CDS tutorial

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First Astro-CC Training Event,
Centro de Astrobiología, 2-4 December 2025

Centre de Données astronomiques de Strasbourg

Background picture by Deepanshu Arora on Unsplash

Observatoire astronomique de Strasbourg | ObAs
cnrs
Université de Strasbourg

Introduction

CDS timeline

- ★ CDS = Centre de Données astronomiques de Strasbourg
- ★ Data center dedicated to the collection and distribution of astronomical data and related information

Presentation outline

★ Part 1: Presentation of the main CDS services, using web access

★ Part 2: Programmatic access to CDS services, an illustration with carbon stars , using Jupyter notebooks

- Gather information on a specific object using SIMBAD,
- Visualise it through survey images using ipyAladin,
- Find and download a catalogue from VizieR,
- Cross-match the sources with a large catalogue using X-match.

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

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Carbon stars as standard candles: I. The luminosity function of carbon stars in the Magellanic Clouds

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ABSTRACT

Our goal in this paper is to derive a carbon-star luminosity function that will eventually be used to determine distances to galaxies at 50–60 Mpc and hence yield a value of the Hubble constant. Cool N-type carbon stars exhibit redder near-infrared colours than oxygen-rich stars. Using Two Micron All Sky Survey near-infrared photometry and the *Gaia* Data Release 2, we identify carbon stars in the Magellanic Clouds (MC) and the Milky Way (MW). Carbon stars in the MC appear as a distinct horizontal feature in the near-infrared ($J - K_s$)$_0$, M_J) colour–magnitude diagram. We build a colour selection ($1.4 < (J - K_s)_0 < 2$) and derive the luminosity function of the colour-selected carbon stars. We find the median absolute magnitude and the dispersion, in the *J* band, for the Large and the Small Magellanic Clouds (LMC/SMC) to be, respectively, ($\bar{M}_J = -6.284 \pm 0.004$ and $\sigma = 0.352 \pm 0.005$) and ($\bar{M}_J = -6.160 \pm 0.015$ and $\sigma = 0.365 \pm 0.014$). The difference between the MC may be explained by the lower metallicity of the SMC, but in any case it provides limits on the type of galaxy whose distance can be determined with this technique. To account for metallicity effects, we developed a composite magnitude, named *C*, for which the error-weighted mean *C* magnitude of the MC are equal. Thanks to the next generation of telescopes (*JWST*, *ELT*, and *TMT*), carbon stars could be detected in MC-type galaxies at distances out to 50–60 Mpc. The final goal is to eventually try and improve the measurement of the Hubble constant while exploring the current tensions related to its value.

Key words: catalogues – stars: carbon – Hertzsprung–Russell and colour–magnitude diagrams – stars: luminosity function, mass function – Magellanic Clouds.

1 INTRODUCTION

Measuring distances has been one of the most crucial, fascinating, and challenging goals in astronomy for centuries. Not only does it enable astronomers to probe the scale of the Universe, it is also key in understanding the physical nature of astronomical objects, which eventually opens up whole new fields of astrophysical research.

Carbon stars were discovered by Secchi (1868) because of a characteristic feature in their spectra: the Swan bands, which are representative of radical diatomic carbon C_2. Carbon stars are usually luminous red giant stars. Bright carbon stars are located on the asymptotic giant branch (AGB), in the Hertzsprung–Russell diagram. Carbon stars originate from main-sequence stars with masses in the range 1–10 $M_\odot$ (Barnbaum, Kastner & Zuckerman 1991; Marigo, Girardi & Bressan 1999). During the third dredge-up, heavy elements (C, O) are brought to the surface from the stellar interior (Iben & Renzini 1984; Busso, Gallino & Wasserburg 1999). In normal (oxygen) stars O > C (in terms of number of atoms), nearly all of the carbon in the atmosphere is trapped in the stable compound CO. However, if C/O > 1, carbon compounds can appear in the stellar atmosphere of AGB stars, forming carbon stars.

In this work, we focus on cool N-type carbon stars; such carbon stars have been known for a long time to show redder near-infrared colours than M-type stars (oxygen-rich stars). Thus, cool carbon stars occupy a specific region of near-infrared colour–magnitude diagrams (CMDs, Richer, Olander & Westerlund 1979; Cohen et al. 1981; Hughes & Wood 1990). There is also evidence of similar carbon-star luminosities between the Magellanic Clouds (MC, Crabtree, Richer & Westerlund 1976; Blanco, McCarthy & Blanco 1980; Richer 1981a, b; Aaronson & Mould 1982; Frogel & Richer 1983; Feast & Whitelock 1992; Demers, Irwin & Kunkel 1993). Demers, Dallaire & Battinelli (2002) obtained luminosity functions for a small sample of carbon stars in the MC using a near-infrared technique and a colour selection similar to the one used in this paper. Since carbon stars are very luminous in the infrared and have a characteristic spectrum, the possibility exists that they

