

# **AST1501 - Introduction to Research**

**Jo Bovy**

# **How to access astronomical data**

# Overview

- Types of astronomical data
- Data from individual papers
- Small data sets
- Large data sets
- Cross-matching

# Types of astronomical data



# Types of astronomical data

- Focus in this class: public data sets useful for your work
- Table in a paper
- Small data sets: online-only table in a paper, small survey
  - CDS
- Large data sets: large surveys
  - Dedicated tools
  - Astroquery

# Table in a paper

Name	Period (d)	Mass (kg)	Average orbit radius (km)	Astronomical unit (1 AU)	Radius weights ( $r_i$ )	Angular velocity ( $\omega$ )
Mercury	87.969	$0.3301 \times 10^{24}$	56 672 443.84	0.38709893	4.69091E-05	26.08840762
Venus	224.701	$4.8676 \times 10^{24}$	108 207 517.8	0.72333199	0.001320004	10.21344422
Earth	365.256	$5.9726 \times 10^{24}$	149 579 112	1.00000011	0.002238882	6.2831853
Mars	686.98	$0.64174 \times 10^{24}$	226 923 421.8	1.52366231	0.000363432	3.340666584
Jupiter	4332.587	$1898.3 \times 10^{24}$	777 657 818.7	5.20336301	3.699505551	0.529699953
Saturn	10 759.22	$568.36 \times 10^{24}$	1 431 426 696	9.53707032	2.038821640	0.213302742
Uranus	30 685.4	$86.816 \times 10^{24}$	2 869 262 907	19.1912393	0.624274378	0.074790328
Neptune	60 189.0	$102.42 \times 10^{24}$	4 494 894 315	30.48168677	1.153633570	0.038129411
Pluto	90 465.0	$0.0131 \times 10^{24}$	5 720 641 564	39.48168677	1.88377E-04	0.025368608

Note: These are basic data from NASA.

# You find a useful (small) table in a paper, now what?

- IOP journals  
(ApJ, ApJS, AJ, ApJL, PASP)

- All tables available in  
ASCII format!

Name	Period (d)	Mass (kg)	Average orbit radius (km)	Astronomical unit (1 AU)	Radius weights ( $r_i$ )	Angular velocity ( $\omega$ )
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THE ASTROPHYSICAL JOURNAL

OPEN ACCESS

## Identification of Superclusters and Their Properties in the Sloan Digital Sky Survey Using the WHL Cluster Catalog

Shishir Sankhyayan<sup>1</sup> , Joydeep Bagchi<sup>2</sup> , Elmo Tempel<sup>1,3</sup> , Surhud More<sup>4,5</sup> , Maret Einasto<sup>1</sup> , Pratik Dabhadse<sup>6,7</sup> , Somak Raychaudhury<sup>4,8</sup> , Ramana Athreya<sup>9</sup> , and Pekka Heinämäki<sup>10</sup> 

Published 2023 November 13 • © 2023. The Author(s). Published by the American Astronomical Society.

[The Astrophysical Journal, Volume 958, Number 1](#)

Citation Shishir Sankhyayan et al 2023 *ApJ* 958 62

DOI 10.3847/1538-4357/acfaeb

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Figures ▾

Tables ▾

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+ Article and author information

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CITATION: SARKAR, SARITADEVAN ET AL. 2020 MNRAS 000 000

DOI 10.3847/1538-4357/acfaeb



Figures ▾ Tables ▾ References ▾ Article data ▾

## Skip to each table in the article

Their Masses			
e	Mass ( $10^{14} M_{\odot}$ )	$N_{\text{mem}}$	$N_{\text{Abels}}$
c)	(%)	(%)	(10)
10	257.106	54	2
59	255.164	57	7
40	210.629	41	10
50	196.421	38	1
10	191.222	44	0

Column (2): R.A. Column (3): decl. Column (4): R.A. of  
center (6): redshift. Column (7): linear comoving size.  
cm.

**Table 3**  
Summary of the Properties of the Observed and Mock Superclusters

	WHL (0.05 $\leq z \leq 0.42$ )	WHL (0.05 $\leq z \leq 0.366$ )	Mock (0.05 $\leq z \leq 0.366$ )
Linking Length $l_o$ (Mpc)	20.65	19.22	19.88
Number of Superclusters	662	456	451
Median Mass ( $10^{14} M_{\odot}$ )	57.80	55.97	46.43
Median Size (Mpc)	64.87	60.49	60.83
Median Density Contrast	11.64	15.40	10.88
Median No. of Members	13	13	12

**Table 3**

superclusters covering a wide range of redshifts and sky areas is essential. Here, we present a large

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Table 3. Summary of the Properties of the Observed and Mock Superclusters

	WHL (0.05 $\leq z \leq$ 0.42)	WHL (0.05 $\leq z \leq$ 0.366)	Mock (0.05 $\leq z \leq$ 0.366)
Linking Length $l_0$ (Mpc)	20.65	19.22	19.88
Number of Superclusters	662	456	451
Median Mass ( $10^{14} M_\odot$ )	57.80	55.97	46.43
Median Size (Mpc)	64.87	60.49	60.83
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Median No. of Members	13	13	12

Download table as:

ASCII

Typeset image

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  - All tables available in ASCII format!

Table 3  
Summary of the Properties of the Observed and Mock Superclusters

	WHL (0.05 < or=z < or=0.42)	WHL (0.05 < or=z < or=0.366)	Mock (0.05 < or=z < or=0.366)
Linking Length l_o (Mpc)		20.65	19.22 19.88
Number of Superclusters	662	456	451
Median Mass (10^14 M_sun)		57.80	55.97 46.43
Median Size (Mpc)	64.87	60.49	60.83
Median Density Contrast	11.64	15.40	10.88
Median No. of Members	13	13	12

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(ApJ, ApJS, AJ, ApJL, PASP)
  - All tables available in ASCII format!
- Other journals: no machine-readable version generally available

Release 17 (DR17; SDSS Collaboration in preparation). The majority of these (9188, or 92 per cent) have Galaxy Zoo: 3D analysis. Detailed Galaxy Zoo (GZ2) classifications

Table 1.  
Galaxy samples and selection in GZ:3D. We release masks from the final phases only, as we only recommend their use for science. The numbers are MaNGA targets shown to GZ:3D volunteers for each workflow task, not the number that have successful masks or clusters.

Task	DR14 (Phase 1)	All MaNGA targets (Phase 2)	DR17* (Subset of Phase 2)	GZ2 Pre-selection
Galaxy centre	2778	29831	9188	All
Foreground stars	2778	29831	9188	All
Bars	175	5456	1355	$N_{\text{bar}} > 0.2N_{\text{tot}}$
Spirals	294	7418	1973	$N_{1-4} > 0.2N_{\text{tot}}$

\*The total DR17 sample size will be 10010 unique galaxies with high quality data cubes (SDSS Collaboration et al., in preparation); the number in this table is the number also in GZ:3D.

Open in new tab

in GZ2 (typically around 50) and  $N_{1-4} > 0.2N_{\text{tot}}$ , where  $N_{1-4}$  is the sum of the number of volunteers who reported seeing 1, 2, 3, or 4 spiral arms. These cuts are aimed to make a complete, but not a clean sample of galaxies with visible bars (this cut should

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  - Can go to arXiv

The screenshot shows a Cornell University arXiv page for a paper titled "Galaxy Zoo: 3D -- Crowd-sourced Bar, Spiral and Foreground Star Masks for MaNGA Target Galaxies". The page includes a navigation bar with links for search, help, and advanced search. On the right, there's a sidebar for "Access Paper" with options for PDF, PostScript, and Other Formats. A red circle highlights the "PostScript" link. The main content area displays the abstract, author list, and a detailed description of the research.

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Cornell University

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arXiv > astro-ph > arXiv:2108.02065

Astrophysics > Astrophysics of Galaxies

[Submitted on 4 Aug 2021]

**Galaxy Zoo: 3D -- Crowd-sourced Bar, Spiral and Foreground Star Masks for MaNGA Target Galaxies**

Karen L. Masters, Coleman Krawczyk, Shoaib Shamsi, Alexander Todd, Daniel Finnegan, Matthew Bershady, Kevin Bundy, Brian Cherinka, Amelia Fraser-McKelvie, Dhanesh Krishnarao, Sandor Kruk, Richard R. Lane, David Law, Chris Lintott, Michael Merrifield, Brooke Simmons, Anne-Marie Weijmans, Renbin Yan

The challenge of consistent identification of internal structure in galaxies – in particular disc galaxy components like spiral arms, bars, and bulges – has hindered our ability to study the physical impact of such structure across large samples. In this paper we present Galaxy Zoo: 3D (GZ: 3D) a crowdsourcing project built on the Zooniverse platform which we used to create spatial pixel (spaxel) maps that identify galaxy centres, foreground stars, galactic bars and spiral arms for 29831 galaxies which were potential targets of the MaNGA survey (Mapping Nearby Galaxies at Apache Point Observatory, part of the fourth phase of the Sloan Digital Sky Surveys or SDSS-IV), including nearly all of the 10,010 galaxies ultimately observed. Our crowd-sourced visual identification of asymmetric, internal structures provides valuable insight on the evolutionary role of non-axisymmetric processes that is otherwise lost when MaNGA data cubes are azimuthally averaged. We present the publicly available GZ:3D catalog alongside validation tests and example use cases. These data may in the future provide a useful training set for automated identification of spiral arm features. As an illustration, we use the spiral masks in a sample of 825 galaxies to measure the enhancement of star formation spatially linked to spiral arms, which we measure to be a factor of three over the background disc, and how this enhancement increases with radius.

