

E-PROFILE

THE NASA ASTROPHYSICS DATA SYSTEM ABSTRACT SERVICE: ASTRONOMY

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The NASA Astrophysics Data System

The Astrophysics Data System (ADS) (<http://adsabs.harvard.edu/>) is an international cooperative project funded by the National Aeronautics and Space Administration (NASA) that provides comprehensive bibliographic and select full-text access to a variety of publications in astronomy, astrophysics, the planetary sciences, solar physics, instrumentation, physics, and geophysics (Kurtz *et al.*, 1999). Through its "Browse Service," users can access six major services: Journal/Volume/ Page Service, Scanned Articles Service, On-Line Proceedings Service, Historical Literature Service, Table of Contents Service and Books Service. Through its "Abstract Service" access is provided to four specialized services: Astronomy and Astrophysics/Planetary Sciences/Solar Physics Abstract Service, Instrumentation Abstract Service, Physics and Geophysics Abstract Service, and the ADS/LANL [Los Alamos National Laboratory] Preprint Abstract Service.

Astrophysics Data System ADS Abstract Service

As of June 2001, the four abstract services collectively provided access to nearly 2.3 million abstracts:

- Astronomy and Astrophysics/Planetary Sciences/Solar Physics (658,866 abstracts).
- Instrumentation (598,523 abstracts).
- Physics and Geophysics (966,264 abstracts).
- ADS/LANL Preprint Service [arXiv.org] (3,522 abstracts).

Abstracts are provided for articles from major and relevant minor journals; papers from major colloquia, symposium, and conference proceedings; select NASA technical reports, as well as books and doctoral dissertations. In addition, select electronic preprints from the Los Alamos National Laboratory e-print server, arXiv.org (McKiernan, 2000) are accessible. On average, these abstract services are currently used by about 40,000 individuals, who execute 2 million queries, and retrieve 20 million references and 1 million scanned article pages per month (Eichhorn *et al.*, 2001). In a recent one-year period, the services were accessed by more than 127,000 users, using 100,000 host computers, from 112 countries (Eichhorn *et al.*, 2000, p. 76). Users of the service include working astronomers, librarians, amateur astronomers, the public, and the media. Based upon reshelving statistics, the number of articles retrieved through ADS has been calculated to be several times greater than the number of all articles read in all astronomy libraries (Eichhorn *et al.*, 2001).

Astronomy and Astrophysics Abstract Service

Searching

Using an "Abstract Query Form" (see Figure 1), the user is offered a variety of options for searching the Astronomy abstract service. The form is divided into three sections: the main search parameters, "Filters", and the "Settings". To create a query, the user provides appropriate data or selects from available options.

Main Search Parameters

Author Searching

There are three options for author searching: author last name and first

initial, author name browse, and exact name search. The second method allows users to browse an A-Z listing of all author names and possible variants and to select candidates for full searching. The third option, "Exact Author Name Search", provides an "Exact Author Name Selection Form" from which users may search for variants of an author's last name and possible forms of his or her first name and initials. Entering an author surname and first initial with or without a period after the first initial will retrieve all variant forms (e.g. last name, first initial; last name, first initial, middle initial; last name, full first name; etc.). Users can use internal as well as forward and backward stemming wildcard symbols ("?" and "*", respectively) in these author searches. From this retrieved list, the user may select all candidate names and execute a collective search. Recognizing that some author names are often transliterated differently, the ADS Astronomy abstract database provides access to a list of these variants. A "List Query" search form (http://adsabs.harvard.edu/list_abs.html) is available for retrieving a list of these name variants as well as Soundex/Phonix alternatives (see Figure 2). This function is particularly useful in identifying variant transcriptions of non-Roman names and those with diacritic marks. Unless disabled by the user, a synonym replacement function for author names (see below) will automatically incorporate the variations of an individual's name within a standard author name search.

