Seamless Astronomy
Enabled by WWT

Alyssa A. Goodman
Harvard-Smithsonian Center for Astrophysics
The Slide to Rule them All...

**Collaborators:**
Alberto Accomazzi, Douglas Burke, Raffaele D'Abrusco, Rahul Davé, Christopher Erdmann, Pepi Fabbiano, Alyssa Goodman, Jay Luker, Gus Muench, Michael Kurtz & Alberto Pepe (Harvard-Smithsonian CfA); Eli Bressert (U. Exeter); Tim Clark (Massachusetts General Hospital/Harvard Medical School); Mercé Crosas (Harvard Institute for Quantitative Social Science; Chris Borgman (UCLA); Jonathan Fay & Curtis Wong (Microsoft Research)
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 you can contact or visit us at:

SEAMLESS ASTRONOMY TEAM  
HARVARD–SMITHSONIAN CENTER FOR ASTROPHYSICS  
60 GARDEN STREET, MS 42  
CAMBRIDGE, MA 02138
Microsoft® Research
WorldWide Telescope

Expert led tours of the Universe

View and compare images from across the electromagnetic spectrum

Finder Scope links to Wikipedia, publications, and data, so you can learn more

Control time to study how the night sky changes

Context bar shows items of interest in current field of view

Context globe shows where you’re looking.

Much more than “just” the sky at night! 3D features can take you to other planets, stars & galaxies.

Seamlessly explore imagery from the best ground and space-based telescopes in the world

Experience WWT at worldwidetelescope.org
SAMP
(Simple Application Messaging Protocol)

FANTASTIC & ESSENTIAL, but not today’s focus.
FANTASTIC & ESSENTIAL, but not today’s focus
(My) Research
Perseus

Serpens

Ophiuchus

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

www.cfa.harvard.edu/COMPLETE
tinyurl.com/completepapers
http://www.worldwidetelescope.org/COMPLETE/WWTCoverageTool.htm
A True Story

Hope Chen
Brand-new Harvard Grad Student
Project: “COMPLETE” Ophiuchus
WISE Image of Rho Oph

From: Alyssa Goodman
Date: Wed, 28 Sep 2011 at 11:54am

Hi Hope,

In preparing a talk for tomorrow, I "Googled" "Star Formation in Ophiuchus," just to see what would happen. Amazingly, I found this: http://wise.ssl.berkeley.edu/gallery_rho_ophiuchi.html.

Check out the fabulous data we can have from WISE!

Best,

Alyssa
WISE - Multimedia Gallery: Rho Ophiuchi

Rho Ophiuchi cloud complex - Wikipedia, the free encyclopedia

WTT Guided Tour

Download Options:
- small (81K): 400 x 392 JPEG
- medium (351K): 800 x 784 JPEG
- large (1.10M): 1600 x 1569 JPEG
- original (113K): 10300 x 10100 TIF

Packaged Image:
- Packaged image: 1.58M, 2400 x 3000 JPG
- Packaged image: 42.5M, 8 x 10 in., PDF

April 1, 2011 - WISE Unveils a Treasure Trove of Beauty
Check out the WorldWide Telescope

Many objects featured in WISE’s infrared images look radically different in visible light. You can check out these differences yourself by using the WorldWide Telescope (WWT). You can also use WWT to compare WISE images to other data sets from missions like Spitzer, Hubble, Chandra or previous infrared surveys. Visualizing WISE images in WWT helps place them in their broader context in the sky.

The WorldWide Telescope (WWT) is a free Web 2.0 visualization software environment that enables your computer to function as a virtual telescope—bringing together imagery from the world's best ground- and space-based telescopes for the exploration of the universe.

The WorldWide Telescope can be downloaded or used online for free from www.worldwidetelescope.org.

To Load WISE Images into the WWT:

1. Download the WISE image onto your computer.
2. Open WWT. On the bottom of the screen, make sure you are looking at the "Sky" and have the "Digitized Sky Survey" as the imagery set.
3. Click on Explore --> Open --> Image, to select the WISE image that you wish to load.
4. Use the "Image Crossfade" to compare the WISE infrared view with the visible light view.
5. You can also compare WISE images with previous infrared surveys (such as IRAS) by clicking on the "Image Comparison" button.
Choosing ADS link gives...