Comments: 13 pages, 9 figures. MNRAS accepted

Subjects: Astrophysics of Galaxies (astro-ph.GA)

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```
\begin{table*}
\caption{\label{tab:samples}Galaxy samples and selection in GZ:3D. We release masks from the final phases only, as we only recommend their use for science. The numbers are MaNGA targets shown to GZ:3D volunteers for each workflow task, not the number which have successful masks or clusters. The total DR17 sample size will be 10,010 unique galaxies with high quality data cubes (SDSS Collaboration et al. in prep.); the number in this table is the number also in GZ:3D.}
\begin{tabular}{lccccc}
Task & DR14 & & DR17$^*\$ & & GZ2 Pre-selection \\
& & & & & \\
& & & & & \\
& & & & & \\
\hline
Galaxy Centre & 2778 & 29831 & 9188 & All & \\
Foreground Stars & 2778 & 29831 & 9188 & All & \\
Bars & 175 & 5456 & 1355 & $N_{\rm bar} > 0.2N_{\rm tot} \$ \\
Spirals & 294 & 7418 & 1973 & $N_{\rm 1-4} > 0.2N_{\rm tot} \$ \\
\end{tabular}
\end{table*}
```

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    - All tables available in ASCII format!
  - Other journals: no machine-readable version generally available
    - Can go to arXiv
    - Download source (rename .zip)
    - Copy and read with astropy

```
In [1]: from astropy.io import ascii

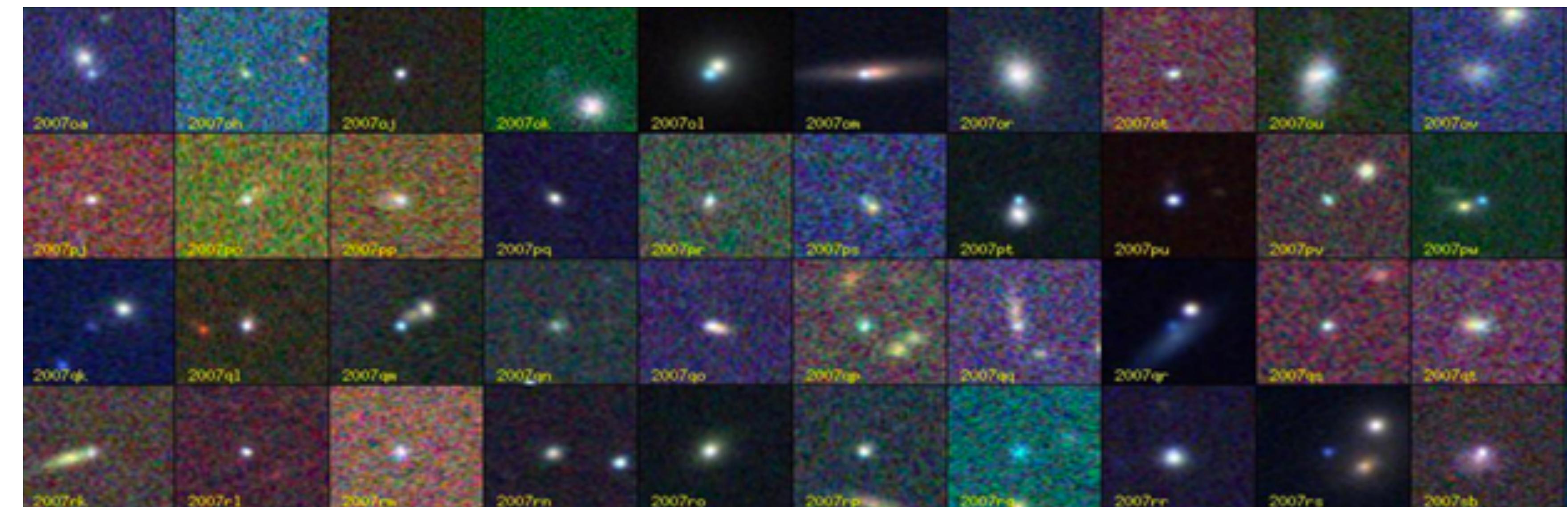
In [2]: table= r"""
...: \begin{table}
...: \caption{\label{tab:samples}Galaxy samples and selection in GZ:3D. We re-
...: lease masks from the final phases only, as we only recommend their use f-
...: or science. The numbers are MaNGA targets shown to GZ:3D volunteers for e-
...: ach workflow task, not the numbers which have successful masks or cluste-
...: rs. The total DR17 sample size will be 10,010 unique galaxies with high-
...: quality data cubes (SDSS Collaboration et al. in prep.); the number in t-
...: his table is the number also in GZ:3D.}
...: \begin{tabular}{lcccc}
...: Task & DR14 & All MaNGA targets & DR17$^*$ & GZ2 Pre-selection \\
...: & (Phase 1) & (Phase 2) & (Subset of Phase 2) & \\
...: \hline
...: Galaxy Centre & 2778 & 29831 & 9188 & All \\
...: Foreground Stars & 2778 & 29831 & 9188 & All \\
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...: Spirals & 294 & 7418 & 1973 & $N_{\rm 1-4} > 0.2N_{\rm tot}$ \\
...: \end{tabular}
...: \end{table*}
...: """

In [3]: tab= ascii.read(table)

