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Networking of Bibliographical Information: Lessons learned for the Virtual Observatory

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Abstract. Networking of bibliographic information is particularly remarkable in astronomy. On-line journals, the ADS bibliographic database, SIMBAD and NED are everyday tools for research, and provide easy navigation from one resource to another. Tables are published on line, in close collaboration with data centers. Recent new developments include the links between observatory archives and the ADS, as well as the large scale prototyping of object links between *Astronomy and Astrophysics* and SIMBAD, following those implemented a few years ago with *New Astronomy* and the *International Bulletin of Variable stars* . This networking has been made possible by close collaboration between the ADS, data centers such as the CDS and NED, and the journals, and this partnership being now extended to observatory archives. Simple, *de facto* exchange standards, like the *bibcode* to refer to a published paper, have been the key for building links and exchanging data. This partnership, in which practitioners from different disciplines agree to link their resources and to work together to define useful and usable standards, has produced a revolution in scientists' practice. It is an excellent model for the Virtual Observatory projects.

1. Introduction

Astronomy is at the forefront of on-line data distribution, from observations in observatory archives to results published in journals, with value-added services such as ADS[1], NED[2], SIMBAD[3] and VizieR[4]. Information networking is well developed, and users can easily navigate from one service to another using Web links.

[1] `http://adswww.harvard.edu`

[2] `http://nedwww.ipac.caltech.edu`

[3] `http://simbad.u-strasbg.fr/Simbad`

[4] `http://vizier.u-strasbg.fr`

Long before the advent of the WWW, astronomers have developed a standard format to describe data (images, spectra, tables), FITS (*Flexible Image Transport system*)[5]. Data stored in FITS format can be distributed easily, and any astronomer can use observations from any instrument and share his/her data with colleagues. Many generic tools for visualization and transformation of FITS data have been developed by the community.

Similarly, astronomical bibliographic information has been rapidly networked, thanks to the existence of a small set of *de facto* disciplinary standards. The usage of the *bibcode*, which describes published references, and of the `ReadMe` description of tabular data, is explained in Section 2. Partnership has been established between journals, data centers, and observatory archives to share standards and to link services. This constitutes an excellent model for the development of the Virtual Observatory (Section 3).

2. The astronomy bibliographic information network

The *bibcode* - also called *refcode* - is a 19-character, human readable description of a published reference (Schmitz et al. 1995): for instance, `1999A&A...351.1003G` refers to the paper published in *Astronomy and Astrophysics*, volume 351, page 1003, in 1999; the first author's name begins by G . It was developed many years ago in a collaboration by the CDS and NED, because the two centers exchanged bibliographic information and needed to refer to publications in a compact and usable form. It was later adopted and extended by the ADS, and the journals used it when they implemented their electronic versions. The *bibcode* has been widely used for building the Web queries which link astronomy bibliographic services: for instance, each reference in the reference list of papers published in electronic journals is linked to its ADS entry, using a Web link which contains the bibcode. ADS provides links to other services such as NED, SIMBAD, VizieR, and ADC, and these services provide links to the ADS, also using the bibcode. More recently, new partners have joined: observatory archives, such as the HST/MAST, ISO or Chandra, retrieve all the papers in which their observations are used. They implement a link from the data in the archive to these papers (e.g. Figure 1). They also provide the ADS with information allowing it to display links from papers to the original data sets they use.

The pre-existence of a *de facto* standard, and the partnership between all service providers, has thus permitted the rapid implementation of astronomy information networking. The correspondence with emerging general standards such as the DOI will be made through correspondence tables to preserve the existing networking and to continue to take advantage of the fact that each service can easily build *bibcodes* for published references. Astronomy journals now use DOI indexing but continue to provide and use *bibcode* links.

Another example of a value-added link between electronic publications and data-bases is the link between object names in publications and SIMBAD or NED. This was implemented in a prototype form by *New Astronomy*. Another early implementation was developed a few years ago for the *Information Bulletin*