Date

A user may restrict a search to a specific date range, if desired. If no date is provided, all records in the database,

Figure 1.
ADS Astronomy “Query Form”

ADS Astronomy Query Form for Mon Jun 4 13:24:41 2001

What's New Feedback Preferences FAQ HELP

Hint: To find articles in a specific journal, click "Selected journals:" in the Filter section and enter the journal code.

Send Query Return Query Form Store Default Form Clear

Databases to query: Astronomy Instrumentation Physics/Geophysics LANL Preprints

Enter Authors: (Last, F.I.) SIMBAD NED LPI IAU Objects:
(one per line) (one per line)

Exact Author name search Object name search
(OR AND simple logic) (OR AND simple logic)

Publication Date:
From: / / To: / /
Month (MM) Year (YYYY) Month (MM) Year (YYYY)

Enter Title Words:
(Combine with: OR AND simple logic boolean logic)

Enter Text Words/Keywords:
(Combine with: OR AND simple logic boolean logic)

Figure 2.
Sample list of synonymous terms

-
- ABUNDANCED (1)
 - ABUNDANCEE (1)
 - ABUNDANCEES (1)
 - ABUNDANCES (14423)
 - ABUNDANCIAS (31)
 - ABUNDANCIES (6)
 - ABUNDANCNS (1)
 - ABUNDANCSE (1)
 - ABUNDANCY (8)
 - ABUNDANDES
 - ABUNDANT (1867)
 - ABUNDANTLY (45)
 - ABUNDNACE (7)
 - ABUNDNCES (1)
 - ADUNDANCE (4)
 - ADUNDANCES (3)
 - ANBUNDANCE (1)
 - ISOABUNDANCE (3)
 - MATALICITY (1)
 - METALABUNDANCE
 - METALICITIES (7)
 - METALICITY (26)
 - METALLHAUFIGKEIT (3)
 - METALLICISM (40)
 - METALLICITE (5)
 - METALLICITES (8)
 - METALLICITIES (1371)
 - METALLICITY (6809)
 - METALLICTY (1)
 - METALLICTY (4)
 - METALLITICITY (1)

unless otherwise limited or restricted (see below), will be searched.

Object Name Field

The ADS Astronomy abstract service can also be searched using the name of an astronomical object (see Figure 1). These include such celestial objects as stars, galaxies, and non-stellar objects within our galaxy or in external galaxies. Sources for object information are:

- SIMBAD (Set of Identification, Measurements, and Bibliographies for Astronomical Data) at the Centre Données Astronomique de Strasbourg (CDS) (France);
- the NASA Extragalactic Database (NED) at the Infrared Processing and Analysis Center (IPAC) of the Jet Propulsion Laboratory (JPL), Pasadena, California (USA);
- a database with objects from publications of the Lunar and Planetary Institute (LPI) in Houston, Texas (USA);
- data from the International Astronomical Union (IAU) Circulars (IAUC) and the Minor Planet Electronic Circulars (MPEC) provided by the Central Bureau for Astronomical Telegrams (CBAT) at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts (USA) (Eichhorn *et al.*, 2000, pp. 63-64).

Title Words and Text Words / Keywords

In the Astronomy abstract service, users have the option of searching titles and abstracts by term or phrase. In a title or abstract text, a phrase can be searched by enclosing it in single or double quotes (e.g. ‘redshift survey’ or “redshift survey”) or by connecting terms with a period (e.g. redshift.survey) or a hyphen (e.g. redshift-survey).

Recognizing that free text searching is limited if not augmented by synonymous term searching, the Astronomy abstract service automatically incorporates designated synonymous terms in a term search as a default. The list of synonymous terms was created manually by reviewing all terms in the database and grouping them according to similar meaning. The synonym collection contains not only identified English-language astronomical synonyms, but

non-English terms with their English-language translations as well, permitting users to retrieve records regardless of whether relevant English or non-English terms are entered (Eichhorn *et al.*, 2000, p. 64). As of 2000, the synonym collection consisted of more than 55,000 words grouped into more than 9,200 sets. The terms in the synonym groups incorporate data from a variety of sources, including the *Multi-lingual Supplement to The Astronomy Thesaurus*. Currently, a more flexible structure for synonym groups that allows for the specification of hierarchical groups and relationships between groups, rather than simple "equivalence", is being implemented. This feature is representative of thesaurus functionality, offering higher order conceptual search options (Accomazzi *et al.*, 2000, pp. 92-3).