In [4]: tab
Out[4]:
<Table length=5>
  Task          DR14      ...      GZ2 Pre-selection
  str16        str9      ...      str30
  -- (Phase 1) ...
  Galaxy Centre    2778 ...          All
  Foreground Stars    2778 ...          All
  Bars            175 ... $N_{\rm bar} > 0.2N_{\rm tot}$
  Spirals         294 ... $N_{\rm 1-4} > 0.2N_{\rm tot}$
```



# Small data sets



# Small, machine-readable data sets

- Extended table in a paper  
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**Table 1.** Properties of 85,686 Groups and Clusters Extracted from the WHL Cluster Catalog within the Redshift Range  $0.05 \leq z \leq 0.42$

ID	RA	Decl.	$z$	$R_{200c}$	$M_{200c}$	SCI
(1)	(2)	(3)	(4)	(5)	(6)	(7)
J000000.6+321233	0.00236	32.20925	0.1274	1.72	5.9478	0
J000002.3+051718	0.00957	5.28827	0.1694	0.94	1.9627	0
J000003.5+314708	0.01475	31.78564	0.0916	0.94	1.6766	0
J000004.7+022826	0.01945	2.47386	0.4179	0.95	0.4769	0
J000006.0+152548	0.02482	15.42990	0.1731	1.13	1.5391	0

**Note.** Columns (1)–(4) are taken from the WHL catalog and columns (5)–(7) have been computed in the current paper (see Sections 3 and 4). Column (1): cluster identifier. Column (2): R.A. of the brightest cluster galaxy (BCG). Column (3): decl. of the BCG. Column (4): redshift of the BCG. Column (5):  $R_{200c}$  of the cluster. Column (6):  $M_{200c}$  of the cluster. Column (7): supercluster number to which the cluster belongs. SCI = 0 means the cluster is not a part of any supercluster.

Only a portion of this table is shown here to demonstrate its form and content. A [machine-readable](#) version of the full table is available.

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Title: Identification of Superclusters and their Properties in the Sloan Digital Sky Survey Using WHL Cluster Catalog

Authors: Sankhyayan S., Bagchi J., Tempel E., More S., Einasto M., Dabade P., Raychaudhury S., Athreya R., Heinamaki P.

Table: Properties of the WHL clusters used in this work

=====

Byte-by-byte Description of file: apjacfaebt1\_mrt.txt

---

Bytes	Format	Units	Label	Explanations
1- 16	A16	---	ID	Cluster identifier as given in WH15
18- 26	F9.5	deg	RAdeg	Right Ascension in decimal degrees of the BCG (J2000)
28- 36	F9.5	deg	DEdeg	Declination in decimal degrees of the BCG (J2000)
38- 43	F6.4	---	z	Redshift of the BCG
45- 48	F4.2	Mpc	R200c	Radius of sphere where matter density is 200 times the critical density
50- 56	F7.4	10+14Msun	M200c	Mass within a sphere of radius R200c
58- 60	I3	---	SCL	Supercluster number

---

J000000.6+321233	0.00236	32.20925	0.1274	1.72	5.9478	0
J000002.3+051718	0.00957	5.28827	0.1694	0.94	1.9627	0
J000003.5+314708	0.01475	31.78564	0.0916	0.94	1.6766	0
J000004.7+022826	0.01945	2.47386	0.4179	0.95	0.4769	0
J000006.0+152548	0.02482	15.42990	0.1731	1.13	1.5391	0
J000006.3+221220	0.02643	22.20558	0.3985	0.84	0.9030	0
J000006.6+100648	0.02755	10.11333	0.3747	0.93	1.8814	0
J000006.6+315235	0.02762	31.87626	0.2092	1.18	1.9203	0
J000006.6+292129	0.02765	29.35813	0.2489	0.92	1.0586	0
J000007.1-092910	0.02957	-9.48607	0.3332	0.80	1.3679	0
J000007.6+155003	0.03177	15.83424	0.1527	1.17	3.3484	0
J000007.7+185245	0.03208	18.87909	0.4085	1.03	2.3615	0
J000008.0+343316	0.03350	34.55436	0.2346	1.05	0.8036	0
J000008.6+085715	0.03580	8.95418	0.2799	0.88	1.2017	0
J000009.4+211655	0.03905	21.28191	0.2997	1.31	3.0975	0
J000000.0+230241	0.04154	23.04467	0.3778	1.06	1.4712	230
J000010.7+134747	0.04439	13.79632	0.1992	0.80	0.4341	0
J000011.4-092850	0.04770	-9.48058	0.4100	0.89	1.3098	0
J000012.6+103806	0.05238	10.63509	0.1694	1.43	3.7158	233
J000012.7+341335	0.05276	34.22628	0.2542	0.96	0.6371	0
J000012.8+070555	0.05317	7.09848	0.1290	0.89	0.8818	0
J000014.2+355136	0.05906	35.86013	0.2606	0.93	1.3806	0
J000015.0+081513	0.06265	8.25366	0.3113	0.98	1.0363	0
J000015.8+223812	0.06595	22.63655	0.3701	1.03	1.5920	230
J000016.9+235043	0.07057	23.84517	0.3106	0.93	0.8565	0
J000017.4-061436	0.07246	-6.24328	0.2921	0.87	0.9014	0
J000017.4-0715540	0.07259	21.02041	0.3076	0.93	2.5395	0

# Small, machine-readable data sets

- Extended table in a paper  
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- Vizier Online Data Catalogs

VizieR Online Data Catalog: CVs from SDSS V (Inight+, 2023)

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Inight, K. ; Gansicke, B. T. ; Schwone, A. ; Anderson, S. F. ; Badenes, C. ; Breedt, E. ; Chandra, V. ; Davies, B. D. R. ; Gentile Fusillo, N. P. ; Green, M. J. ; Hermes, J. J. ; Huamani, I. A. ; Hwang, H. ; Knauff, K. ; Kurpas, J. ; Long, K. S. ; Malanushenko, V. ; Morrison, S. ; Quiroz, C. I. J. ; Ramos, G. N. A. ; ...

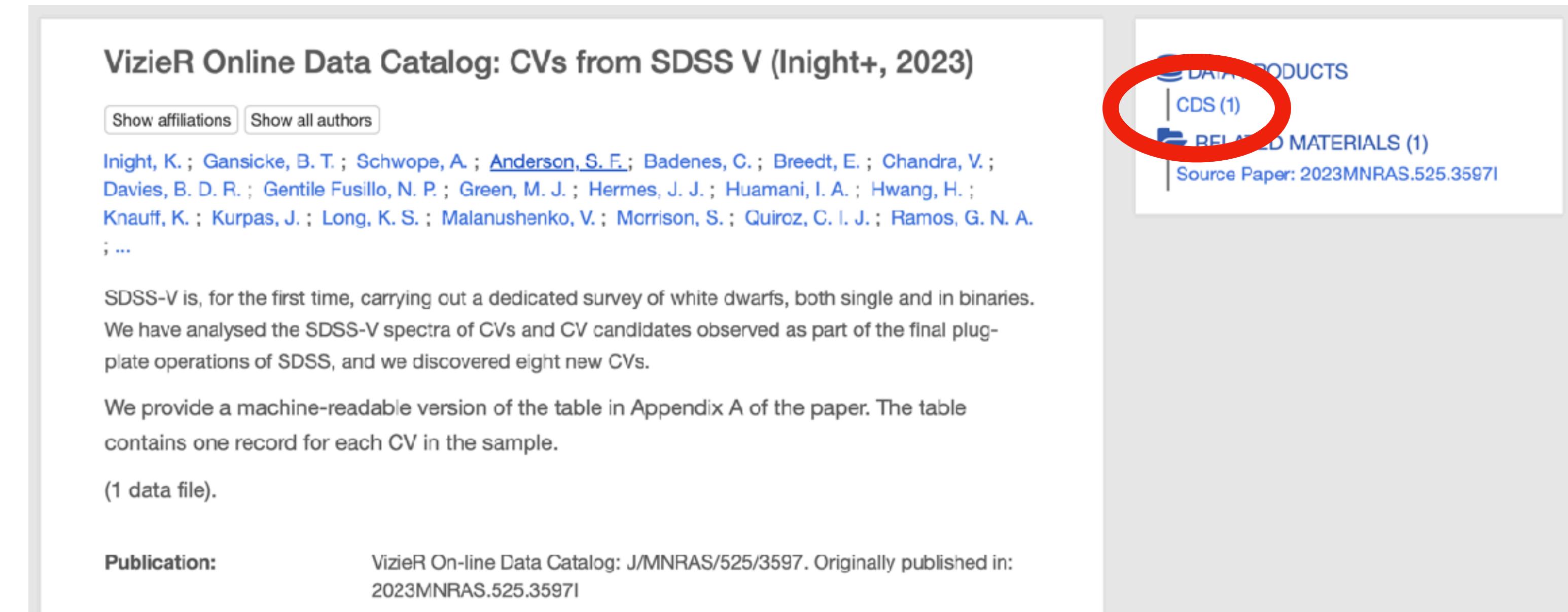
SDSS-V is, for the first time, carrying out a dedicated survey of white dwarfs, both single and in binaries. We have analysed the SDSS-V spectra of CVs and CV candidates observed as part of the final plug-plate operations of SDSS, and we discovered eight new CVs.

We provide a machine-readable version of the table in Appendix A of the paper. The table contains one record for each CV in the sample.

(1 data file).

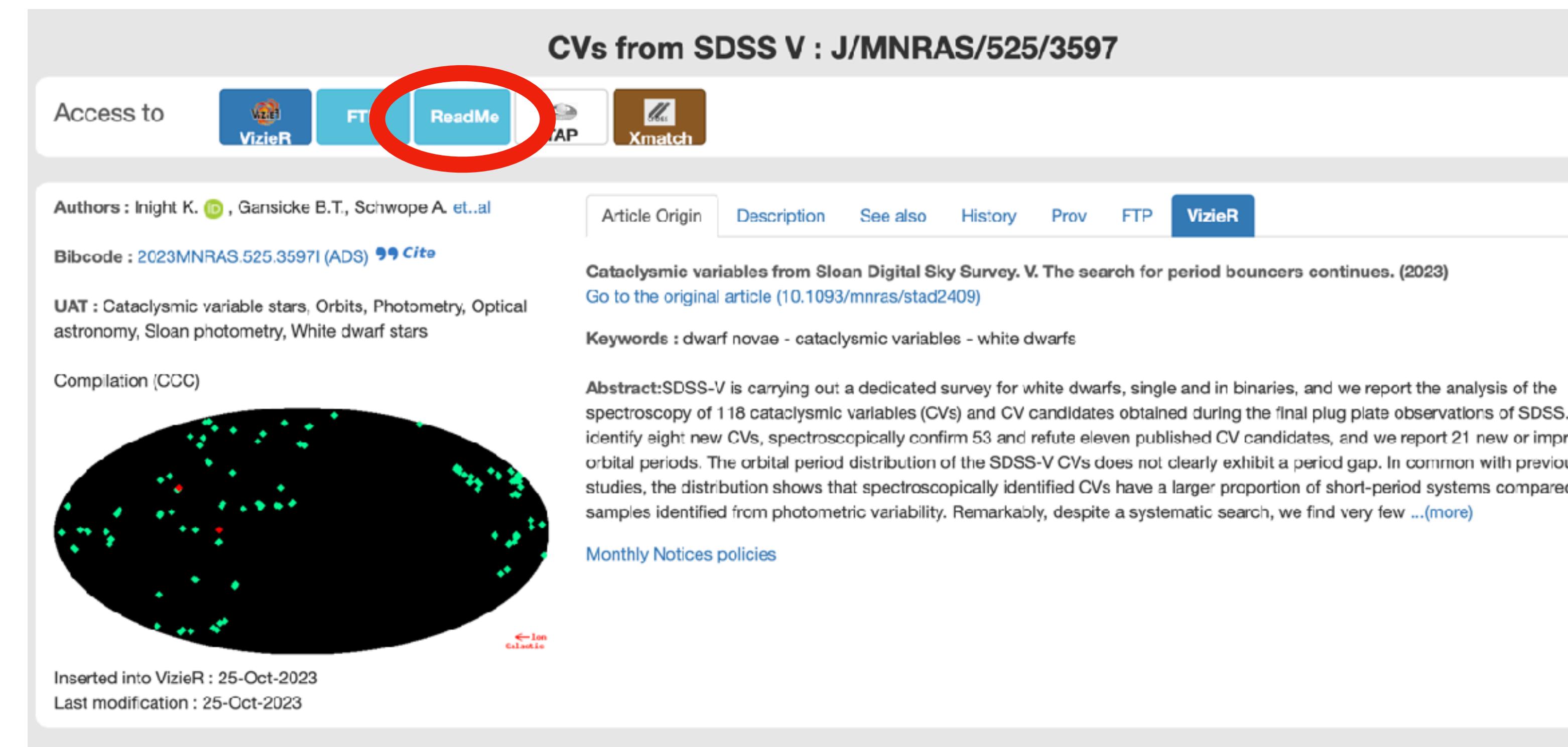
Publication: VizieR On-line Data Catalog: J/MNRAS/525/3597. Originally published in: 2023MNRAS.525.3597I

DATA PRODUCTS  
CDS (1)  
RELATED MATERIALS (1)  
Source Paper: 2023MNRAS.525.3597I



# Small, machine-readable data sets

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- Vizier Online Data Catalogs



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J/MNRAS/525/3597	CVs from SDSS V	(Inight+, 2023)		
Cataclysmic variables from Sloan Digital Sky Survey. V. The search for period bouncers continues.				
