

THE VIRTUAL OBSERVATORY (VO)

Discovery and Exploration in the VO

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Why Discovery and Exploration?

- Astronomy is a resource intensive research field
 - We require data data to plan our proposals, write papers, and answer the interesting questions.
 - We rely on access to non-data resources which enable us to utilize the data
- Discovery versus Exploration
 - Discovery: The act of searching for and finding a resource that we can use
 - Exploration: The act of “informed wandering”, which may or may not lead us to a resource we can use
- All in the context of the VO



How do astronomers explore and discover?

- Google
 - Search the web (and hope for the best)
- Journals and their portals
 - Go to the published source
- Data “Ingesters”
 - The data collectors
- Archive Centers
 - The data guardians
- The VO



Astronomy via Google



- I know of the name or descriptor of a resource (e.g., data for M31).
- I then simply type, click, and search the WWW
- I then get re-directed to another resource, usually a Journal article, occasionally another web page, and rarely a data source).
- I get my data or resources from this other source.



m31

Search

[Advanced Search](#)
[Preferences](#)

[Messier Object 31](#)

Messier 31 (**M31**, NGC 224) is the famous Andromeda galaxy, our nearest large neighbor
The brightest globular cluster of the Andromeda Galaxy **M31**, G1, ...
www.maa.clell.de/Messier/E/m031.html - 21k - [Cached](#) - [Similar pages](#) - [Note this](#)

[Andromeda Galaxy - Wikipedia, the free encyclopedia](#)

Charles Messier catalogued it as object **M31** in 1764 and incorrectly credited ... To support his claim that "Great Andromeda Nebula" (**M31**) was an external ...
en.wikipedia.org/wiki/Andromeda_Galaxy - 126k - [Cached](#) - [Similar pages](#) - [Note this](#)

[The Andromeda Galaxy - Google Books Result](#)

by Paul W. Hodge - 1992 - Science - 358 pages
With the current developments in instrumentation with which increasingly detailed studies of the Andromeda Galaxy can be made, this book provides a solid...
books.google.com/books?isbn=0792316541...

[Chandra :: Photo Album :: Andromeda Galaxy \(M31\) :: 22 May 07](#)

May 22, 2007 ... Chandra X-ray Image of Andromeda Galaxy (**M31**) ... References, X-ray



Astronomy via Google

Works Well When:

- You just want to type and click to search the WWW
- You want to search every posted PDF paper
- You want to find out everything about something
- You want search results sorted by “relevance”

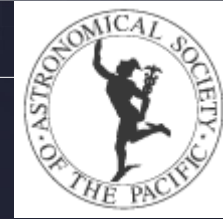
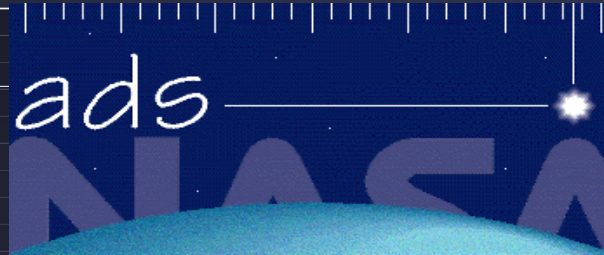
Doesn't Work Well When:

- The data you want is not searchable “in” the WWW
- You really don't want all of those “un-refereed” papers
- You don't want to find out everything
- You want order out of chaos



Astronomy via Journals

IOP Institute of Physics




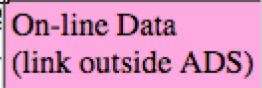
- I read an article and "see" data.
- I phone or email the author for data-on-media.
- I transcribe journal tables into electronic format.
- I copy and paste HTML/LaTeX versions of tables.
- I access electronic tables directly



[SAO/NASA Astrophysics Data System \(ADS\)](#)

Query Results from the ADS Database

[Go to bottom of page](#)Retrieved **200** abstracts, starting with number **1**. Total number selected: **6309**.Sort options 

