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The CDS information hub

On–line services and links at the Centre de Données astronomiques de Strasbourg

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Abstract. The *Centre de données astronomiques de Strasbourg* (CDS) provides homogeneous access to heterogeneous information of various origins: information about astronomical objects in SIMBAD; catalogs and observation logs in VIZIER and in the catalogue service; reference images and overlays in ALADIN; nomenclature in the *Dictionary of Nomenclature*; Yellow Page services; the AstroGLU resource discovery tool; mirror copies of other reference services; and documentation. With the implementation of links between the CDS services, and with other on–line reference information, CDS has become a major hub in the rapidly evolving world of information retrieval in astronomy, developing efficient tools to help astronomers to navigate in the world-wide "Virtual Observatory" under construction, from data in the observatory archives to results published in journals.

The WWW interface to the CDS services is available at: http://cdsweb.u-strasbg.fr/

Key words: astronomical data bases: miscellaneous — catalogs — publications, bibliography — surveys — standards

1. Introduction

The *Centre de données astronomiques de Strasbourg* (CDS) was founded in 1972 as the *Centre de Données Stellaires*, and installed in Strasbourg as the result of an agreement between the INAG (*Institut National d'Astronomie et de Géophysique*), now INSU (*Institut National des Sciences de l'Univers*), and *Université Louis Pasteur*. This was the outcome from the very prospective vision of Jean Delhaye, then Director of INAG, who anticipated the importance of computer-readable data. It was decided to found CDS as a part of the French research system, as a Data Center serving the international astronomical scientific community.

The objectives of CDS at its creation could be summarized as follows:

– collect "useful" data about astronomical sources, in electronic form;
– improve them by critical evaluation and combination;
– distribute the results to the international community;
– conduct research programs using the data collected.

Insertion of the CDS into a research institution, the *Observatoire astronomique de Strasbourg*, helps to maintain direct contacts with the evolution of astronomy, and with researchers' actual needs.

At the beginning, CDS was dealing with stellar data, aiming at the study of the galactic structure. In 1983, it was decided that SIMBAD, one of the two important CDS services at that time, would also deal with other galactic and extragalactic objets – i.e., with all astronomical objects outside the Solar System. The CDS's name was changed to *Centre de Données astronomiques de Strasbourg*, thus preserving the acronym which was already well known.

In recent years, research activities in astronomy have evolved significantly, with the very rapid development of on-line information at all levels, from observatory archives to results published in journals. The challenge is now to deal with *information* more than with *data*, which includes data, but also know-how about data, technical information about instruments, published results, compilations, etc.

The CDS goals can now be summarized as **collect, homogenize, distribute, and preserve astronomical information for the scientific use of the whole astronomical community**. This "mission statement" still contains all the drivers from the early CDS charter: dealing with electronic

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data, taking up an international role, developing expertise on astronomical data, having research as a goal.

All on-line CDS services can be accessed from the CDS home page on the World-Wide Web[1].

2. The present context of CDS activities

The ground- and space-based observatories, the sky surveys, and the deep field observations, produce large amounts of data, obtained at different wavelengths with different techniques. To understand the physical phenomena at work in objects, astronomers need to access this wealth of data, to understand their meaning (error bars, etc.), and to combine the use of data from different origins, especially with the development of *panchromatic* astronomy. At all steps of an astronomer's work, it is thus more and more necessary to re-use data obtained by others and to take into account previous results, often from other fields of astronomy.

Astronomers and funding Agencies are now well aware of the necessity of preserving and diffusing data and results. This leads to several types of developments:

– the data producing teams, which have the knowledge of instruments and observation techniques, have to preserve all or part of their data, in a form usable by all astronomers – in the majority of recent large projects, the building of the *observatory archive* is now considered as one of the project missions;
– in some domains, a *specialized center* provides access to and information about data in a given subfield of astronomy – this is the case in particular of the disciplinary NASA Centers, HEASARC[2] for High Energy astrophysics, IRSA[3] at IPAC[4] for Infrared data, and MAST[5] at the Space Telescope Science Institute[6], for optical and UV data;
– as a Data Center, the role of CDS is to bridge the gap between the specialized approach of the scientific teams, and the general approach of the community of researchers. In the present context, with the very rapidly growing number of on-line services of interest to astronomers, this means in practical terms the definition, development, and distribution of tools for retrieving useful information among the vast array of possible sources (Sects. 3, 5).