Inight K., Gansicke B.T., Schwöpe A., Anderson S.F., Badenes C., Breedt E., Chandra V., Davies B.D.R., Gentile Fusillo N.P., Green M.J., Hermes J.J., Huamani I.A., Hwang H., Knauff K., Kurpas J., Long K.S., Malanushenko V., Morrison S., Quiroz C.I.J., Ramos G.N.A., Roman-Lopes A., Schreiber M.R., Standke A., Stutz L., Thorstensen J.R., Toloza O., Tovmassian G., Zakamska N.L. <Mon. Not. R. Astron. Soc., 525, 3597–3625 (2023)> <a href="#">=2023MNRAS.525.3597I</a> (SIMBAD/NED BibCode)				
ADC_Keywords: Binaries, cataclysmic ; Photometry, SDSS ; Binaries, orbits ; Stars, white dwarf				
Keywords: dwarf novae – cataclysmic variables – white dwarfs				
Abstract: SDSS-V is carrying out a dedicated survey for white dwarfs, single and in binaries, and we report the analysis of the spectroscopy of 118 cataclysmic variables (CVs) and CV candidates obtained during the final plug plate observations of SDSS. We identify eight new CVs, spectroscopically confirm 53 and refute eleven published CV candidates, and we report 21 new or improved orbital periods. The				
Byte-by-byte Description of file: table1.dat				
Bytes	Format	Units	Label	Explanations
1– 19	A19	---	SDSS	Unique reference for the SDSS object (JHHMMSS.ss+DDMMSS.s)
21– 49	A29	---	Name	Other name (where available)
51– 69	I19	---	GaiaEDR3	The unique source_id of the Gaia EDR3 counterpart source_id
71– 81	F11.8	h	Per	? Orbital period in hours
83– 92	F10.8	h	e_Per	? Error on orbital period
94	A1	---	n_Per	[*:] Note on Per (1)
96–100	F5.2	mag	Gmag	G-band magnitude from the Gaia EDR3 survey
102–105	I4	pc	Distance	? Distance from Bailer-Jones et al. ( <a href="#">2021AJ....161..147B</a> , Cat. <a href="#">I/352</a> )
107–117	A11	---	VType	Classification using the taxonomy defined in the paper (2)
119–132	A14	---	Cartons	Cartons (3)
136–162	A27	---	Ref-disc	BibCode of the earliest identification of this CV
164–182	A19	---	Ref-sp	BibCode of the first published spectrum
184–204	A21	---	Ref-P	BibCode of the source of the orbital period
206–223	F18.14	deg	RAdeg	Right ascension (J2000)
225–243	F19.15	deg	DEdeg	Declination (J2000)

# Small, machine-readable data sets

- Extended table in a paper  
“Only a portion of this table is shown here to demonstrate its form and content. A machine-readable version of the full table is available.”
- Vizier Online Data Catalogs

CVs from SDSS V : J/MNRAS/525/3597

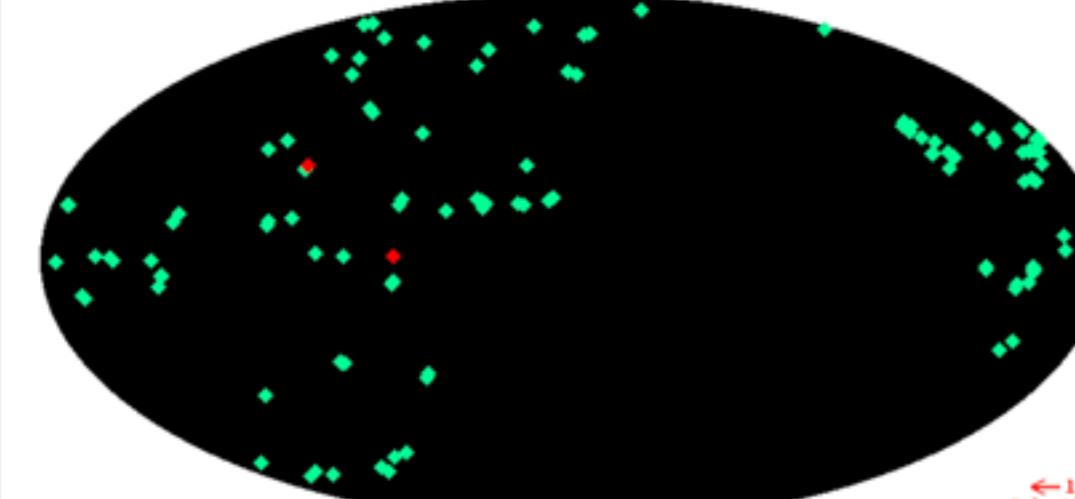
Access to [VizieR](#) [FTP](#) [ReadMe](#) [TAP](#) [Xmatch](#)

Authors : Inglot K. , Gansicke B.T., Schworer A. et.al

Bibcode : [2023MNRAS.525.3597I](#) (ADS)  

UAT : Cataclysmic variable stars, Orbits, Photometry, Optical astronomy, Sloan photometry, White dwarf stars

Compilation (CCC)



Article Origin Description See also History Prov [FTP](#) [VizieR](#)

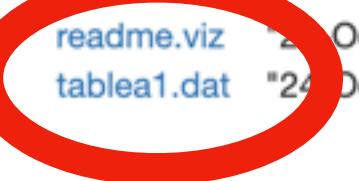
Archives are available through FTP in standardized format described in the ReadMe. VizieR tables are built from archives with additional transformations.

J/MNRAS/525/3597 CVs from SDSS V (Inglot+, 2023)  
The following files can be converted to FITS (extension .fit or fit.gz)  
`tablea1.dat`

Query from: <http://vizier.cds.unistra.fr/viz-bin/VizieR?-source=J/MNRAS/525/3597>

Go to [ftp](#) - web page - Download all tables in [tar.gz](#)

 <a href="#">readme.viz</a>	"25-Oct-2023 08:56"	-r--r--r--	5.7K
 <a href="#">tablea1.dat</a>	"25-Oct-2023 08:59"	-r--r--r--	5.7K
	"24-Oct-2023 11:19"	-r--r--r--	29K
		- txt - txt.gz - fits - fits.gz - html	



← Ion Galactic

Download time: 2023-10-25 09:00:00

# Small, machine-readable data sets

- Extended table in a paper  
“Only a portion of this table is shown here to demonstrate its form and content. A machine-readable version of the full table is available.”
- Vizier Online Data Catalogs

J000600.15+012129.8			2738755406045571968	1.52	0.10	19.57	352	WZ Sge:PS : gg,u2,wd	*This work
work	1.50064345676278	1.35827514714031							
J003827.05+250925.0	1RXS J003828.7+250920		2806802123399581056	2.26826	0.00002	18.63	503	SU UMa	cv,gg,u1,u2
et al in prep	9.61272342040272	25.1569563739546							*VSNET 12318
J003941.08+005427.5	SDSS J003941.06+005427.5		2543387617312121216	1.523	0.002	20.76	1078	WZ Sge:	cv,u1,u2,u4
2010A&A...524A..86S	9.92118587245779	0.907630946264153							2005AJ....129.2386S
J004335.16-003729.7	SDSS J004335.14-003729.8		2530961280492678528	1.3721	0.0014	19.85	447	WZ Sge:	cv,gg,u2,wd
2008MNRAS.391..591S	10.8965127441555	-0.624919920328629							2004AJ....128.1882S
J014227.07+001729.8			2510205490257050496	1.88	0.04	19.89	697	Polar:	cv,u1,u2
work	25.6128096966956	0.291604463777139							2017ApJS..228...19C
J015543.47+002807.4	FL Cet		2507796391561705728	1.452389	0.000001	18.65	317	Polar+E	cv,gg,u1,u2
2005ApJ...620..422S	28.9311192294966	0.468710388240133							2002AJ....123..430S
J020712.72-014116.3	SDSS J020712.71-014116.2		2494386992562185088	1.55	0.15	20.27		Polar:	cv
work	31.8030160472918	-1.68784823887102							2023MNRAS.524.4867I
J020809.57+565239.7			505110900157013376			18.77	2961	CV	u4
32.0398758932033	56.8777045605961								2021A&A...648A..44M
J021008.33+571121.0	UV Per		457106501671769472	1.557	0.003	17.75	250	SU UMa	cv
1997PASP..109.1359T	32.5347258071429	57.1891648736762							1985AJ....90.1837S
J021315.48+533822.9	MASTER OT	J021315.37+533822.7	455380951309048320	2.549	0.007	* 20.05	3224	SU UMa	cv
2017PASJ...69...75K	33.3145094962966	53.6396813044143							2013ATel.5536....1Y
J022102.79+732245.0	ASASSN-14jq		546910213373341184	1.32427	0.00031	* 19.94	425	WZ Sge	cv,gg,wd
2015PASJ...67...105K	35.2616338626198	73.3791783513299							*ASAS-SN CV candidate
J022623.34+711831.5	AM Cas		545338083544363392	3.9576	0.0003	14.37	420	U Gem	cv,gg,u1,u2
1996PASP..108..894T	36.5972449914027	71.3087570542901							1988AN....309...91R
J023322.61+005059.4	HP Cet		2500552912036565120	1.601	0.002	20.12	683	WZ Sge:PS : cv	2002AJ....123..430S
2006MNRAS.373..687S	38.3442161025676	0.849827971521724							
J024131.07+593630.5	ASASSN-16jv		464373929923792384			19.84	607	U Gem	cv
40.3794706143822	59.6084629440548								*ASAS-SN CV candidate



# Read with astropy

## ApJ table

