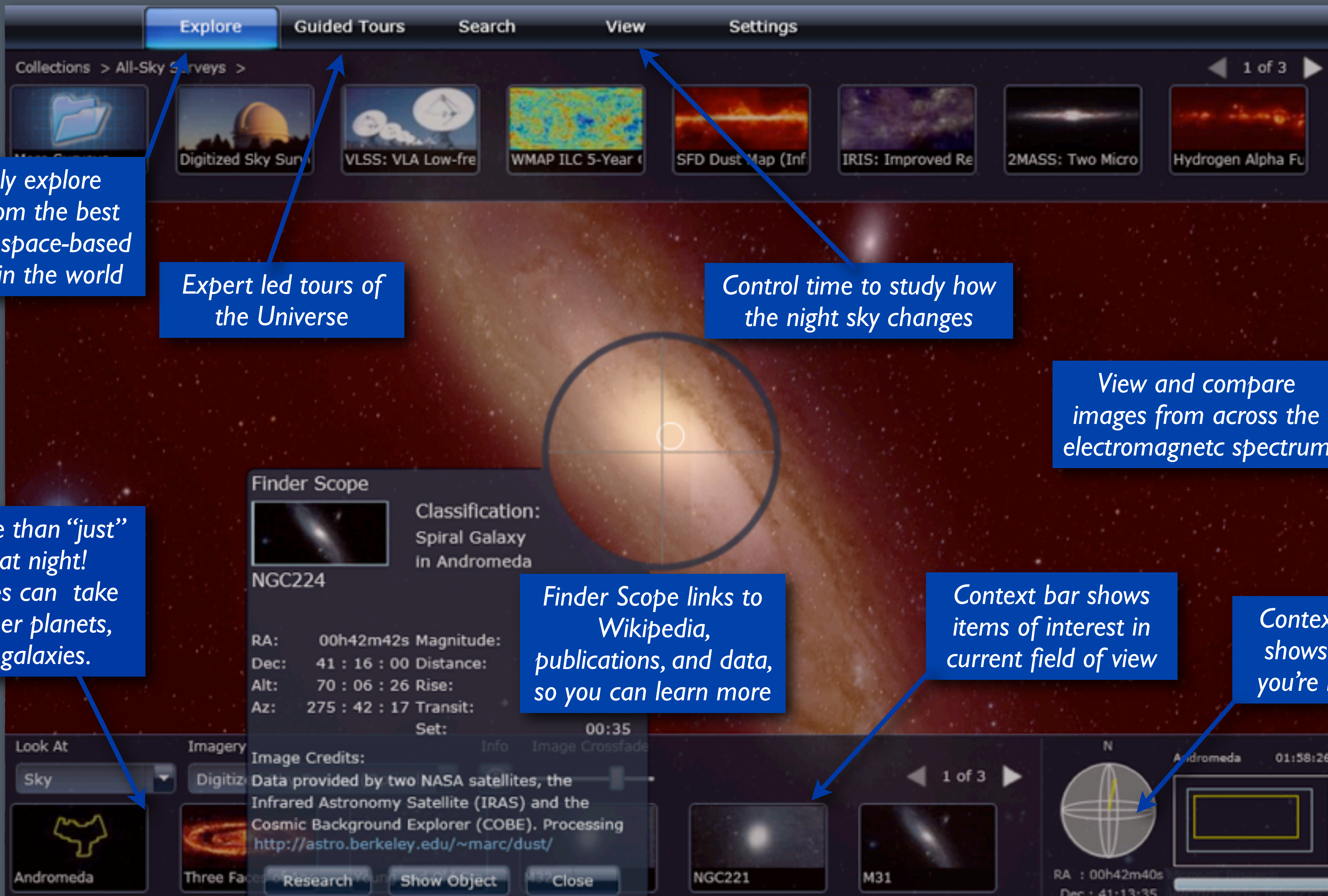
albertoconti: @thenakedshort but your argument can be reversed: supporting commercial crew now would have made #JWST science impossible.

albertoconti: RT @Unstrung: RT @jeff_foust Bolden says FY2013 NASA budget proposal will "adequately" support key priorities: SLS/MPCV, ISS/Comm'l Crew ...

