The Origins, Formation, and Scientific Promise of the Virtual Observatory

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What is [a,the] Virtual Observatory?

- "A suite of software applications on a set of computers that allows users to uniformly find, access, and use resources (data, software, document, and image products and services using these) from a collection of distributed product and service providers." [B. Weigel, GMU; ViRBO]
- "A distributed, scalable education and research environment for searching, integrating, and analyzing observational, experimental, and model databases." [P. Fox, NCAR; VSTO]
- "A collection of integrated astronomical data archives and software tools that utilize computer networks to create an environment in which research can be conducted." [answers.com]
- "Computers have made it easier to construct and retrieve information from archival data bases. Computer networks are under construction that will make it possible for these archival databases to be made available to other observatories so as to create a *virtual observatory*, with gains in productivity and cost-effectiveness for the observatories that participate in it. [answers.com]

What is [a,the] Virtual Observatory?

- “The power of the World Wide Web is its transparency_it is as if all the documents in the world are inside your PC. The idea of the Virtual Observatory (VO) is to achieve the same transparency for astronomical data. In the VO all the world's data is available from your desktop. All archives understand the same query language, can be accessed through a uniform interface, and diverse data can be analysed by the same tools. A central goal is democratisation: the power the scientist has at her fingertips should be independent of location. Such an infrastructure will also enable collaboratories: informal distributed research teams sharing data, workflows, and analysis results in a transparent virtual storage system.” [Quinn, Hanisch, & Lawrence]
- “The Virtual Observatory is an international astronomical community-based initiative. It aims to allow global electronic access to the available astronomical data archives of space and ground-based observatories, sky survey databases. It also aims to enable data analysis techniques through a coordinating entity that will provide common standards, wide-network bandwidth, and state-of-the-art analysis tools.” [euro-vo.org]

What is [a,the] Virtual Observatory?

- Distributed
- Networked
- Collaborative

} virtual organizations

- Uniform interfaces
- Standards-based
- Scalable
- Democratizing
- Supporting innovation and efficiency in research

Origins

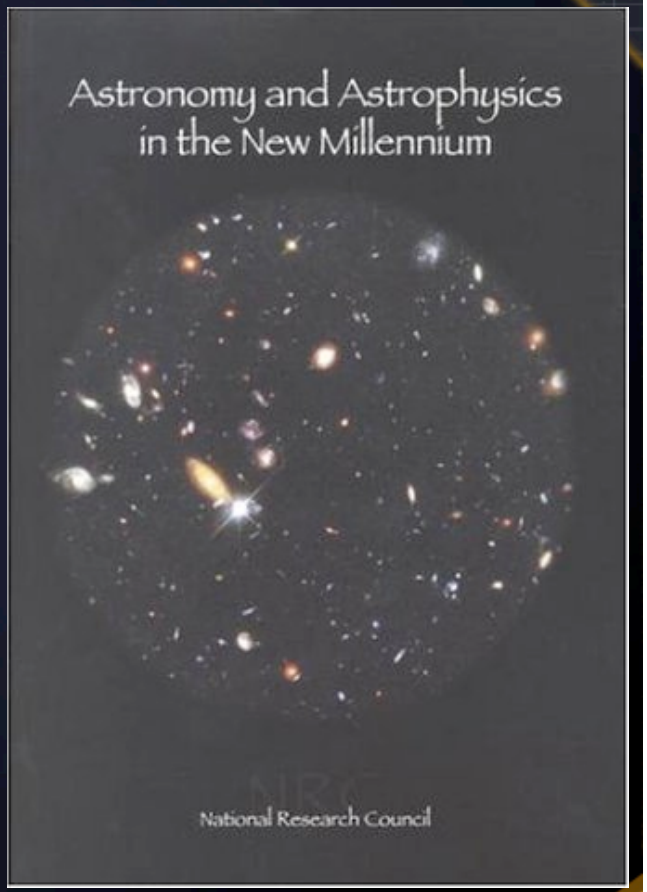
- 1990s: NASA establishes wavelength-oriented science archive centers; multiple large ground-based digital sky survey projects initiated
- April 1999, Decadal Survey Panel on Theory, Computation, and Data Discovery met in Los Alamos
  - Szalay, Prince, and Alcock coin the name “National Virtual Observatory”
- November 1999, NVO organizational workshop at JHU
- June 2000, conference held at Caltech, “Towards a Virtual Observatory”
- February 2001, AASC/NAS report “Astronomy and Astrophysics in the New Millennium” released
- April 2001, proposal submitted to NSF ITR program, 17 collaborating organizations, led by A. Szalay (JHU) and P. Messina (Caltech)
- September 2001, NSF announces proposal selection
- June 2002, “Toward an International Virtual Observatory” conference at ESO; International VO Alliance formed
- January 2003, first NVO science prototypes shown at Seattle AAS
- January 2003, AVO (EuroVO) “first light”

Motivation

- National Academy of Sciences Decadal Survey recommended NVO as highest priority small (<$100M) project

" Several small initiatives recommended by the committee span both ground and space. The first among them—the National Virtual Observatory (NVO)—is the committee's top priority among the small initiatives. The NVO will provide a "virtual sky" based on the enormous data sets being created now and the even larger ones proposed for the future. It will enable a new mode of research for professional astronomers and will provide to the public an unparalleled opportunity for education and discovery."

—Astronomy and Astrophysics in the New Millennium, p. 14

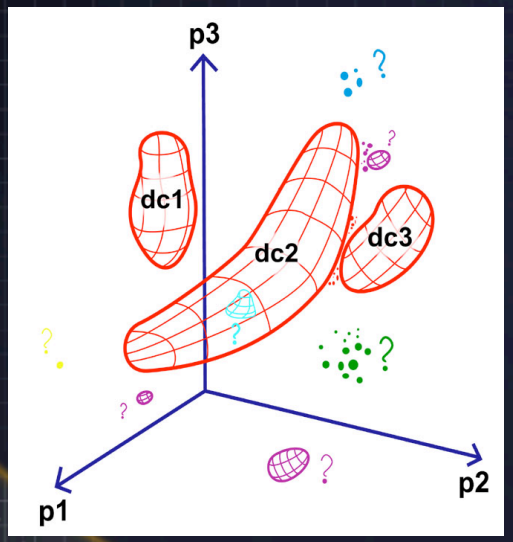


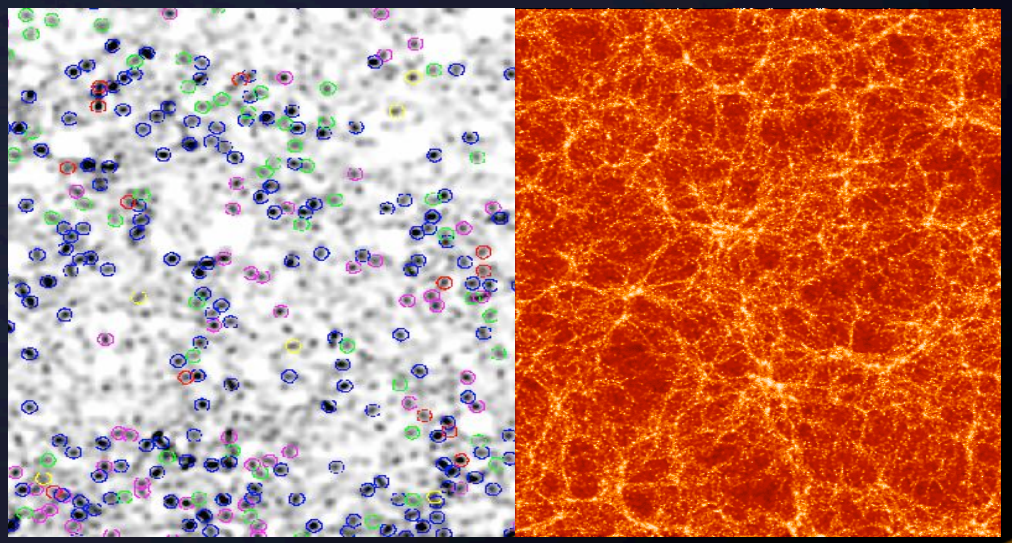
Toward a “new astronomy”

- Past: Observations of small, carefully selected samples (often with *a priori* prejudices) of objects in one or a few wavelength bands

Toward a “new astronomy”

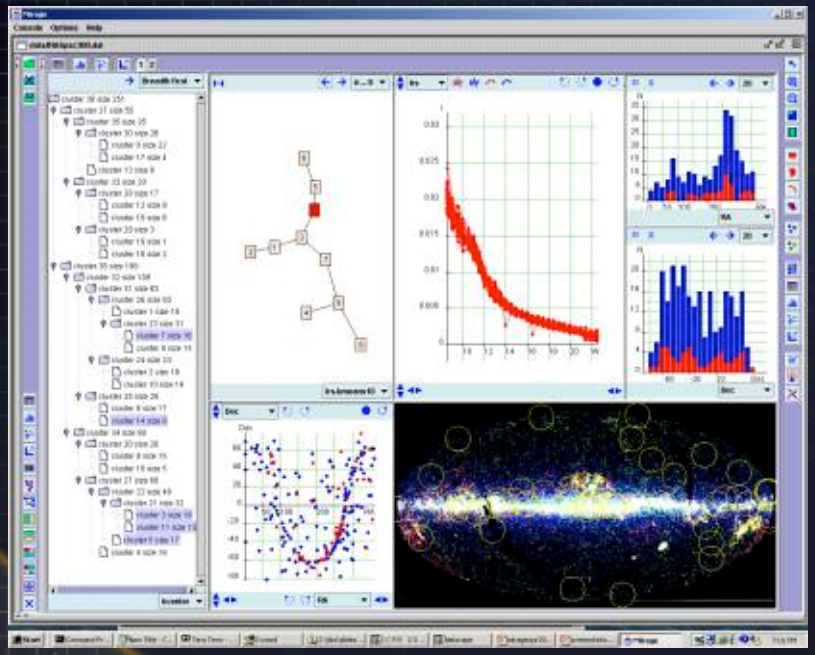
- Future: Multi-wavelength data for millions of objects, allowing us to:
  - Discover significant patterns from the analysis of statistically rich and unbiased image/catalog databases
  - Understand complex astrophysical systems via confrontation between data and sophisticated numerical simulation

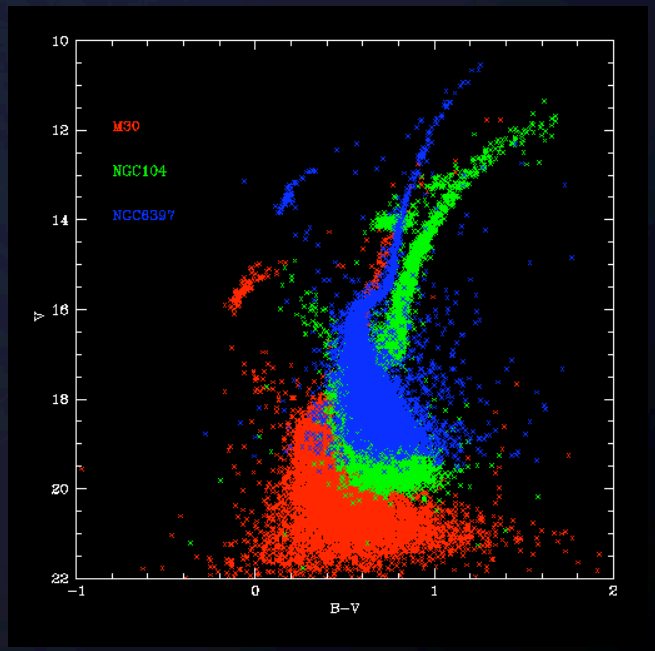




Toward a “new astronomy”