```
[In [1]: from astropy.io import ascii  
  
[In [2]: tab= ascii.read("apjacfaebt1_mrt.txt", format='cds')
```

```
[In [3]: tab  
Out[3]:  
<Table length=85686>

| ID               | RAdeg   | DEdeg    | z       | R200c   | M200c      | SCL   |
|------------------|---------|----------|---------|---------|------------|-------|
| str16            | float64 | float64  | float64 | float64 | 1e+14 Msun | int64 |
| J000000.6+321233 | 0.00236 | 32.20925 | 0.1274  | 1.72    | 5.9478     | 0     |
| J000002.3+051718 | 0.00957 | 5.28827  | 0.1694  | 0.94    | 1.9627     | 0     |
| J000003.5+314708 | 0.01475 | 31.78564 | 0.0916  | 0.94    | 1.6766     | 0     |
| J000004.7+022826 | 0.01945 | 2.47386  | 0.4179  | 0.95    | 0.4769     | 0     |
| J000006.0+152548 | 0.02482 | 15.4299  | 0.1731  | 1.13    | 1.5391     | 0     |
| J000006.3+221220 | 0.02643 | 22.20558 | 0.3985  | 0.84    | 0.903      | 0     |
| J000006.6+100648 | 0.02755 | 10.11333 | 0.3747  | 0.93    | 1.8814     | 0     |
| J000006.6+315235 | 0.02762 | 31.87626 | 0.2092  | 1.18    | 1.9203     | 0     |
| J000006.6+292129 | 0.02765 | 29.35813 | 0.2489  | 0.92    | 1.0586     | 0     |
| J000007.1-092910 | 0.02957 | -9.48607 | 0.3332  | 0.8     | 1.3679     | 0     |
| J000007.6+155003 | 0.03177 | 15.83424 | 0.1527  | 1.17    | 3.3484     | 0     |
| J000007.7+185245 | 0.03208 | 18.87909 | 0.4085  | 1.03    | 2.3615     | 0     |
| J000008.0+343316 | 0.0335  | 34.55436 | 0.2346  | 1.05    | 0.8036     | 0     |
| J000008.6+085715 | 0.0358  | 8.95418  | 0.2799  | 0.88    | 1.2017     | 0     |


```



# Read with astropy

## ApJ table

```
[In [1]: from astropy.io import ascii ]  
  
[In [2]: tab= ascii.read("apjacfaebt1_mrt.txt",format='cds') ]  
WARNING: UnitsWarning: 'the' did not parse as cds unit: At col 0, Unit 'the' not  
supported by the CDS SAC standard. Did you mean TH, Te, Th or he? If this is me  
ant to be a custom unit, define it with 'u.def_unit'. To have it recognized insi  
de a file reader or other code, enable it with 'u.add_enabled_units'. For detail  
s, see https://docs.astropy.org/en/latest/units/combining_and_defining.html [ast  
ropy.units.core]  
-----  
KeyError Traceback (most recent call last)  
File ~/miniforge3/envs/py310/lib/python3.10/site-packages/astropy/io/ascii/core.  
py:721, in BaseHeader.get_col_type(self, col)  
    720     type_map_key = self.get_type_map_key(col)  
--> 721     return self.col_type_map[type_map_key.lower()]  
    722 except KeyError:  
  
KeyError: 't'  
  
During handling of the above exception, another exception occurred:  
  
ValueError Traceback (most recent call last)  
Input In [2], in <cell line: 1>()  
----> 1 tab= ascii.read("apjacfaebt1_mrt.txt",format='cds')  
  
File ~/miniforge3/envs/py310/lib/python3.10/site-packages/astropy/io/ascii/ui.py  
:426, in read(table, guess, **kwargs)  
    424     else:  
    425         reader = get_reader(**new_kwargs)  
--> 426         dat = reader.read(table)  
    427         _read_trace.append(  
    428             {  
    429                 "kwargs": copy.deepcopy(new_kwargs),  
    (...)  
    File ~/miniforge3/envs/py310/lib/python3.10/site-packages/astropy/io/ascii/core.  
py:723, in BaseHeader.get_col_type(self, col)  
    721     return self.col_type_map[type_map_key.lower()]  
ji 722 except KeyError:  
--> 723     raise ValueError(  
    724         f'Unknown data type "{col.raw_type}" for column "{col.name}"'  
    725     )  
  
ValueError: Unknown data type ""times"" for column "critical"  
[In [3]: ]
```



# Read with astropy

## ApJ table

astropy / astropy

Type ⌂ to search | > | + | ⌂ | ⌂

Code Issues 1.2k Pull requests 49 Actions Projects 2 Wiki Security Insights

### Incorrect reading of multi-line Explanations in MRT/CDS ReadMes #15608

**Open** jobovy opened this issue 3 minutes ago · 0 comments

**jobovy** commented 3 minutes ago Member ...

**Description**

I'm trying to read [this table](#) (Table 1 from [this paper](#)) using `astropy.io.ascii` and this fails with

```
ValueError: Unknown data type "'times'" for column "critical"
```

This error points to a multi-line Explanation in the ReadMe being read wrong. This seems to happen because the first non-whitespace character in the second line is a number (the line is " 200 times the critical density"), because just adding a letter in front of the 200 lets the table be read. It seems like what's happening is that the parser thinks the line is a new column because it starts with a number.

**Expected behavior**

Read the table without error

**How to Reproduce**

Download the table:

```
curl -0 "https://content.cld.iop.org/journals/0004-637X/958/1/62/revision1/apjacfaebt1_mrt.txt?Expires=1" 5.
```

Assigees  
No one assigned

Labels  
**Bug**

Projects  
None yet

Milestone  
No milestone

Development  
No branches or pull requests

Notifications      Customize  
**Unsubscribe**

You're receiving notifications because you authored the thread.



# Read with astropy

## CDS table

- Download the ReadMe and the data file

```
[In 1]: from astropy.io import ascii  
[In 2]: tab= ascii.read("tablea1.dat",format='cds',readme='ReadMe')  
  