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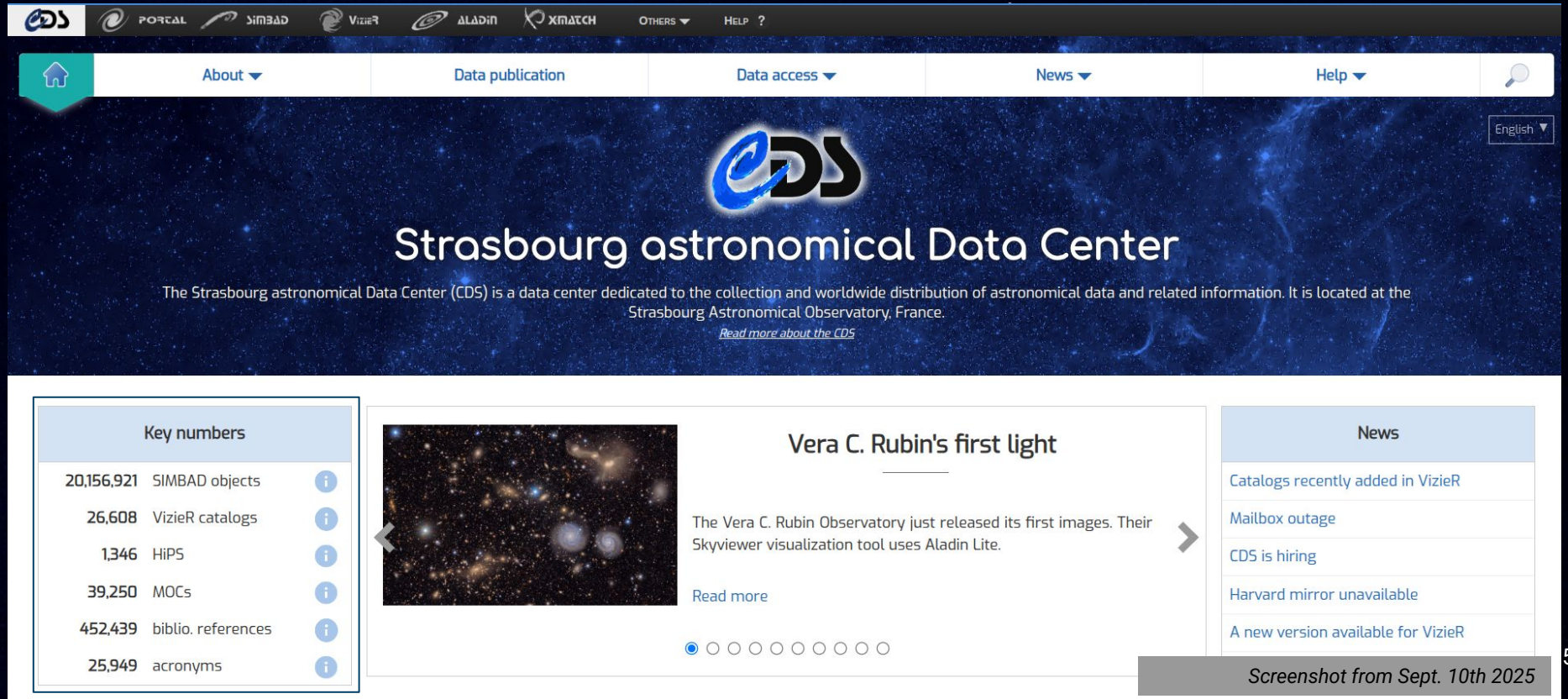
https://cds.unistra.fr/



Screenshot from Sept. 10th 2025

The main CDS services

SIMBAD

Objects

VizieR

Catalogues

ALADIN

Sky atlas

Key numbers	
20,156,921	SIMBAD objects
26,608	VizieR catalogs
1,346	HiPS
39,250	MOCs
452,439	biblio. references
25,949	acronyms