- Discovering new phenomena and patterns in these datasets will require simultaneous access to multi-wavelength archives, advanced visualization and statistical analysis tools





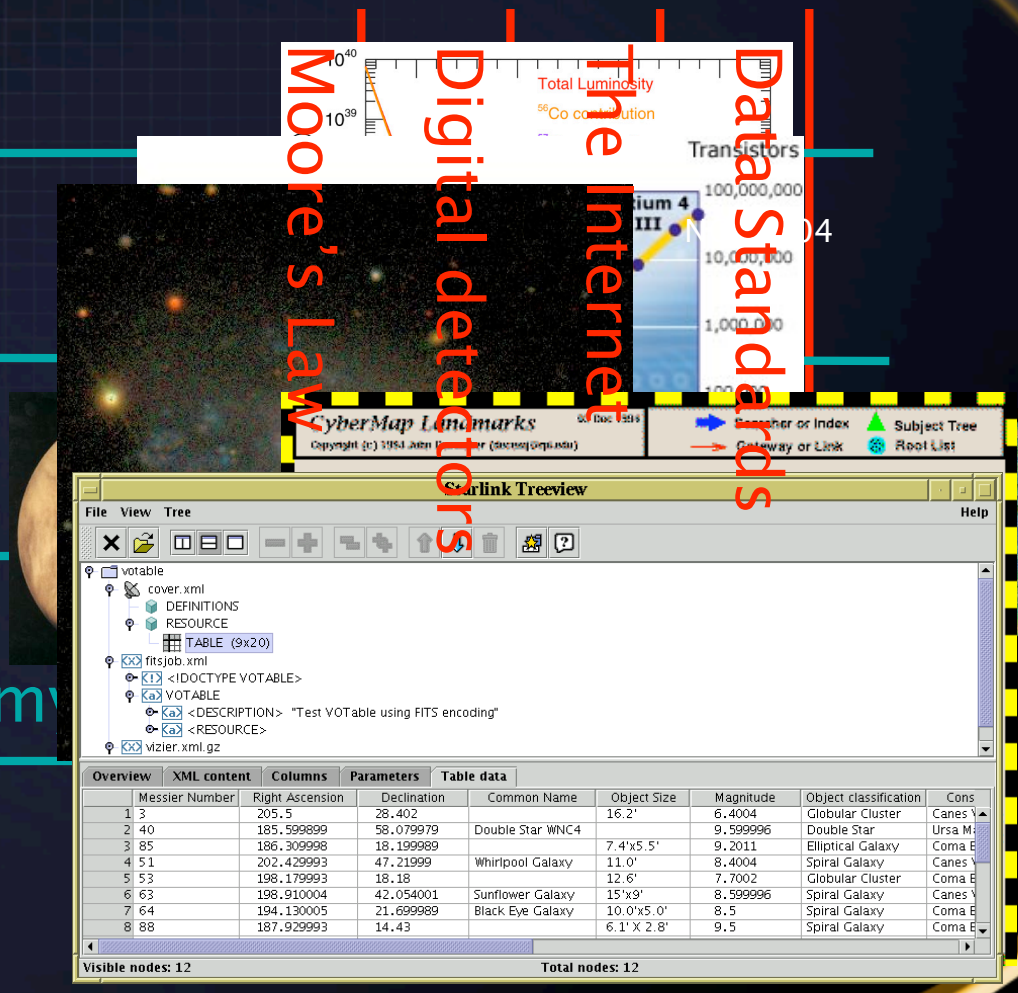
Threads of the the VO Fabric

Multiwavelength astrophysics

Archival Research

Survey astronomy

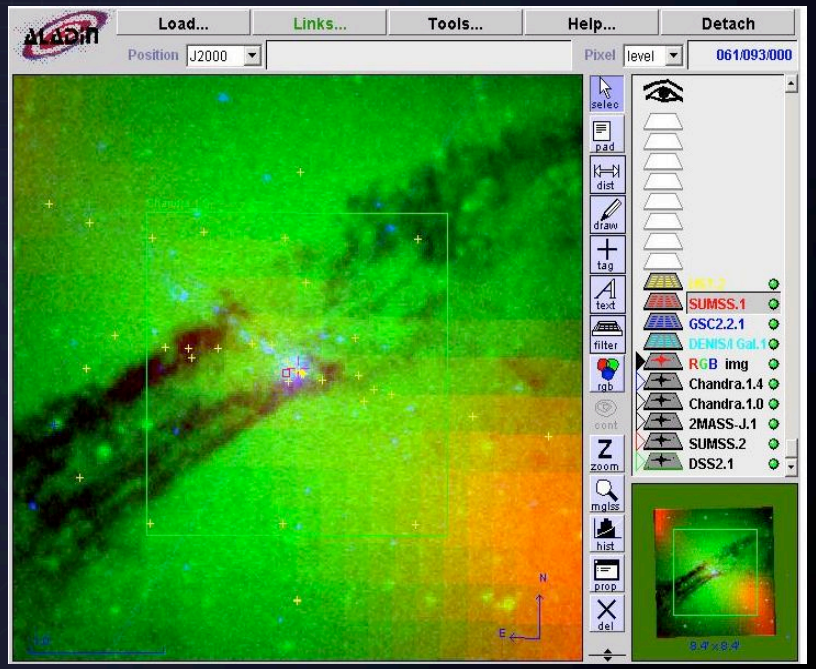
Temporal astronomy



	Messier Number	Right Ascension	Declination	Common Name	Object Size	Magnitude	Object classification	Cons
1	3	205.5	28.402		16.2'	6.4004	Globular Cluster	Canes V
2	40	185.599899	58.079979	Double Star WNC4		9.599996	Double Star	Ursa M
3	85	186.309998	18.199989		7.4'x5.5'	9.2011	Elliptical Galaxy	Coma B
4	51	202.429993	47.21999	Whirlpool Galaxy	11.0'	8.4004	Spiral Galaxy	Canes V
5	53	198.179993	18.18		12.6'	7.7002	Globular Cluster	Coma B
6	63	198.910004	42.054001	Sunflower Galaxy	15'x9'	8.599996	Spiral Galaxy	Canes V
7	64	194.130005	21.699989	Black Eye Galaxy	10.0'x5.0'	8.5	Spiral Galaxy	Coma B
8	88	187.929993	14.43		6.1' X 2.8'	9.5	Spiral Galaxy	Coma B

DataScope

Discover and explore data in the Virtual Observatory



Using the NVO DataScope scientists can discover and explore hundreds of data resources available in the Virtual Observatory. DataScope uses the VO registry and VO access protocols to link to archives and catalogs around the world. Users can immediately discover what is known about a given region of the sky: they can view survey images from the radio through the X-ray, explore archived observations from multiple archives, find recent articles describing analysis of data in the region, find known interesting or peculiar objects and survey datasets that cover the region. A summary page provides a quick précis of all of the available data. Users can download images and tables for further analysis on their local machines, or they can go directly to a growing set of VO enabled analysis tools, including Aladin, OASIS, VOPlot and VOStat.

The VO DataScope

National Virtual Observatory: Hosted at the HEASARC

What do we know about a region of the sky? Use the Virtual Observatory DataScope to gather and organize information from astronomy archives and data centers around the world.

Enter a position(or name) and the maximum size of the region of sky you are interested in.

Object Name or J2000 Position:	Abell 1656	(3c273 *or* 12 29 06, +2 3 8.6 *or* 187.27 2.05)
Region size:	0.25	(in degrees)

Send Request | Reset Form

☐ **Bypass cache.** DataScope will issue a fresh request even if an identical request is in the cache.

Display:

☑ **Images**	☑ *Optical*	☑ *Radio*	☑ *IR*	☑ *UV*	☑ *X-ray*	☑ *Other*
☑ **Catalogs**	☑ *Observations* ☑ Optical ☑ Radio ☑ IR ☑ UV ☑ X-ray ☑ Other	☑ *Objects* ☑ Survey ☑ Galaxies ☑ Stars ☑ Other	☑ *Unknown*			

You can limit the categories of results diplayed by unchecking categorites in the table above. Results are sorted according to a hierarchy of criteria shown here are row, column header, and column elements. Each resource is shown only once. If you deselect one category (e.g., Images/Optical), then a service may show up as Images/Radio if it has both Optical and Radio data.

The Images/Other, Catalogs/Observations/Other, Catalogs/Objects/Other and Catalogs/Unknown are catch-alls that match anything that has not matched earlier in their sub-hierarchies. Deselecting a supercategory, e.g., Catalogs/Objects, disables all subcategories, but Object resources will then match Catalogs/Unknown unless that is also deselected.

A service of the Laboratory for High Energy Astrophysics (LHEA)
and the High Energy Astrophysics Science Archive Research Center (HEASARC) at NASA/ GSFC

DataScopeResults for Abell 1656

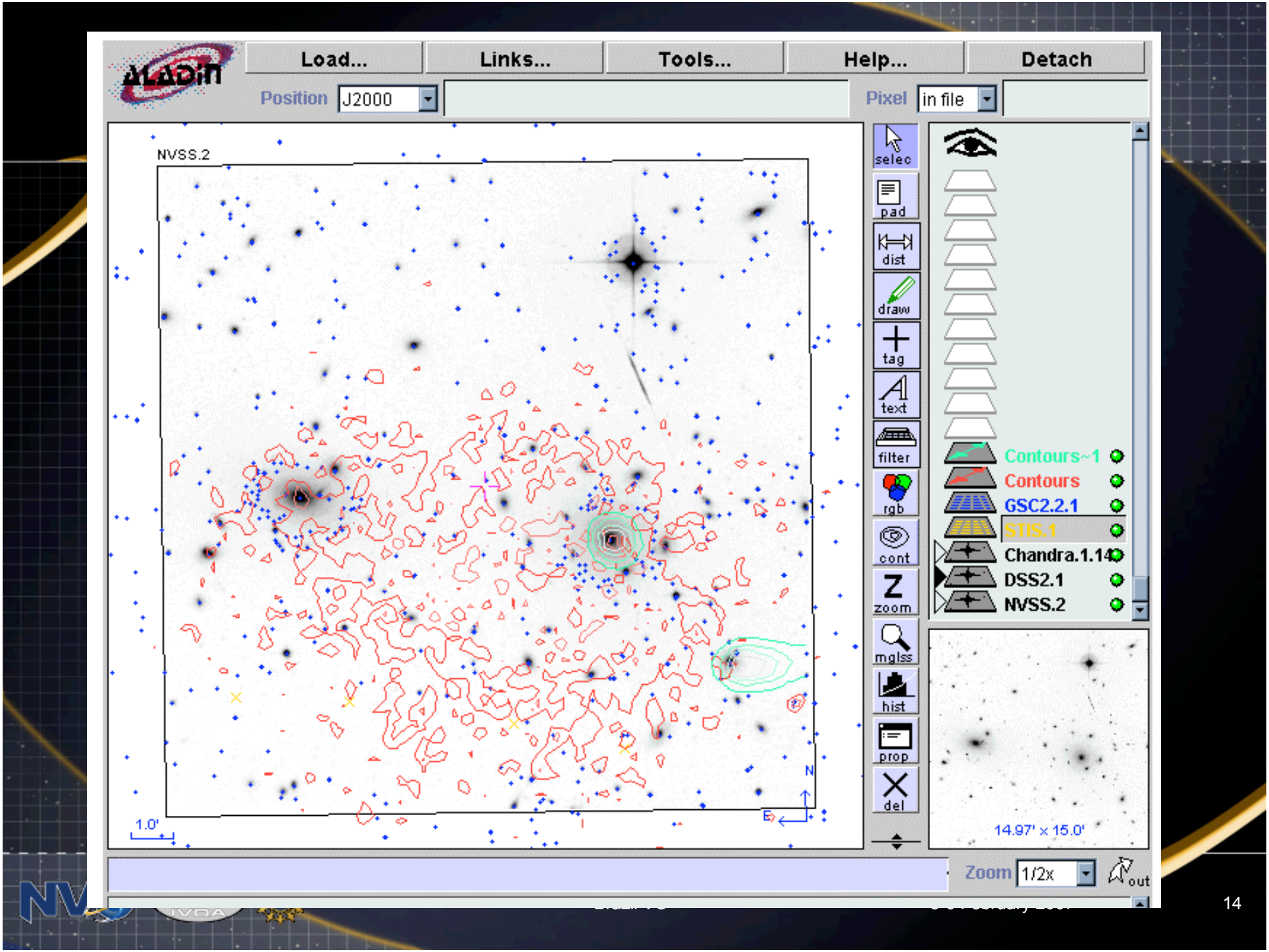
Waiting for... - Help Home

National Virtual Observatory: Hosted at the HEASARC

Request Status: Awaiting 2 resources. Refresh halted. Use manual refresh to get latest resources.

