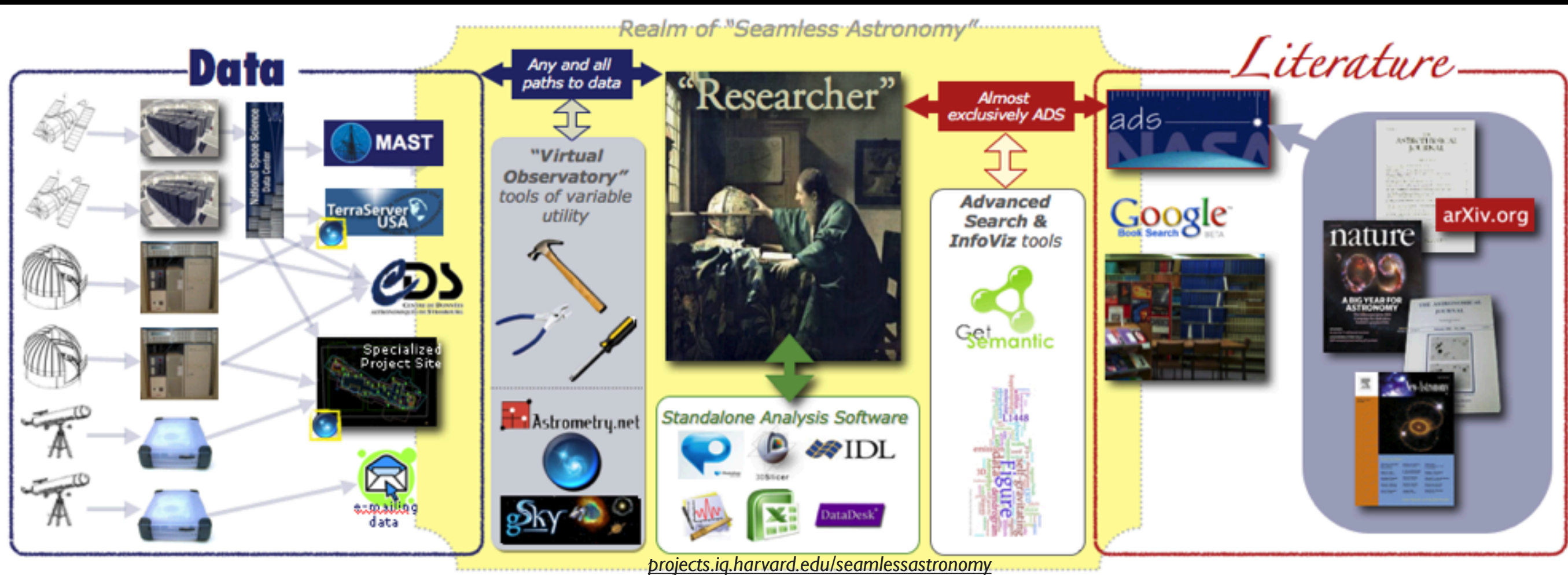


# Seamless Astronomy

## How astronomers share, explore & discover



Alyssa A. Goodman  
Harvard-Smithsonian Center for Astrophysics

with

Alberto Accomazzi, Douglas Burke, Raffaele D'Abrusco, Rahul Davé, Christopher Erdmann, Pepi Fabbiano, 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 (US) Backstory


2001 ..... 2008 (2010)

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Proposal Preparation and

## Management and Operation of the Virtual Astronomical Observatory



CONTACTS

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Eileen D. Friel	<a href="mailto:efriel@nsf.gov">efriel@nsf.gov</a>

PROGRAM GUIDELINES

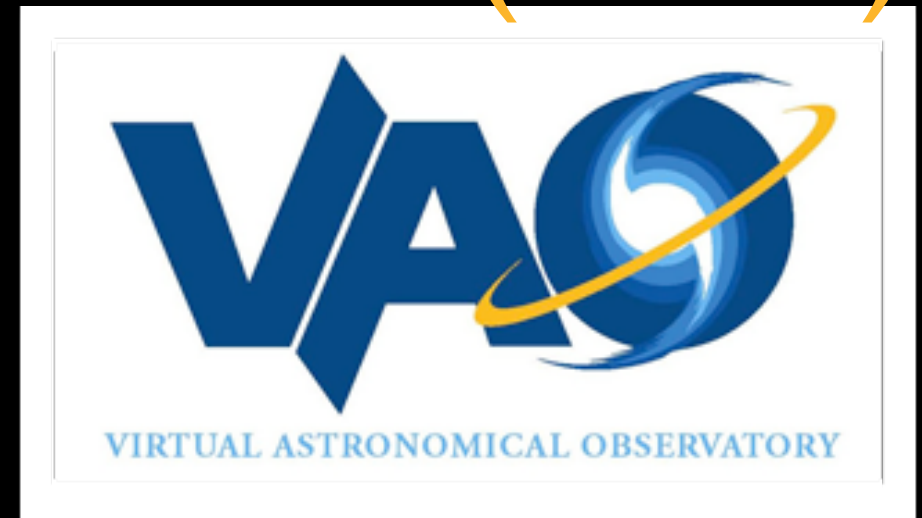
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Please be advised that the NSF Proposal & Award Policies & Procedures (PAPPG) includes revised guidelines to implement the mentoring pro... the America COMPETES Act (ACA) (Pub. L. No. 110-69, Aug. 9, 2007.) specified in the ACA, each proposal that requests funding to support postdoctoral researchers must include a description of the mentoring that will be provided for such individuals. Proposals that do not comp... this requirement will be returned without review (see the PAPP Guide Grant Proposal Guide Chapter II for further information about the implementation of this new requirement).





2001 ..... 2008 (2010)



and meanwhile...