As a default, all ADS abstract service searches use a "synonym replacement" function. Users can, however, completely or selectively disable the function in the "Settings" section of the query search form (see below) (Eichhorn *et al.*, 2000, pp. 64-5).

A list of terms considered synonymous can be retrieved using the "synonym template" found within the "List Query" search form (http://adsabs.harvard.edu/list_abs.html), the same form used to retrieve variant forms of an author's name. The alphabetical listing includes identified English as well as non-English terms and their variants and misspellings and an indication of the term frequency within the Astronomy database (see Figure 2). The "List Query" form with its author template and synonym template is linked from the "Enter Title Words" and "Enter Text Words/Keywords" headings on the main "Abstract Query Form" (see Figure 1).

An AD once supported keyword (index term) queries but does not currently do so due to the incompatibility of the original indexing vocabulary and the indexing vocabulary used by astronomy source journals (Kurtz *et al.*, 2000, p. 45).

Filters

To focus search results, the ADS Astronomy abstract service query form allows users to limit a search by various criteria ("Filters"). Searches may be limited by record entry date, relevancy

score, publication type, content, or, by the availability of citations, SIMBAD or NED astronomical objects, author comments, citing articles, or, similar and "also-read" articles, among other categories (Eichhorn *et al.*, 2000, pp. 65-6) (see Figure 3).

Date

While the ADS service does not presently offer an automated e-mail current awareness alerting service, users may limit search results to a specific retrospective or recent period. For example, users can retrieve items added to the database in the past week by simply entering "-7" in the "Day" field of the "Entry Date" (See Figure 3). Users may also adjust the minimum relevancy score for search results ("Min Score") below the default values (Relative Wghts) (see below).

Publication

Users also have the option of limiting retrieved results to "All Bibliographic Sources", "All Refereed Journals", "All Non-Refereed Publications", or "Selected Journals". Hotlinks are provided for each of these options to their respective lists of publications and the publications' standardized ADS abbreviations (Bibliographic Code Abbreviations, undated). To limit a query to one or more specific "Selected Journals", the user must provide the standardized abbreviation of the journal used by the astronomical research community and the ADS Astronomy database. These abbreviations can be determined by linking to the Bibliographic Code Abbreviations source lists from the "Selected Journals" field hotlink (see Figure 3). Multiple journal abbreviations can be searched by separating their entries with a semicolon (";").

"Groups"

The Astronomy abstract service also allows users to restrict a search to one or more sets of specialized electronic collections. These are:

- A Lunar and Planetary Institute (LPI) bibliography from 1975-1994 [LPI].
- Articles contained in the Astronomical Digital Image Library

(ADIL) at the National Center for Supercomputing Applications (NCSA) [NSCA/ADIL].

- Papers written in 1994 and 1995 by researchers at the Harvard-Smithsonian Center for Astrophysics (CfA).
- Papers about variable stars in globular clusters (VSGC).
- Bibliographical entries from the online catalog of the library of the European Southern Observatory, the intergovernmental, European organization for astronomical research headquartered in Garching, Germany.

Sorting

Records retrieved from a query can be sorted by relevancy score ("Sort by score"), by the last name of the first author ("Sort by the first author name"), most recently published ("Sort by date (most recent first)"), by the least recently published ("Sort by date (oldest first)"), or by entry into the ADS database ("Sort by entry date").