TAR selected resources | Start Aladin | Start OASIS

Images (FITS)					
Optical	☐ DSS1 SV ?	☐ DSS2B ?	☐ DSS2 ?	☐ DSS2R ?	☐ DSS2IR ?
	☐ DSS1 ?	☐ HST Previews(144) ?			
Radio	☐ VLA-FIRST ?	☐ NVSS ?			
Infrared	☐ 2MASS-H ?	☐ LGA(3) ?	☐ 2MASS-J ?	☐ 2MASS-K ?	☐ 2MASS QL(18) ?
	☐ ISO SIAP AIO(7) ?				
X-ray	☐ XMM-Newton(15) ?	☐ Chandra(12) ?	☐ RASS B ?		
Catalogs (VOTable) ...					
...Observations					
Optical	☐ STIS(53) ?	☐ HST(100) ?	☐ HSTPAEC(421) ?	☐ WFPC1(4) ?	☐ HSTAEC(421) ?
	☐ WFPC2(100) ?				
Infrared	☐ NICMOS(93) ?	☐ ISOLOG(25) ?			
UV	☐ HUT(4) ?	☐ IUE(3) ?	☐ FUSE(1) ?	☐ IUELOG(19) ?	☐ EUVEMAST(6) ?
	☐ UIT(2) ?	☐ EUVE(3) ?			
X-ray	☐ ROSAT(11) ?	☐ MPCRAW(91) ?	☐ A2LCSCAN(3) ?	☐ Ariel5(1) ?	☐ HRIPHOT(2) ?
	☐ EXOLOG(25) ?	☐ GINGALOG(31) ?	☐ CHANMAST(13) ?	☐ RASSPUBL(1) ?	☐ A2POINT(1) ?
	☐ IPCPHOT(5) ?	☐ ASCA(14) ?	☐ EXOSAT(22) ?	☐ WFCPONT(5) ?	☐ IPCIMAGE(3) ?
	☐ FPCSFITS(4) ?	☐ GINGALAC(1) ?	☐ CHANPUB(13) ?	☐ SSSRAW(25) ?	☐ GINGARAW(84) ?
	☐ XTEMAST(114) ?	☐ Einstein(13) ?	☐ A2LCPONT(1) ?	☐ HRIIMAGE(2) ?	☐ A2LED(1) ?
	☐ XTEINDEX(2) ?	☐ Ariel3A(1) ?	☐ XMMPUBL(13) ?	☐ ROSPUBLC(11) ?	☐ XMM(19) ?
	☐ SAXNFILG(3) ?	☐ XTEPUBL(108) ?	☐ EXOMAST(22) ?	☐ EXOGSPC(7) ?	☐ SSS(6) ?
	☐ XMMMAST(17) ?	☐ EINLOG(15) ?	☐ CMAIMAGE(10) ?	☐ RXTE(114) ?	☐ ROSATLOG(50) ?
	☐ BBXRT(1) ?	☐ A3MC(1) ?	☐ A2SPECTR(1) ?	☐ EXOME(9) ?	☐ ASCAMAST(14) ?
	☐ XTEOBS(261) ?	☐ OSO8ALC(1) ?	☐ EXOPUBS(2) ?	☐ XTESLEW(152) ?	
Other	☐ OSSE(5) ?	☐ SAS2RAW(2) ?	☐ COMPTEL(44) ?	☐ OSSE(7) ?	☐ COSBRAW(1) ?
	☐ EGRETDAT(26) ?	☐ MGGRCAT(4) ?	☐ COSBMAPS(4) ?		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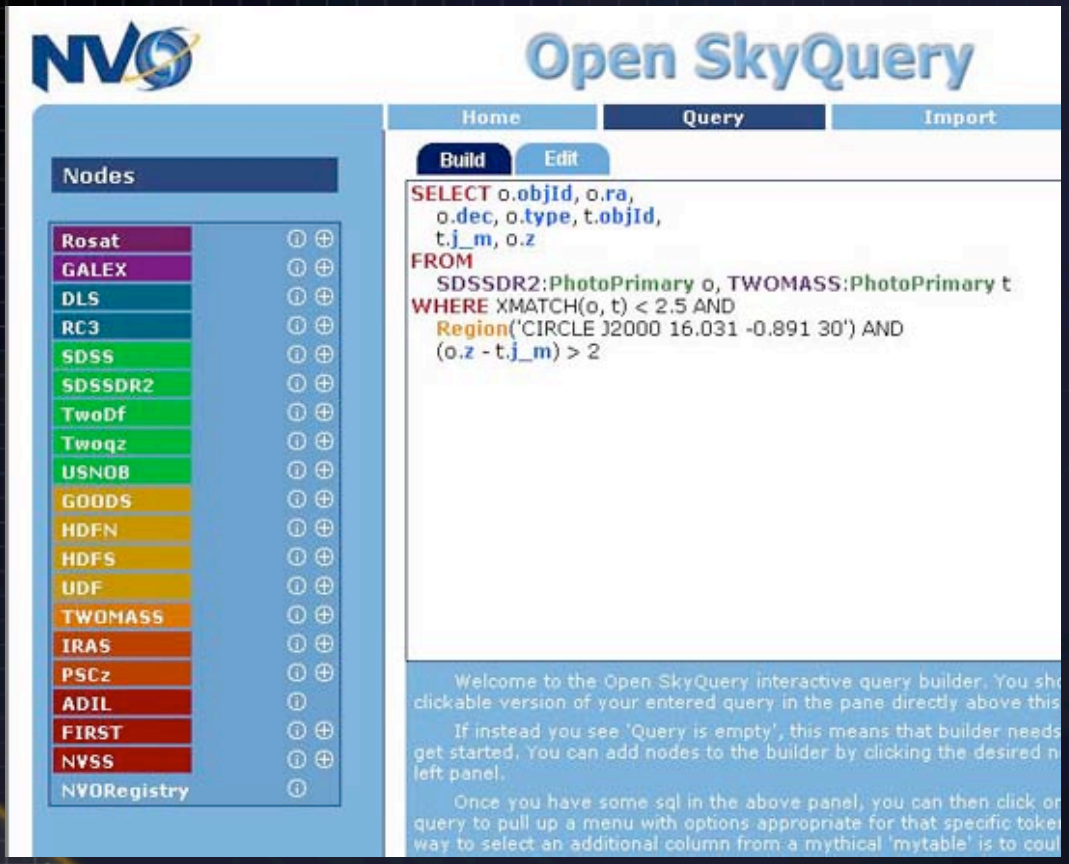
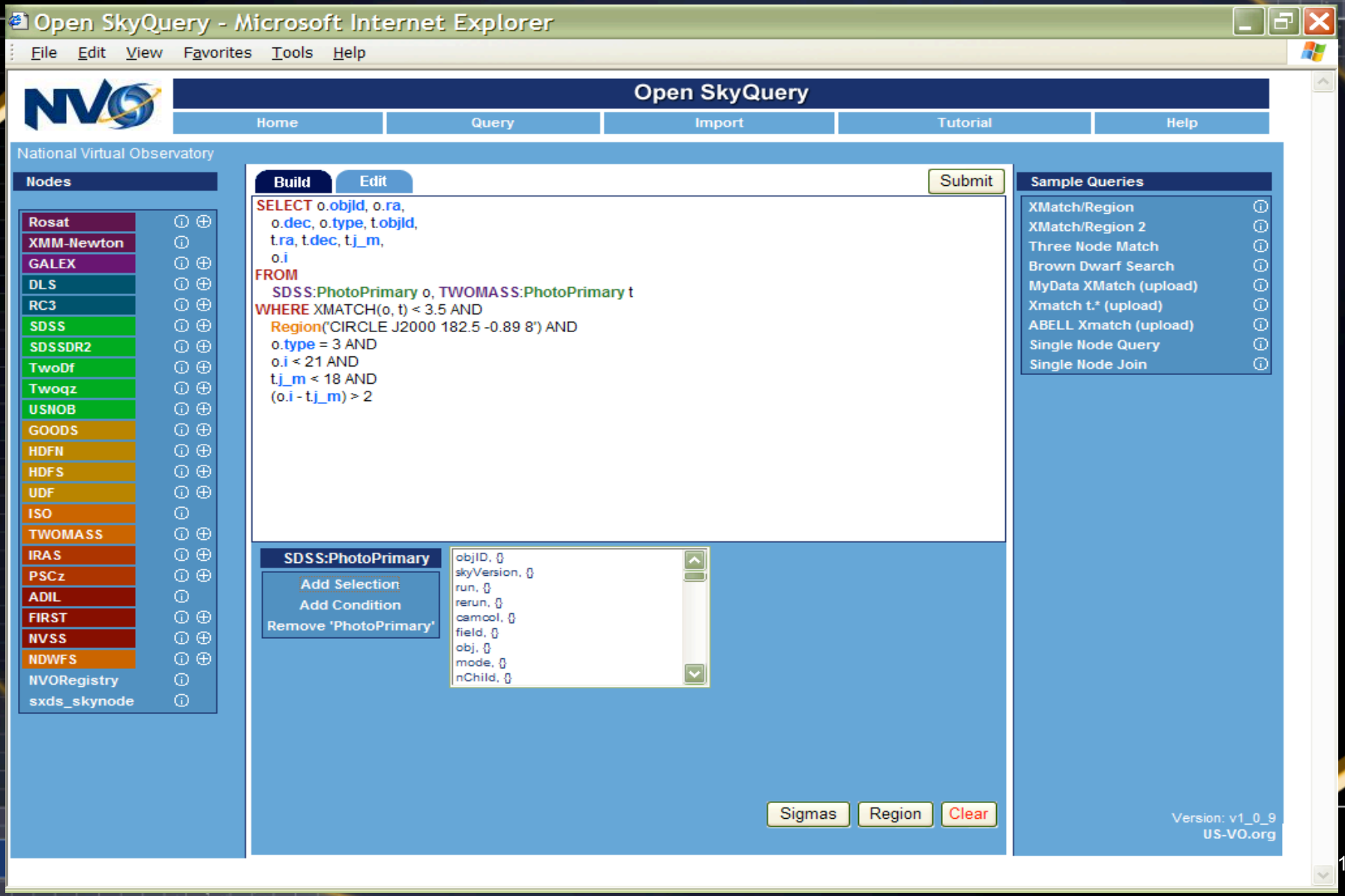
Open SkyQuery

Cross-match your data with numerous catalogs



OpenSkyQuery allows you to cross-match astronomical catalogs and select subsets of catalogs with a general and powerful query language. You can also import a personal catalog of objects and cross-match it against selected databases.

