CDS - an astronomy data centre for reference data

Mark Allen & CDS team
Observatoire de Strasbourg, France

LineA Webinar, 16 February 2018
Centre de Données astronomiques de Strasbourg

hosted at the Observatoire astronomique de Strasbourg, Université de Strasbourg
Since 1972...

- Collect useful data on objects in electronic form
- Improve them by critical evaluation and combination
- Distribute the results to the international community
- Conduct research using the data

Science Driven:

- *Necessary evolutions to meet the scientific reference service needs of the astronomy community*
- *Innovations to meet challenges and ensure sustainability*
  - *Science is changing, technology is changing*
CDS – a part of the global astronomy infrastructure

Ground and Space Observatories, Instruments and missions

Reference Data Centre

Journals

Data e-Infrastructures

Astronomy Data Centres

CADC, MAST, HEASARC, IPAC, + ...

Virtual Observatory

20 members

Archives, Services

Astronomy & Astrophysics

+ ...

EUDAT

+ RDA Europe

RESEARCH DATA ALLIANCE

WORLD DATA SYSTEM
Status

- Supported as a French Research Infrastructure (via CNRS/INSU), plus international partners
  - serving global community
- ~38 staff: Scientists, Software Engineers, Documentalists, Admin
- VO-compliant, evolving, collaborative
- Certification - Data Seal of Approval
Reference Data

- From refereed Journals
  - Astronomical Object IDs, Tables, Science-ready data

- From major surveys and projects
  - subsets of the data that make sense to have alongside reference data

- CDS is for reference data (distinguished from observatory archives or processing data centres)
Astronomy

- Publishing and Reference services must evolve because science is constantly changing
- Era of big surveys (but also detailed individual studies)
- Multi-wavelength astronomy, Time Domain astronomy, multi-messenger astronomy coming.
Inter-connected science

- Multi-wavelength, multi-messenger...

  messengers: photons, \( \nu \), grav. waves, VHE\( \gamma \)

- using multiple instruments/telescopes
- combining data from multiple sources

- more open and collaborative
  - using tools and services that fit the purpose
  - distributed teams/collaborations/projects
CDS services

Astronomical Objects:
IDs, bibliography, measurements (550 k queries/day)

Catalogue Service:
Catalogues, published tables, observation logs, surveys, associated data (300 k q/day)

Visualisation and integration:
images, catalogues, VO portal, All-sky

X-Match: Catalogue cross-match

Portal: Single entry point to all services
Making information useable

• **Add value** - by homogeneous description of heterogeneous data
• **Standardisation** - formats, conventions, VO protocols
• **Metadata** - a level of ‘meaning’ to the data
• **Connections** - literature, archives, tools
• **Relies on trust** - of authors, publishers, data centres, data producers

Interoperability
New Portal - released 2016

Target:
Object name or position

Guided tour: click for an interactive introduction of the CDS portal.

http://cdsportal.u-strasbg.fr
SIMBAD

• Database of astronomical objects extracted and curated from the literature

• object types, coordinates, cross-identifications, citations, basic data

• 9.3 million objects, 27 million identifiers, 14 million citation links
• well known via the ‘object name resolver’

**Sombrero ➔ 39 59.43185 −11 37 22.9954**

• widely used: \(~550 \text{ 000 queries/day in 2017}\)**
Vizier

Catalogues, published tables, observation logs, surveys, associated data

- Heterogeneous tables described by standardised metadata
- Curated by professional ‘documentalists’
- Cooperation with major journals and ADS
- Added value - interoperability, usability, services (e.g. X-Match, visualisation, complex queries - ADQL TAP)
Simple query interface

VizieR provides access to the most complete library of published astronomical catalogues and data tables available online organized in a self-documented database. Query tools allow the user to select relevant data tables and to extract and format records matching given criteria. Currently, 13348 catalogues are available. more info

Free text search: catalogue name, author, ...

Position: position or object name

Find catalogues

Go to the classic form: Advanced search

VizieR
- How to publish my catalog
- Help and tutorials
- View large catalogs
- Rules of usage
- Mirrors

Other related services
- TAPVizieR
- Photometry viewer
- CDS cross-match service
- VizieR using the batch mode
- VO compatibility

Simple browsing modes
- By hierarchical organisation
- By acronyms or abbreviations
- By popularity
- Recently entered into VizieR
- Catalogs having images, spectra
Advanced query interface
Query interface for single table
# Query result

**VizieR Result Page**

The 3 columns in color are computed by VizieR, and are not part of the original data.