In addition, journals are recent, but very active actors in the on-line distribution of information in astronomy. Electronic publication has made rapid progress and many journals now have on-line versions, which often display external links. Moreover, NASA *Astrophysics Data System*[7] (ADS, Kurtz et al. 2000) has become a major reference tool for astronomers. Several aspects of the ADS are described in a set of companion papers. The bibliographic astronomy network, and the CDS role in this networking, are described in more detail in Sect. 5.2.

On the other hand, computers and networks evolve very rapidly: the high rate of increase in the volume of data and results, the irruption of the Internet and World Wide Web, the widespread usage of graphical interfaces, the lower and lower cost of information storage, completely changed the technical context of the CDS activities in the last few years.

3. The CDS activities

CDS activity has different aspects. Some are directly visible to the users, whereas others, though fundamental for maintaining the CDS expertise and role, may be less conspicuous.

The most perceptible activity of CDS is certainly the development, maintenance and on-line diffusion of reference, value-added databases and services, such as Simbad, VizieR, Aladin, the *Dictionary of Nomenclature of astronomical objects outside the solar system* (Lortet et al. 1994), the AstroGLU discovery tools (Egret et al. 1998), etc. The CDS services are described in more detail in Sect. 4, and in the set of companion papers by Wenger et al. (2000a), Ochsenbein et al. (2000), and Bonnarel et al. (2000).

From the point of view of contents, CDS deals with selected information: raw observational data are generally not available at CDS, but rather upper level data such as observation logs, catalogues, results, etc. This "reference" information is then documented, organized, and made accessible in the CDS services.

In addition, in order to cope with the congestion of inter-continental connections, CDS has developed an active policy of mirror copy implementation. The redundant availability of data on several sites is also important to ensure data security. Mirror copies of Simbad and ADS are installed in CfA and CDS respectively (Eichhorn et al. 1996). Mirror copies of VizieR are installed at NASA ADC[8] and NAOJ ADAC[9] (which also hosts a copy of the *Dictionary of Nomenclature*), another one is foreseen at the Indian Data Center (IUCAA[10], Pune). CDS hosts mirror copies of several electronic journals and of CFHT documentation.

[1] http://cdsweb.u-strasbg.fr/
[2] http://heasarc.gsfc.nasa.gov/
[3] http://irsa.ipac.caltech.edu/
[4] http://www.ipac.caltech.edu/
[5] http://archive.stsci.edu/mast.html
[6] http://www.stsci.edu/
[7] http://ads.harvard.edu/, with several mirror sites, including one at CDS at http://cdsads.u-strasbg.fr/
[8] http://adc.gsfc.nasa.gov/
[9] http://adac.mtk.nao.ac.jp/
[10] http://www.iucaa.ernet.in/

Less visible from the users, but an important field for networking international partnership, CDS develops generic tools and distributes them to other information providers: for example, the GLU (*Générateur de Liens Uniformes*), for maintaining links to distributed heterogeneous databases (Fernique et al. 1998, Sect. 5.1), or the SIMBAD client/server package, which allows archive services and the ADS to use SIMBAD as a name resolver.

CDS is also active in the development of exchange standards, such as the *bibcode*, first defined by NED[11] and the CDS (Schmitz et al. 1995), and now widely used by the ADS and the on-line journals, or the standard description of tables, defined by CDS and shared with the other data centers and the journals (Ochsenbein et al. 2000). CDS collaboration with journals is described in Sect. 5.2.