WorldWide Telescope

created by Curtis Wong & Jonathan Fay (Microsoft Research)
Alyssa Goodman is "official astronomer/consultant/troublemaker" for WWT

Microsoft® Research
WorldWide Telescope



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http://www.spitzer.caltech.edu/Media/releases/ssc2003-06/ssc200

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Credit: NASA/JPL-Caltech/A. Noriega-Crespo (SSC/Caltech), Digital Sky Survey

HH46/47

This image from NASA's Spitzer Space Telescope transforms a dark cloud into a silky translucent veil, revealing the molecular outflow from an otherwise hidden newborn star. Using near-infrared light, Spitzer pierces through the dark cloud to detect the embedded outflow in an object called HH 46/47. Herbig-Haro (HH) objects are bright, nebulous regions of gas and dust that are usually buried within dark clouds. They are formed when supersonic gas ejected from a forming protostar, or embryonic star, interacts with the surrounding interstellar medium. These young stars are often detected only in the infrared.

The Spitzer image was obtained with the infrared array camera. Emission at 3.6 microns is shown as blue, emission from 4.5 and 5.8 microns has been combined as green, and 8.0 micron emission is depicted as red.

HH 46/47 is a striking example of a low-mass protostar ejecting a jet and creating a bipolar, or two-sided, outflow. The central http://www.flickr.com/photos/66496709@N00/3175344278/

flickr

Signed in as Alyssa_Goodman (1 new) Help Sign Out

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HH4647

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WWT Ambassadors: WorldWide Telescope For Interactive Learning

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Microsoft Research, WWT Creator

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Sarah Block
Web site development

Using WWT to give experts and learners access to the Universe

WWT Ambassadors Program

Recruiting, Vetting, Coordination

wwtambassadors.org

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About the WWT Telescope Ambassadors Program

WorldWide Telescope (WWT) is a rich visualization environment that functions as a virtual telescope, allowing anyone to make use of professional astronomical data to explore and understand the universe. As of early 2010, the new WWT Ambassadors Program is recruiting astronomically-literate volunteers, including retired scientists engineers—all of whom will be trained to be experts in using WWT as a teaching tool. Ambassadors will give volunteer presentations at public libraries, community centers, museums, and schools, demonstrating WWT's power to help laypeople visualize and understand our universe.

Read more

John Huchra's Universe

Submitted by patudom on Jan. 11

John Huchra, former president of the **American Astronomical Society**, passed away on October 8, 2010.

John's colleagues at the Harvard-Smithsonian Center for Astrophysics, in collaboration with the creators of WorldWide Telescope at Microsoft Research, have created a new, interactive, WWT Tour to honor John and his career. The Tour primarily focuses on John's quest to map the Universe in three dimensions. It is 12.5 minutes long.

The Tour is best experienced inside the WorldWide Telescope program itself. (**Note: You must have the version of WWT released on 1/13/2011 to view all of this Tour's content. You can download it from here.**) As viewed within the WWT program, the Tour content is interactive, allowing users to pause and explore the parts of the Universe featured in the tour, explore web hyperlinks, and more. For those who do not have the desktop client, the Tour has been posted as a video as well.

Video (Interactive WWT features will be disabled)

John Huchra's Universe

Friends of John Huchra have released a new WWT Tour to honor John and his work. The Tour primarily focuses on John's quest to map the Universe in three dimensions. You can view the Tour here.