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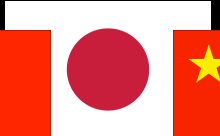
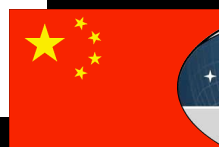




Virtual Observatory Software for Astronomers

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## Welcome to AstroGrid

AstroGrid is the doorway to the Virtual Observatory (VO). We provide a suite of dependable astronomical resources from around the world, find in VOSpace, query databases, plot and manipulate tables, cross-match catalogues, and to automate sequences of tasks. Tools from other Euro-VO projects inter-operate with







The Aladin Sky Atlas

Download Aladin on your machine

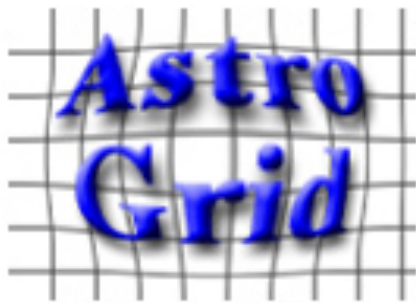
Start Aladin applet

Jump to Aladin previewer

New: Aladin release 6 - April 2009  
Measurement browser by interactive histogram, Outreach mode, Full screen, SAMP compatible, RICE compression support, etc...

New: The Aladin manual - April 2009 - The full user manual in English and French...

Description Aladin is an interactive software sky atlas allowing the user to visualize digitized astronomical images, superimpose entries from astronomical catalogues or databases, and interactively access related data and information from the Simbad database, the VizieR service and other archives for all known sources in the field (see available data). Created in 1999, Aladin has become a widely-used VO portal capable of addressing challenges such as locating data of interest, accessing and exploring distributed datasets, visualizing multi-wavelength data. Compliance with existing or emerging VO standards, interconnection with other visualisation or analysis tools, ability to easily compare heterogeneous data are key topics allowing Aladin to be a powerful data exploration and integration tool as well as a science enabler. The Aladin sky atlas is available in three modes: a Java Standalone application, a Java applet interface and a simple previewer.





~~The~~ VO

From: Abstract Service <ads@cfa.harvard.edu>  
 Subject: myADS Notification (Astronomy database)  
 Date: March 23, 2010 12:19:23 AM EDT  
 To: Alyssa Goodman



myADS Personal Notification Service  
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 Date: March 26, 2010 3:52:30 AM EDT  
 To: Alyssa Goodman  
 Reply-To: Kayak Alert <alert@kayak.com>



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Instead, we are building an integrated "seamless" virtual observatory





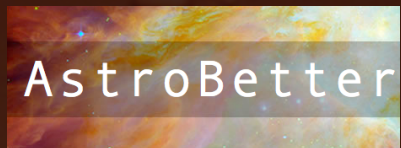
*How?*



# Literature



WIKIPEDIA  
The Free Encyclopedia



Blogs, Wikis, etc.

# Data



“Registries”



DataScope

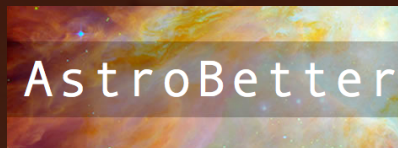
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# Literature



WIKIPEDIA  
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Blogs, Wikis, etc.

# "Seamless Astronomy" (Tools)



WorldWide Telescope



TOPCAT



ds9



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# Data



"Registries"



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# Literature



# "Seamless Astronomy" (Tools)



# Data



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# Literature



Blogs, Wikis, etc.

# "Seamless Astronomy" (Tools)



SAMP



# Data



"Registries"



DataScope

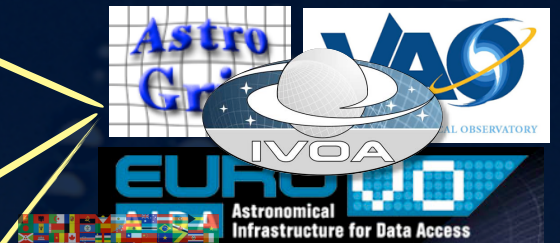
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# Literature

# "Seamless Astronomy" (Tools)

# Data



Registries"



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# SAMP

(Simple Application Messaging Protocol)

The image shows a desktop environment with three overlapping windows representing astronomical software:

- Aladin v6.0** (left): A window with a French flag icon. It displays a grayscale astronomical image of a star-forming region with red triangles marking specific objects. The title bar reads "Aladin v6.0 \*\*\* BETA VERSION (based on v6.021) \*\*\*".
- Microsoft WorldWide Telescope** (right): A window with an American flag icon. It shows a 3D view of a star-forming region with white circles highlighting various stars. The title bar reads "Microsoft WorldWide Telescope".
- TOPCAT** (bottom): A window with a British flag icon. It displays a scatter plot of red data points. The plot has a y-axis ranging from 68.15 to 68.30. The title bar reads "TOPCAT".

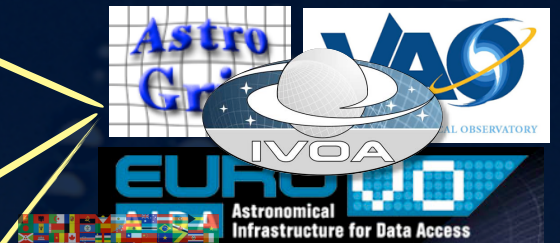
[link](#) to 12/2010 IVOA recommendation



# Literature

# "Seamless Astronomy" (Tools)

# Data



Registries"



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Astronomy

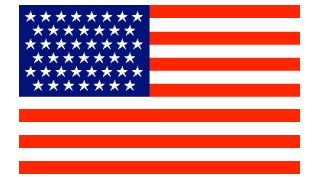
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### Sort by

- Most recent
- Most relevant
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### Explore the field