#	Bibcode Authors	Score	Date	List of Links Access Control Help	
1	<input type="checkbox"/> 2008MNRAS.388...56B Bogdán, Á.; Gilfanov, M.	1.000	07/2008	A E F X D R C S U	
2	<input type="checkbox"/> 2008MNRAS.387.1361B Boyarsky, Alexey; Iakubovskiy, Dmytro; Ruchayskiy, Oleg; Savchenko, Vladimir	1.000	07/2008	A E F X R C S U	
3	<input type="checkbox"/> 2008ApJS..177..362C Cortés, C.; Catelan, M.	1.000	07/2008	A E F R C S U	
4	<input type="checkbox"/> 2008ApJS..177..174N Narbutis, D.; Vansevičius, V.; Kodaira, K.; Bridžius, A.; Stonkutė, R.	1.000	07/2008	A E F X R S U	

Astronomy via Journals

Works Well When:

- You personally know the author and their specialty
- You want to explore related research
- You are searching for an “entity”
- You have lots of time and good book keeping skills

Doesn't Work Well When:

- You want to search near a position or within a footprint
- You want “raw” data
- You have >10s of entities
- You want to spatially cross-match between entities



Astronomy via the Data Ingesters



-
-
- I want to search a “Database of Everything”.
- I have an object name or a position on the sky.
- I search and see links to 100s or 1000s of objects, each with their own references.
- I browse through the top N of these objects and their references to decide which data are the ones I want.
- I then use the ingested data values or the original references to create a useful datatable.

NASA/IPAC EXTRAGALACTIC DATABASE

Date and Time of the Query: 2008-09-02 T08:41:28 PDT

[Help](#) | [Comment](#) | [NED Home](#)

Searching NED within 10.0 arcmin of object "ABELL 1882"

873 objects found in NED. [Skyplot\(first 100\)](#)

Object list is sorted on Distance to search center

Row No.	Object Name (* => Essential Note)	EquJ2000.0		Type	Velocity/Redshift		Separ.		Number of					
		RA	DEC		km/s	z	Qual	arcmin	Refs	Notes	Phot	Posn	Vel/z	D
1	ABELL 1882	14h14m39.9s	-00d19m57s	GClstr	>30000	0.136700		0.0	17	0	0	1	0	
2	[MD2000] J141441.443-001955.66	14h14m41.4s	-00d19m56s	VisS	...	...		0.4	1	0	0	0	0	
3	QUEST 130703	14h14m42.1s	-00d20m18s	VisS	...	...		0.7	1	0	0	0	0	
4	[MD2000] J141439.232-002038.36	14h14m39.2s	-00d20m38s	G	...	...		0.7	1	0	0	0	0	
5	[MD2000] J141440.486-001914.62	14h14m40.5s	-00d19m15s	G	...	...		0.7	1	0	0	0	0	
6	[MD2000] J141441.702-001919.17	14h14m41.7s	-00d19m19s	G	...	...		0.8	1	0	0	0	0	
7	[MD2000] J141442.650-002022.67	14h14m42.6s	-00d20m23s	VisS	...	...		0.8	1	0	0	0	0	
8	[MD2000] J141437.809-001907.12	14h14m37.8s	-00d19m07s	G	...	...		1.0	1	0	0	0	0	
9	SDSS J141436.09-002017.2	14h14m36.1s	-00d20m17s	G	...	...		1.0	2	0	1	1	0	
10	[MD2000] J141438.055-001901.52	14h14m38.0s	-00d19m02s	G	...	...		1.0	1	0	0	0	0	
11	[MD2000] J141442.439-001904.40	14h14m42.4s	-00d19m04s	G	...	...		1.1	1	0	0	0	0	
12	[MD2000] J141444.130-001941.09	14h14m44.1s	-00d19m41s	G	...	...		1.1	1	0	0	0	0	
13	[MD2000] J141438.302-001852.72	14h14m38.3s	-00d18m53s	G	...	...		1.1	1	0	0	0	0	
14	[MD2000] J141435.108-001955.39	14h14m35.1s	-00d19m55s	G	...	...		1.2	1	0	0	0	0	
15	QUEST 130614	14h14m36.1s	-00d19m13s	VisS	...	...		1.2	1	0	0	0	0	
16	[MD2000] J141444.851-002003.24	14h14m44.8s	-00d20m03s	G	...	...		1.2	1	0	0	0	0	
17	[MD2000] J141443.898-001912.58	14h14m43.9s	-00d19m13s	G	...	...		1.2	1	0	0	0	0	
18	SDSS J141442.74-001855.2	14h14m42.7s	-00d18m55s	G	>30000	0.138643		1.3	2	0	21	3	2	
19	[MD2000] J141443.416-001900.49	14h14m43.4s	-00d19m00s	G	...	...		1.3	1	0	0	0	0	
20	[MD2000] J141434.385-001937.25	14h14m34.4s	-00d19m37s	G	...	...		1.4	1	0	0	0	0	