OpenSkyQuery



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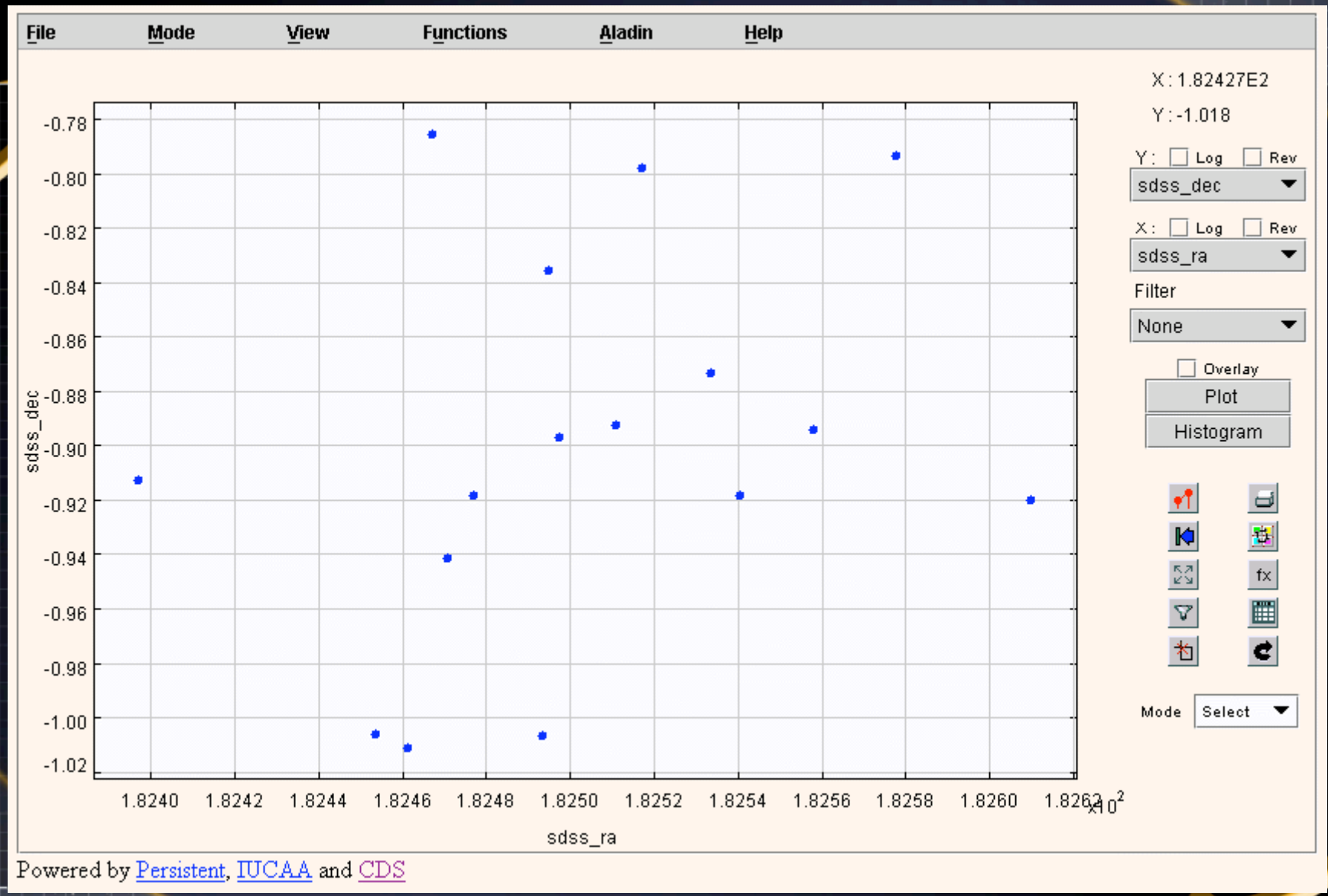
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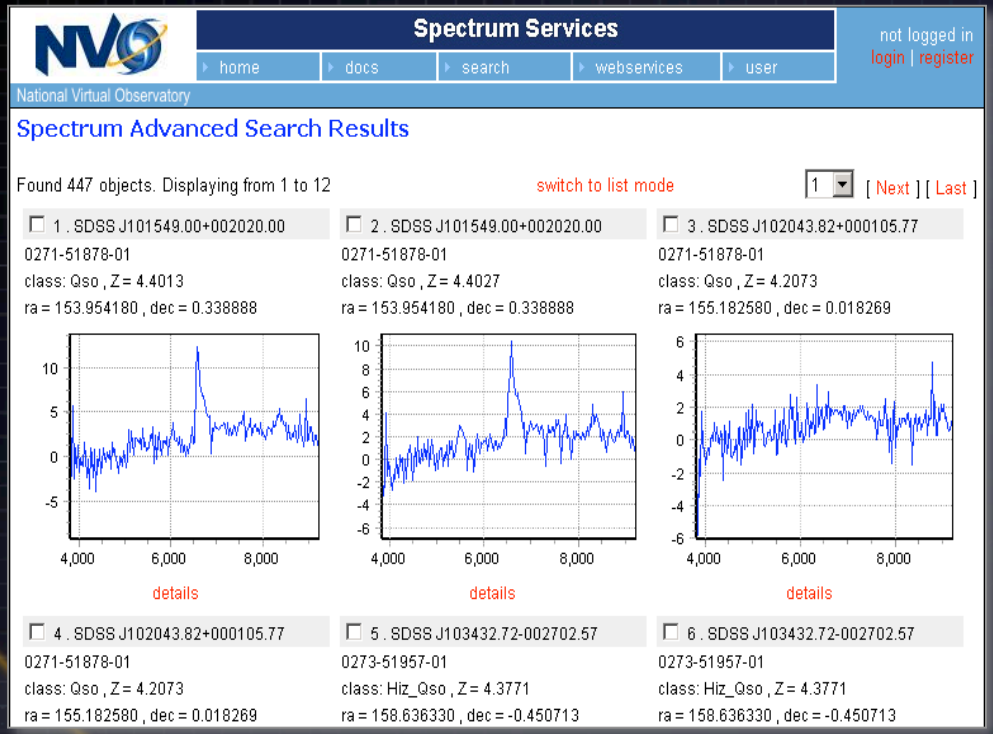
Powered by Persistent, IUCAA and CDS

Spectrum Services

Search, plot, and retrieve SDSS, 2dF, and other spectra



The Spectrum Services web site is dedicated to spectrum related VO services. On this site you will find tools and tutorials on how to access close to 500,000 spectra from the Sloan Digital Sky Survey (SDSS DR1) and the 2 degree Field redshift survey (2dFGRS). The services are open to everyone to publish their own spectra in the same framework. Reading the tutorials on XML Web Services, you can learn how to integrate the 45 GB spectrum and passband database with your programs with few lines of code.

NVO Spectrum Services

Spectrum Services for the Virtual Observatory

not logged in
login | register

home | filters | spectra | webservices | user

Spectrum Cone Search Results

Found 189 objects. Displaying from 1 to 12 switch to list mode 1 [Next] [Last]

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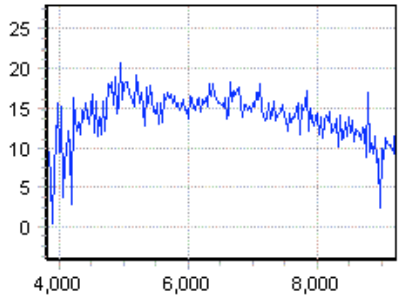

details

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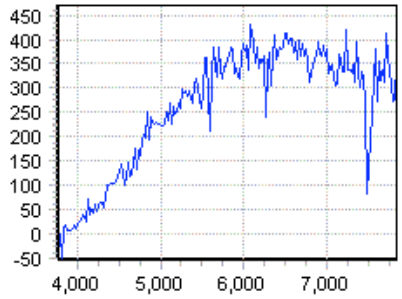

details

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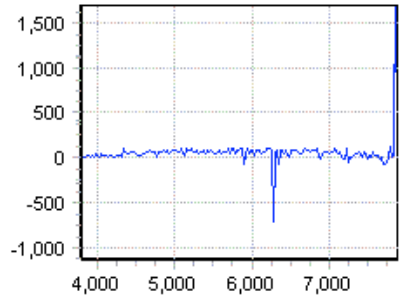

details

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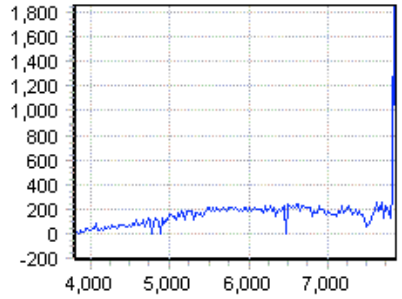

details

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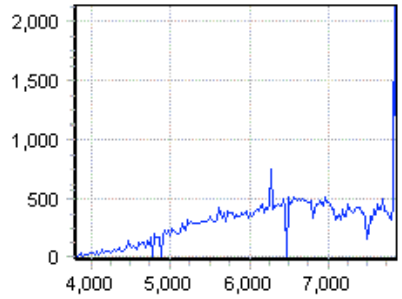

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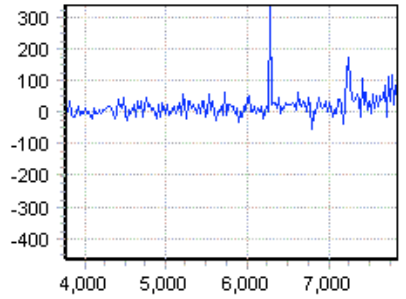
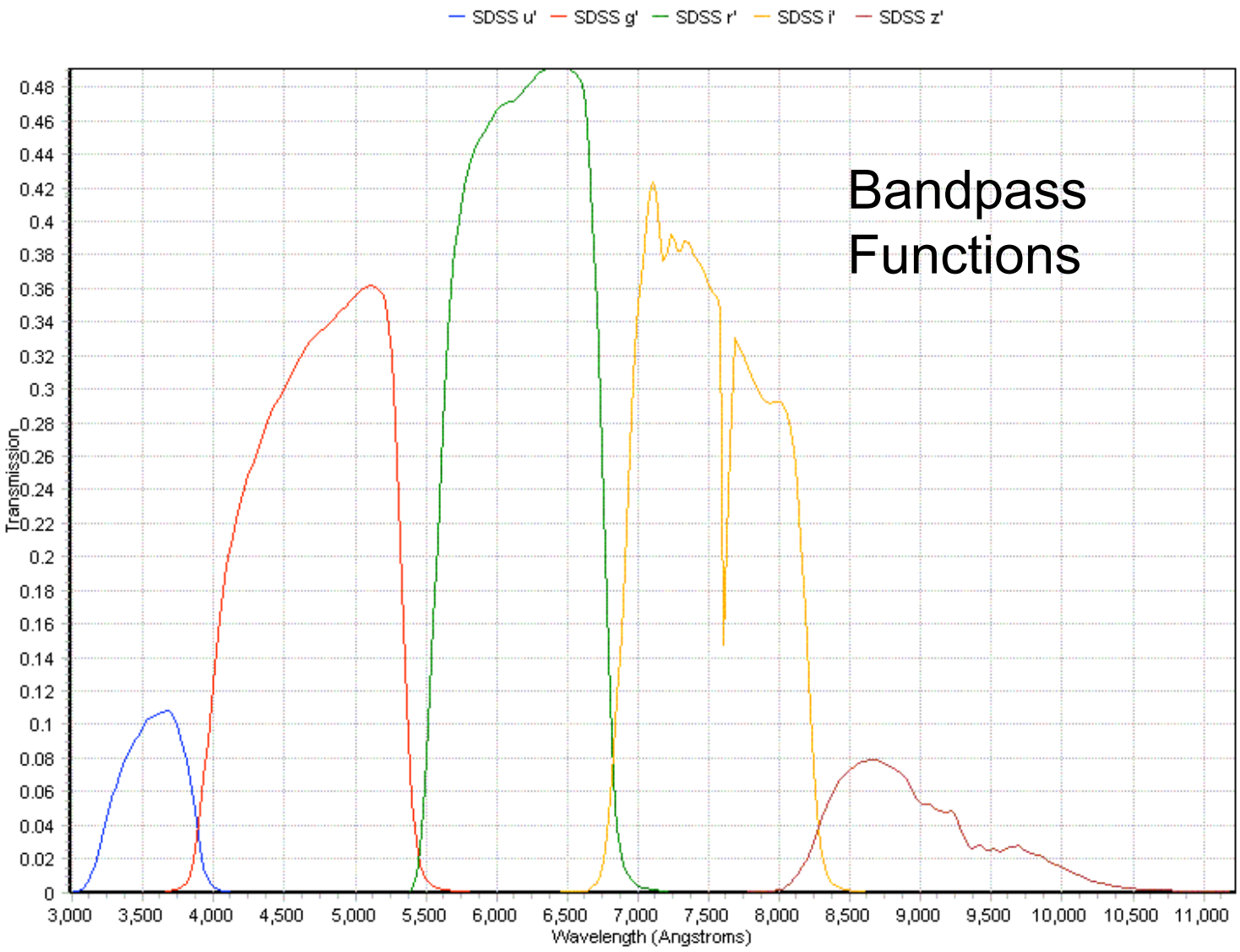