[5] `http://fits.gsfc.nasa.gov; http://www.cv.nrao.edu/fits`

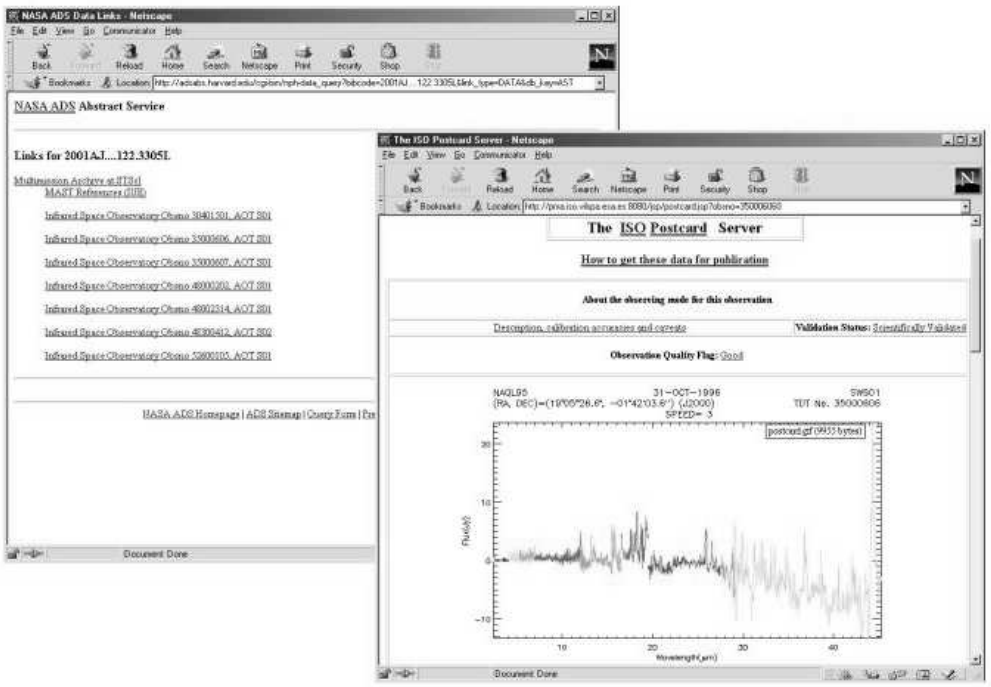

Figure 1. List of observations cited in a published paper, from MAST and ISO archives (ADS Web page, `adswww.harvard.edu`, right), with one of the linked archive pages (ISO, `www.iso.vilspa.esa.es/`, left).

on Variable Stars by A. Holl from Konkoly Observatory, in collaboration with CDS (Figure 2): in addition to all the information about the object contained in SIMBAD, further links available from SIMBAD allow the reader to get, e.g., an image of the object from Aladin, or the data from the *General Catalogue of Variable Stars* (GCVS) through a direct link from SIMBAD to VizieR. A wider scale prototype has been implemented in April 2001 with *Astronomy and Astrophysics*, as described by Ochsenbein et al. in these proceedings.

The evolution in the implementation and usage of tables published in articles is another example of collaboration between journals and data centers, and of the usefulness of *de facto* standards. As early as 1993, CDS began to distribute 'long' tables from papers published in *Astronomy and Astrophysics*, as part of the journal publication process - these tables are not printed any more but are made directly available on-line and usable for computer analysis. The standard description of tabular information proposed by CDS in 1994 (Ochsenbein & Lequeux 1995) has since then been adopted by the other data centers and the other journals. The `ReadMe` is an ascii (i.e. human readable) description[6], which details the table structure in terms of format, units, and column naming and gives a short description of the information (e.g. 'Right Ascension in equinox 1950, epoch 1983.5', or 'Johnson B magnitude'). This description thus links the