X-MATCH

Cross-match

CDS PORTAL

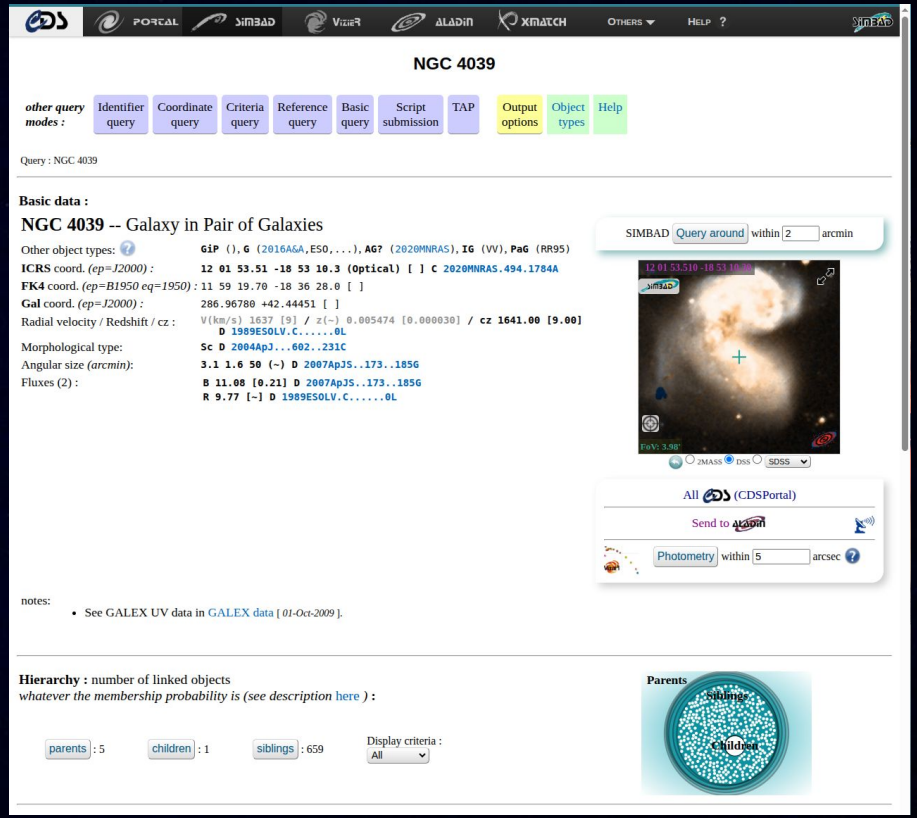
All-in-one

Statistics from Sept. 10th 2025

SIMBAD

Objects
Dictionary
Bibliography
Name resolver
TAP

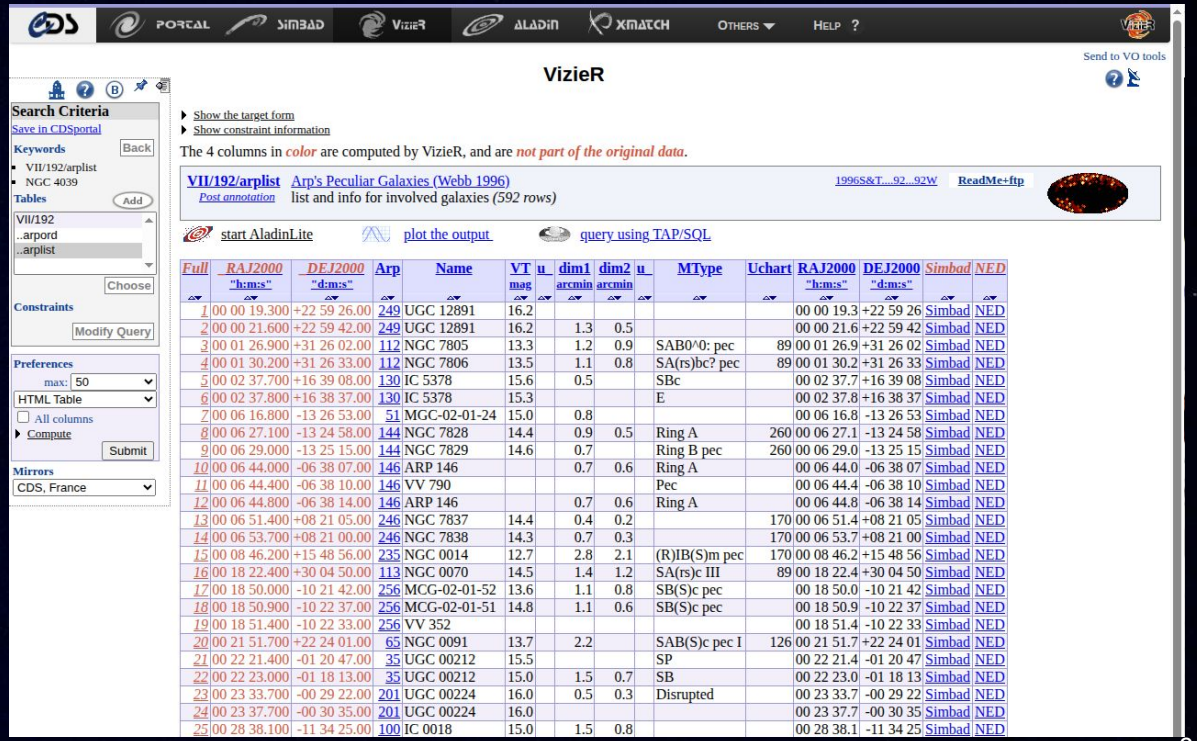
- ★ Astronomical database
- ★ Provides basic data such as identifiers, measurements and links to bibliographic studies
- ★ Can be queried by object name, coordinates and various criteria. Lists of objects and scripts can be submitted.