details

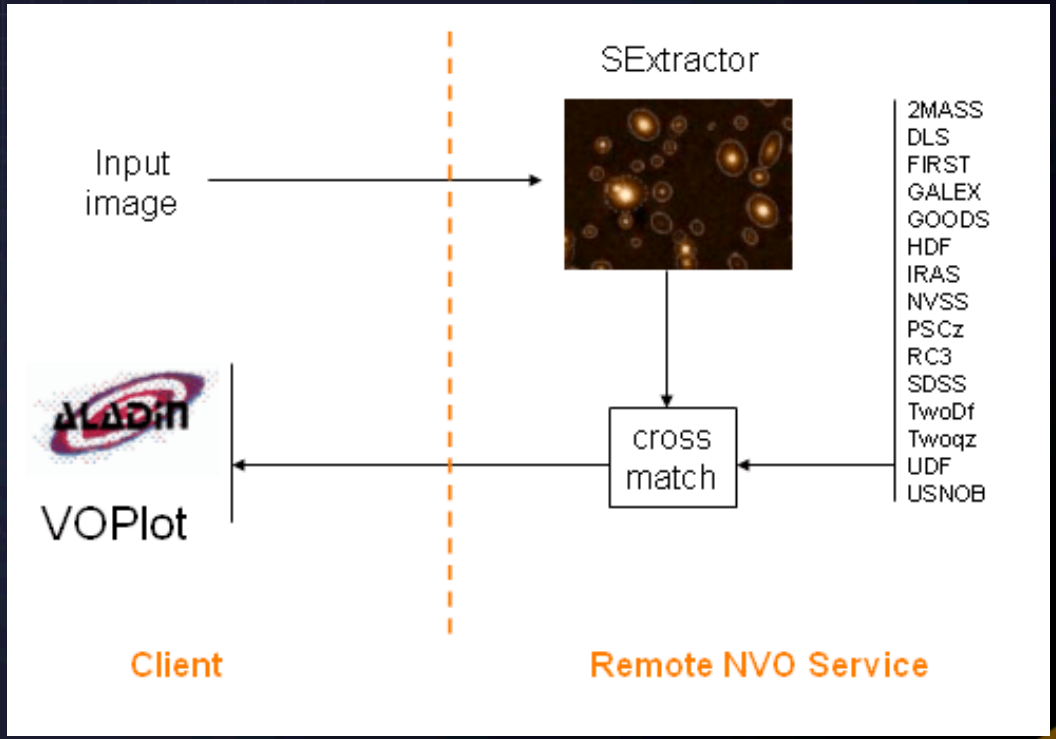
NVO: Spectrum Services



Web Enabled Source Identification with Cross-Matching (WESIX)

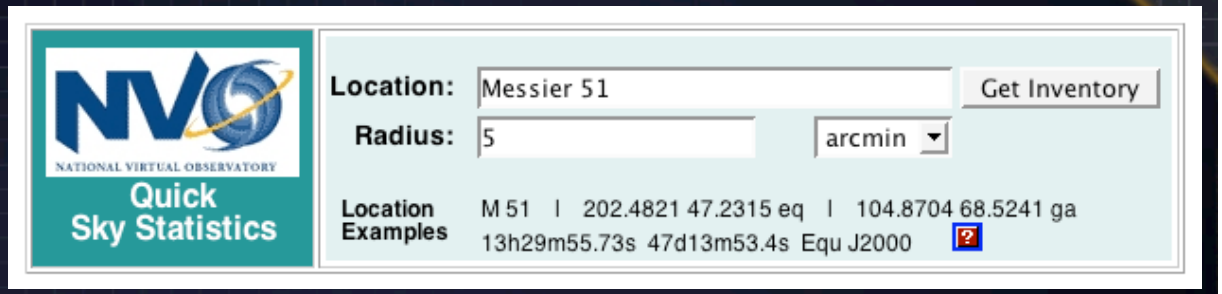
Upload images to SExtractor and cross-correlate the objects found with selected survey catalogs.

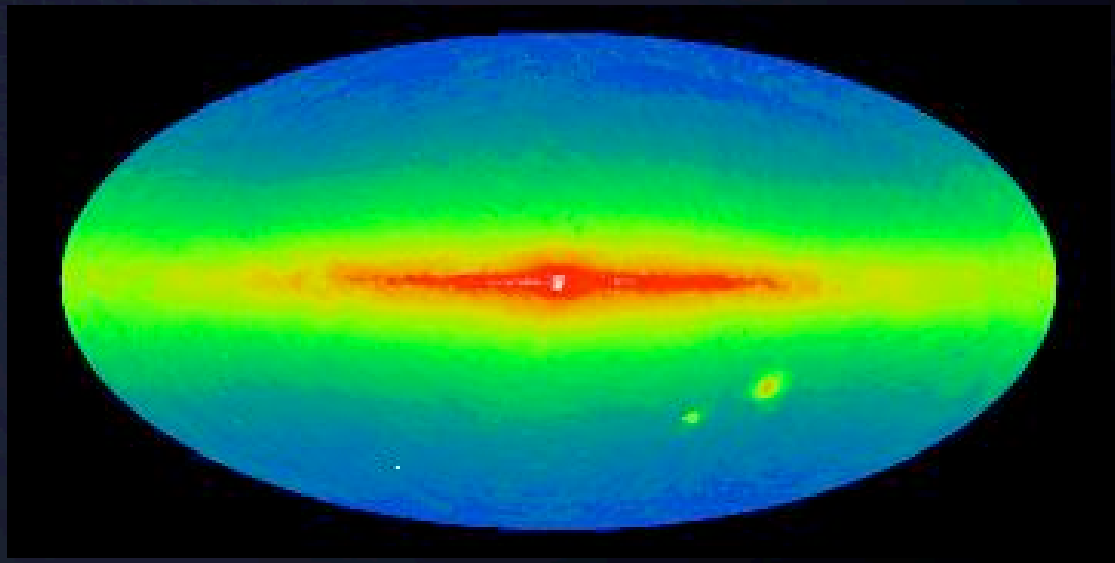
This NVO service does source extraction and cross-matching for any astrometric FITS image. The user uploads a FITS image, and the remote service runs the SExtractor software for source extraction. The resulting catalog can be cross-matched with any of several major surveys, and the results returned as a VOTable. The web page also allows use of Aladin or VOPlot to visualize results.



Coverage Maps

View catalog coverage maps and source inventories for a position or object of interest.

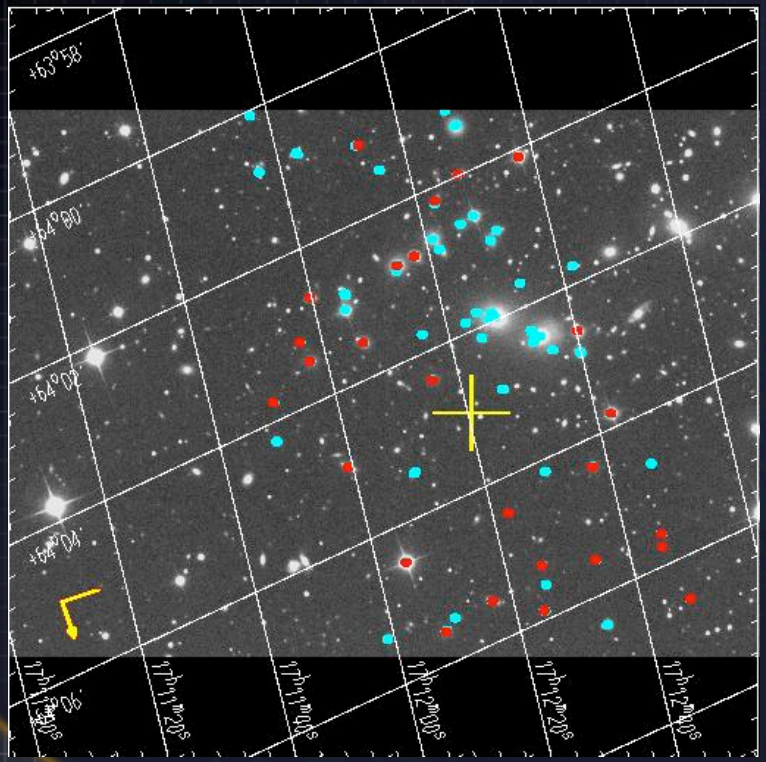


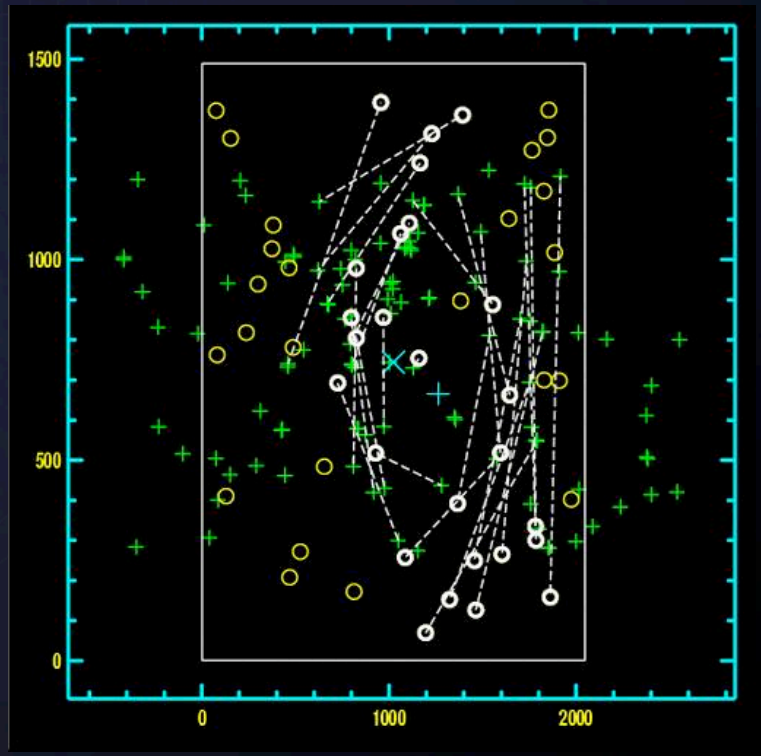


The NVO Sky Statistics Service generates source counts, coverage maps, and links to downloadable data for catalog holdings available through the NVO protocols, including IRSA, NED and CDS VizieR

WCS Fixer

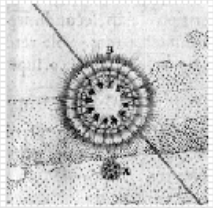
Repair image coordinates in images with inaccurate or misaligned coordinate systems.