Astronomy via the Data Ingesters

Works Well When:

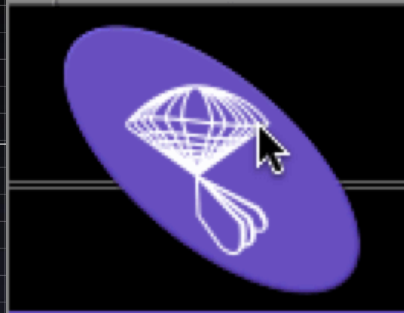
- Searching for anything of a single entity or position.
- You know catalog or table names
- You can define categories or types of objects
- You want more or less "complete" coverage

Doesn't Work Well When:

- You need the "right" data, the "best data" or the "most popular data"
- You want to "data mine"
- You need "raw" data
- You will cross-match > 10s of objects
- You find more than 100s of objects



Astronomy via the Data Archives



- I know the SDSS/HST/Spitzer archive exists and probably contains the data I am seeking.
- I go to the specific archive, learn the details of the mission and the data, and build advanced queries to find the data I need.
- I bring over to my desktop large catalogs and/or their imaging data to do my science.
- I then analyze these images or use these monolithic, homogenous catalogs to do my science.

Object name [M31](#) resolved by [NED](#) to **MESSIER 031** (G [from Cache])
RA: 0 42 44.32 Dec: 41 16 8.54 (J2000)

```
SELECT *
FROM mast..hst_science_view
WHERE (sci_aec LIKE 'S')
AND (sci_ra BETWEEN 10.534990102 AND 10.8343432314)
AND (sci_dec BETWEEN 41.1565388889 AND 41.3815388889)
```

100 rows displayed, but 552 are available.

Click on Dataset or Target Name entries to preview information on data set.

Click on Ref entries to display list of published papers.

Click on Proposal ID entries to display information on observing program.

Records with a @ character next to the mark button are proprietary, and may only be retrieved by authorized users.

Click on top column headers to sort the table on the column contents.

Click on bottom column headers for more information about the data in that column.

[Plot marked spectra](#) [Submit marked data for retrieval from STDADS](#)

[Mark all](#) [Unmark all](#) [Mark public](#) [Unmark public](#) [Mark proprietary](#) [Unmark proprietary](#)

◀ [Previous](#) [Next](#) ▶ Page 1 of 3

Mark	Dataset	Target Name	RA (J2000)	Dec (J2000)	Ref	Start Time	Stop Time	Exp Time	Instrument	Apert
<input type="checkbox"/>	Y1C8030HT	NGC224-S2	00 42 44.31	+41 16 08.6		1993-06-13 04:40:10	1993-06-13 05:02:50	1300.162	FOS	0.3
<input type="checkbox"/>	Y2IO010HT	NGC224-S1	00 42 44.33	+41 16 08.6		1995-02-22 08:12:40	1995-02-22 08:38:47	1499.985	FOS	0.3
<input type="checkbox"/>	Y1C8030FT	NGC224-S1	00 42 44.33	+41 16 08.6		1993-06-13 02:43:48	1993-06-13 03:04:19	1200.000	FOS	0.3



Astronomy via the Data Archives

Works Well When:

- You already know data was taken by an instrument
- You work with “lower level” data (e.g., original reduced or raw images).
- You need resources for intensive queries
- You want searches to be “complete”
- You use/need many 1000s of objects

Doesn't Work Well When:

- You need multi-wavelength data
- You do not have expert knowledge of the mission
- You want an overview of what is available
- You want to explore



Discovery and Exploration: The role of the VO

Discovering and exploring astronomical resources via all of the above techniques

You want something as simple as “Google for astronomy”

You want the tried-and-true ability to discover and explore through Journal articles and their tables

You want to access the “databases-of-everything”

You want the compute power and tailored services of the individual archive services

And you do not want to despise the process of doing these things



Using the VO with your browser

Like many other disciplines, astronomy through the IVOA, is enabling the constructions of web portals and shared community use.