VizieR

Catalogues
Photometry service
Associated data service
FTP
TAP

- ★ Catalogue service
- ★ Provides access to thousands of astronomical catalogs and tables published in academic journals
- ★ Query tools allow the user to select relevant data tables. Then records can be extracted and formated matching given criteria.



CDS PORTAL SIMBAD VIZIER ALADIN XMATCH OTHERS HELP ?

Send to VO tools

VizieR

Search Criteria
Save in CDSportal
Keywords Back
- VII/192/arplist
- NGC 4039

Tables Add
VII/192
..arpord
..arplist
Choose

Constraints
Modify Query

Preferences
max: 50
HTML Table
All columns
Compute
Submit

Mirrors
CDS, France

Show the target form
Show constraint information

The 4 columns in *color* are computed by VizieR, and are *not part of the original data*.

VII/192/arplist Arp's Peculiar Galaxies (Webb 1996) 1996S&T....92...92W ReadMe+ftp
Post annotation
list and info for involved galaxies *(592 rows)*

start AladinLite plot the output query using TAP/SQL

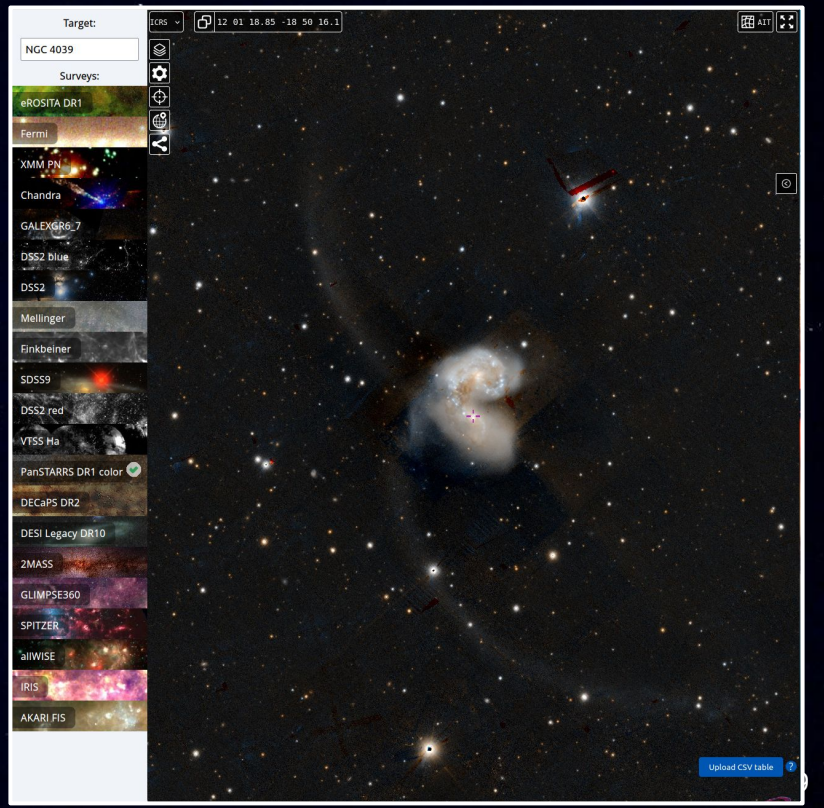
Full	RAJ2000 "h:m:s"	DEJ2000 "d:m:s"	Arp	Name	VT mag	u	dim1 arcmin	dim2 arcmin	u	MType	Uchart	RAJ2000 "h:m:s"	DEJ2000 "d:m:s"	Simbad	NED
1	00 00 19.300	+22 59 26.00	249	UGC 12891	16.2							00 00 19.3	+22 59 26	Simbad	NED
2	00 00 21.600	+22 59 42.00	249	UGC 12891	16.2		1.3	0.5				00 00 21.6	+22 59 42	Simbad	NED
3	00 01 26.900	+31 26 02.00	112	NGC 7805	13.3		1.2	0.9		SAB0^0: pec	89	00 01 26.9	+31 26 02	Simbad	NED
4	00 01 30.200	+31 26 33.00	112	NGC 7806	13.5		1.1	0.8		SA(rs)bc? pec	89	00 01 30.2	+31 26 33	Simbad	NED
5	00 02 37.700	+16 39 08.00	130	IC 5378	15.6		0.5			SBc		00 02 37.7	+16 39 08	Simbad	NED
6	00 02 37.800	+16 38 37.00	130	IC 5378	15.3					E		00 02 37.8	+16 38 37	Simbad	NED
7	00 06 16.800	-13 26 53.00	51	MGC-02-01-24	15.0		0.8					00 06 16.8	-13 26 53	Simbad	NED
8	00 06 27.100	-13 24 58.00	144	NGC 7828	14.4		0.9	0.5		Ring A	260	00 06 27.1	-13 24 58	Simbad	NED
9	00 06 29.000	-13 25 15.00	144	NGC 7829	14.6		0.7			Ring B pec	260	00 06 29.0	-13 25 15	Simbad	NED
10	00 06 44.000	-06 38 07.00	146	ARP 146			0.7	0.6		Ring A		00 06 44.0	-06 38 07	Simbad	NED
11	00 06 44.400	-06 38 10.00	146	VV 790						Pec		00 06 44.4	-06 38 10	Simbad	NED
12	00 06 44.800	-06 38 14.00	146	ARP 146			0.7	0.6		Ring A		00 06 44.8	-06 38 14	Simbad	NED
13	00 06 51.400	+08 21 05.00	246	NGC 7837	14.4		0.4	0.2			170	00 06 51.4	+08 21 05	Simbad	NED
14	00 06 53.700	+08 21 00.00	246	NGC 7838	14.3		0.7	0.3			170	00 06 53.7	+08 21 00	Simbad	NED
15	00 08 46.200	+15 48 56.00	235	NGC 0014	12.7		2.8	2.1		(R)IB(S)m pec	170	00 08 46.2	+15 48 56	Simbad	NED
16	00 18 22.400	+30 04 50.00	113	NGC 0070	14.5		1.4	1.2		SA(rs)c III	89	00 18 22.4	+30 04 50	Simbad	NED
17	00 18 50.000	-10 21 42.00	256	MCG-02-01-52	13.6		1.1	0.8		SB(S)c pec		00 18 50.0	-10 21 42	Simbad	NED
18	00 18 50.900	-10 22 37.00	256	MCG-02-01-51	14.8		1.1	0.6		SB(S)c pec		00 18 50.9	-10 22 37	Simbad	NED
19	00 18 51.400	-10 22 33.00	256	VV 352								00 18 51.4	-10 22 33	Simbad	NED
20	00 21 51.700	+22 24 01.00	65	NGC 0091	13.7		2.2			SAB(S)c pec I	126	00 21 51.7	+22 24 01	Simbad	NED
21	00 22 21.400	-01 20 47.00	35	UGC 00212	15.5					SP		00 22 21.4	-01 20 47	Simbad	NED
22	00 22 23.000	-01 18 13.00	35	UGC 00212	15.0		1.5	0.7		SB		00 22 23.0	-01 18 13	Simbad	NED
23	00 23 33.700	-00 29 22.00	201	UGC 00224	16.0		0.5	0.3		Disrupted		00 23 33.7	-00 29 22	Simbad	NED
24	00 23 37.700	-00 30 35.00	201	UGC 00224	16.0							00 23 37.7	-00 30 35	Simbad	NED
25	00 28 38.100	-11 34 25.00	100	IC 0018	15.0		1.5	0.8				00 28 38.1	-11 34 25	Simbad	NED

