Connectivity in the Astronomy Digital Library

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Abstract.

The Astrophysics Data System (ADS) provides an extensive system of links between the literature and other online information. Recently, the journals of the American Astronomical Society (AAS) and a group of NASA data centers have collaborated to provide more links between online data obtained by space missions and the online journals. Authors can now specify which data sets they have used in their article. This information is used by the participants to provide the links between the literature and the data.

The ADS is available at:

http://ads.harvard.edu

1. Introduction

The Smithsonian/NASA Astrophysics Data System (ADS) provides access to the astronomy and physics literature. As of September 2006 it provides a search system for almost 4.9 million records, covering all of the astronomical literature (including planetary sciences and solar physics) and a large part of the physics literature (including geosciences). The ADS has been described in detail in a series of articles in Astronomy and Astrophysics Supplements (Kurtz et al. 2000; Eichhorn et al. 2000; Accomazzi et al. 2000; Grant et al. 2000).

The literature in astronomy is by now almost completely available online. All data collected by space missions, as well as many data obtained from ground based observations are available online as well. In order to facilitate astronomy research, it is desirable to connect the literature with the data that are used in the research articles.

This article describes some aspects of the linking between the ADS and other online resources. In particular, it describes the collaborative effort between the NASA data centers and the American Astronomical Society’s publisher, the University of Chicago Press (UChP), to improve and extend the linking between the literature and online data.

2. Current Data in the ADS

As of September 2006, the ADS holds almost 4.9 million records, 2/3 of these have abstracts, the rest are titles only. These records are divided in four
databases (astronomy, including planetary sciences and solar physics, physics, including geosciences, arXiv e-prints, and general sciences). There are a total of almost 14 million links in the ADS, about 5 million of these are links to outside resources, the remainder are links internal to the ADS. Internal links are links to abstracts, scanned articles, reference and citation lists, among others. Internal links point to about 3.2 million abstracts, 1.7 million reference lists and 1.7 million citation lists. External links point to on-line journals, other library systems, and on-line data. Of the external links almost 325,000 point to on-line data in various forms. Table 1 shows the list of links in the ADS.

A more detailed description of the resources in the ADS that these links point to is provided in Grant et al. (2000).

3. External Links

3.1. On-line Journals

Most journal publishers work with the ADS to facilitate linking to the on-line journals from the ADS. They provide us with the information how to build these links.

Since on-line journals generally require subscriptions, users need to authenticate themselves. This can be done in various ways:

1. Password authentication: If the user has an account name and password, authentication can be done directly by the user.
2. IP address authentication: Some publishers provide access on an IP address basis. This means that users can access these publishers from their computers at work.
3. Proxy servers: Some libraries have set up proxy servers that are authenticated with some publishers. If access to the articles is done through the proxy server, the user has direct access. This works from any computer, not just from a restricted range of IP addresses. The user needs to authenticate with the proxy server and then has access to the participating publishers. The ADS fully supports the use of proxy servers. It can be configured so that only external links go through the proxy server.
4. OpenURL servers: Links to an OpenURL server at a library provides a service similar to the proxy server system, except that all other links can go directly to their destination without having to go through a proxy server. The ADS fully supports OpenURL linking.

The ADS has recently (in September 2006) implemented OpenURL linking. This new capability makes use of OpenURL servers that are set up by libraries or institutions. It makes it much easier for users to access subscription journals. In the ADS Preferences section is now a link to a page for “OpenURL Settings”. This page allows our users to specify their OpenURL server. In order to make it easier for our users, we provide a list of servers for major institutes for selection on this page. If you have an OpenURL server that is not in this list, let us know about it and we will include it.

Any library that has an OpenURL server can include a link to our setup page on their library page, which includes their OpenURL server. If a user of
Table 1. Link types in the ADS database.