[In 3]: tab  
Out[3]:  
<Table length=118>  
SDSS  
str19  
str29  
Name  
...  
DEdeg  
deg  
float64  
---  
J000600.15+012129.8  
J003827.05+250925.0  
J003941.08+005427.5  
J004335.16-003729.7  
J014227.07+001729.8  
J015543.47+002807.4  
J020712.72-014116.3  
J020809.57+565239.7  
J021008.33+571121.0  
J021315.48+533822.9  
J022102.79+732245.0  
J022623.34+711831.5  
J023322.61+005059.4  
J024131.07+593630.5  
J040834.99+511448.2  
J041844.44+510731.2  
J042609.34+354144.5  
...  
J183052.72+265514.9  
J183211.36+615505.9  
J192914.75+202759.5  
J192927.83+202035.0  
1RXS J003828.7+250920  
SDSS J003941.06+005427.5  
SDSS J004335.14-003729.8  
FL Cet ...  
SDSSJ020712.71-014116.2  
ASASSN-14jq ...  
UV Per ...  
MASTER OT J021315.37+533822.7  
ASASSN-14jv ...  
AM Cas ...  
HP Cet ...  
ASASSN-16jv ...  
FO Per ...  
NS Per ...  
MASTER OT J042609.34+354144.8  
MGAB-V733 ...  
ASASSN-13ah ...  
NQ Vul ...  
1RXS J192926.6+202038 ...  
25.1569563739546  
0.907630946264153  
-0.624919920328629  
0.291604463777139  
0.468710388240133  
-1.68784823887102  
56.8777045605961  
57.1891648736762  
53.6396813044143  
73.3791783513299  
71.3087570542901  
0.849827971521724  
59.6084629440548  
51.2467108817714  
51.1253428797512  
35.6957043579609  
...  
26.9208015070436  
61.9183113412746  
20.4665332884149  
20.343046807248
```

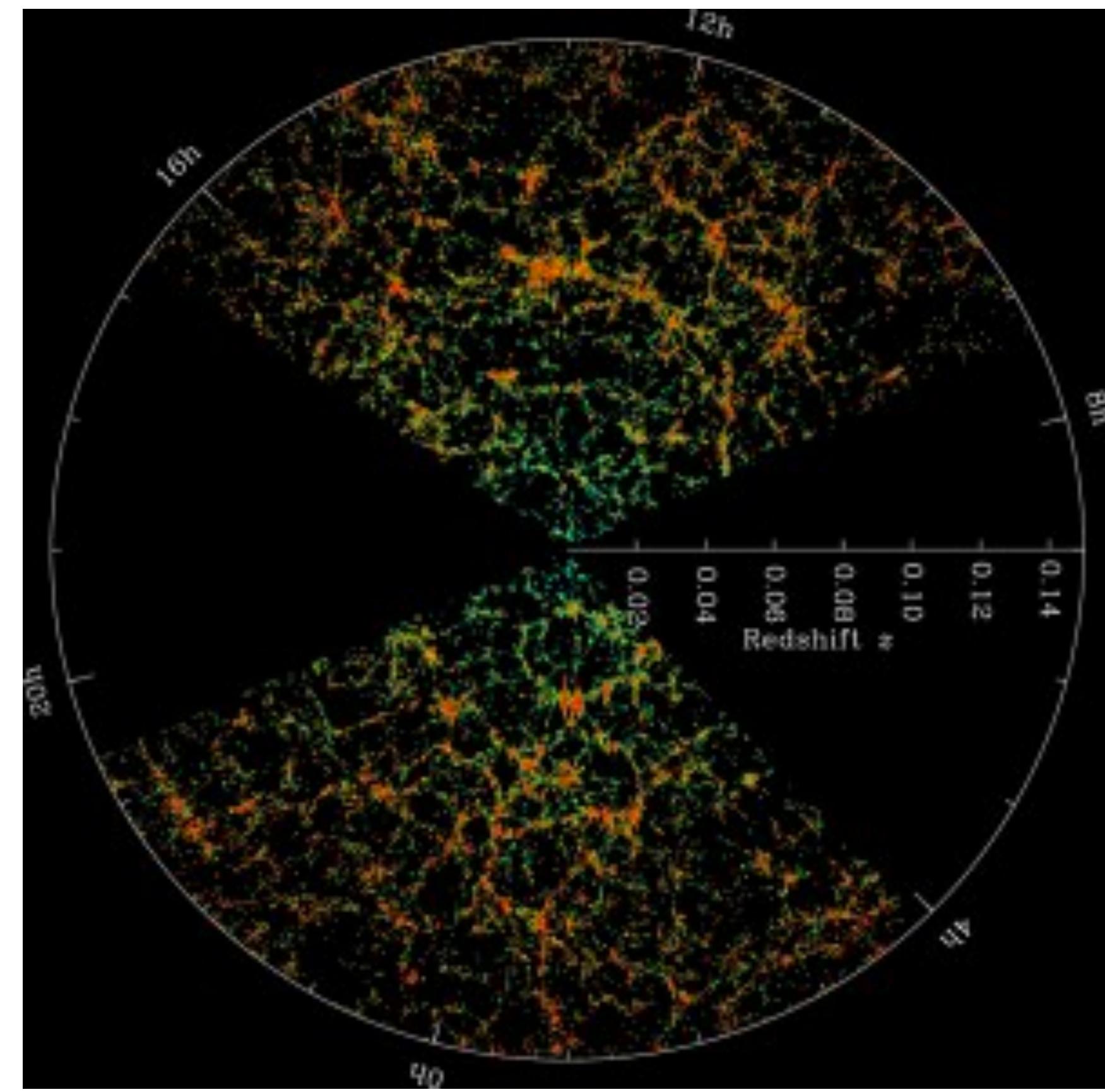
- (In javascript, use <https://github.com/jobovy/vizier.js>)

# CDS best practices

- For reproducibility, always use the full files if you can
- Don't use the query interface aside from experimentation:

The screenshot shows the CDS VizieR catalog search interface. At the top, there's a navigation bar with links to Portal, Simbad, VizieR, Aladin, X-Match, Other, and Help. The main title is "Catalog". On the left, there's a sidebar titled "Search Criteria" with sections for "Keywords" (J/MNRAS/525/3597), "Tables" (J/MNRAS/525/3597, ..tablea1), and "Preferences" (max: 50). The main area has tabs for "Simple Target" (selected) and "List Of Targets". It includes fields for "Target Name (resolved by Sesame) or Position:" (with "Clear" and "J2000" dropdowns) and "Target dimension:" (with "2 arcmin" dropdown). A note says "NB: The epoch used for the query is the original epoch of the table(s)" with options for "Radius" (radio button) and "Box size" (radio button). Below this, it shows "CVs from SDSS V (Inight+, 2023)" and "CVs from the plate survey (118 rows)". There are links for "Similar Catalogs", "2023MNRAS.525.3597I", "ReadMe+ftp", and a thumbnail image. At the bottom, there's a "Simple Constraint" section with a table showing columns like "recno", "SDSS", "Name", "GaiaEDR3", "Per", "e\_Per", "n\_Per", "Gmag", "Distance", and "VType" with their respective constraints and explanations. Buttons for "Submit" and "Reset All" are at the bottom right.

# Large data sets



# Large survey data

- Astrophysics has many large surveys and more so over time
  - E.g., SDSS (+APOGEE/MaNGA), 2MASS, Gaia, DES, DESI, LAMOST, PanSTARRS, WISE, FIRST, GALEX, Fermi  
Future: Rubin, Euclid, SKA, etc.
- Most efficient way to interact with collection of many objects is a *database*
- Databases can be search using SQL (Structured Query Language) or an astro-extension of it ADQL (Astronomical Data Query Language)
- Surveys often contain their own data + helpful data from other surveys in one database

# Example: SDSS

The screenshot shows the SciServer SkyServer homepage. At the top, there is a navigation bar with links for Home, Visual Tools, Search Tools, CrossMatch Tools, More Tools, Support, CasJobs, and Sign In. Below the navigation bar is a large logo featuring a stylized cluster of stars within an oval frame, followed by the text "SkyServer". Underneath the logo, the tagline "EXPLORE THE UNIVERSE WITH THE SLOAN DIGITAL SKY SURVEY" is displayed. A dropdown menu labeled "Data Release 18" is open. Below the main title, there is a section titled "Choose a tool..." containing six buttons: "Navigate" (with a map icon), "Explore" (with a map icon), "Finding Chart" (with a magnifying glass icon), "Quick Look" (with a document icon), "Radial Search" (with a magnifying glass icon), and "SQL Search" (with a magnifying glass icon). At the bottom of the page, there are three footer sections: "About the Sloan Digital Sky Survey" (purple background), "How do I get data?" (green background), and "Visual Tools" (blue background). Each footer section has a "+" sign at the end.

# Example: Gaia

The screenshot shows the homepage of the Gaia Archive. At the top, there is a navigation bar with links for 'HOME', 'SEARCH', 'SINGLE OBJECT', 'VISUALISATION', and 'HELP'. Below this is a main content area with a red header featuring the 'gaia archive' logo and the 'esa' logo. The header also includes a 'SIGN IN' button and a 'Relaunch to update' button. The main content area has a title 'Welcome to the Gaia ESA Archive' and a paragraph describing the mission's goals. To the right of the text is a circular logo for 'gaia' with the 'esa' logo above it. Below the welcome message, there is a section titled 'Top Features' with eight items, each with an icon and a brief description.

← → ⌂ gea.esac.esa.int/archive/

EUROPEAN SPACE AGENCY ABOUT ESAC SIGN IN Relaunch to update

## gaia archive

HOME SEARCH SINGLE OBJECT VISUALISATION HELP

### Welcome to the Gaia ESA Archive

Gaia is a European space mission providing astrometry, photometry, and spectroscopy of nearly 2000 million stars in the Milky Way as well as significant samples of extragalactic and solar system objects. The Gaia ESA Archive contains deduced positions, parallaxes, proper motions, radial velocities, and brightness measurements. Complementary information on multiplicity, photometric variability, and astrophysical parameters is provided for a large fraction of sources.



#### Top Features

-  **Gaia Mission**  
News, Gaia alerts, information, and resources on the Gaia mission for the scientific community.
-  **Gaia DR3**  
Direct access to Gaia DR3 papers, known issues, tools, auxiliary data, etc.
-  **Gaia FPR**  
Direct access to all information of the Focused Product Release.
-  **Download**  
Direct bulk download of Gaia data in ECSV format.
-  **Software Tools**  
Software tools for resampling of spectra, calibration of data, etc.
-  **Auxiliary Data**  
Small data sets related to calibration, photometric pass bands, exoplanets, asteroids, etc.
-  **Citation**  
How to cite and acknowledge the use of Gaia data and where to find DOIs.
-  **Partners**  
Partner data centres also serving Gaia data.

# Example: Gaia

The screenshot shows the Gaia archive search interface on a web browser. The URL in the address bar is `gea.esac.esa.int/archive/`. The page has a red header with the "gaia archive" logo and the "esa" logo. The navigation menu includes links for "HOME", "SEARCH", "SINGLE OBJECT", "VISUALISATION", and "HELP". Below the menu, there are tabs for "Basic", "Advanced (ADQL)", and "Query Results", with "Advanced (ADQL)" currently selected.

In the main search area, there is a dropdown menu set to "gaia". A "Job name:" input field is present. To the right, there is a "Query examples" section. A tooltip for "Ctrl+Space for query autocompletion" is displayed over a dropdown menu containing a list of database schema names and tables:

- agn\_cross\_id
- alerts\_mixedin\_sourceids
- allwise\_best\_neighbour
- allwise\_neighbourhood
- apassdr9\_best\_neighbour
- apassdr9\_join
- apassdr9\_neighbourhood
- astrophysical\_parameters
- astrophysical\_parameters\_supp
- binary\_masses

Below the dropdown, a message says "No results found". There is a table with columns: Status, Job, Creation date, Num. rows, and Size. At the bottom of the page, there are buttons for "Reset Form" and "Submit Query". The footer includes links for "Download format: VOTable", "Apply jobs filter", "Filter this session", "Select all jobs" (with a checked checkbox), and "Delete selected jobs".

# Very basic SQL

- Start query with SELECT then say what you want and what you want if FROM

```
SELECT ra, dec FROM PhotoPrimary  
SELECT top 10 ra, dec, psfmag_i-extinction_i AS mag_i FROM  
SpecPhoto
```

- Add constraints (WHERE) and JOIN on other table