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**Notes:**
- The columns in color are not part of the original data.
- The data is from the CANDELS multiwavelength catalog (Galametz+., 2013).
- The table contains 3932 rows of data.
Vizier: Multiple Interfaces

Vizier web page, Aladin interface, CDS Portal, direct URL queries, Topcat interface, DS9, VO TAP, VO Cone Search, VizQuery
Vizier TAP service

- web interface
- ADQL checking
- examples
- VO compliant
- Topcat +
Photometry in catalogues
3c273 (12 29 6.695+02 03 8.662), radius : 1 arcsec

Mouse position:
Wavelength : 2.96e+3 \(\mu\)m
Frequency : 1.01e+2 GHz
Energy : 4.18e-4 eV
Flux density or F(v) : 5.70e+2 Jy
vF(v) :
5.77e-13 W.m\(^{-2}\)
F(\(\lambda\)) :
1.95e+4 erg.s\(^{-1}\).cm\(^{-2}\).\(\mu\)m\(^{-1}\)
• ~17,000 catalogues, containing 30,000 tables

• ~1200 new catalogues per year

• total of ~21 billion rows

• ~300,000 queries per day (working to decrease this by making queries ‘smarter’)
Vizier ‘associated data’

• Science ready data ‘associated’ with a journal publication
• Catalogues/tables
  • Time-series
  • Spectra
  • Images

• evolving very quickly with ‘data publication’ efforts (indexation via bibcodes and DOIs in preparation)
This web page is an access to the VizieR Associated data (images, spectra, timeseries, SED) which comes from publications. This tool is the result of the documentation assigned by the authors of the catalogues (in particular by A&A authors) and supervised by the CDS documentalist team (see the VizieR ingestion tool).

**VO compatibility**

The meta-data and the search engine are built according to the VO framework (SIA, SSA, ObsTAP) and can be queried by VO softwares. The data are gathered with the Saada engines, and the VO data model ObsCore has been chosen for the documentation.

**Simple search**

- **Search by position**: 40.6689792, -0.0132889
- **Search by spectral band**: min, max
- **Search by time data**: start, stop
- **Search by catalog/Identifier**:
- **Spectrum / Time series**: Image

**Results**

- **NGC1055**: J/A+A/659/A91, Ra: 40.437, Dec: 0.443, Band min: 315.000, Band max: 390.000, Facility: SDSS
- **NGC1068**: J/A+A/659/A91, Ra: 40.670, Dec: -0.013, Band min: 315.000, Band max: 390.000, Facility: SDSS
CDS X-Match

- Positional 2 table cross-match
  - epoch and proper motion taken into account where possible
  - cross-match done in J2000
- 17,000 Vizier cats, & SIMBAD, & upload
- Fast big catalogue matching:
  - SDSS vs. 2MASS in ~6 minutes
- Web interface
- HTTP API
Access to data via Aladin
Aladin - v10 released
Aladin Lite
Aladin

**Aladin Desktop**
- high level features **desktop**
- access images, catalogs, footprints
- **full range of functionalities**
- interoperable with VO tools
  - Aladin is a VO portal
  - used to validate most standards
- Used for observation preparation tools (APT, GuideCam)
- going all hierarchical now! (HiPS)

**Aladin Lite**
- **Web** HiPS visualizer
- preview mode
- embed in any webpage
- **easy appropriation**
- **highly used in wide range of sites/services**
- basic functions… but more and more!
SDSS DR9 band r image of APG 240 pair of galaxies, with an overlaid HST image and a WFPC2 footprint.

**Javascript**

```javascript
var aladin = A.aladin('#aladin-lite-div', {fov: 0.15, tax
aladin.setBaseImageLayer(aladin.createImageSurvey('SDSS-
aladin.getBaseImageLayer().getColorMap().update('rainbow
var simbad = A.catalog({name: 'Simbad', sourceSize: 16,
aladin.addCatalog(simbad);
simbad.addSources({A.marker(204.97010833333336, 0.840016

var overlay = A.graphicOverlay({color: 'aa2222', lineW
aladin.addOverlay(overlay);

overlay.addFootprints(A.polygon([[204.970214, 0.81206],
aladin.displayJPG('http://images.ipac.caltech.edu/stsci/
```
Radio Astronomy Survey
Visualisation Monitoring Tool
(ICRAR)

Spitzer GLIMPSE 360

NOAO Datalab

LIGO
Skymap Viewer

Aladin Lite implementations
ESA Sky - built on Aladin Lite
Recent developments

• **Hierarchical representation** of large image surveys, catalogues and cubes - a structuring development at CDS

• **Coverage maps** open up new possibilities for manipulating surveys and catalogues

  ➡ new interactions between images, cubes and catalogues
HiPS: Hierarchical Progressive Surveys

- Multi-resolution HEALPix data structure for
  - Images
  - Catalogues
  - 3-dimensional data cubes
- Conserves scientific data properties alongside visualisation considerations (*FITS & png/jpeg*)
- Mechanisms for links to original data
- Implemented for ~300 data sets and growing
HEALPix