Settings

The third and bottom section of the ADS Abstract service query form ("Settings") allows a user to change the default query conditions (see Figure 4). As noted, the search system will automatically incorporate variant and "equivalent" forms of terms ("synonyms") in a title or abstract (text) search. By clicking off the title and the abstract in the "synonym replacement" option, users can disable this function entirely for text queries. If the option is activated, users can selectively exclude a word for replacement by placing the equal sign ("=") before the word (e.g. "=ABUNDANCES"); if the option is not activated, a word may be included for replacement by placing a pound sign ("#") before it (e.g. "#METALLICITY"). As noted, author name variants are searched automatically in an author query. The user can disable this function by changing the default setting in the synonym replacement option for "Authors" (see Figure 4).

Score

After the execution of a query, the results by default are sorted in order by a relevancy "score" for each record. This score is calculated by the relative

Figure 3.
Filter categories and options



Figure 4.
Screen print of default settings



match between a record with the search parameters and other factors (see below). Two scoring algorithms are used in the ADS service: proportional scoring and weighted scoring. The ADS provides default weights as follows:

- Authors: 1.0
- Objects: 1.0
- Title: 0.3
- Text: 3.0.

These default weights were determined on theoretical grounds and by trial and error experimentation (Eichhorn *et al.*, 2000, p. 65). A user can give greater or lesser importance to one or more fields by changing the default values of the relative weight settings (“Relative Weights”) (see Figure 4). Three additional settings allow the user to control the use of fields and their weights for scoring (“Use for Weighting” and “Weighted Scoring”) or determine the logical combination of authors, objects, or terms across fields (see Figure 4).

A variety of journal query and browse options are also offered from the main ADS Astronomy query form page (i.e. “Journal/Volume/Page”, “Current Journals”, and “Unread Journals”).

Preferences

The ADS Astronomy abstract service offers users the opportunity to personalize and customize select features and functions (“Preferences”) (see Figure 1), and include:

- Preferred Database (i.e. “Astronomy”, “Instrumentation”, “Physics/Geophysics”, or “LANL Preprints”).
- Use of tables.
- Use of multiple windows.
- Highlighting of query words.
- Preferred article format (i.e. PDF or Postscript) for external article servers, if multiple formats are available.
- Preferred language (English, French, German, Italian, Portuguese, or Spanish) for translation of references and abstracts (Eichhorn *et al.*, 2000, p. 72).

Users may also set the mirror sites for ADS article services, SIMBAD objects database, commercial publisher electronic journal Web sites (e.g. Elsevier Science, IDEAL Online Library,

Springer-Verlag), and arXiv.org, the Los Alamos National Laboratory e-print service, among others (Abstract Service Preference Settings Form (undated) on <http://adsabs.harvard.edu>). Text font size, as well as background, text, and link colors may also be specified. The format for custom formatting references may also be selected from three options (i.e. AASTeX, Icarus, or MNRAS), or defined by the user.

Search Results

For searches where the default parameters and other options have not been modified, the system will display a relevancy ranked list of references that meet the conditions of the query (e.g. see Figure 5). Unless modified by the user, results are displayed in groups of 100 brief records, sorted by relevancy score. At the bottom of each group, users are offered a variety of format, delivery, and display options (see Figure 6). They may display a merged list for all or selected records from a group, with full abstracts, in one of several formats (i.e. HTML, plain text (ASCII), "generic tagged", BibTeX, or AASTeX), display the record set on the screen ("View on screen"), or print ("Send to printer"), download ("Save to file"), or e-mail the results. In addition, the results may be displayed by citation count, with higher cited publications listed before those with fewer. Users may re-sort the original results by the first author surname, or by date of entry or date of publication.

Users need not merge the abstracts for all or selected records. If preferred, they may review each brief record individually from the display listing (see Figure 5). For each record, the following data or information is provided:

- Bibliographic Code (e.g. "2000ApJ...538...29C").
- Relevancy Score (e.g. "1.000").
- Date of Publication ("7/2000").
- Links (e.g. "A E F D R C S U").
- Author(s) (e.g. "Cohen, Judith G.; Hogg, David W.; Blandford, Roger; Cowie, Lennox L.; Hu, Esther; Songaila, Antoinette; Shopbell, Patrick; Richberg, Kevin").
- Publication Title (e.g. "Caltech Faint Galaxy Redshift Survey. X. A Redshift Survey in the Region of the Hubble Deep Field North").