CDS expertise in the domain of astronomical data is also useful for projects. Strasbourg Observatory has been deeply involved in construction of the input and result catalogues of Hipparcos & Tycho (1997), and SIMBAD has been used as a basis for ROSAT identification tools. At present, the XMM Survey Science Center[12] relies on the CDS services to build a cross-identification database for the X-ray sources observed by the satellite. The CDS participation to the DENIS and TERAPIX/MEGAPRIME surveys is described in Sect. 5.4.

Finally, to keep up with the pace of technical evolution, CDS has to develop a resolute activity in the domain of technological and methodological watch, and to undertake Research and Technology (R&T) actions to assess new techniques. The GLU development (Fernique et al. 1998, Sect. 5.1.), and the ALADIN Java interface (Fernique & Bonnarel 2000), are examples of R&T actions which came out as operational services. More recently, one can cite the *ESO/CDS Data Mining Project* (Ortiz et al. 1999), or the assessment of commercial object oriented database systems (Wenger et al. 2000b) (Sect. 5.4).

In practice, the main challenge in the CDS activity is to constantly tune the contents and the services to the rapid scientific and technical evolution, to be able to deal with ever increasing volumes of information, and to be ready to respond to the new projects and to the evolution of the policy of the national and international Agencies. The guidelines in prioritizing the tasks are several: offer the best service to the users, ensure the quality of contents, and make the best of technological innovation. This implies that new developments are begun neither too early, to rely on techniques which are as secure as possible, nor too late, to offer the best possible services and improve the functionalities – hence the importance of technical watch. A balance has constantly to be kept, between very long term activities, on time scales of several ten years, to build up the contents; the development and maintenance of database systems and user interfaces, on time scales of a few months to a few years; R&T activities, on similar times scales; and operational constraints on a day-to-day basis. Hence the importance of careful strategy definition and activity scheduling.

[11] http://nedwww.ipac.caltech.edu/
[12] http://xmmssc-www.star.le.ac.uk/

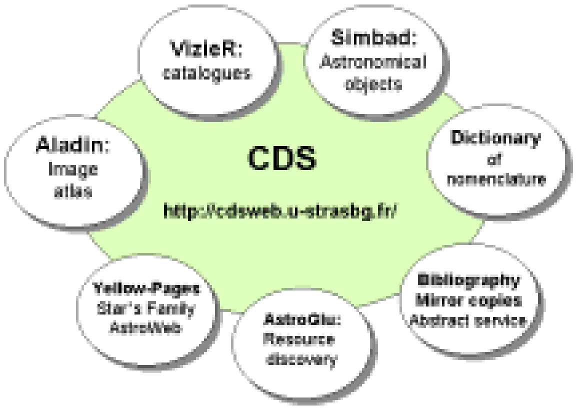

Fig. 1. The main CDS on-line services

Fig. 2. CDS home page on the World-Wide Web

4. The main CDS services

A diagram of the main CDS services is shown in Fig. 1, and their list is given in the CDS Home Page (Fig. 2).

The first two main products of CDS have been the collection of information about astronomical objects from published papers and reference catalogues in SIMBAD, and the collection, documentation, long term storage and distribution of catalogues in the catalogue service, with the recent addition of the catalogue browser functionality of the VIZIER service. More recently, the ALADIN project has permitted us to construct an image server, and a comprehensive tool to overlay the information from SIMBAD, VIZIER, and from other sources such as NED or data archives, on digitized images of the sky. These services are described in companion papers (Wenger et al. 2000a; Ochsenbein et al. 2000; Bonnarel et al. 2000).

The CDS also has the responsibility of the *Dictionary of Nomenclature* (Lortet et al. 1994), hosts bibliographical information, with mirror copies of the ADS and of the *Astrophysical Journal*, the *Astronomical Journal*, and the *Publications of the Astronomical Society of the Pacific*, and develops bibliographic information retrieval tools (Poinçot et al. 1998). It maintains the AstroGLU information discovery tool (Egret et al. 1998), and hosts two Yellow Page services: AstroWeb (Jackson et al. 1995), and the *Star*s Family of Astronomy and Related Resources* (Heck 1997). CDS is the French IUE National host, the host of a copy of the CFHT user documentation and of the unpublished data on variable stars of IAU Commission 27.