- What people are reading
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ADS Labs/Seamless Astronomy Core Collaboration  
 A. **Accomazzi**, A. Goodman, M. **Kurtz**, R. **Davé**, J. Luker, G. Muench, A. Pepe





## zeeman effect ch - *Most recent*

[Export to ADS Classic](#)Object:  Other object [X] OR  Nebula [X]

### FILTER BY:

#### Authors

- Uitenbroek, H (4)
- Amano, T (2)
- Angel, J (2)
- Asensio Ramos, A (2)
- Balasubramaniam, K (2)



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#### Archives

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#### SIMBAD Objects

- Other object (3)
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 NGC 7027 (1)

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- SIMBAD Info
- World Wide Telescope
- Aladin applet

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#### Refereed status

#### Dates

3. [2010ApJ...716L...1A](#) **The J = 1-0 Transitions of 12CH+, 13CH+, and 12CD+**  
Amano, T.  
*The Astrophysical Journal Letters, Volume 716, Issue 1, pp. L1-L3 (2010). Jun 2010*
4. [2009ApJ...705L.176S](#) **Detection of the Zeeman Effect in the 36 GHz Class I CH3OH Maser Line with the EVLA**  
Sarma, A. P.; Momjian, E.  
*The Astrophysical Journal Letters, Volume 705, Issue 2, pp. L176-L179 (2009). Nov 2009*
11. [2003A&A...412..513B](#) **The molecular Zeeman effect and diagnostics of solar and stellar magnetic fields. II. Synthetic Stokes profiles in the Zeeman regime**  
Berdyugina, S. V.; Solanki, S. K.; Frutiger, C.  
*Astronomy and Astrophysics, v.412, p.513-527 (2003) Dec 2003*
12. [2000PASP..112..873W](#) **Magnetism in Isolated and Binary White Dwarfs**  
Wickramasinghe, D. T.; Ferrario, Lilia  
*The Publications of the Astronomical Society of the Pacific, Volume 112, Issue 773, pp. 873-924. Jul 2000*





# WWT/Seamless Astronomy Core Collaboration

J. **Fay** (MSR), A. Goodman (CfA), G. Muench (CfA), C. **Wong** (MSR)

“shift-click”  
on object



**Finder Scope**



Classification:  
Planetary Nebula  
in Cygnus

NGC7027

RA:	21h07m01s	Magnitude:	10.5
Dec:	42 : 14 : 10	Distance:	n/a
Alt:	-02 : 33 : 41	Rise:	23:50
Az:	342 : 18 : 46	Transit:	09:40
		Set:	19:35

Image Credits:  
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Info  
<http://gsss.stsci.edu/Acknowledgements/DataCo>

Research Show Object Close

Look At: Sky

Imagery: Digitized Sky Survey (Color)

Cygnus

NGC7027

N

Cygnus 00:03:37



RA : 21h07m02s  
Dec : 42:14:09





NGC 7027



WorldWide Telescope

click  
"Research,  
Information"

Finder Scope



Classification:  
Planetary Nebula  
in Cygnus

NGC7027

RA:	21h07m01s	Magnitude:	10.5
Dec:	42 : 14 : 10	Distance:	n/a
Alt:	02 : 36 : 57	Rise:	23:50
Az:	042 : 29 : 00	Transit:	09:40
		Set:	19:35

- Name: NGC7027
- Information
- Imagery
- Virtual Observatory Searches
- Set as Foreground Imagery
- Set as Background Imagery
- Properties
- Copy Shortcut
- Share on Facebook



- Look up on SIMBAD
- Look up on SEDS
- Look up on Wikipedia
- Look up publications on ADS
- Look up on NED
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...more data

...or more literature



Look At: Sky

Imagery: Digitized Sky Survey (Color)




Cygnus NGC7027

1 of 1



ads labs

RA : 21h07m02s  
Dec : 42:14:09





# Literature



# "Seamless Astronomy" (Tools)



SAMP



# Data



Registries"