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<tr>
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<td>del Valle, María Victoria; Romero, Gustavo E.; Luque-Escamilla, Pedro Luis; Martí, Josep; Ramón Sánchez-Sutil, Juan</td>
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<td>Herschel Measurements of Molecular Oxygen in Orion</td>
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<td>Goldsmith, Paul F.; Liseau, René; Bell, Tom A.; Black, John H.; Chen, Jo-Hsin; Hollenbach, David; Kaufman, Michael J.; Li, Di; Lis, Dariusz C.; Melnick, Gary; and 25 coauthors</td>
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<td>Jenkins, Edward B.; Tripp, Todd M.</td>
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<td>Similarity Between the C18O (J = 1-0) Core Mass Function and the Initial Mass Function (IMF) in the S140 Region</td>
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<td>The Age of the Local Interstellar Bubble</td>
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Starting with ADS Labs gives...
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<th>Rank</th>
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<tr>
<td>1</td>
<td>2009ApJS..181..321E The Spitzer c2d Legacy Results: Star-Formation Rates and Efficiencies; Evolution and Lifetimes</td>
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<td>2</td>
<td>1998A&amp;A...336..150M The initial conditions of star formation in the rho Ophiuchi main cloud: wide-field millimeter continuum mapping</td>
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<td>3</td>
<td>1987IAUS..115....1L Star formation - From OB associations to protostars</td>
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<td>4</td>
<td>1993AJ....106.2005G The multiplicity of T Tauri stars in the star forming regions Taurus-Auriga and Ophiuchus-Scorpius: A 2.2 micron speckle imaging survey</td>
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<td>5</td>
<td>1987ApJ...312..788A Spectral evolution of young stellar objects</td>
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<td>6</td>
<td>1993ApJ...406..122A Submillimeter continuum observations of Rho Ophiuchi A - The candidate protostar VLA 1623 and prestellar clumps</td>
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<td>7</td>
<td>2007ApJ...663.1069F Infrared Extinction toward Nearby Star-forming Regions</td>
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<td>8</td>
<td>1995ApJ...443..625S A lunar occultation and direct imaging survey of multiplicity in the Ophiuchus and Taurus star-forming regions</td>
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<tr>
<td>9</td>
<td>1978ApJ...224..857E A study of the Taurus dark cloud complex</td>
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Also yesterday...

Chris Beaumont
Hawaii-Harvard Grad Student
Proposal: M17 Polarimetry
Author: "Dotson" Polarimetry - Most relevant

1. 2000PASP..112.1215H A Primer on Far-Infrared Polarimetry
   Hildebrand, R. H.; Davidson, J. A.; Dotson, J. L.; Dowell, C. D.; Novak, G.; Vaillancourt, J. E.
   Matches in Abstract / Matches in fulltext

2. 2000ApJS..128..335D Far-Infrared Polarimetry of Galactic Clouds from the Kuiper Airborne Observatory
   Dotson, Jessie L.; Davidson, Jacqueline; Dowell, C. Darren; Schleuning, David A.; Hildebrand, Roger H.
   Matches in Abstract / Matches in fulltext

3. 1998ApJ...504..588D Submillimeter Array Polarimetry with Hertz
   Dowell, C. Darren; Hildebrand, Roger H.; Schleuning, David A.; Vaillancourt, John E.; Dotson, Jessie L.; Novak, Giles; Renbarger, Tom; Houde, Martin
   Matches in Abstract / Matches in fulltext

4. 2010ApJS..186..406D 350 μm Polarimetry from the Caltech Submillimeter Observatory
   Dotson, Jessie L.; Vaillancourt, John E.; Kirby, Larry; Dowell, C. Darren; Hildebrand, Roger H.; Davidson, Jacqueline A.
   Matches in Abstract / Matches in fulltext

5. 2004ApJ...604..717H Tracing the Magnetic Field in Orion A
   Houde, Martin; Dowell, C. Darren; Hildebrand, Roger H.; Dotson, Jessie L.; Vaillancourt, John E.; Phillips, Thomas G.; Peng, Ruisheng; Bastien, Pierre
   Matches in Abstract / Matches in fulltext

   Houde, Martin; Bastien, Pierre; Dotson, Jessie L.; Dowell, C. Darren; Hildebrand, Roger H.; Peng, Ruisheng; Phillips, Thomas G.; Vaillancourt, John E.; Yoshida, Hiroshige
   Matches in Abstract / Matches in fulltext

7. Other object (15)
   GAL CENTER (7)
   SGR B2 (7)
   M 17 (6)
   180° 78 (4)
   OMC-1 (4)
   OIII MOL CLOUD (4)
   SAGITTARIUS A REGION (4)

8. Radio Source (7)
   Star (5)
   Infrared Source (4)
   Galaxy (1)
back to...

COMPLETE
many thanks to A. Accomazzi, R. Davé, M. Kurtz, G. Di Milia, A. Pepe
Yes, this is Google Sky... WWT version coming soon!
c.2012

The ADS All-Sky Survey

A. Goodman (CfA)
A. Muench (CfA)
A. Pepe (CfA)
with A. Accomazzi (CfA),
A. Conti (STScI),
R. Davé (CfA)
T. Boch (CDS),
J. Fay (MSR),
D. Hogg (NYU)
The Future
universe3d.org
Perseus

3D Viz made with VolView

Astronomical Medicine @ IIG

COMPLETE
Projects

Seamless integration of scientific data and literature
Astronomical data artifacts and publications exist in disjointed repositories. The conceptual relationship that links data and publications is rarely made explicit. In collaboration with ADS and ADSlabs, and through our work in conjunction with the Institute for Quantitative Social Science (IQSS), we are working on developing a platform that allows data and literature to be seamlessly integrated, interlinked, mutually discoverable.