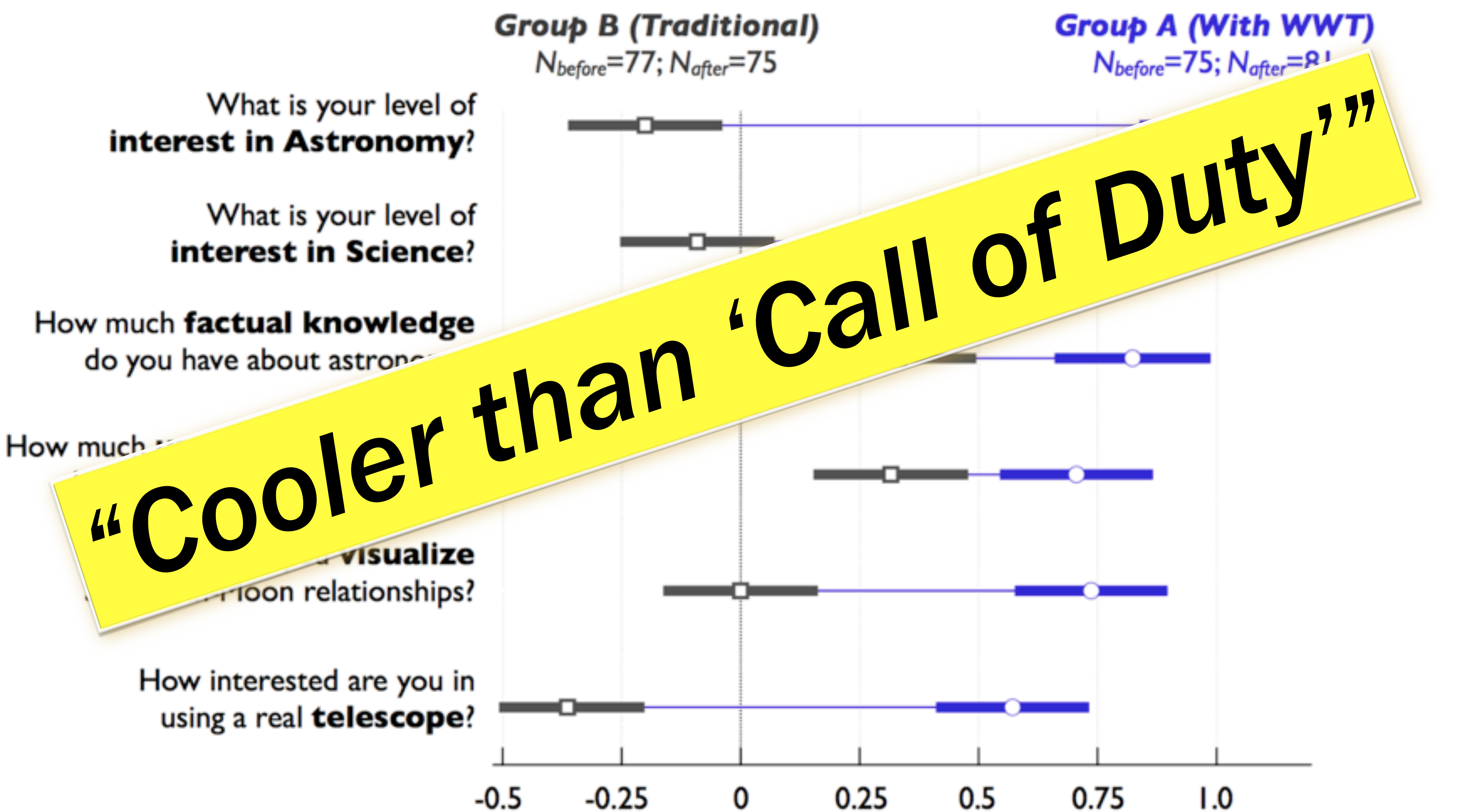
Upcoming

- Cyberlearning Tools for STEM Education Conference
  Mar. 8 - Mar. 9
- Cambridge Science Festival
  Apr. 30 - May. 10

Clarke Middle School, Lexington, MA (WWT Ambassadors Pilot School)

Gains in Student Interest and Understanding

("Traditional Way" vs "WWT Way")