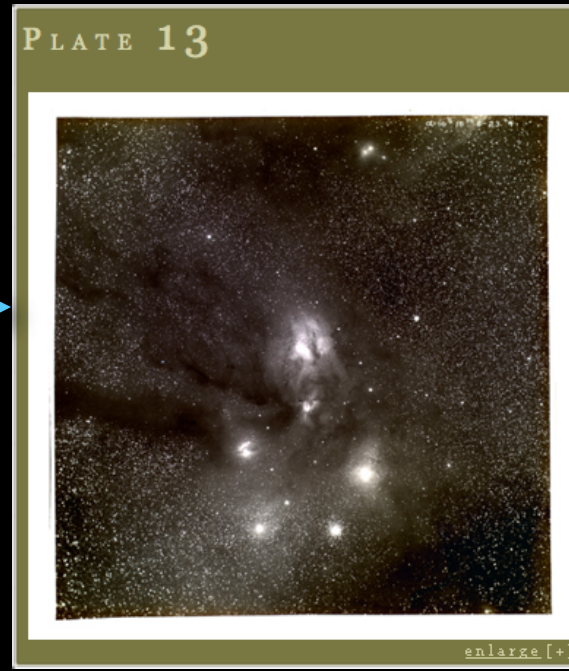
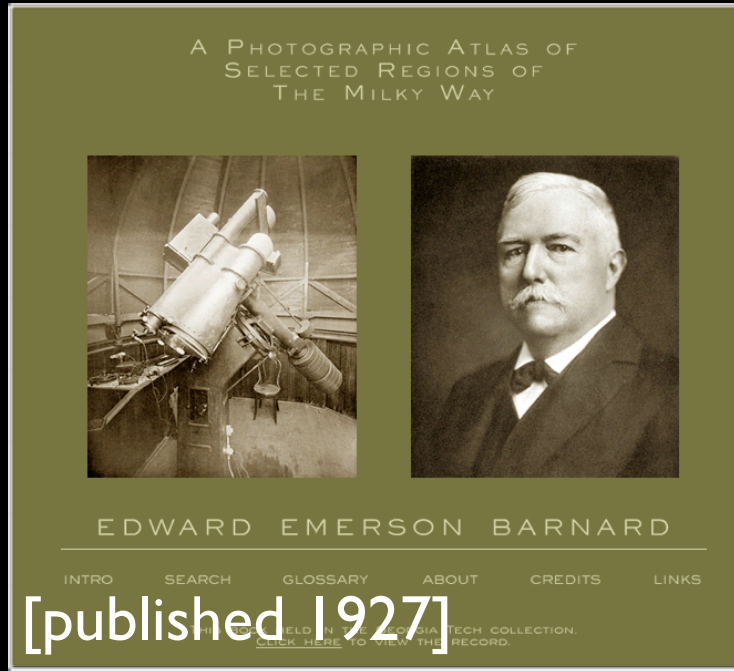
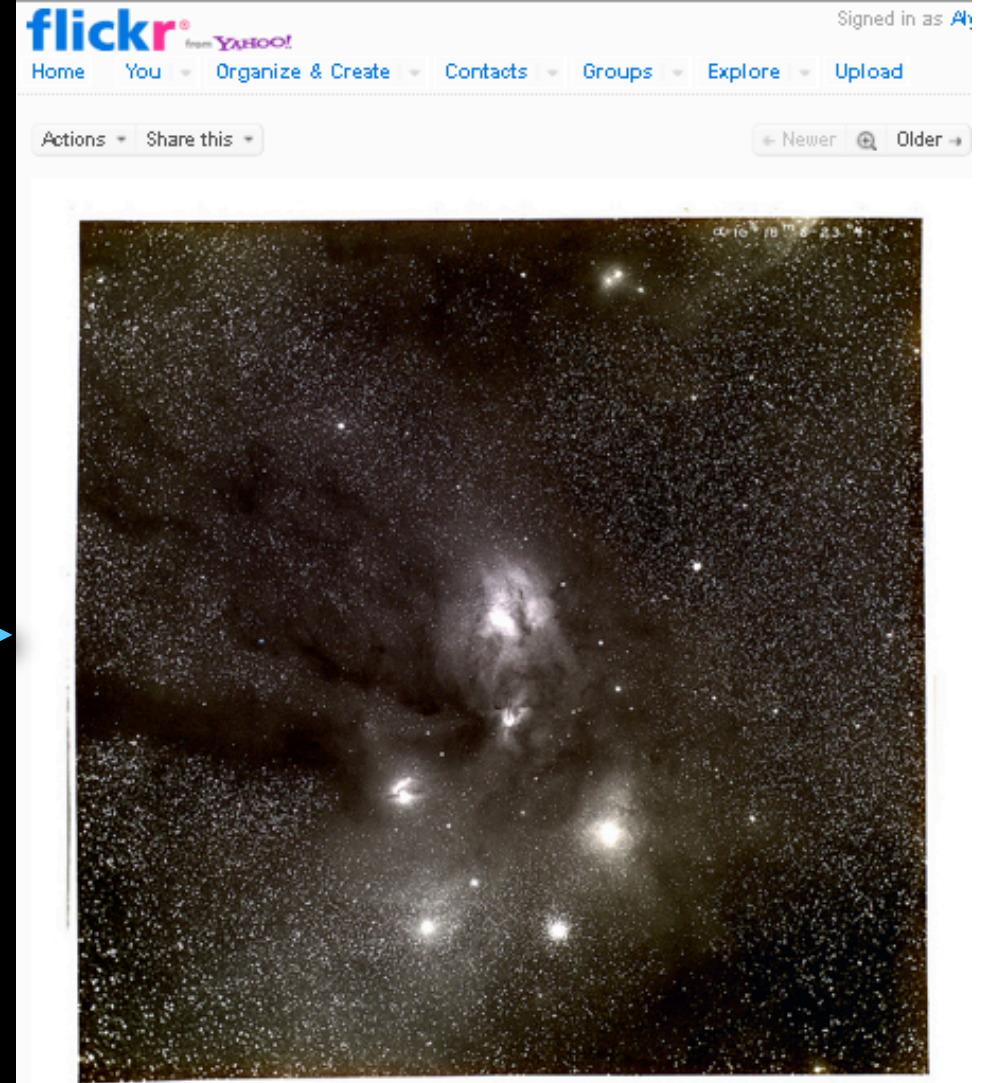
DataScope

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# “Seamless Astronomy” ...

astrometry.net + flickr + WWT



## barnardoph

E.E. Barnard's image of Ophiuchus  
[www.library.gatech.edu/bpdi/bpdi.php](http://www.library.gatech.edu/bpdi/bpdi.php)