| Link | Resource            | Description                                                                 |
|------|---------------------|-----------------------------------------------------------------------------|
| A    | Abstract            | Full abstract of the article. These abstracts come from different sources.   |
| C    | Citations           | A list of articles that cite the current article. This list is not necessarily complete (see ‘R’ References). |
| D    | On-line Data        | Links to on-line data at other data centers.                                |
| E    | Electronic Article  | Links to the on-line version of the article. These on-line versions are in HTML format for viewing on-screen, not for printing.\(^a\) |
| F    | Printable Article   | Links to on-line articles in PDF or Postscript format for printing.\(^a\)    |
| G    | GIF Images          | Links to the images of scanned articles in the ADS Article Service.         |
| H    | HEP/SPIRES          | Links to the High Energy Physics digital library SPIRES.                    |
| I    | Author Comments     | Links to author supplied additional information (e.g. corrections, additional references, links to data). |
| J    | Document Delivery   | Links to on-line document delivery systems at the publisher/owner of the article. |
| K    | Library Entries     | Links to entries in various library systems.                               |
| L    | OpenURL             | Links to an OpenURL server.                                                |
| M    | Multi-media         | Links to on-line multi-media information.                                   |
| N    | NED Objects         | Access to lists of objects for the current article in the NED database.     |
| O    | Associated Articles | A list of articles that are associated with the current article. These can be errata or other articles in a series. |
| P    | Planetary Data System | Links to data in the Planetary Data System.                             |
| R    | References          | A list of articles referred to in the current article. These lists are not necessarily complete, they contain only references to articles that are in the ADS database. |
| S    | SIMBAD Objects      | Access to lists of objects for the current article in the SIMBAD database.  |
| T    | Table of Contents   | Links to the list of articles in a books or proceedings volume.             |
| U    | Also-Read Articles  | Links to the list of articles that were read by the same people that read the current article. |
| X    | arXiv e-prints      | Links to the arXiv e-print of an article.                                  |
| Z    | Custom format       | Link to the abstract formatted according to the user’s preferences.        |

\(^a\) There is generally access control at the site that serves these on-line articles.
that library follows this link, s/he will have the OpenURL address automatically filled in.

The link to this page for libraries has the following form:

\[ \text{OpenURL} = \text{serverURL} & \text{Icon} = \text{iconURL} \]

The parameter OpenURL specifies the URL of the OpenURL server of the library. The parameter Icon specifies the name of the icon that is used for the OpenURL links. If it is specified without a full URL (as in the above example), the server OpenURL is pre-pended. The parameter names are case sensitive.

3.2. Data Linking

For astronomers it is frequently important to be able to access data that were used in an article, as well as the data published in the article (data tables, etc.). The ADS is provided with the information on what data are correlated with articles on a regular basis by several data centers. The ADS includes the links from the articles to the on-line data.

There are two types of data that the ADS links to. One type are data in data services that aggregate and process information, the other are original data collected by telescopes or spacecraft.

Aggregated data are collected by several data archives. The most important of these archive services are:

- SIMBAD \cite{Wenger2000} for information about astronomical objects
- Vizier \cite{Ochsenbein2000} for data catalogs and data tables
- NASA Extragalactic Database \cite{Madore1992} for extragalactic objects

The distribution of the links to the aggregating data archives is by now fully automated. There are on the order of 220,000 links to these services in the ADS.

The archives that hold original data also provide some information on what data were used in articles. This information has so far been collected by hand by the different data centers that hold the data.

Since collecting this information is a very time consuming task, the Astrophysics Datacenter Executive Committee (ADEC) initiated efforts to improve the linking between journal articles and on-line data. The data centers, the ADS and the UChP developed a system that allows authors to specify which data sets they have used for their article. The system was designed to allow for automatically processing and verifying data set identifiers specified by authors. Following is a brief description of this system.

Data Set Identifiers

The basis for this system is the identification of data sets. The data centers assign unique identifiers to each set of data. It is up to the data center to decide what they call a data set. It could be one spectrum, or one exposure, or it could be a set of exposures of the same object in different wavelengths. This is left completely up to the data centers. In some cases,
data sets are defined by the query parameters to a database query. Some data centers also provide the means for authors to define a collection of data sets that they used in an article and give this collection a unique identifier. The main requirement for data set identifiers is that they have to be unique and permanent. This means that the data centers have to agree to recognize published identifiers in perpetuity. This is extremely important for the long term viability of this system.

The ADEC has agreed on a format for data set identifiers that is compatible with current International Virtual Observatory Alliance (IVOA, Quinn et al. (2004)) designs for identifiers:

\[ \text{ADS/FacilityId#PrivateId} \]

“ADS” specifies the ADS as the managing authority for these identifiers. Verification and linking is done through the ADS master verifier and link resolver. “FacilityId” specifies the facility that collected the data, and “PrivateId” is an identifier assigned by the data center. The ADEC decided that the data center should not be part of the identifiers, since data sets can potentially move between data centers, which would invalidate identifiers that contain the data center.

The data centers provide the data set identifiers with each data set that they send to their users. These identifiers should be prominently visible so that authors can easily find them and include them in their manuscripts.

**Identifier Verification**  Once publishers receive manuscripts that contain data set identifiers, they verify that the identifiers are correct. During the verification process they obtain the permanent link for identifiers that are valid. This is done through the ADS Verifier. The verifier can be accessed through SOAP (Simple Object Access Protocol) or through a simple CGI interface. During copy-editing, the publisher sends the data set identifiers cited in the paper to the ADS master verifier for verification. The master verifier contacts the relevant local verifier at the data center that currently has the data sets for the facility specified in the identifier. It then returns the status of the identifier as returned from the data center verifier, and the permanent link to the data set if it is a valid identifier.