VOEvent Net

Explore the multiwavelength sky in the vicinity of transient events.



voeventnet.caltech.edu

- Home
- Project Description
- Personnel
- GCN VOEvent Information
- IVOA VOEvent pages

VOEventNet is sponsored by NSF Grant No. CNS-0540369 and includes collaborators at California Institute of Technology, University of California Berkeley, and Los Alamos National Laboratory

VOEventNet: Real-Time Astronomy with a Rapid-Response Telescope Grid

GCN VOEvent Information

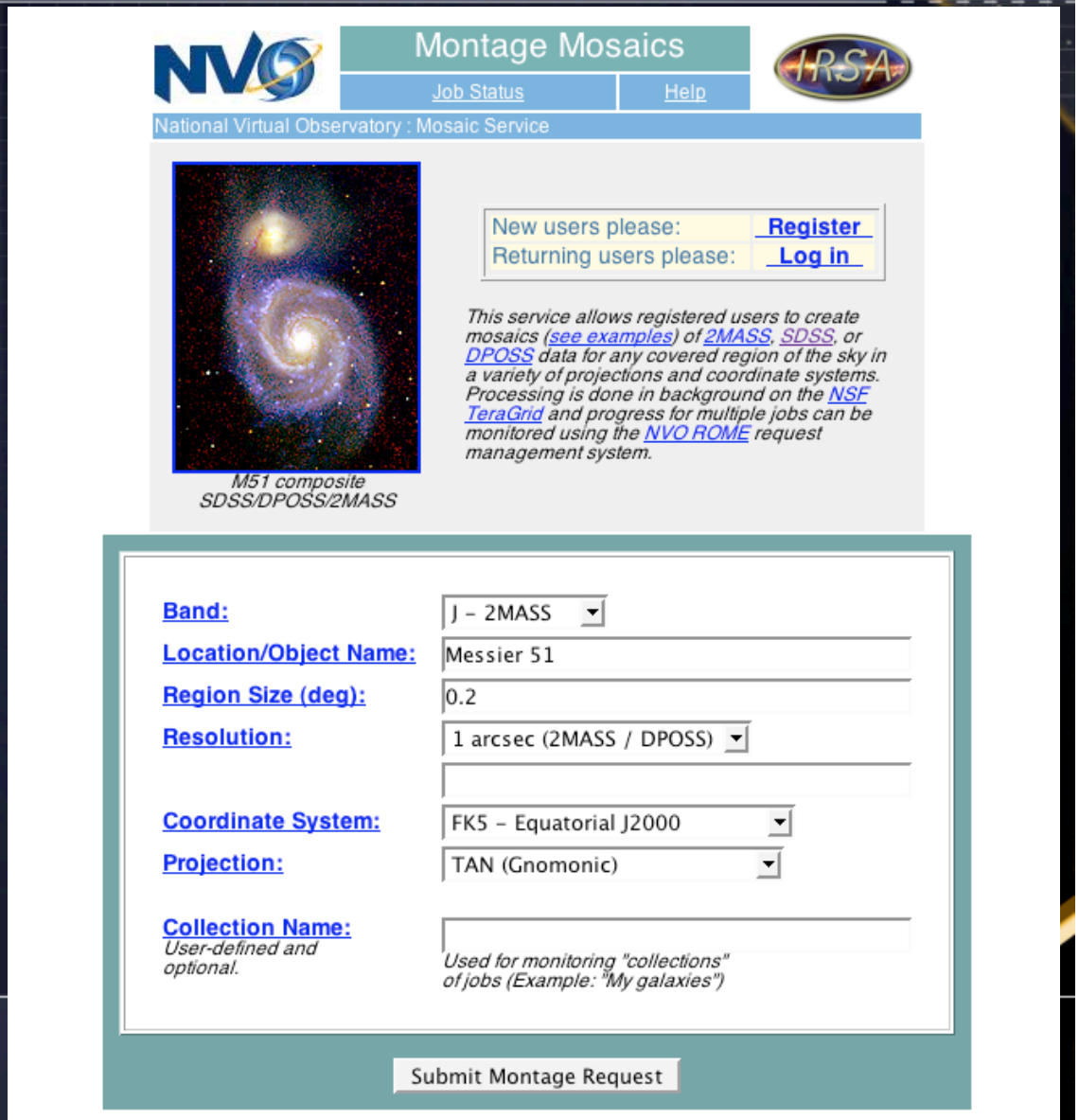
- This page is generated automatically as incoming GCN events are received and was last updated at UTC **2006-02-20T15:56:21**.
- A list of GCN notice types that are available in VOEvent format is **here** .
- Information on subscribing to receive xml GCN notices with jabber in **real time** is here:
- A near real time feed is available here: XML RSS
- This table contains information about Gamma Ray Bursts obtained from GCN notices (Table Help).

GCN GRB Triggers

GRB/Trigger			Observation					
Trig-SubNums	Date/Time	Instrument alert type	RA (deg)	Dec (deg)	Error	Inten	Comments	DataScope
72-1	2006-02-20T15:56:21	MILAGRO_Source	231.2581	37.5785	0.5400	12	Possible GRB	View data
▸191157	2006-02-20T14:52:42	SWIFT_FOM_Observe	230.4188	-80.0121	n/a	n/a	Not a new GRB.	View data
4024-1	2006-02-20T09:04:24	HETE_SC_Alert_Source	n/a	n/a	n/a	n/a	Probable GRB.	
4023-1	2006-02-19T23:20:05	HETE_SC_Alert_Source	n/a	n/a	n/a	n/a	Probable GRB.	
▸191512	2006-02-19T23:10:42	SWIFT_UVOT_Findchart	241.8283	32.3293	n/a	n/a	Possible GRB	View data
70-1	2006-02-19T21:23:55	MILAGRO_Source	12.9834	32.4332	0.5400	177	Possible GRB	View data
65-1	2006-02-19T13:51:50	MILAGRO_Source	274.5200	59.8026	0.5400	11	Possible GRB	View data
64-1	2006-02-19T04:09:02	MILAGRO_Source	148.6903	33.3708	0.5400	14	Possible GRB	View data
62-1	2006-02-19T00:13:57	MILAGRO_Source	357.8785	1.6341	0.5400	12	Possible GRB	View data
61-1	2006-02-18T18:42:43	MILAGRO_Source	314.1713	16.4237	0.5400	190	Possible GRB	View data
60-1	2006-02-18T15:54:48	MILAGRO_Source	288.2583	32.0106	0.5400	7	Possible GRB	View data
57-1	2006-02-18T10:37:34	MILAGRO_Source	164.7976	64.7670	0.5400	67	Possible GRB	View data
54-1	2006-02-17T11:51:58	MILAGRO_Source	238.4783	0.3821	0.5400	65	Possible GRB	View data

Montage Mosaics

Make mosaics from 2MASS, DPOSS, or SDSS images.



VO Tools

- VOTable display and analysis
  - VOPlot, Topcat, Mirage
- Image display and analysis
  - Aladin, OASIS
  - Other standard display tools for downloaded data
- Spectrum display and analysis
  - VOSpec, SpecView

International collaboration

- NVO is co-founder of the International Virtual Observatory Alliance

http://ivoa.net

- IVOA now has 16 member projects
- Adopted a standards process based on W3C
- Forum for discussion and sharing of experience
- IVOA and open archives endorsed by OECD (Organization for Economic Cooperation and Development) Global Science Forum report on "The Management, Storage, and Utilization of Astronomical Data in the 21st Century"

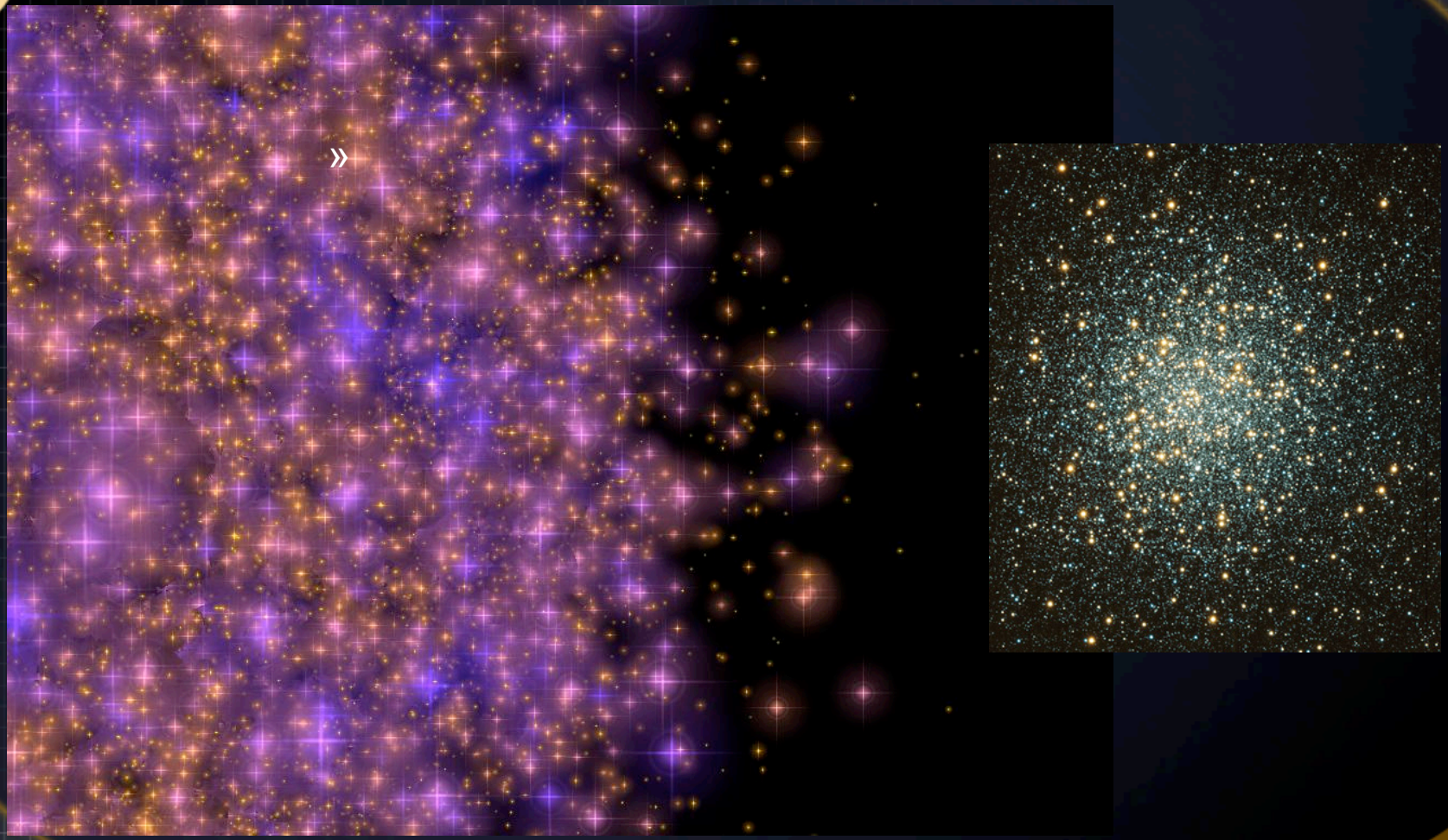
VO Science – New Capabilities

- Large Scale Surveys: 1-10 Tb --> PB
- New Facilities: ~ 10 Tb/day
- High Bandwidth Data Transmission
- All Imply a New Paradigm for Research
  - Cross Match of 1-10 Million Objects
  - New Patterns in Statistics
  - New Relations; Unseen Physical Processes
  - Serendipity