- 12 quadrilateral pixels
- 2x2 division at each level
- Equal area
- Iso-latitude
- Nested index scheme encodes inheritance
- Libraries

*Gorski et al. 2005*
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<td>$2^{22}$</td>
<td>$2.11 \times 10^{14}$</td>
<td>50.3 mas</td>
<td>22</td>
<td>805,306,368</td>
<td>25°8</td>
</tr>
<tr>
<td>23</td>
<td>$2^{23}$</td>
<td>$8.44 \times 10^{14}$</td>
<td>25.1 mas</td>
<td>23</td>
<td>$3.22 \times 10^9$</td>
<td>12°9</td>
</tr>
<tr>
<td>24</td>
<td>$2^{24}$</td>
<td>$3.38 \times 10^{15}$</td>
<td>12.6 mas</td>
<td>24</td>
<td>$1.29 \times 10^{10}$</td>
<td>6°44</td>
</tr>
<tr>
<td>25</td>
<td>$2^{25}$</td>
<td>$1.35 \times 10^{16}$</td>
<td>6.28 mas</td>
<td>25</td>
<td>$5.15 \times 10^{10}$</td>
<td>3°22</td>
</tr>
</tbody>
</table>

--- Tiles ---

- WMAP
- PLANCK HFI
- IRAS
- NVSS
- SCUBA
- DSS
- SDSS
- CFHTLS
- HST ACS
Use an archive as a survey

- HiPS of the WFPC2 HST archive images (filter by filter)
• Fermi
• EGRET
• XMM
• INTEGRAL
• RASS
• GALEX
• DSS
• SDSS
• CFHTLS
• HST
• 2MASS
• ULTRAVISTA
• WISE
• ALLWISE
• DIRBE
• IRIS
• GLIMPSE360
• SPITZER
• AKARI
• SCUBA
• BGPS
• WMAP
• PLANCK
• NVSS
• CHIPASS
• SUMSS
• DWINGELOO
• HASLAM408
• VLSSR
• WENSS
• SHS
• SHASSA
• VTSS
• GASS
• CGPS
• GALFA
• CALIFA
• MUSE
• HARP/JCMT
• Gaia GUMS
• SIMBAD
• GOODS
• PHAT
Survey/image outlines

- MOC: Multi-Order Coverage maps

IVOA Recommendation, Python library: MOCPy
• Comparing coverage of 1000s of data sets
• Intersection/union/complement trivial
• Catalogue coverage
  - ~17000 (Vizier)
• MOC Server powers the CDS Portal

• Queries based on coverage and catalogues
  - e.g. Veron quasars in HST, XMM and SDSS images
Hierarchical views of Catalogues

- Same idea: HiPS Catalogue. Important when dealing with/visualizing $10^6$, $10^7$, $10^8$ + catalogues

- Allows zooming into large or deep catalogue

- HiPS catalogues - provide progenitor links to HiPS images

- Hierarchy can be defined in different ways - brightness, parallax, local density

- e.g. SIMBAD progressive Survey (hierarchy based on size of object and number of citations)
bringing it all together:

e.g. Gaia DR1 CDS

Gaia DR1 at CDS:
- DPAC partner
- VizieR
- TAPVizieR
- Cross-Match Service
- Aladin
- HiPS catalogue

Density Map of 1 billion Gaia sources
SELECT avg(RAJ2000) as ra, avg(DEJ2000) as dec, avg(HRV) as HRV, healpix(RAJ2000, DEJ2000, 7) as h
FROM "III/272/ravedr4"
group by h

SELECT avg(ra) as ra, avg(dec) as dec, avg(pmra) as pmra, avg(pmdec) as pmdec, healpix(ra, dec, 3) as h
FROM "I/337/tgas"
group by h
Advanced usage of HiPS and MOCs

Exploring large catalogs within non-trivial spatial coverage, defined by brightness cuts and/or the availability of additional data sets

Thomas Boch and Caroline Bot, CDS
Detecting the Unexpected, Discovery in the Era of Astronomically Big Data
Space Telescope Science Institute, February 27 — March 2, 2017
in conclusion...

- Science driven data centre providing services for reference data
- Getting ready for era of Big Data
- Contributing to, and compliant with VO
- Interoperability via IVOA, collaborations and shared tools and infrastructure
thanks
Links

- Hierarchical Progressive Surveys
  - Fernique et al. 2015, A&A 578, 114
  - HiPS on CDS web pages: http://aladin.u-strasbg.fr/hips
- Aladin http://aladin.u-strasbg.fr/AladinDesktop/
- Aladin Lite http://aladin.u-strasbg.fr/AladinLite/
- HiPS generation tools: http://aladin.u-strasbg.fr/hips/#tools