The main evolution of the CDS in recent years, is the rapid development of the *World Wide Web* access to the services[13]. Before 1996, the only CDS service available on the Web, besides documentation, was the access to the catalogues and tables (via ftp) and to the on-line abstracts of the journal *Astronomy and Astrophysics*. VIZIER was released in February 1996, the first Web version of SIMBAD in November 1996, and the Web access to ALADIN in November 1998 (Previewer) and February 1999 (ALADIN Java). Now all the services are accessible from the CDS Home Page (Fig. 2).

The usage of the CDS services has been continuously increasing, with over 6 000 queries submitted to the CDS services and their mirror copies every day, and over 25 000 hits per day on the Web pages (November 1999).

5. Major evolution trends

With the development of the World Wide Web, building links between heterogeneous, distributed information, has been an important evolution trend recently, and it is also an important topic for international partnership among service providers.

5.1. Building links between heterogeneous services

Historically, the CDS services had developed separately, with different contents, functionalities, database management systems and user interfaces. The World Wide Web opened the possibility to increase the synergy between the services, by building links allowing the users to navigate in a transparent way. Maintenance is a major challenge however, as soon as one tries to build links between distributed, heterogeneous services: any change in the service address, or in the query syntax, breaks links. This is particularly difficult when "anchors" (links in HTML syntax) are hard-coded in the HTML pages. CDS has solved this problem by developing the *Générateur de Liens Uniformes* (GLU), a software package which manages a distributed dictionary of resources (Fernique et al. 1998). Each resource is described by its address, the query syntax, test information, links to description and help files, etc. The *GLU Dictionary* descriptions are maintained up-to-date by each service provider and shared among all participants. The *GLU Resolver* allows the service manager to use symbolic names, instead of physical names, for the links; these names are then translated on the fly using the information contained in the *GLU Dictionary*.

The GLU development has allowed CDS to build reliable links between its own services, to manage mirror copies, and to implement a common presentation of the CDS pages, with homogenized headers.

Moreover, the GLU is being shared with all the partners of the AstroBrowse NASA initiative: information retrieval tools are being developed for providing a homogeneous access to a large list of resources maintained in a common GLU Dictionary (Heikkila et al. 1997). One of these tools, AstroGLU (Egret et al. 1998), is developed by CDS. It permits us to search on-line services such as observatory archives, databases, etc., by coordinates, astronomical object names, astronomer names, keywords, etc. In fact, AstroGLU is a Web interface to the GLU Dictionary.

GLU is also used by the French *Centre de Données de la Physique des Plasmas* (CDPP)[14].

5.2. The CDS role in the bibliographic network

Starting with the *Bibliographical Star Index* (BSI, Ochsenbein 1982) as early as 1975, CDS has always been dealing with bibliographic data: references and objects citations in published papers are stored in SIMBAD, and published tables in the catalogue service. The last few years have seen a revolution in this domain, with the extremely rapid development of electronic publication, which has led to major conceptual evolutions in the work of journal editors and publishers, and in the usage of published information by scientists.

[13] http://cdsweb.u-strasbg.fr/

[14] http://cdpp.cesr.fr/

The collaboration with the journal *Astronomy and Astrophysics*, for which CDS implements on-line abstracts and tables in close cooperation with the editors, was settled in 1993, very early in the history of electronic publication (Ochsenbein & Lequeux 1995). As explained in the companion paper by Ochsenbein et al. (2000), the standard description of tabular catalogues proposed by CDS in 1994 has since then been accepted by other reference journals and by the collaborating data centers. It is now one of the important exchange standards for astronomy, allowing for data exchange, transformation and checks, complementary to FITS which is widely used for binary and image data. A new standard in XML is presently being implemented for formatting tables (Ochsenbein et al. 2000), and to facilitate interoperability between services. In particular, this standard has been implemented in VizieR, and is already used for data ingestion by Aladin.