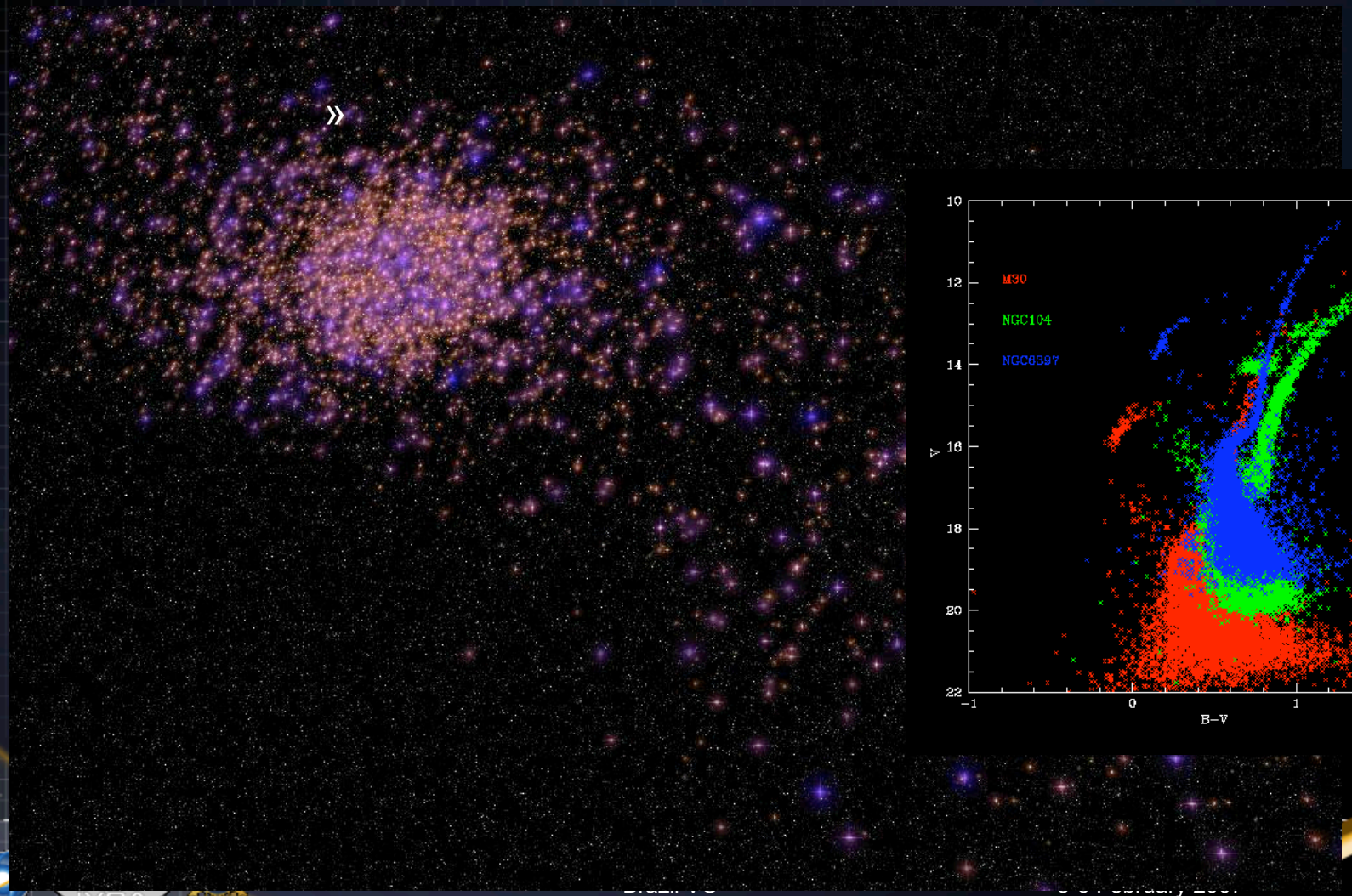
VO Science and Theory

- Translate theory results to observational parameters
- Cross-match theory “surveys” and observational surveys
- Direct new observations

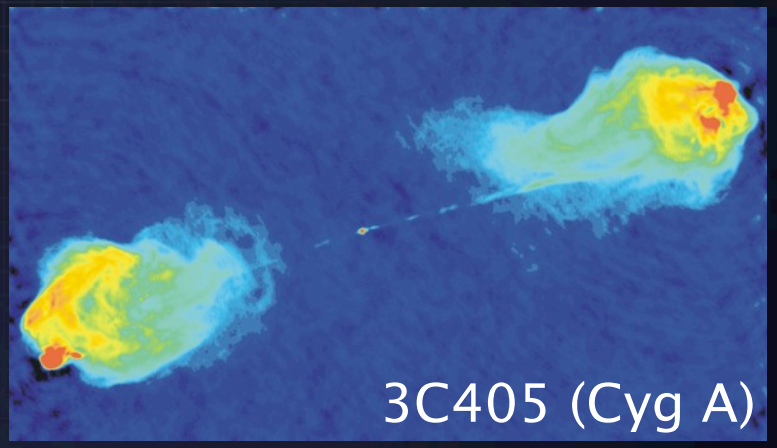
N Body Simulations of Globular Cluster Evolution

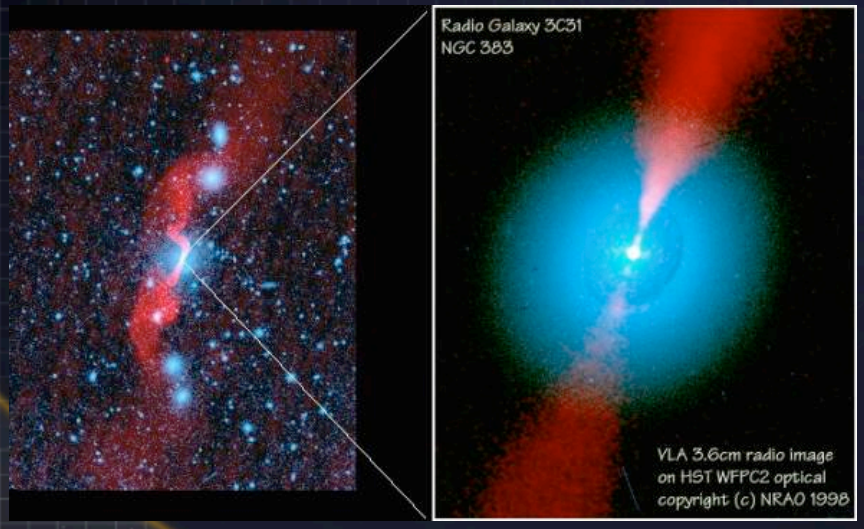


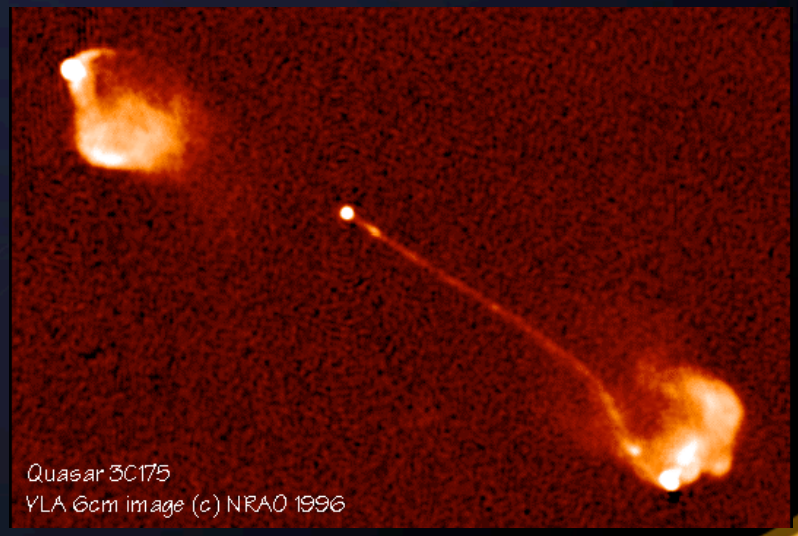
N Body Simulations of Globular Cluster Evolution



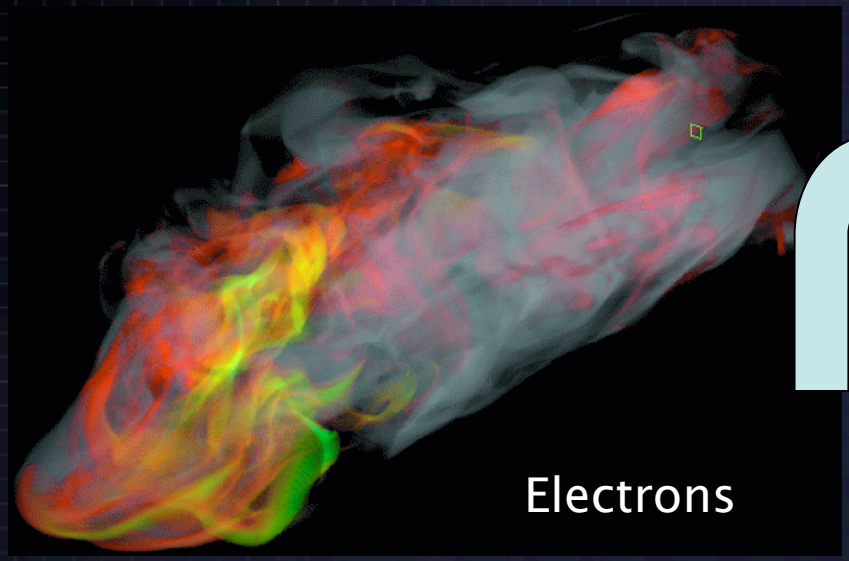
Collimated Outflows from AGN

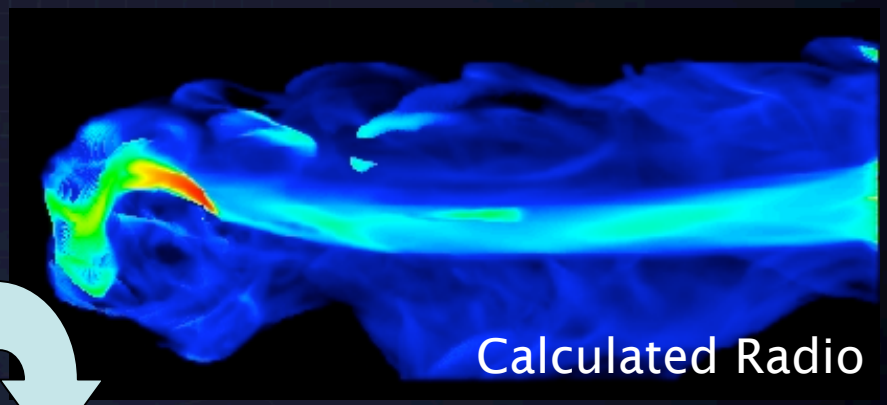






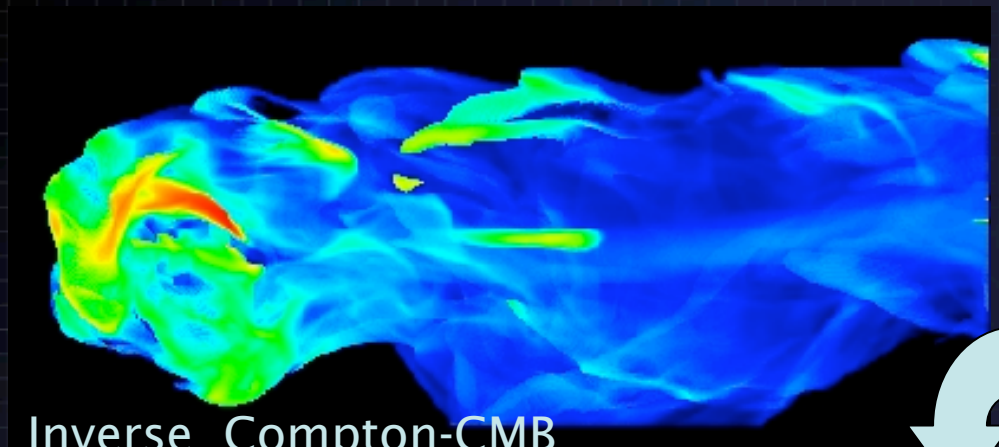
MHD Simulations of Collimated Outflows from AGN – Virtual Observations