Figure 5.

Screen print of sample query results in brief record format

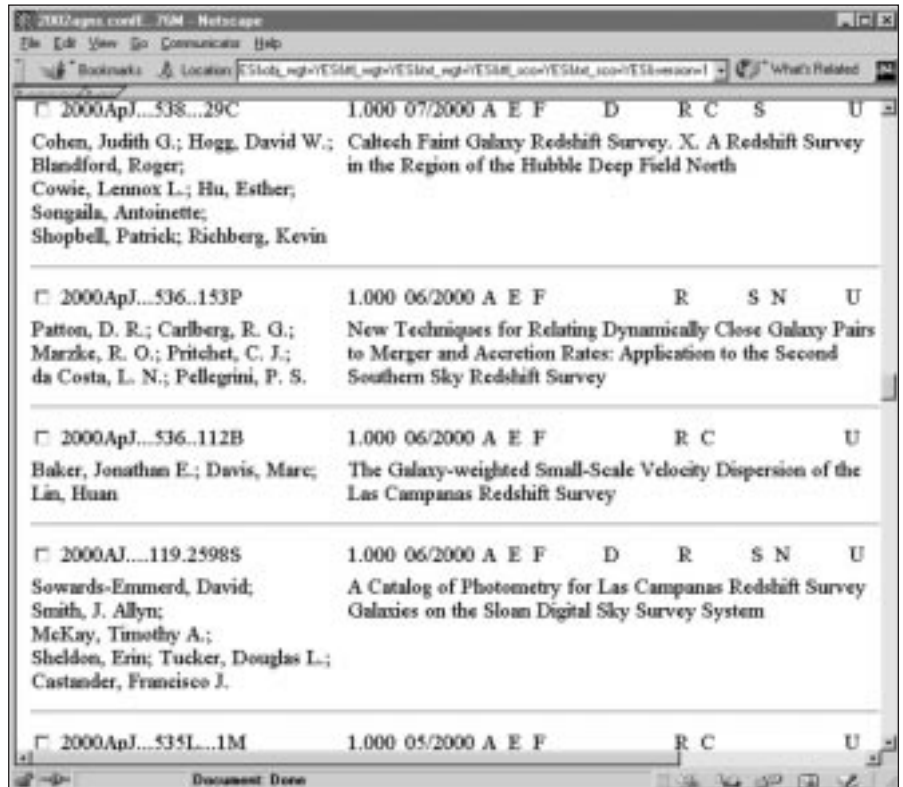
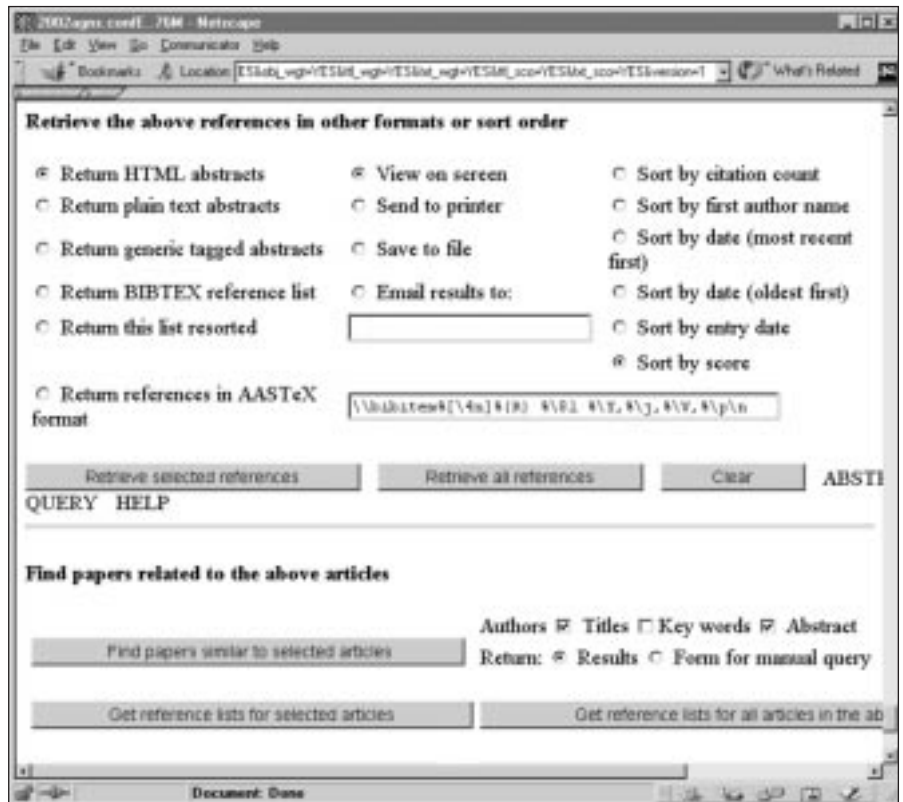