The CDS role in the world-wide astronomy bibliographical network, sometimes called *Urania* (Boyce 1998), has several aspects (Lesteven et al. 1998):

- provision of selected and homogenized bibliographic information in Simbad and VizieR;
- publication of "long" tables on behalf of some of the major astronomy journals;
- implementation of mirror copies of the *Astrophysical Journal*, *Astronomical Journal*, and *Publications of the Astronomical Society of the Pacific*, in collaboration in particular with the *University of Chicago Press*, and of NASA *Astrophysics Data System* abstracts and scanned images of articles;
- active participation to the definition of exchange standards;
- R&T efforts to handle "textual" information, which have led to the development of *Document maps*, using the technique of "Self-Organizing maps" (Kohonen 1982) for displaying references classified on the basis of the semantic proximity of their contents (Poinçot et al. 1998).

The definition of exchange standards such as the bibcode and the standard description of tables, the close collaboration with the journals and the ADS, have permitted an excellent synergy among the on-line bibliographic services. For instance, data exchange, links, exchange and installation of mirror copies, have been implemented between CDS and ADS, which also uses Simbad as a name resolver. The on-line versions of *Astronomy and Astrophysics* and the *Supplement Series* contain links to the CDS catalogue service, as part of the publication, and to the list of Simbad objects for each paper.

The Data Center has also brought new methods to validate the journal contents, complementary to the referees' work: tools have been developed to check the consistency of data in electronic tables, and detected errors are reported directly to the author by CDS before publication, and corrected.

In addition, the development of semi-automatic methods for recognition of astronomical object names in texts is being studied (Lesteven et al. 1998). This is rendered difficult by the extreme complexity of astronomical nomenclature, but there are potentially innovative applications, such as building links between object names in journal articles and the information contained in Simbad. A prototype implementation is operational at CDS in a simple case (object names in abstract keywords). *New Astronomy* also provides links from object names in articles to Simbad and NED, with manual tagging and verification. But many fundamental questions remain to be solved, e.g. the management of links between object names in journals that remain unchanged, and object names contained in databases which may change.

5.3. The CDS role for the access to observation archives

The objective is to use the CDS as a "hub" to observatory archives: each CDS service, with its own functionalities, allows the user to select the observation he or she would like to check, and to access these observations through an http link to the archive service.

VizieR is potentially a major tool to access observatory databases: the archive holdings are normally listed in a "log", i.e. in a table which contains the list of available observations with some additional information, such as the instrument mode, time and duration of observation, target position, target name, PI name, etc. Data in tabular form are very easy to include in VizieR – one just has to build their description in standard format. A data archive log included in VizieR can be searched by querying any of its fields, thus allowing the user to select the information of interest. The next step is to build links between the log entries in VizieR, and the data in the archive: this is already operational for several archives, in collaboration with the data providers, and using the GLU to implement the links. One also has to update evolving logs, for implementing links to on-going space missions or ground-based programs. This has been developed in recent years, and is now fully operational. In November 1999, VizieR was able to access the FIRST/VLA survey data, and the IUE and HST archives. Discussions are under way with several other projects.

Implementation of links from Simbad to data archives is less straightforward, since the logs are usually not easy to cross-identify with the database. This is done on a case-by-case basis. Links to IUE and HEASARC are available at present time: the IUE log has been cross-identified with Simbad, taking advantage of the fact that CDS had homogenized the mission target nomenclature on behalf of ESA (Jasniewicz et al. 1990); for the links to HEASARC, the high energy objects are recognized by checking the list of identifiers for names coming from a high-energy mission (e.g., RX or 1RXS, among others, for ROSAT). More will be done in the future through the implementation in SIMBAD of links pointing to VIZIER.