Aladin

Sky Atlas
Data integration
Surveys
HiPS/MOC

+ Aladin Lite Embeddable widget

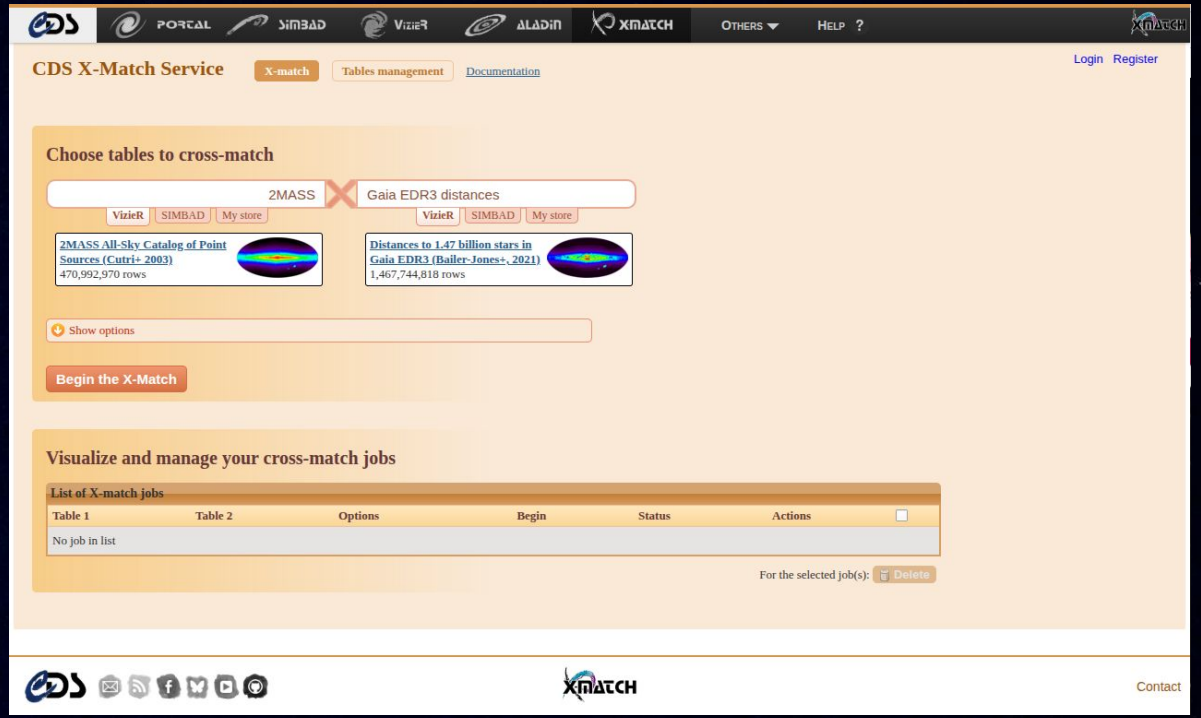
- ★ Interactive sky atlas
- ★ Access, visualization and analysis of astronomical images surveys catalogs and other databases
- ★ Aladin uses the HiPS (Hierarchical Progressive Survey) technology.