```
SELECT p.ra, p.dec, s.psfmag_i-s.extinction_i AS mag_i  
FROM PhotoPrimary AS p  
JOIN SpecPhoto AS s ON p.objID = s.objID  
WHERE (s.class='QSO')
```

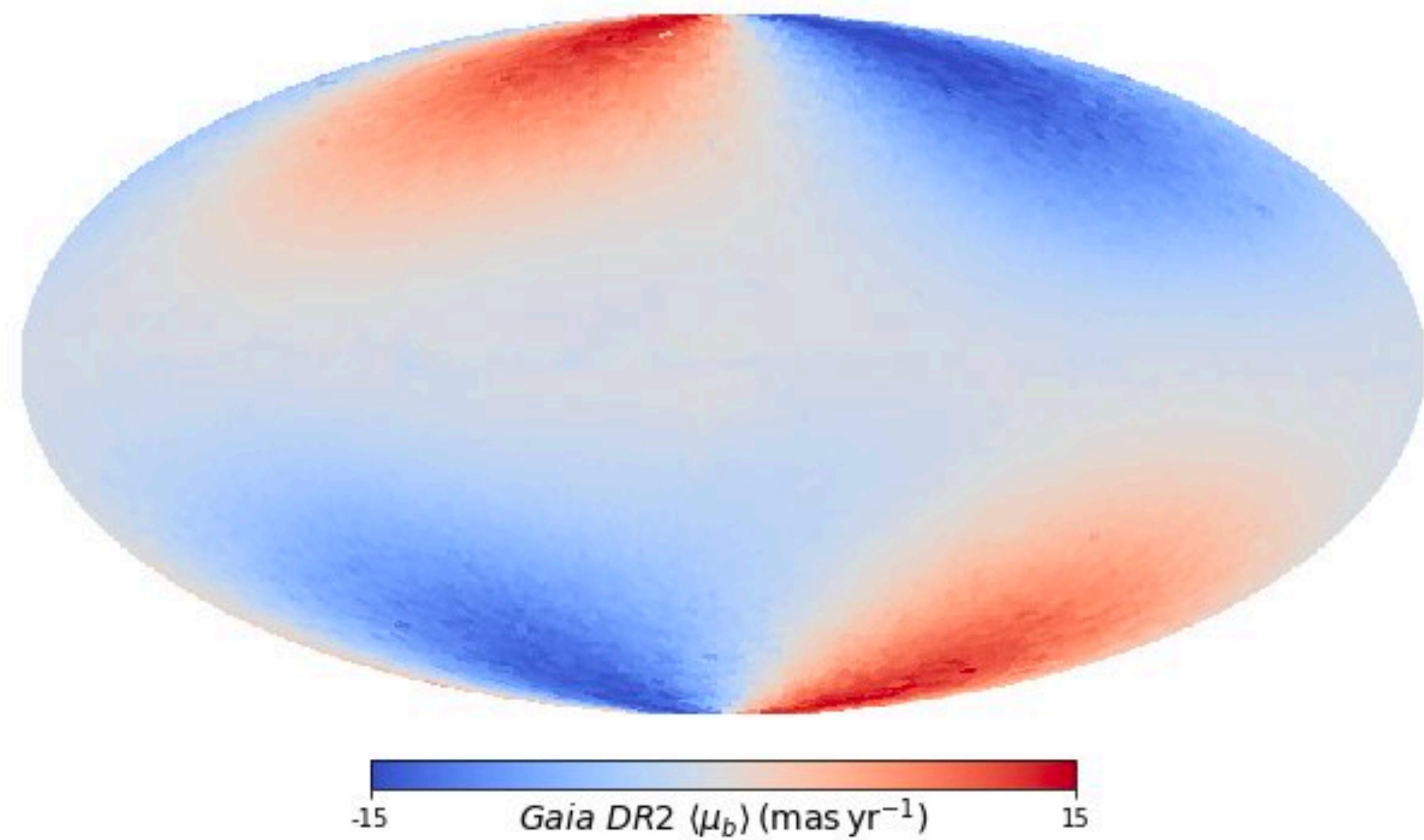
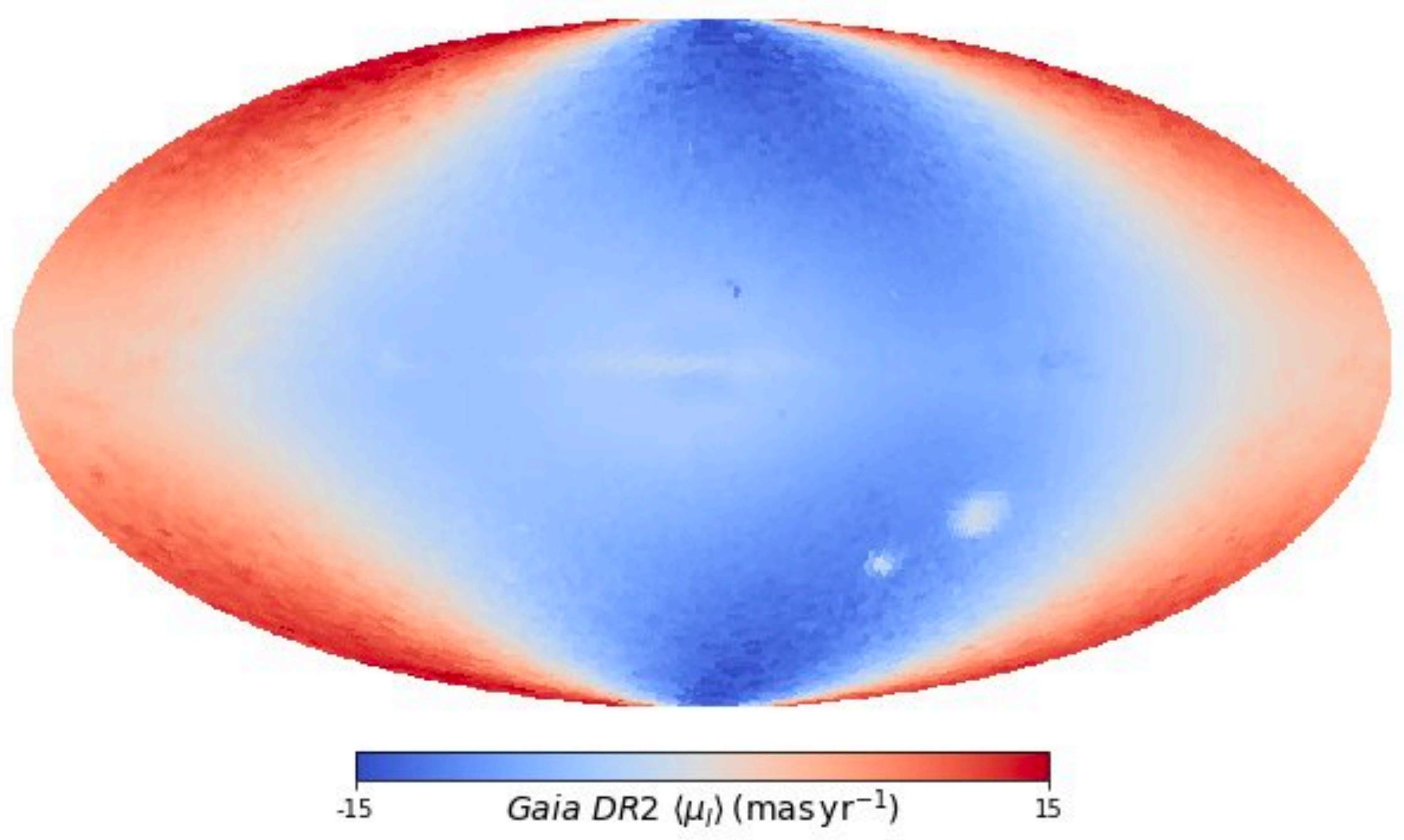
# More advanced SQL

- Very powerful, e.g., can do calculations and histograms (Gaia example)

```
SELECT hpx5, AVG( (c1*pmra+c2*pmdec)/cos(b_rad) ) AS mpml1,
AVG( (-c2*pmra+c1*pmdec)/cos(b_rad) ) AS mpmbb
FROM (
    SELECT source_id/562949953421312 as hpx5,
    pmra, pmdec, radians(b) as b_rad, parallax,
    0.4559838136873017*cos(radians(dec))
    -0.889988068265628*sin(radians(dec))
    *cos(radians(ra-192.85947789477598)) as c1,
    0.889988068265628*sin(radians(ra-192.85947789477598)) as c2
    FROM gaiadr2.gaia_source
    WHERE phot_g_mean_mag < 17.
) tab
GROUP BY hpx5
```

- ADQL adds functions to do things like calculate offsets on the sky

# More advanced SQL





# astroquery

- Convenient Python interface to many astronomical data sets

```
python -m pip install -U --pre astroquery
```

- E.g., SDSS

```
from astroquery.sdss import SDSS
query = f"""select top 1 r-extinction_r as r0
FROM PhotoObjAll
WHERE objid=1237668367999172911"""
res= SDSS.query_sql(query,data_release=17)
print(f"The observed r-band magnitude is {res['r0']}
[0]:.2f}")
```



# astroquery

- Convenient Python interface to many astronomical data sets

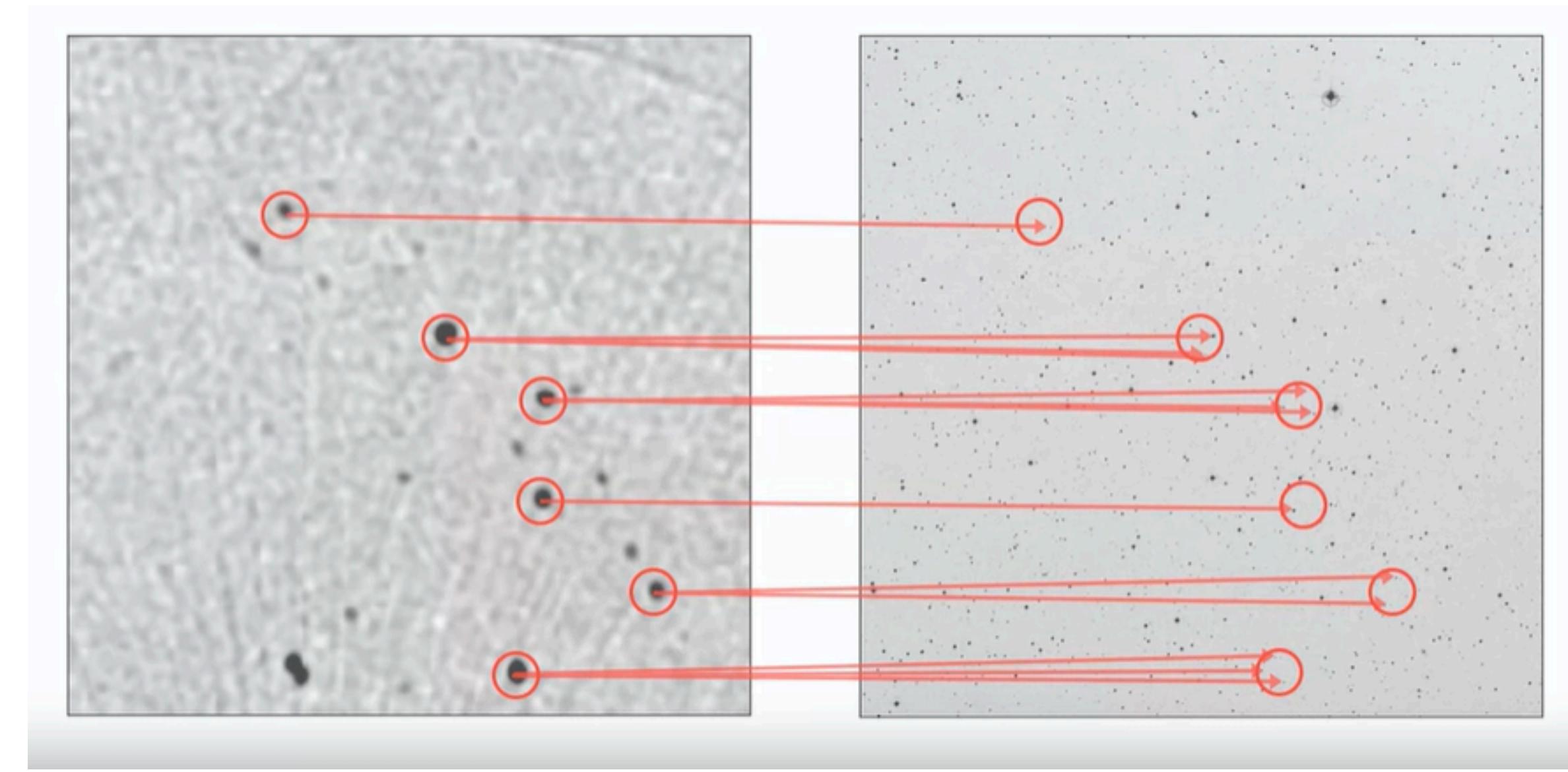
```
python -m pip install -U --pre astroquery
```

- E.g., Gaia