ALADIN gives access to data archives through their logs in VIZIER, and is also able to display archive images. This is a major evolution towards a comprehensive tool permitting comparison of images at different resolutions or wavelengths, with active links to the original data.

5.4. Dealing with large surveys

The large surveys underway or planned at different wavelengths, such as DENIS and 2MASS in the infrared, SLOAN at optical wavelengths, the large Schmidt telescope plate catalogues (GSC I and II, USNO, APM, etc.), play an important role, both for multi-wavelength studies, and by providing reference objects. Astronomers thus need easy access to the data of each survey, and also tools to use the data from one survey, together with information from other origins. These needs have recently been summarized in the concept of "Virtual Observatory" (see e.g. Szalay & Brunner 1998).

CDS has been involved in active discussions with the major survey projects in the last few years. As explained in Ochsenbein et al. (2000), an efficient method to query very large tables by position has been implemented in the CDS catalogue service, with the same user interface as VIZIER, for tables larger than the few million objects manageable in relational systems. The USNO catalogue (520 million objects), the public data of DENIS and 2MASS, have been made rapidly available in this service. The APM catalogue will also be installed soon, as well as GSC II as soon as it will be publicly available. ALADIN gives access to the surveys implemented in VIZIER, and is very useful for data validation and for the assessment of criteria for statistical cross-identification.

Moreover, CDS has been contributing to the DENIS project, by developing an on-line service to distribute public and private information (Derriere et al. 2000), and data comparison with the information in the other CDS services has already served for data validation. CDS also participates in TERAPIX (data pipeline of the CFHT MEGAPRIME project): it will distribute the result catalogue and probably also summary images.

In addition to the present access to very large catalogues by coordinate queries, evaluation of the usage of commercial Object Oriented database systems for multicriteria access to very large catalogues is under way (Wenger et al. 2000b). Moreover, the *ESO/CDS Data Mining project* aims at accessing and combining information stored at ESO or CDS, and to perform cross-correlations in all the parameter space provided by the data catalogues – not restricting the correlations to positional ones (Ortiz et al. 1999).

6. Conclusion

The usage of the CDS services has undergone a revolution in the last few years, with the outcome of the World Wide Web, allowing easy access to on-line information, the integration of data and documentation, and navigation between distributed information. This means an explosion in the usage of the services, new functionalities, new concepts in the partnership of data centers and journals, since published information can now be considered as data (e.g., published tables are now usable like reference catalogues), and an increase in international partnership, to build up links and to define exchange standards. In parallel, the construction of the database contents remains a long-term activity, with increasing volume of information to deal with, and high standards of scientific and technical expertise needed in the value-added data center activities.

Navigation and links will certainly remain important keywords for the future, and the topic of interoperability is clearly emerging. One aspect is the construction of links between distributed services. Another one is the building of comprehensive information retrieval tools, as stressed in the AstroBrowse NASA initiative. To go further, one needs to be able to integrate the result of queries to heterogeneous services (ISAIA project, Hanisch 2000). In this context, the elaboration of exchange standards and metadata descriptions common to all service providers are fundamental keys to success. On a technical point of view, XML may be one important tool for data integration. ALADIN is an example of a comprehensive tool, allowing integration of reference images, with information from catalogues, databases and data archives.

The rapid development of the world-wide "bibliographic network" has been particularly impressive, and the "data archive network" seems well under way. The CDS is a major hub in the on-line "Virtual Observatory" presently under construction: its services allow astronomers to select the information of interest for their research, and to access original data, observatory archives and results published in journals.

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Developing and maintaining the data-bases is a collective undertaking. The expertise and dedicated work of the documentalists, engineers and astronomers who work for CDS in Strasbourg and elsewhere are the foundations of the quality of the services. All of them are associated with this paper. Long term support from Institut d'Astrophysique de Paris, Observatoire de Paris (DASGAL), Observatoire de Bordeaux, GRAAL (Montpellier) and Observatoire Midi-Pyrénées (Toulouse), is gratefully acknowledged.

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