X-match

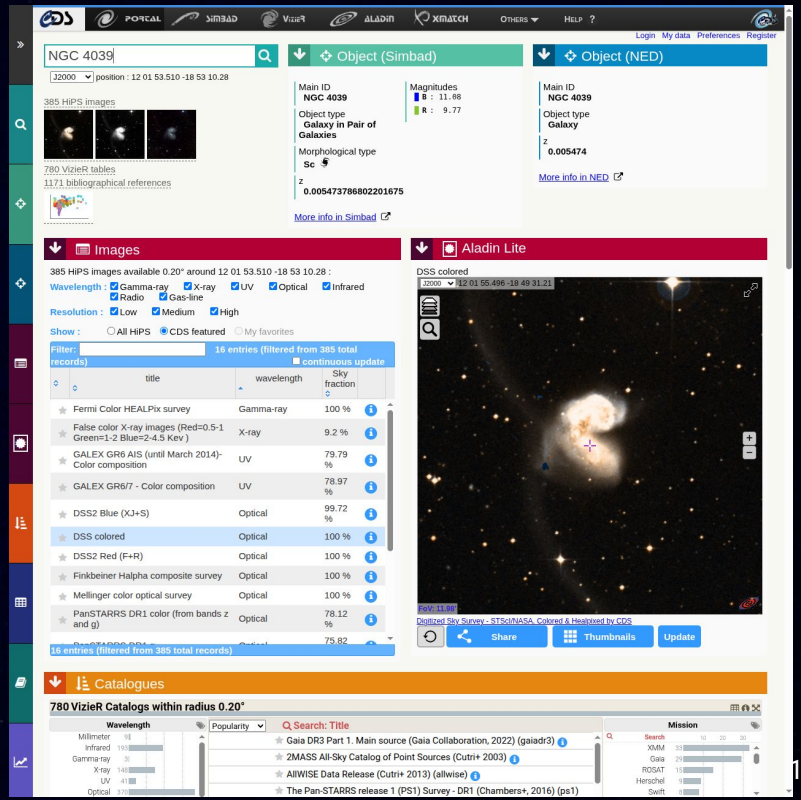
Catalogue Cross-matching service

- Tool to efficiently cross-identify sources between very large catalogues (up to 1 billion rows) or between a user-uploaded list of positions and a large catalogue.
- Available tables include 20,000+ VizieR tables and SIMBAD data.



CDS Portal

- Mashup application:
  - Provide a single entry point to search and access the different CDS services, querying simultaneously SIMBAD, VizieR and Aladin
  - Facilitate the workflow between the services



More services

Scientific content curation

Processing of published literature and reference data

Acronyms
Identifiers
Citations
Basic Data
Cross-identifications
Catalogues/Tables
Associated data
All-sky surveys, HiPS
Models/Simulations

Vizier and SIMBAD data ingestion pipelines
Tools: DJIN, COSIM, BCS

DJIN · BCS · COSIM

Dictionary of Nomenclature of Celestial Objects

INFO IDIC

Designations of astronomical objects are often confusing. Astronomical designations (also called Object Identifiers) have been collected and published by Lortet and collaborators in Dictionaries of Nomenclature of Celestial Objects outside the solar system.