**Data Set Links**  The permanent links in the on-line journal article to data sets do not point directly to the data center, but rather to the ADS link resolver. The reason for this is that data sets can move between data centers. The ADS is automatically kept up-to-date about the location of all data sets and forwards data set link requests to the data center that currently holds the data. The link resolver consults the current data center profiles to determine which data center currently holds the data for the specified FacilityId, and retrieves the current link to the specified data set from the data center. It then forwards the request to that address. This assures that the links in the on-line journals are permanent and do not have to be changed if data sets move.

**Link Distribution**  In order to fully utilize the linking information, the ADS harvests the correlation between data set identifiers and articles from the participating publishers. This information is then used to link from the ADS records to the on-line data. The ADS also makes these correlations available to the participating data centers. We provide an HTTP interface for harvesting of these
correlations by data centers. The data centers use this information to link from their data back to the journal articles.

4. Current Status

The following are the data centers that currently participate in this system:

- Chandra X-ray Center (CXC)
- High Energy Astrophysics Science Archive Research Center (HEASARC)
- Infrared Science Archive (IRSA)
- Legacy Archive for Microwave Background Data Analysis (LAMBDA)
- Multimission Archive at Space Telescope Science Institute (MAST)
- Spitzer Science Center (SSC)

Currently the only publisher participating is the University of Chicago Press, publisher of the Astronomical Journal, the Astrophysical Journal with its Letters and Supplements, and the Publications of the Astronomical Society of the Pacific. Currently there are less than 100 articles with a few hundred identifiers that used this system. Hopefully this number will increase as more authors become aware of this new capability.

5. The Future

We encourage other data centers and publishers to participate in this service. The ADS has software packages that facilitate the setup of the data center registration, identifier verification and linking services.

The requirements for a data center to participate are as follows:

1. Provide data set identifiers with the data in the data center. These identifiers need to be available to the users of the data. They need to be permanent identifiers.
2. Provide a data center profile. This will let the ADS determine which data sets are at that data center. This profile is a simple XML file. It needs to be in a specific location. The ADS will automatically retrieve this profile regularly to get the latest status of the data center.
3. Provide a data set identifier verification utility. The ADS master verifier connects to this verification utility when a publisher tries to verify an identifier. This utility also needs to provide the current links to the data.

The ADS has examples of profiles and software toolkits for a verifier available, in order to facilitate the participation of data centers in this system.

The requirements for a publisher to participate are as follows:

1. Provide a macro in the LaTeX macros that allows authors to specify data set identifiers.
2. Verify identifiers that authors specify during the editorial process.
3. Link to data sets from the on-line journal. This is optional, but encouraged.
4. Provide the correlation between identifiers and articles for harvesting by the ADS. This can be done either by providing the data for downloading by the ADS, or by including them in the regular abstract feed to the ADS.
6. Conclusion

The efforts to improve the linking between the literature and on-line data have only now started. There are already some links to data in the AAS journals, and more are coming on-line. As this system becomes more widely known the number of links should increase. Hopefully more data centers and publishers will join this effort to increase the coverage of this system and provide more utility to the astronomical community.

7. Links

ADEC: [http://www.adccc.org/](http://www.adccc.org/)
ADS: [http://ads.harvard.edu/](http://ads.harvard.edu/)
ADS Data Linking: [http://vo.ads.harvard.edu/](http://vo.ads.harvard.edu/)
CXC: [http://asc.harvard.edu/](http://asc.harvard.edu/)
HEASARC: [http://heasarc.gsfc.nasa.gov/](http://heasarc.gsfc.nasa.gov/)
IRSA: [http://irsa.ipac.caltech.edu/](http://irsa.ipac.caltech.edu/)
LAMBDA: [http://lambda.gsfc.nasa.gov/](http://lambda.gsfc.nasa.gov/)
MAST: [http://archive.stsci.edu/mast.html](http://archive.stsci.edu/mast.html)
NED: [http://nedwww.ipac.caltech.edu/](http://nedwww.ipac.caltech.edu/)
SIMBAD: [http://simbad.u-strasbg.fr/](http://simbad.u-strasbg.fr/)
SSC: [http://ssc.spitzer.caltech.edu/](http://ssc.spitzer.caltech.edu/)
Vizier: [http://vizier.u-strasbg.fr/](http://vizier.u-strasbg.fr/)

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