Astronomy Dataverse
Astronomers use, peruse and produce vast amounts of scientific data. Making these data publicly available is important because it supports the reproducibility of results, and ensures their long term preservation and reuse. While raw astronomical data are normally stored and made public available via large-scale archives, reduced data are often left out entirely from both astronomical archives and related publications.

In a pilot study in 2011, we are evaluating the Dataverse, an open data archive hosted by Harvard University and managed by the Institute for Quantitative Social Science (IQSS), as a project-based repository for the storage, access, and citation of reduced astronomical data. We have interviewed a set of 10 astronomers about their needs, and the prototype CfA Dataverse is now online.

WorldWide Telescope (WWT)
WorldWide Telescope provides a rich contextual visualization environment for astronomical data. Our group collaborates with the WWT Team at Microsoft Research both to enrich WWT for use in research as well as in teaching. On the research end, we seek to integrate WWT “Seamlessly” with VAO-sponsored projects, as well as with ADS Labs. On the teaching end, we founded and now run the WorldWide Telescope Ambassadors outreach effort.
The whole-Galaxy CO survey presented in Dame et al. (2001) is a composite of 37 separate surveys that are described and numbered in Table 1 of the paper. The data from most of these surveys can be accessed by clicking on the survey number in the map below, which is Figure 1 from the paper. Larger composites of these individual surveys are available from the link below. More >>
Pinky: "Gee, Brain, what do you want to do tonight?"

The Brain: "The same thing we do every night, Pinky—try to take over the world!"

Pinky: "universe3d.org?"
Tools for Taking over the World:

WWT + more SAMP-enabled tools
+ Linked Views (+...)

Jan Vermeer. The Astronomer. (1668)
The Dendrogram Algorithm by Erik Rosolowsky; Applet by Douglas Alan

http://am.iic.harvard.edu/index.cgi/DendroStar/applet
COMPLETE Perseus Column Density

(Dust Emission, Extinction & Gas Emission)

Seamless Astronomy
Enabled by WWT

Alyssa A. Goodman
Harvard-Smithsonian Center for Astrophysics
The “travel” analogy seems to resonate best...
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 $(p-v)$ data cube into an easily visualized representation called a ‘dendrogram’. Although well-developed in other data-intensive fields, it is curious that the application of free methodologies so far in astrophysics has been rare, and almost exclusively within the arena of galaxy evolution, whereas ‘merger trees’ are being used with increasing frequency.

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’s spectral-line data cube allows for the estimation of key physical properties associated with volumes bounded by isosurfaces, such as radius ($R$), velocity dispersion ($\sigma$), and luminosity ($L$). The volumes can have any shape, and in other work 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 $M_{\odot} = \frac{L_{\odot}}{2 \times 10^2}$ (Jy km s$^{-1}$), and $R/km$. In principle, extended portions of the tree (Fig. 2c, yellow highlighting) where $\sigma < 2\sigma$ (where gravitational energy is comparable to or larger than kinetic energy) correspond to regions of $p-v$ space where self-gravity is significant. As $\sigma$ only represents the ratio of kinetic energy to gravitational energy at one point in time, and does not explicitly capture external pressure and/or magnetic fields, its measured value should only be used as a guide to the longevity (boundness) of any particular feature.
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 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’ 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–y–z) data cube into an easily visualized representation called a ‘dendrogram’. Although well-developed in other data-ontology fields, 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.

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 refer to the dendrograms of 3D data (see Fig. 3 and its legend), by sorting their ‘branches’ in order of decreasing mass. The dendrogram is determined almost entirely by the data itself, and it has negligible sensitivity to algorithm parameters. The dendrogram (blue) can be constructed by calculating the virial parameter, where \( T / 2 \) is the luminosity at the virial point, and it has negligible sensitivity to algorithm parameters. The dendrogram (blue) can be constructed by calculating the virial parameter, where \( T / 2 \) is the luminosity at the virial point, and it has negligible sensitivity to algorithm parameters.

In principle, extended portions of the tree (Fig. 2, yellow highlighting) are found, and connected as shown. 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. The dendrogram (blue) can be constructed by calculating the virial parameter, where \( T / 2 \) is the luminosity at the virial point, and it has negligible sensitivity to algorithm parameters. The dendrogram (blue) can be constructed by calculating the virial parameter, where \( T / 2 \) is the luminosity at the virial point, and it has negligible sensitivity to algorithm parameters.