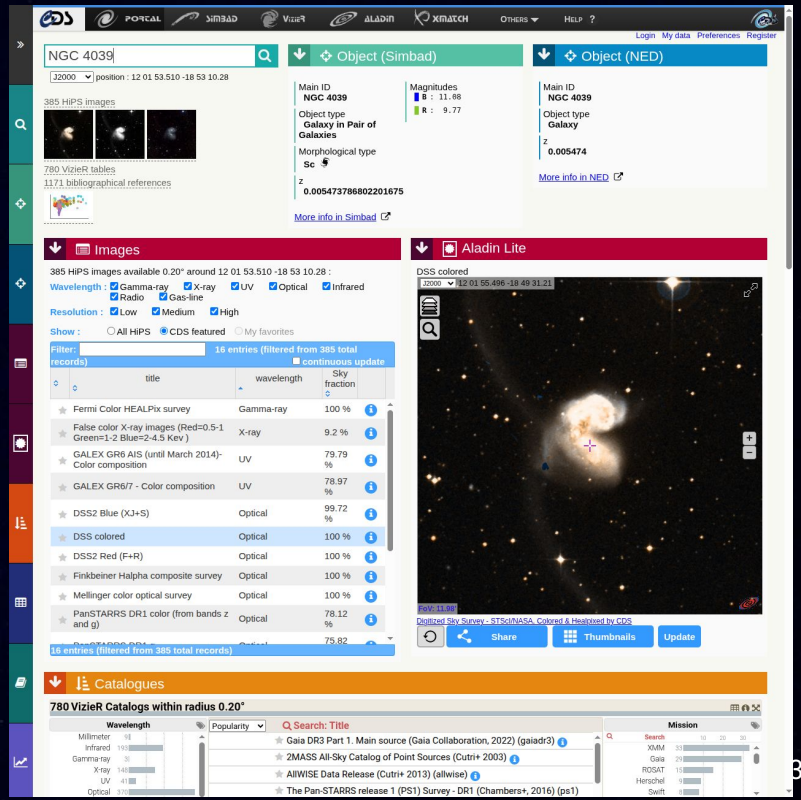
This Info service is the electronic look-up version of the Dictionary which is updated on a regular basis; it provides full references and usages about 25,984 different acronyms.

Let's practice!

★ Link: https://cds.unistra.fr/

★ Go and explore the different CDS services online, using your favorite object or some of the examples below:

- M101
- NGC 2024
- HR 6165
- 3C 326



Tutorial

Programmatic access to CDS services, an illustration with carbon stars

Tutorial: link

https://cds.unistra.fr/meetings/voschool2025

Requirements: A browser - not Chrome (no installation needed!)

Tutorial: Outline (1/2)

★ Programmatic access to CDS services, an illustration with carbon stars, using Jupyter notebooks

- Tutorial inspired by a paper from Ripoche et al. 2020

- Gather information on a specific object using SIMBAD,
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- Find and download a catalogue from VizieR,
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ABSTRACT

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Key words: catalogues – stars: carbon – Hertzsprung–Russell and colour–magnitude diagrams – stars: luminosity function, mass function – Magellanic Clouds.

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Carbon stars were discovered by Secchi (1868) because of a characteristic feature in their spectra: the Swan bands, which are representative of radical diatomic carbon (C_2). Carbon stars are usually luminous red giant stars. Bright carbon stars are located on the asymptotic giant branch (AGB), in the Hertzsprung–Russell diagram. Carbon stars originate from main-sequence stars with masses in the range 1–10 $M_\odot$ (Barnbaum, Kastner & Zuckerman 1991; Marigo, Girardi & Bressan 1999). During the third dredge-up, heavy elements (C, O) are brought to the surface from the stellar interior (Iben & Renzini 1984; Busso, Gallino & Wasserburg 1999). In normal (oxygen) stars O > C (in terms of number of atoms), nearly all of the carbon in the atmosphere is trapped in the stable compound CO. However, if C/O > 1, carbon compounds can appear in the stellar atmosphere of AGB stars, forming carbon stars.

In this work, we focus on cool N-type carbon stars; such carbon stars have been known for a long time to show redder near-infrared colours than M-type stars (oxygen-rich stars). Thus, cool carbon stars occupy a specific region of near-infrared colour–magnitude diagrams (CMDs, Richer, Olander & Westerlund 1979; Cohen et al. 1981; Hughes & Wood 1990). There is also evidence of similar carbon-star luminosities between the Magellanic Clouds (MC, Crabtree, Richer & Westerlund 1976; Blanco, McCarthy & Blanco 1980; Richer 1981a, b; Aaronson & Mould 1982; Frogel & Richer 1983; Feast & Whitelock 1992; Demers, Irwin & Kunkel 1993). Demers, Dallaire & Battinelli (2002) obtained luminosity functions for a small sample of carbon stars in the MC using a near-infrared technique and a colour selection similar to the one used in this paper. Since carbon stars are very luminous in the infrared and have a characteristic spectrum, the possibility exists that they

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Tutorial: Outline (2/2)

Step #1: Carbon stars in SIMBAD

Simbad

SIMBAD is a compilation of the literature. It is edited each working day by a team of astronomers and documentalists.

Figure I-1: SIMBAD compiles the literature in a single database.

Set of Identifications, Measurements and Bibliography for Astronomical Data

CW Leo in the SIMBAD database

Step #2: Using the `ipyaladin` widget

Aladin

Let's now visualise the source on the Aladin sky atlas.

Figure II-1:
The Aladin software suite allows to display and manipulate surveys, coverages, and catalogs.