## Comments and faves astrometry.net

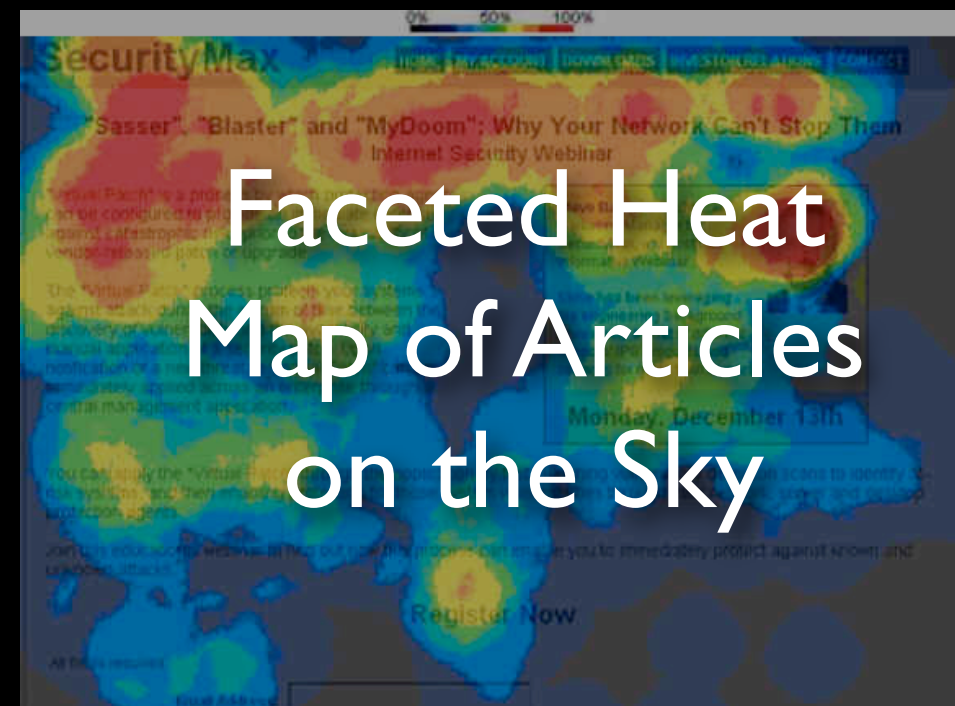
astrometry.net (6 days ago | reply | delete)  
 Hello, this is the blind astrometry solver. Your results are:  
 (RA, Dec) center:(246.421365149, -23.6749819397) degrees  
 (RA, Dec) center (H:M:S, D:M:S):(16:25:41.128, -23:40:29.935)  
 Orientation:178.34 deg E of N  
 Pixel scale:52.94 arcsec/pixel  
 Parity:Reverse ("Left-handed")  
 Field size :9.41 x 9.41 degrees  
 Your field contains:  
 The star Antares ( $\alpha$ Sco)  
 The star Graffias ( $\beta$ 1 Sco)  
 The star Al Niyat ( $\sigma$ Sco)  
 The star  $\tau$ Sco  
 The star  $\omega$ 1 Sco  
 The star  $\nu$ Sco  
 The star  $\omega$ 2 Sco  
 The star  $\omega$ Oph  
 The star 13 Sco  
 The star  $\rho$ Sco  
 IC 4592  
 IC 4601  
 NGC 6121 / M 4  
 IC 4603  
 IC 4604 / rho Oph nebula  
 IC 4605

[View in World Wide Telescope](#)



# Coming (using astrometry.net++) in 2011...

Historical Image Layer  
Extracted from ALL  
ADS holdings (using  
astrometry.net)



[e.g. ADS-CDS-WWT]

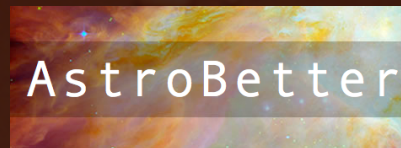
Collaborators: Alberto Accomazzi (CfA); Jonathan Fay (MSR); Alyssa Goodman (CfA); David Hogg (NYU); Gus Muench (CfA); Alberto Pepe (CfA)+advice from Pierre Fernique (CDS) & Thomas Bock (CDS)



# Literature



WIKIPEDIA  
The Free Encyclopedia

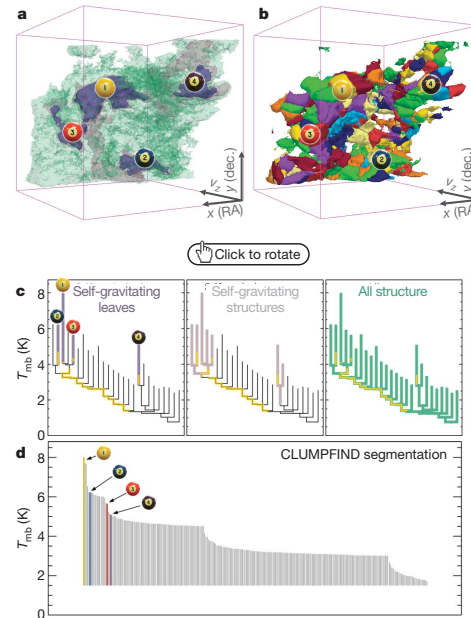


Blogs, Wikis, etc.

# "Seamless Astronomy" (Tools)

LETTERS

NATURE | Vol 457 | 1 January 2009



**Figure 2 | Comparison of the 'dendrogram' and 'CLUMPFIND' feature-identification algorithms as applied to  $^{13}\text{CO}$  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  $T_{\text{mb}}$  (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 ( $-0.5 \text{ km s}^{-1}$ ) to back ( $8 \text{ km s}^{-1}$ ).

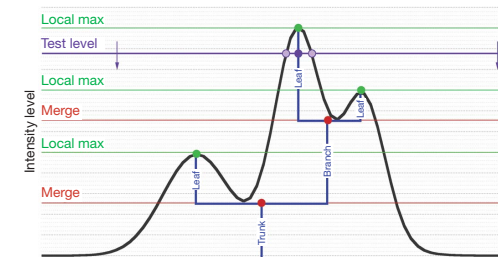
data, CLUMPFIND typically finds features on a limited range of scales, above but close to the physical resolution of the data, and its results can be overly dependent on input parameters. By tuning CLUMPFIND's two free parameters, the same molecular-line data set<sup>8</sup> can be used to show either 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'<sup>9</sup> 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'<sup>10</sup>. Although well developed in other data-intensive fields<sup>11,12</sup>, 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<sup>13</sup>.