Figure 6.

Screen print (top half) of format, delivery, and display options



BibCodes

The Bibliographic Code (BibCode) is a unique identifier for records in the Astrophysical Data System. For journal articles in the Astronomy abstract service, a journal article BibCode is generated from the journal citation and can be easily deciphered. The journal BibCode is a 19-character alphanumeric string consisting of several defined segments in the following generic format:

YYYYJJJJVVVVMPPPA

where:

- **YYYY** is the field and characters number (4) allotted for the full publication year (e.g. "2000").
- **JJJJ** is the field and maximum character number (5) allotted for a standardized form of the journal title (e.g. "ApJ").
- **VVVV** is the field and maximum character number (4) allotted for the journal volume number (e.g. "538").
- **M** is a one character allotted for a publication qualifier. Qualifiers can be included for publication type (e.g. "L" for Letter), a code letter for "unduplicating" a code (e.g. "Q", "R", "S", etc.), or to designate an issue.
- **PPPP** is the field and maximum character number (4) allotted for the first page of the article (e.g. "29").
- **A** is a one character field allotted for the first letter of the first author's last name (e.g. "C" (for Cohen)).

Other types of publications in the ADS Astronomy abstract service (e.g. proceedings, books, doctoral dissertations, etc.) have analogous bibliographic codes (Grant *et al.*, 2000, pp. 113-14).

Links

In the brief record display, a formatted string of alphabetical codes is included and provides direct access to information or data associated with the record. (e.g. "A E F D R C S U"). Link codes, type, and brief description are noted in Table I.

Abstract

A full abstract record for a reference can be displayed (see Figure 7 and Figure 8) by clicking its hotlinked BibCode (e.g. "2000ApJ...538...29C")

or the associated link code (i.e. "A") from the brief record listing (see Figure 7). This record will include the:

- publication title ("Title");
- full names of authors ("Authors");
- author affiliations and mail address ("Affiliations");
- journal citation, including the unabbreviated title of the source journal ("Journal");
- publication date;
- contributing agency ("Origin");
- publication index terms ("ApJ Keywords");
- abstract copyright;
- bibliographic code;
- full abstract.

Table I.