- OpenSkyQuery Portal
 - Search catalog databases distributed globally via Archive Centers (like a database-of-everything).
- The NOAO VO Portal
 - Visually browse image archive holdings spatially and temporally.
- The US-VO Portal
 - Single point of access to the NVO registry, services, tools.



Using the VO with your browser

www.us-vo.org



NATIONAL VIRTUAL OBSERVATORY

...the Universe at your fingertips

Discover, retrieve, and analyze astronomical data from archives and data centers around the world.



Need help? Not sure how to start?

>> [Getting Started with NVO](#)



Collect all data at a given position.

>> [DataScope](#)



Count matches between catalog entries and given positions.

>> [Inventory](#)



Query databases and cross-match object lists

>> [Open SkyQuery](#)



Find data collections and catalogs by searching their descriptions.

>> [Directory](#)



Integrate data from multiple positions and datasets.

>> [VIM](#)



Query the VO from the command line.

>> [VO-CLI](#)



Convert text tables to the VOTable format used by VO applications.

>> [Table Tools](#)



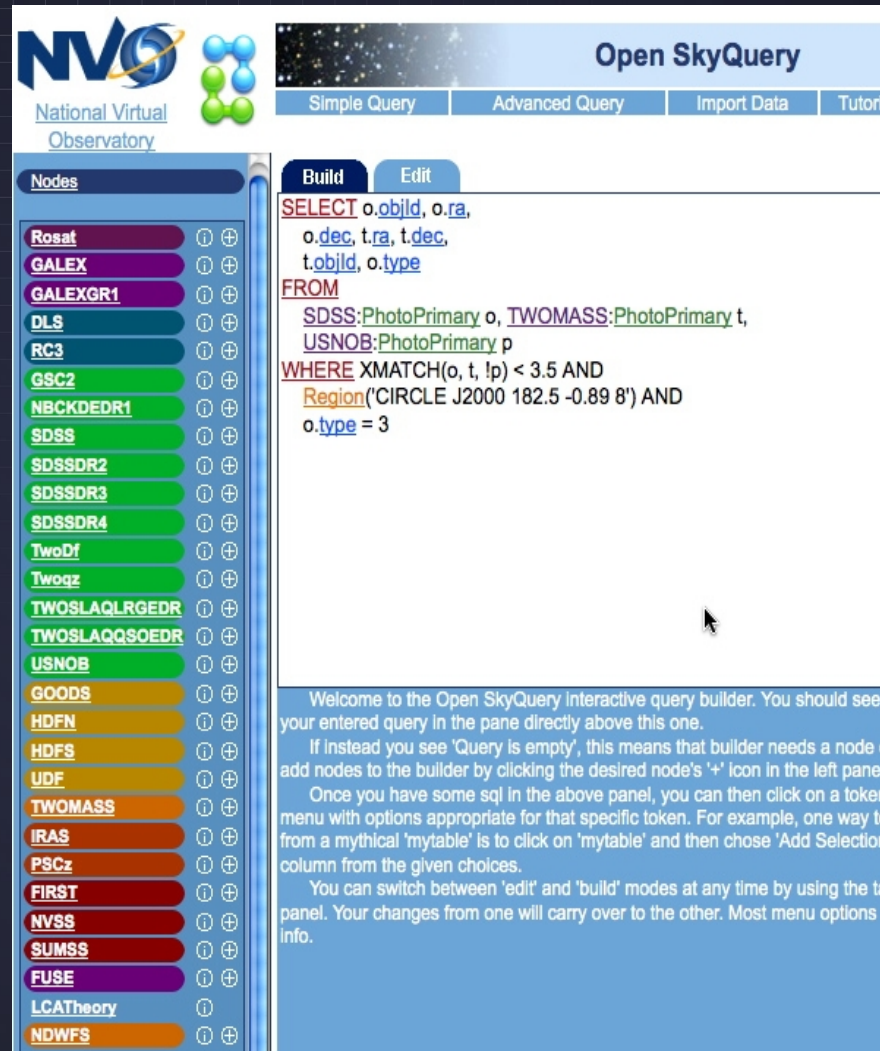
Do more with NVO.