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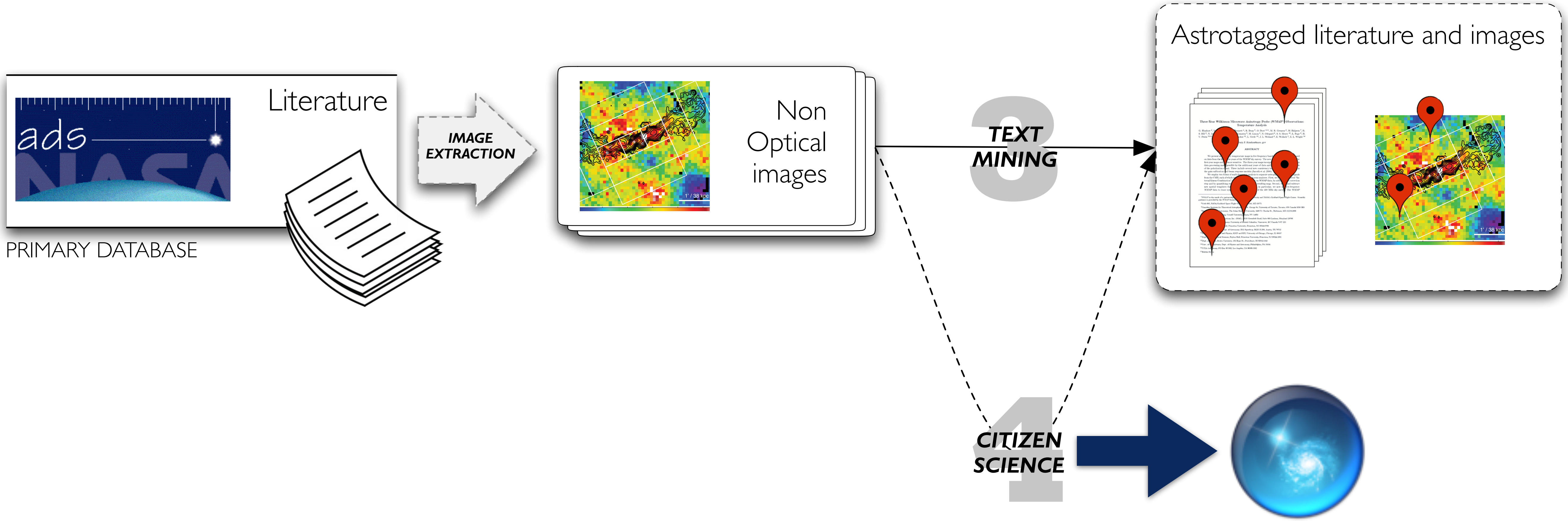
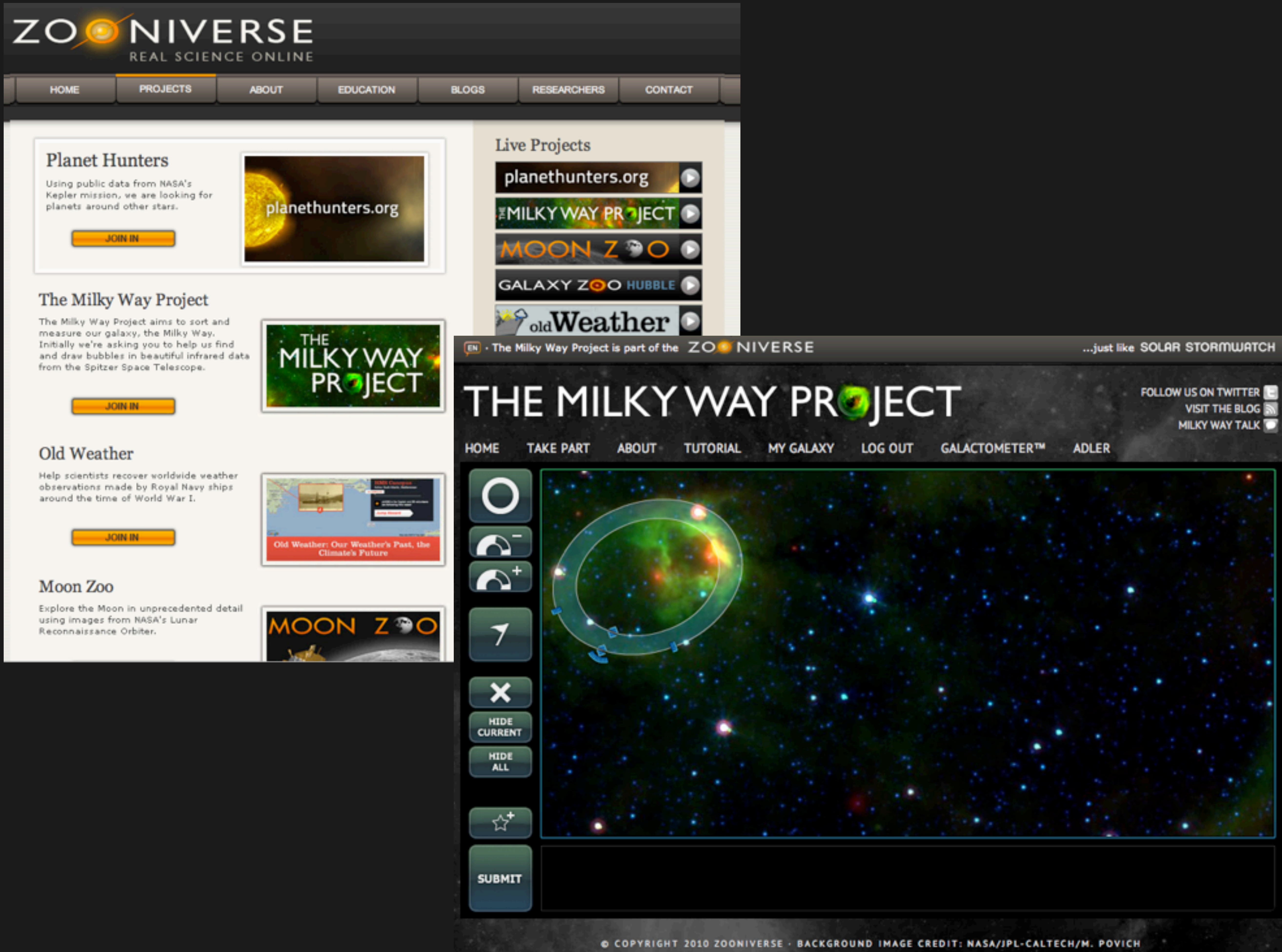
Research+Education