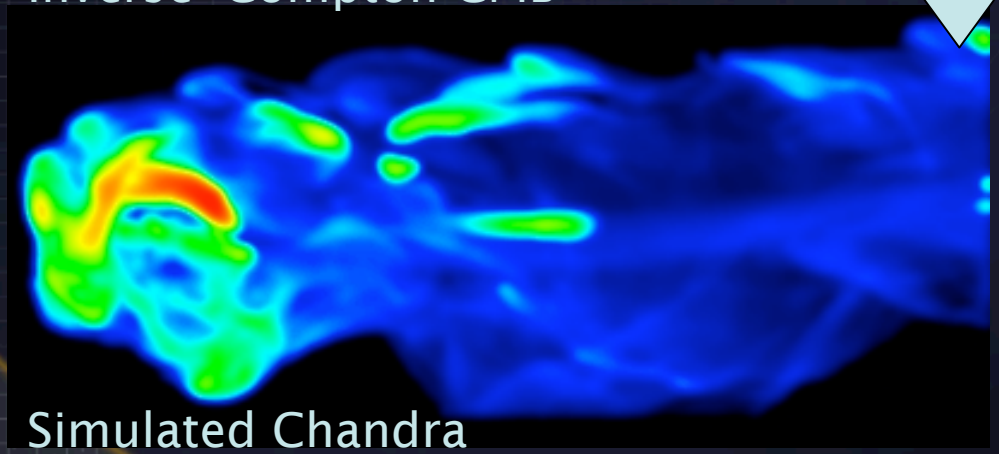


Compare with radio archives

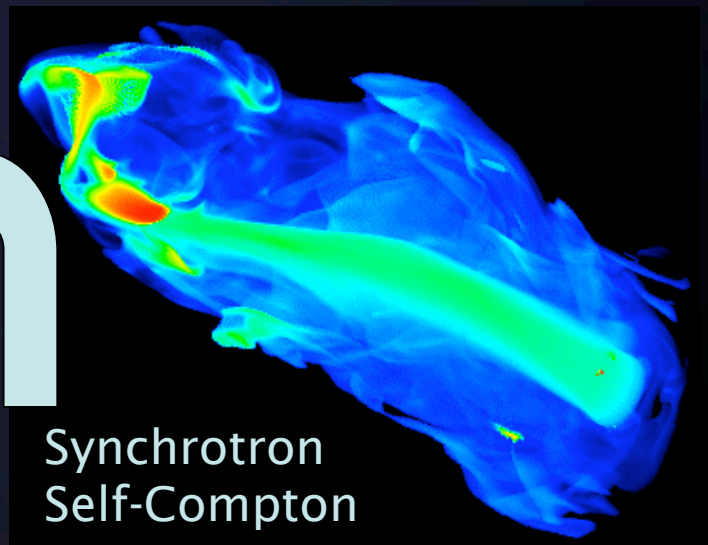
MHD Simulations of Collimated Outflows from AGN – Virtual Observations



Inverse Compton-CMB



Simulated Chandra

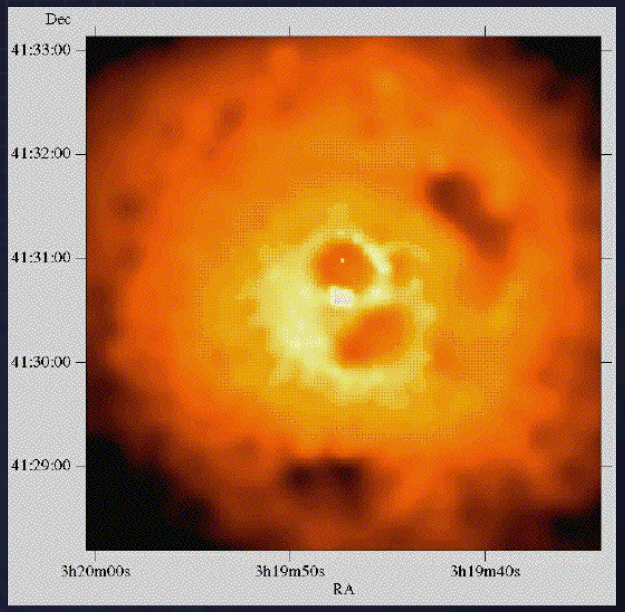


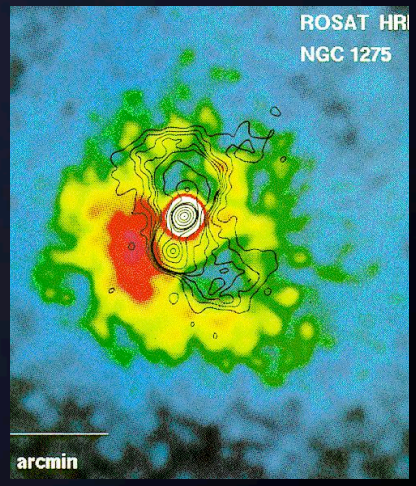
Synchrotron Self-Compton

Compare with Chandra archives

Clusters of Galaxies and "Cooling Flows"

Perseus Cluster - NGC 1275

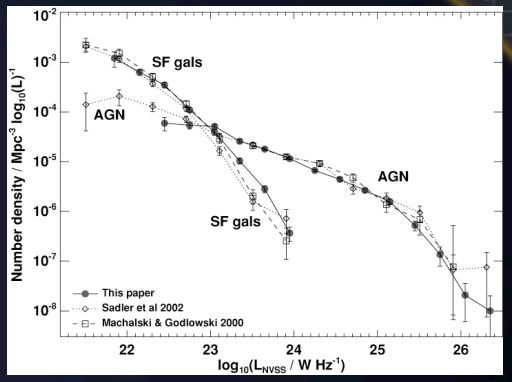


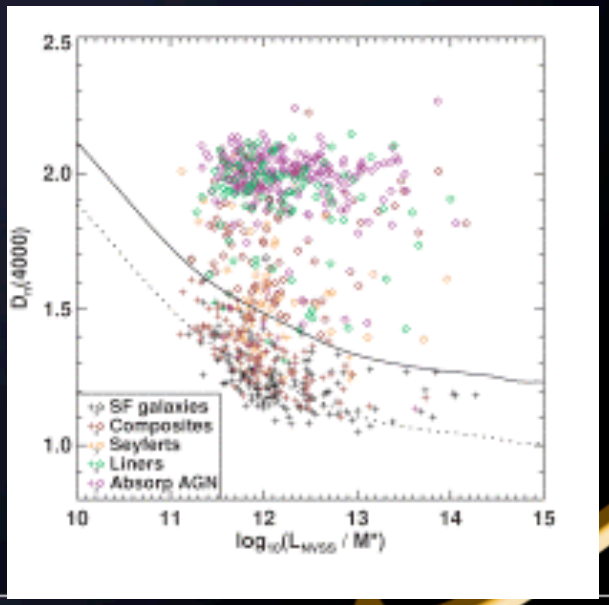


- Can reheating of the intracluster medium by AGN "solve" the cooling flow problem?

VO-Enabled Research

- Radio-loud AGN in the SDSS (Best et al. 2005)
  - Cross-match SDSS DR2, NVSS, FIRST
  - SDSS spectral data
  - 2712 radio galaxies
  - Radio emission due to AGN vs. star bursts





VO-Enabled Research

- Is there an AGN – starburst connection?
  - » (Heckman et al. 2006)
  - – Does a common accretion torus produce both?
  - – Both phenomena produce X-rays
  - – Cross correlate 80,000 X-ray sources with > 500,000 galaxies (with z) from SDSS DR4
  - – Look for common hosts
  - – Look for evolution with redshift

VO-Enabled Research

- Detecting embedded intermediate mass stars
  - » (Kerton et al. 2006)
  - – Star of 5-10 Mo – at boundary between solar type and very massive stars
    - Hence crossover of different physical processes
  - – Young B stars buried in molecular clouds
  - – Radio + mm spectral line surveys + 2MASS, IRAS
  - – Data cube analysis (x-y-λ)

VO-Enabled Research

- Merging galaxies
  - » (Allam et al. 2006)
  - Galaxy mergers: create starbursts, form central CDs in clusters, feed AGN, produce ULIRGS….
  - Optical (SDSS) surveys bias toward high SFR
  - IR traces mass distribution (red stars)
  - Search 2MASS eXtended Source Catalog (1.6M galaxies)
    - Expect ~ 30,000 merging pairs
  - Do multi-wavelength follow-up

Research results

- Padovani et al. (2004), “Discovery of optically faint obscured quasars”
- Richards et al. (2005), “Hunting post-AGB/RSG objects…”
- Tsalmantza et al. (2006), “Luminous AGB stars in nearby galaxies…”
- Suchkov et al. (2006), “SDSS AGN with X-ray emission from ROSAT PSPC pointed observations”
- Wadadekar et al. (2006), “Multiwavelength characterization of faint VLA FIRST radio sources seen in the Spitzer SWIRE survey”
- dos Santos et al. (2007), “Search for fossil groups…”

IAU VO Science Session - Prague

- Guinazzi, “The origin of soft x-ray emission in obscured AGN.”
- Volmer, “Determination of radio spectra from catalogues and identification of GHz peaked sources.”
- Shirasaki, “Environment of z=1.3 QSOs.”
- Prema, “Galaxy formation and evolution using multiwavelength, multiresolution data.”
- Solano, “Discovery and characterization of brown dwarfs.”
- Lucas, “Multiwavelength study of a sample of Texas Radio Survey steep spectrum sources.”
- Dalla, “Solar active region emergence and flare productivity.”
- Thuillot, “Physical and dynamical characterization of asteroids.”

Summary

- To date: IVOA establishes infrastructure
  - Almost done with “Phase 1”
- Beginning now: VO enables new research
- The transition is in progress
  - Infrastructure development concluding, phasing into operational support
  - Focus changing to implementation of research capabilities
  - Engaging and informing the astronomical community
  - Broadening participation of data and service providers through national and international collaboration

The VO and Brazil

- Get more from Brazilian astronomy resources
  - Comparison with other data
  - Publication for others to use: relevance, reputation
- Foster collaboration among Brazilian research institutions
- Participate in the international standards process
  - VO is not finished, will evolve