Link types in the ADS Astronomy Abstract Service

A	Abstract	Full abstract of the article
C	Citing Publication(s)	Listing of articles that cite the current article. This is NOT a comprehensive listing of all citings
D	Online Data	Links to online data sources
E	Electronic Article	Links to online version of article
F	Printable Article	Links to online version of article (PDF)
G	GIF Image(s)	Links to scanned images of articles in the ADS Article Service
I	Author Comment(s)	Author-supplied additional information (e.g. corrections, additional references, additional data, etc).
L	Library entries	Links to entries in the Library of Congress online catalog
M	Mail Order	Links to publisher online document delivery services
N	NED Objects	List of objects in the article in the NED database
O	Associated Articles	Items associated with the current article (e.g. errata or other articles in a series)
P	Planetary Data System	Links to datasets at the Planetary Data System (PDS)
R	References	Cited articles and other publications in the current article
S	SIMBAD Objects	List of objects in the article in the SIMBAD database
T	Table of Contents	Links to table of contents for items in a book or proceedings
U	"Also-Read" Articles	Articles read by users who read the current article

Source: Eichhorn *et al.* (2000) and "Welcome to the ADS Abstract Services. Available Items" (undated).

Note: The user need not memorize the functionality of each code, as mouse rollover will display the nature of the code in a Javascript applet box beneath the code letter

Each author name is hotlinked to an "Author Information Form" which offers access to a directory that provides the author's e-mail address, phone and FAX numbers, and another directory that provides access to the Web pages of professional astronomers and related space scientists. In addition, the name is embedded in an author query function that permits a direct search for all publications of the individual in the ADS Astronomy database.

At the bottom of the abstract record, users are offered an option to search the Astronomy abstract database and/or other ADS abstract services (i.e. Instrumentation, Physics and Geophysics, and the ADS/LANL Preprint Service) for

articles similar to the one under review. For such a search, the user may accept the default search fields (i.e. "title", or "abstract text") or choose to deactivate one or more of these options and/or include the author(s) of the current article in this subsequent search.

Links

In the upper left-hand corner of the abstract record, users are provided with a list of all the link options available for the particular record (see Figure 7). Sample links include:

- "Find Similar Abstracts"
- "Electronic Refereed Journal Article" [E]
- "Full Refereed Journal Article" [F]
- "On-line Data" [D]
- "References in the Article" [R]
- "Citations to the Article" [C]
- "SIMBAD Objects" [S]
- "Also-Read Articles" [U]

In addition, the abstract record includes a hotlink ("Translate Abstract") to BabelFish (babelfish.altavista.com), the AltaVista online translation service that offers the user an opportunity to translate an abstract record into one of several major European or Asian languages (e.g. English to French; English to Chinese).

Related Papers

The ability to identify similar articles, retrieve associated references, citing article lists, or references to "also-read" articles is not limited to an individual record in the ADS Astronomy abstract service. At the bottom of each brief record display group, the user is presented with a variety of options for finding similar articles from this group (see Figure 9). The default fields for such a search can be accepted or modified depending on user needs (Eichhorn *et al.*, 2000, p. 68).

For this group of records, the user may only display the citations ("references") associated with a publication or retrieve a listing of citing articles for all records or only selected records. Any number of records from each group can be selected by clicking the check box to the left of the record BibCode (see Figure 5). In addition, users can retrieve a brief record display of articles "also-read" by individuals