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 iso-surfaces, such as radius ( $R$ ), velocity dispersion ( $\sigma_v$ ) and luminosity ( $L$ ). The volumes can have any shape, and in other work<sup>14</sup> 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  $M_{\text{lum}} = X_{13\text{CO}} L_{13\text{CO}}$ , where  $X_{13\text{CO}} = 8.0 \times 10^{20} \text{ cm}^{-2} \text{ K}^{-1} \text{ s}$  (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,  $\alpha_{\text{obs}} = 5\sigma_v^2 R/GM_{\text{lum}}$ . In principle, extended portions of the tree (Fig. 2, yellow highlighting) where  $\alpha_{\text{obs}} < 2$  (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  $\alpha_{\text{obs}}$  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<sup>16</sup>, 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.

# Data



# "Registries"



DataScope

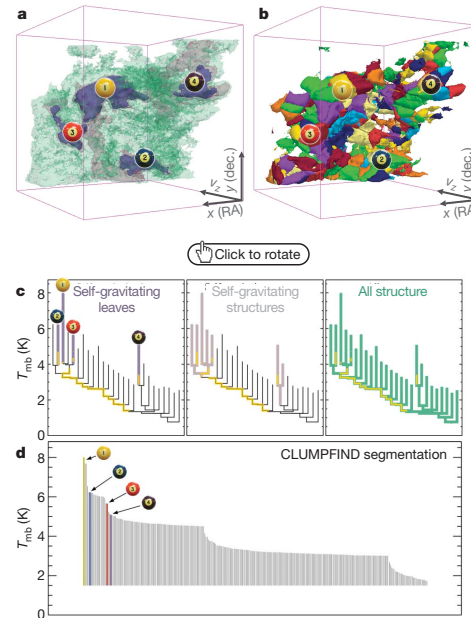
**Disclaimer:** This slide shows key excerpts from within the astronomy community & excludes more general s/w that is used, such as Papers, Zotero, Mendeley, EndNote, graphing & statistics packages, data handling software, search engines, etc.



# Data in Literature

LETTERS

NATURE | Vol 457 | 1 January 2009



**Figure 2** | Comparison of the ‘dendrogram’ and ‘CLUMPFIND’ feature-identification algorithms as applied to  $^{13}\text{CO}$  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 ( $-0.5 \text{ km s}^{-1}$ ) to back ( $8 \text{ km s}^{-1}$ ).

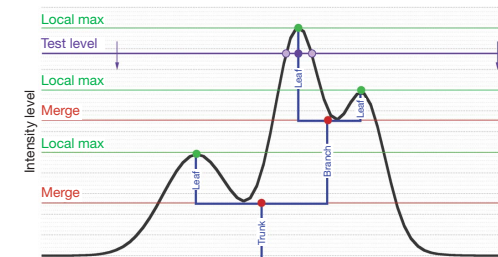
data, CLUMPFIND typically finds features on a limited range of scales, above but close to the physical resolution of the data, and its results can be overly dependent on input parameters. By tuning CLUMPFIND’s two free parameters, the same molecular-line data set<sup>8</sup> can be used to show either 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’<sup>9</sup> 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’<sup>10</sup>. Although well developed in other data-intensive fields<sup>11,12</sup>, 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<sup>13</sup>.

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 iso-surfaces, such as radius ( $R$ ), velocity dispersion ( $\sigma_v$ ) and luminosity ( $L$ ). The volumes can have any shape, and in other work<sup>14</sup> 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  $M_{\text{lum}} = X_{13\text{CO}} L_{13\text{CO}}$ , where  $X_{13\text{CO}} = 8.0 \times 10^{20} \text{ cm}^{-2} \text{ K}^{-1} \text{ km}^{-1} \text{ s}$  (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,  $\alpha_{\text{obs}} = 5\sigma_v^2 R / GM_{\text{lum}}$ . In principle, extended portions of the tree (Fig. 2, yellow highlighting) where  $\alpha_{\text{obs}} < 2$  (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  $\alpha_{\text{obs}}$  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<sup>16</sup>, 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.

Note: This work came from the “AstroMed” project [am.iic.harvard.edu](http://am.iic.harvard.edu)



Goodman et al. Nature, 2009





# More Data in/from Literature coming in 2011

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[Version 2.1.2 Downloads Now Available on Sourceforge](#)

[Yale Law School Roundtable Recommends the Dataverse Network](#)

[Version 2.1.1 Downloads Now Available on Sourceforge](#)

[Version 2.1.1 Rolled Out to IQSS Dataverse Network](#)

Harvard Institute for Quantitative Social Science (Gary King, Mercé Crosas)  
+ Seamless Astronomy Group, (Chris Erdmann, Alberto Pepe, Gus Muench et al.)



*But awareness is not high enough  
...and skepticism is not hard to find.*

Good news is that the young & young at heart  
are headed in the right direction.

Funding agencies have been slow to come along  
...industrial collaboration is a better bet at present  
(e.g. Microsoft Research/WorldWide Telescope).



*data links*



# ADS may be our "way in" via killer apps

The screenshot displays the ADS Labs interface for a search on "magnetic fields in molecular clouds". The top navigation bar includes "Home", "Labs Home", "ADS Classic", "Help", and "Sign on". The search results are listed on the left, with the top entry being "1999ApJ...520..706C Magnetic Fields in Molecular Clouds: Observations Confront Theory" by Crutcher, Richard M. An orange arrow points from the "View as network" button to the "Author network" option in a dropdown menu.

Below the search results, there are controls for "Selection type" (set to "Neighbors (shift+alt)") and "Filter by author weight" (with a slider from min to max). A button labeled "View papers for selected authors" is also present.