[6] `http://vizier.u-strasbg.fr/doc/catstd.htx`

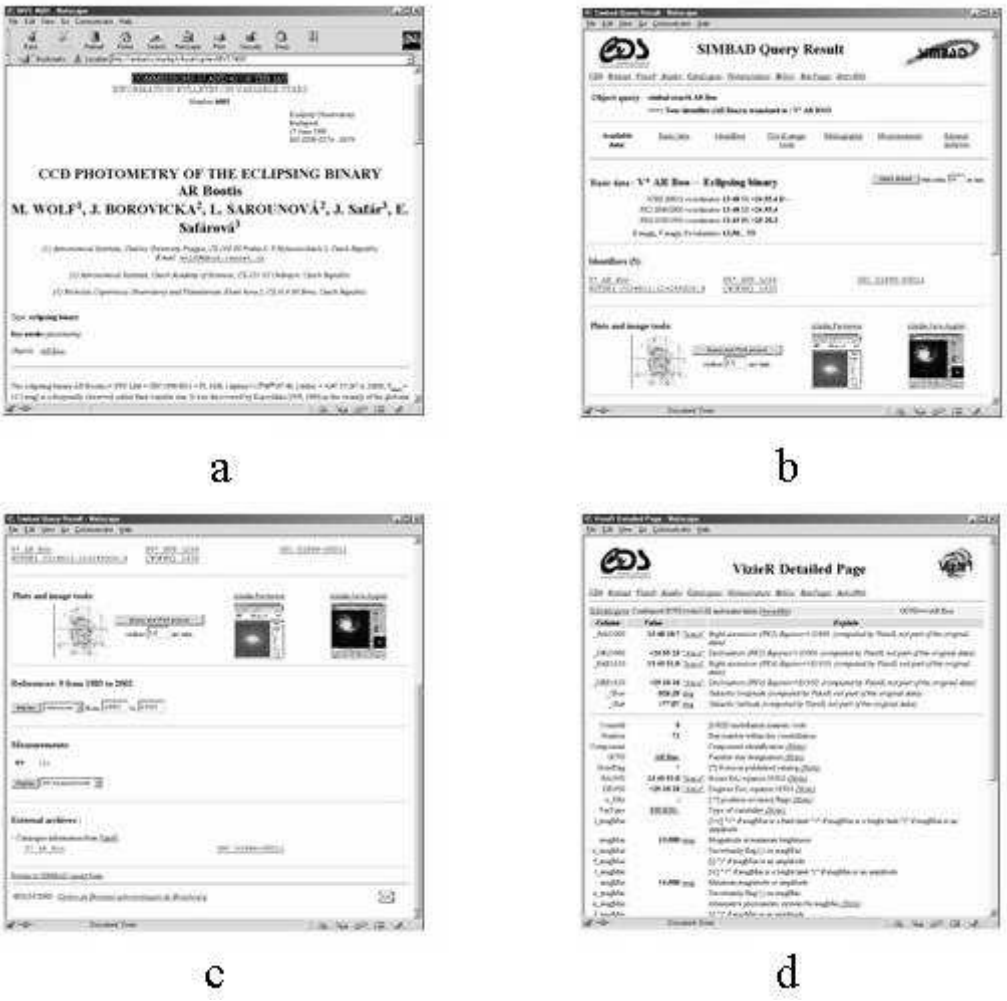

Figure 2. Link from a star name in IBVS (a) to SIMBAD (b), with further links from SIMBAD to VizieR (c), and the corresponding GCVS page (d). Respective URLs for these sites are `www.konkoly.hu/IBVS/IBVS.html`, `simbad.u-strasbg.fr/SIMBAD`, `vizier.u-strasbg.fr/viz-bin/VizieR`, and `vizier.u-strasbg.fr/viz-bin/VizieR-S?V*%20V%20Tri`.

physical organization of the table to its contents, and it permits data exchange, format transformation, and data checking. This also means that tables published in journals are now data which can easily be reused, and that tables from all journals which agree to use the same standard can be made available in services common to all kinds of data in tabular form, together with catalogues, and with the large surveys and lists of observations contained in archives. The VizieR catalogue Browser and the Aladin image tool are good examples of services allowing homogeneous access to this very heterogeneous set of information.

3. Toward the Virtual observatory

The concept of an Astronomical Virtual Observatory has been emerging in recent years, and several projects are beginning (see the review by Quinn in these proceedings). The Virtual Observatory is a science driven project aimed at realizing the full scientific potential of astronomical data in the context of rapidly increasing volume and complexity of data produced by observatories and large surveys, and of new technical developments such as the GRID. Common metadata and standards are the key for the development of a truly international Virtual Observatory, and it is highly significant that the first milestone of the International Virtual Observatory Alliance has been the definition of a standard, VOTable, which has been discussed by a wide international collaboration[7].

The network of bibliographic services, developed in a remarkably short time in astronomy, has rapidly become an everyday tool for scientists around the world. The Virtual Observatory should go much further by implementing new tools for data distribution, integration, and interpretation. One important lesson for this new endeavor can be learned from the experience gained in the development of the bibliographic network: the importance of *de facto* standards, discussed by a limited set of practitioners, to remain usable, then propagated and expanded in a wider community, as shown by the collaboration between data centers, the ADS, journals and archives. Another important lesson is that the quality of participating services and information and links validation by specialists are fundamental elements of the global quality and the usefulness of the network. On the other hand, networking can help to increase the individual service quality: additional checking, complementary to the referee's, can now be performed for the list of references and tables in published papers, using the links to ADS for references and the `ReadMe` for the tables.

Collaborators in the VO projects include new astronomy institutes and Information Technology specialists, and the continuation of the spirit of partnership is an important element for the success of the project. The experience gained in the implementation of the astronomy bibliographic network thus constitutes strong foundations to build the Virtual Observatory.

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[7] VOTable documentation: `http://cdsweb.u-strasbg.fr`;
VOTable discussions: `http://archives.us-vo.org/VOTable/`

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