Citizen Science in ADS All Sky Suvey (Coming Soon...)

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The Milky Way Project aims to sort and measure our galaxy, the Milky Way. Initially we're asking you to help us find and draw bubbles in beautiful infrared data from the Spitzer Space Telescope.
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THE MILKY WAY PROJECT
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Help scientists recover worldwide weather observations made by Royal Navy ships around the time of World War I.
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Old Weather: Our Weather's Past, the Climate's Future
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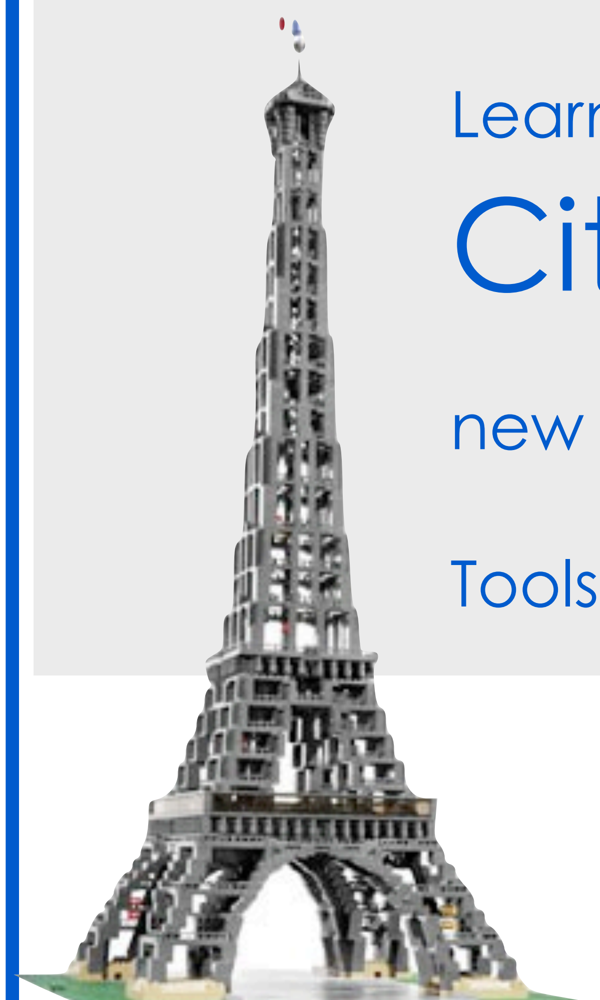
Cool Tools 2011.1

Online Astronomy Research Tools from the CfA

Come have COFFEE & BAGELS
from 10-11 AM in PHILLIPS on TUESDAY, 11/22



Learn more about ADS Labs, options for valuable Data Citations, the ADS All-Sky Survey, cool new SED and Data-Mining Tools, WorldWide Telescope, and More!

...and you might even find out why a Lego Eiffel Tower is on this poster.