The suite has three flavors:

- **Aladin desktop**. It is the most complete version and offers a complete graphic interface to find catalogs and HiPS surveys and manipulate them (cutouts, operations, stacks...).
- **Aladin Lite**. Is a lighter version that runs in the browser. With the advance of browser technologies, it is gaining more and more functionalities every day.
- **iPyAladin**. It is a port of Aladin Lite in python notebooks. This is the flavor we'll use here.

Step #3: Catalogues manipulation with VizieR and X-match

Simbad Aladin Vizier Xmatch

Introduction

The remaining of the tutorial is inspired by a work from Ripoche and collaborators, where they used "Carbon stars as standard candles":

- Ripoche et al. 2020, 2020MNRAS.495.2858R (Paper I)
- Parada et al. 2021, 2021MNRAS.501..933P (Paper II)
- Parada et al. 2023, 2023MNRAS.522..195P (Paper III)

Their idea is to derive a carbon-star luminosity function that will eventually be used to determine distances to galaxies at 50-60 Mpc and hence yield a value of the Hubble constant.

To do, they focused primarly on the Large and Small Magellanic clouds (LMC and SMC). Later they expanded their sample with Local group galaxies (eg. NGC 6822, IC 1613, Wolf-Lundm

Data selection / datasets

- To build their sample in Paper I, Ripoche et al. 2020 queried 2MASS over a polygon centered on the LMC and SMC.
- They removed the foreground contamination from Milky Way stars, by cross-matching the 2MASS stars with those found in Gaia DR2.
- They used proper motions to select stars considered to be LMC and SMC members.
- Finally, they corrected the apparent magnitudes for extinction and reddening, and included the true distance moduli to these galaxies.

Tutorial

Let’s dig into steps 1-2

https://cds.unistra.fr/meetings/voschool2025

Credit: P. Vonflie

Tutorial

Let’s continue step 3

https://cds.unistra.fr/meetings/voschool2025

Wrap-up

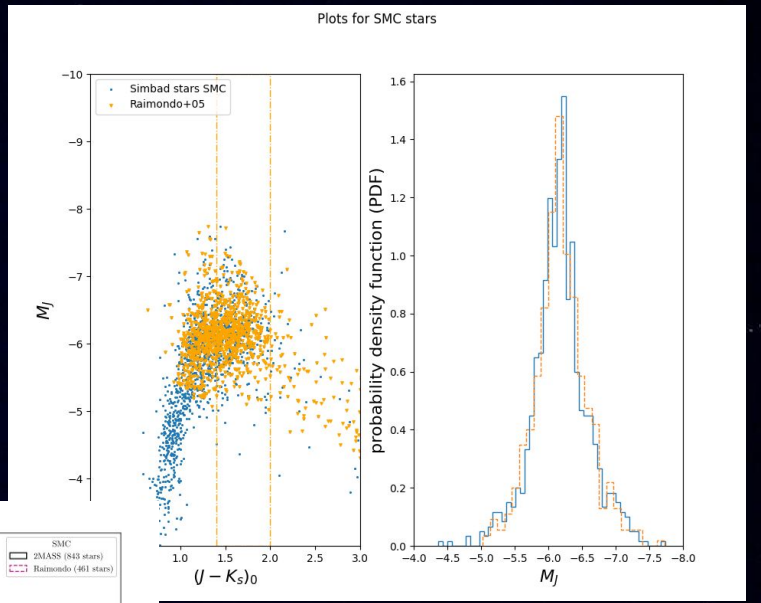
Wrap-up

- ★ Luminosity functions agree with the ones from Ripoche et al. 2020

- ★ CDS services used in this tutorial:
  - SIMBAD, Aladin, VizieR, X-match

- ★ VO standards introduced in this tutorial:
  - HiPS, MOC, TAP/ADQL

- ★ Jupyter notebook reusable
- ★ Design similar queries for your own research!



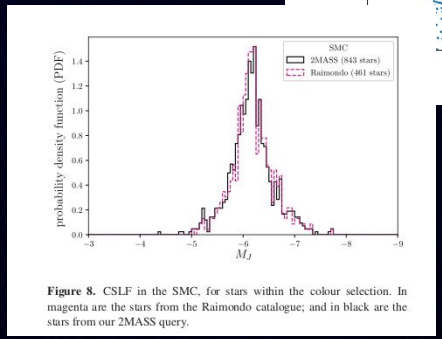


Figure 8. CSLF in the SMC, for stars within the colour selection. In magenta are the stars from the Raimondo catalogue; and in black are the stars from our 2MASS query.

Any questions?

Credit: P. Vonflie

Thanks for your attention

Useful links

- CDS: https://cds.unistra.fr/
- Presentation of CDS (from Dr. Sébastien Derrière): https://www.youtube.com/watch?v=dGssNN-YZkY
- Great video about the major CDS services (from Dr. Pooja Sharma): https://www.youtube.com/watch?v=2dC1R7PnuU4
- CDS tutorials: https://cds.unistra.fr/help/tutorials/