>> [Data Analysis & More](#)



Using the VVO with your browser

www.openskyquery.net



The screenshot displays the Open SkyQuery web interface. At the top left is the NVO logo (National Virtual Observatory) and the text "National Virtual Observatory". To the right is the "Open SkyQuery" title and navigation tabs for "Simple Query", "Advanced Query", "Import Data", and "Tutorial". Below the navigation is a "Build" and "Edit" mode selector. The main content area shows a SQL query:

```
SELECT o.objId, o.ra,
       o.dec, t.ra, t.dec,
       t.objId, o.type
FROM
  SDSS:PhotoPrimary o, TWOMASS:PhotoPrimary t,
  USNOB:PhotoPrimary p
WHERE XMATCH(o, t, !p) < 3.5 AND
      Region('CIRCLE J2000 182.5 -0.89 8') AND
      o.type = 3
```

On the left side, there is a "Nodes" list with various astronomical survey names and their corresponding icons:

- Rosat
- GALEX
- GALEXGR1
- DLS
- RC3
- GSC2
- NBCKDEDR1
- SDSS
- SDSSDR2
- SDSSDR3
- SDSSDR4
- TwoDf
- Twoqz
- TWOSLAQLRGEDR
- TWOSLAQQSOEDR
- USNOB
- GOODS
- HDFN
- HDFS
- UDF
- TWOMASS
- IRAS
- PSCz
- FIRST
- NVSS
- SUMSS
- FUSE
- LCATheory
- NDWFS

Below the query, there is a welcome message and instructions for using the query builder:

Welcome to the Open SkyQuery interactive query builder. You should see your entered query in the pane directly above this one. If instead you see 'Query is empty', this means that builder needs a node to add nodes to the builder by clicking the desired node's '+' icon in the left pane. Once you have some sql in the above panel, you can then click on a token in the menu with options appropriate for that specific token. For example, one way to add a column from a mythical 'mytable' is to click on 'mytable' and then chose 'Add Selector' from the given choices. You can switch between 'edit' and 'build' modes at any time by using the tabs at the top of the panel. Your changes from one will carry over to the other. Most menu options have help info.

Using the VO with your browser

www.nvo.noao.edu

NOAO NVO Portal v5.7
A web application for the VO

Persistence: On >> Sky Time Access/Analyze SIA Query Sign out (chrism)

Description
Add a Marker and Crossmatch
Specify Object Name or Sky Location
Display and Search by Archive

- Cart
- SDSS
- CHANDRA
- NSA
- XMM
- HST
- INT
- GALEX

Search

Search Region on the Sky:
0.00 < RA < 360.00
-90.00 < DEC < 90.00

Zoom=2
RA=0.00,Dec=0.00



MOSAIC data from NOAO PROP ID:
2005B-0045



Using the VO with your favorite language

Astronomers have their favorite software languages, like FORTRAN, IRAF, IDL, SuperMongo, Python.

- Some “Native” libraries exist to use the VO
- VO-CLI is an API which allows almost any programming or scripting language to utilize VO data, tools, and services
 - The use of these libraries is the exception, not the rule



Using the VO with your Desktop

There exist downloadable software which have the mechanisms to access VO objects

- VO-CLI
- AstroGrid (now cancelled)
 - A desktop environment for the VO
- Topcat/Aladin/DS9
 - Primarily table manipulators and image viewers
 - They contain hooks to VO image and catalog services.
 - They use the SAMP messaging protocol to pass messages between applications.



Using the VO with Journals

- IVOA Identifiers and ADS Dataset Identifiers
 - ivo://AuthorityId/ResourceKey#PrivateId
 - ADS/FacilityId#PrivateId
- Journal tables? ApJ, volume 365, page 66
 - ivo://CDS/VizieR/J/ApJ/365/66/table2



Discovery and Exploration Summary

Astronomers know how to discover and explore

The VO is trying to make discovery and exploration easier and more productive

We (and others) build Portals

Due to the protocols and standards defined by the IVOA Portals are becoming easy to build

Portals can be built and designed by anyone for any purpose

- The VO lives inside the archives, data centers, resources, etc.



Where do you start?

Here:

- www.us-vo.org
 - Type and go
 - Direct access to online services (catalog generators, WCS fixers, MOSAIC builders).
- www.astrogrid.org
 - Download the desktop VO environment
- www.euro-vo.org
 - VO Science Recipes
 - Links to many VO tools