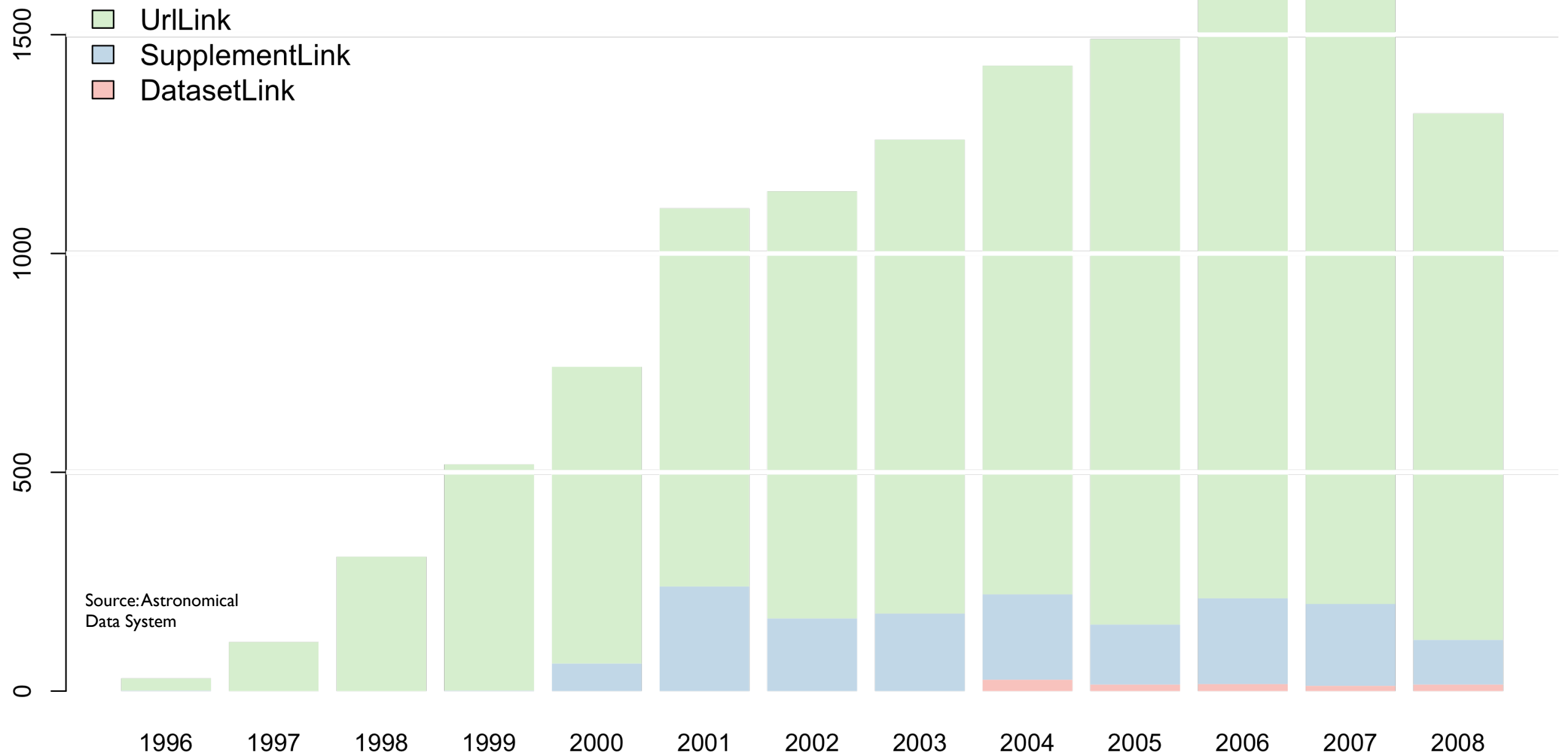
The main visualization is an author network graph. Nodes represent authors, and edges represent connections between them. The graph shows a dense cluster of authors, with some nodes highlighted in yellow. The authors included in the network are: Nakamura, F; Mouschovias, T; Troland, T; Matthews, B; Helle, C; Crutcher, R; Heyer, M; Ostriker, E; Kazes, I; Goodman, A; Kirby, L; Houde, M; Li, H; Vaynshteyn, L; Ward-Thompson, D; Vaillancourt, J; Dowell, C; Stone, J; McKee, C; Andre, P; Hildebrand, R; Klessen, R; Mac Low, M; Norman, M; Vazquez-Semadeni, E; Kim, J; Heitsch, F; Feigelson, E; Ballesteros-Paredes, J; Pudritz, R; Padoan, P; and Nordlund, A.

At the bottom of the interface, there is a "Dates" filter and a "Author network" button. The text "IN: Annual review of astronomy and astrophysics. Volume 27 (A90-29983 12-90). Palo Alto, CA, Annual Reviews, Inc. 1989" is visible at the bottom right.



# DATA IN “LITERATURE”

NUMBER OF ASTRONOMY PUBLICATIONS WITH LINKS, BY YEAR (ADS)







Welcome! This website provides a platform for sharing resources, workflows, and basic organizational information about networked tools, websites and databases in astronomy. Its intended audience is any scientist performing astronomical research online. It originated from the activities of scientists at the Harvard Smithsonian Center for Astrophysics in Cambridge, MA.

By online astronomy, we mean all forms of networked tools, databases and websites that are utilized for astronomical research, including scholarly discourse and social interactions through blogs, forums and other web media.

By *user group*, we mean a group of individuals who meet approximately monthly to discuss their solutions and problems with doing their research online.