```
>>> from astroquery.gaia import Gaia
>>> job = Gaia.launch_job_async("select top 100 designation,ra,dec "
...                               "from gaiadr3.gaia_source order by source_id")
INFO: Query finished. [astroquery.utils.tap.core]
>>> r = job.get_results()
>>> print(r)
      DESIGNATION          ra          dec
              deg          deg
-----
  Gaia DR3 4295806720  44.99615537864534  0.005615226341865997
  Gaia DR3 34361129088  45.00432028915398  0.021047763781174733
  Gaia DR3 38655544960  45.004978371745516  0.019879675701858644
  Gaia DR3 309238066432  44.99503714416301  0.03815169755425531
...
Length = 100 rows
```

- astroquery caches and is great for reproducibility

# Cross-matching



# Cross-matching

- Every time you point a telescope at the sky, you have to figure out where it's pointing and what's in it
- Cross-matching is non-trivial because of resolution/crowding, proper motion, SEDs, ...
- Typically, cross-matching is done by 2D position, requiring a close match in RA and Dec, but can also use magnitude/color or other properties → expensive for large surveys

# Finding all data on a single object

- Easiest using Simbad, either web:

**M87**

**other query modes :** Identifier query Coordinate query Criteria query Reference query Basic query Script submission TAP Output options Help

Query : M87  submit id

---

**Basic data :**

**M 87 -- Active Galaxy Nucleus**

Other object types: LIN (), BiC (), Rad (2020A&A,BWE,...), G (2014ApJS,APG,...), X (1A,2A,...), gam (1FGL,2FGL,...), AGN (2011ApJ,[VV2000c],...), GiC (ACSVCS,GIN,...), UV (2EUVE,EUVE,...), rG (2012MNRAS), IR (IRAS,[DML87]), QSO (QSO), GiG ([CHM2007]), AG? (2020MNRAS), \* (Gaia), Opt (SDSS)

**ICRS coord. (ep=J2000) :** 12 30 49.42338414 +12 23 28.0436859 (Radio) [ 0.0304732 0.0308 0 ] A 2020A&A...644A.159C

**FK4 coord. (ep=B1950 eq=1950) :** 12 28 17.60290329 +12 40 01.3345803 [ 0.0304732 0.0308 0 ]

**Gal coord. (ep=J2000) :** 283.77775499474 +74.49115452365 [ 0.0304732 0.0308 0 ]

Proper motions mas/yr: -8.029 10.734 [1.178 0.932 90] A 2018yCat.1345....0G

Radial velocity / Redshift / cz: V(km/s) 1256 [36] / z(spectroscopic) 0.00420 [0.00012] / cz 1259.1 [36.0] (Opt) E 2009ApJS..182..543A

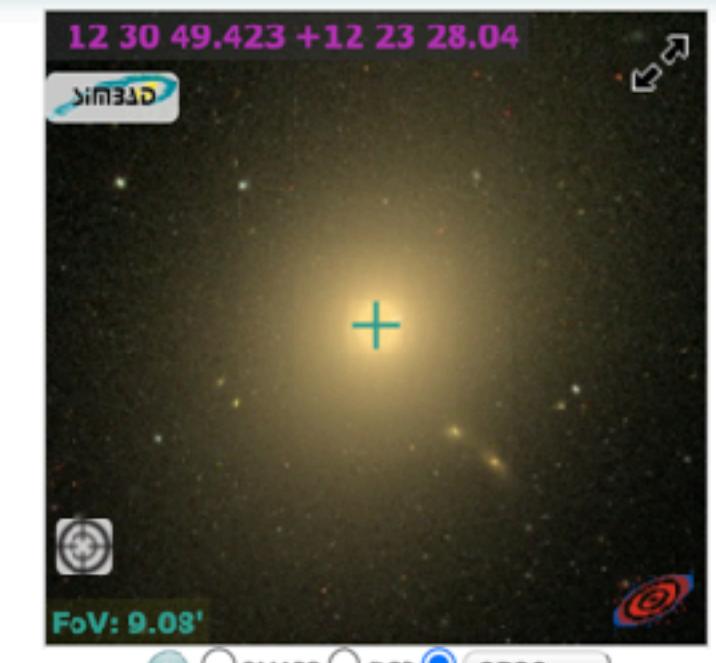
Morphological type: E-E/S0 C 2014A&A...569A.124V

Angular size (arcmin): 9.12 7.94 ~ (Opt) D 2003A&A...412...45P

Fluxes (13) :

U	10.16	[0.04]	D	2007ApJS..173..185G
B	9.59	[0.04]	D	2007ApJS..173..185G
V	8.63	[0.04]	D	2007ApJS..173..185G
G	15.7940	[0.0117]	C	2018yCat.1345....0G
I	7.49	[~]	D	2012A&A...538A..69L
J	6.719	[0.017]	C	2006AJ....131.1163S
H	6.074	[0.018]	C	2006AJ....131.1163S
K	5.812	[0.019]	C	2006AJ....131.1163S
u	(AB)	13.480	[0.003]	C 2009ApJS..182..543A
g	(AB)	11.563	[0.002]	C 2009ApJS..182..543A
r	(AB)	10.703	[0.002]	C 2009ApJS..182..543A
i	(AB)	10.272	[0.002]	C 2009ApJS..182..543A
z	(AB)	9.917	[0.002]	C 2009ApJS..182..543A

SIMBAD [Query around](#) within  arcmin



12 30 49.423 +12 23 28.04

FoV: 9.08'

2MASS DSS SDSS

All [CDS](#) (CDSPortal)

Send to [AIA](#) [EOP](#)

Photometry within  arcsec

# Finding all data on a single object

- Easiest using Simbad, either web or through astroquery

```
[In [4]: from astroquery.vizier import Vizier

[In [5]: result = Vizier.query_object("M87")

In [6]: print(result)
TableList with 760 tables:
'0:METAobj' with 5 column(s) and 7 row(s)
'1:ReadMeObj' with 5 column(s) and 7 row(s)
'2:I/122/bd' with 9 column(s) and 1 row(s)
'3:I/151/table3' with 5 column(s) and 1 row(s)
'4:I/252/out' with 8 column(s) and 2 row(s)
'5:I/267/out' with 16 column(s) and 50 row(s)
'6:I/272/m2000' with 6 column(s) and 2 row(s)
'7:I/284/out' with 14 column(s) and 13 row(s)
'8:I/297/out' with 19 column(s) and 18 row(s)
'9:I/300/pm2000' with 12 column(s) and 3 row(s)
'10:I/302/xcfields' with 9 column(s) and 2 row(s)
'11:I/304/out' with 9 column(s) and 6 row(s)
'12:I/313/lqrf' with 10 column(s) and 1 row(s)
```

# Finding all data on a single object

- Easiest using Simbad, either web or through astroquery
- Other similar service is NED, focused on external galaxies (linked to by Simbad)
- Can also do regional searches with rectangles or circles using astroquery for given catalogs (e.g., Gaia)
  - This is often also possible on the survey's website

# Cross-matching a catalog to another catalog

- Suppose you have a relatively large set of objects that you want to match to another large set of objects (could be a large survey)
  - Can do this locally with astropy:

```
>>> c = SkyCoord(ra=ra1*u.degree, dec=dec1*u.degree)
>>> catalog = SkyCoord(ra=ra2*u.degree, dec=dec2*u.degree)
>>> idx, d2d, d3d = c.match_to_catalog_sky(catalog)
```
  - Sometimes possible on a survey's website
  - CDS x-matching service: <http://cdsxmatch.u-strasbg.fr/>
    - Cross-match two VizieR catalogs to each other
    - Cross-match user catalog to VizieR catalog
    - Can be done programmatically (e.g., using cURL) or through `astroquery.xmatch`