## Blog

**[Research Blogs, Forums and Q&A websites](#)** Our January 25, 2011 meeting topic will be "Research Blogs, Forums and Q&A websites." We will hold an open discussion on how everyone uses these tools in their everyday ...  
 Posted Jan 23, 2011 9:11 PM by August Muench

**[Expo of Online Astronomy tools \(aka, a VO expo\)](#)** We are holding our "VO Expo" tomorrow morning (1 Dec, 9am-noon) in Phillips Auditorium. We will be covering the role of the CfA VO User group for scientists (and ...  
 Posted Dec 15, 2010 9:34 AM by August Muench

**[ADASS Day 1: A new portal, new Aladin features](#)** Monday was the first full day of the Astronomical Data Analysis Software and Systems 2010 meeting. As there are new tools being presented and demo'd, I'm going to ...  
 Posted Nov 9, 2010 7:09 PM by August Muench

Showing posts 1 - 3 of 18. [View more »](#)

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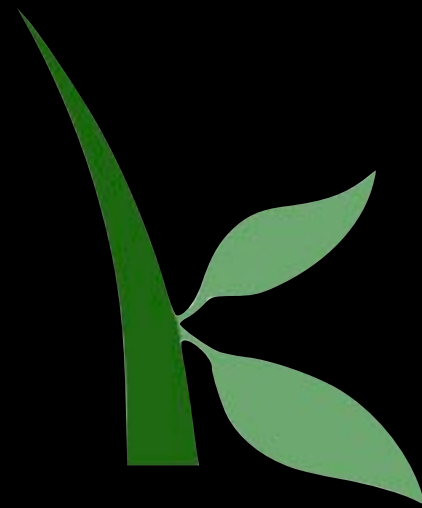
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- [Astropython](#)
- [IVOA](#)
- [VAO](#)

**15**  
 days since  
**January 2011 Mtg**

*The figure (above) diagrams the relationship between astronomical research and the data and literature sources that the research draws upon. The researcher stands between the literature and data, taking information from each, integrating their*



*How do we increase the number of people who create and interlink new tools?*



**Kiva** model: WWT Partners & “VAO Associates”

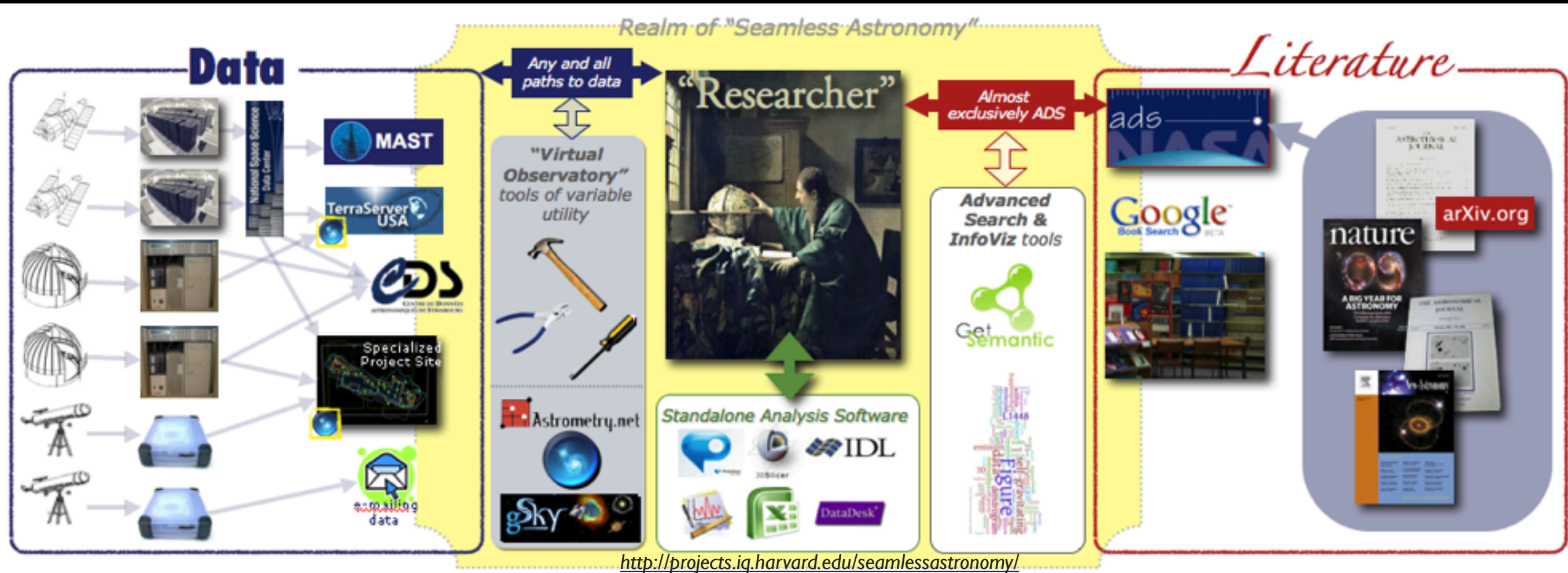


*How do we organize such diverse tools, so as to make them interoperably useful?....*

“SAMP” is a great technical start, but offers a very significant user interface challenge.

# Seamless Astronomy

[projects.iq.harvard.edu/seamlessastronomy](http://projects.iq.harvard.edu/seamlessastronomy)



Alyssa A. Goodman  
 Harvard-Smithsonian Center for Astrophysics



with

Alberto Accomazzi, Douglas Burke, Raffaele D'Abrusco, Rahul Davé, Christopher Erdmann, Pepi Fabbiano, 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)



### Planet Hunters

Using public data from NASA's Kepler mission, we are looking for planets around other stars.

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- THE MILKY WAY PROJECT
- MOON ZOO
- GALAXY ZOO HUBBLE
- oldWeather

### The Milky Way Project

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.

JOIN IN



### Old Weather

Help scientists recover worldwide weather observations made by Royal Navy ships around the time of World War I.

JOIN IN



### Moon Zoo

Explore the Moon in unprecedented detail using images from NASA's Lunar Reconnaissance Orbiter.



“Citizen Science”

EN · The Milky Way Project is part of the ZOO NIVERSE ...just like SOLAR STORMWATCH

# THE MILKY WAY PROJECT

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