Figure 7.
Portion of partial abstract record with list of link options

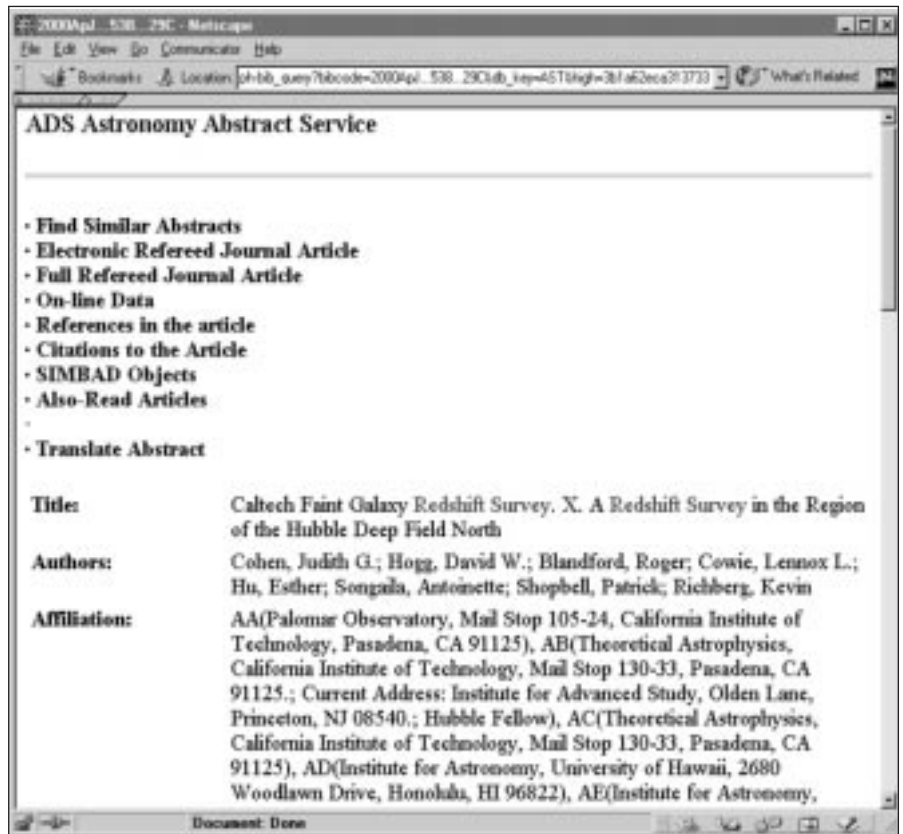


Figure 8.
Portion of partial abstract record



Figure 9.
Related papers retrieval options

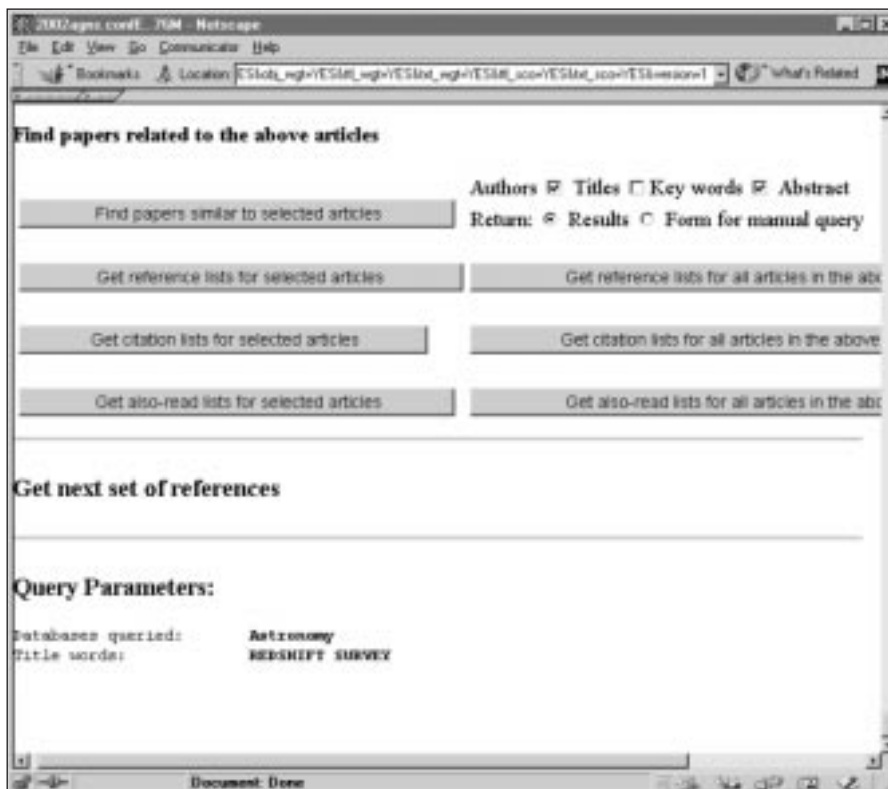
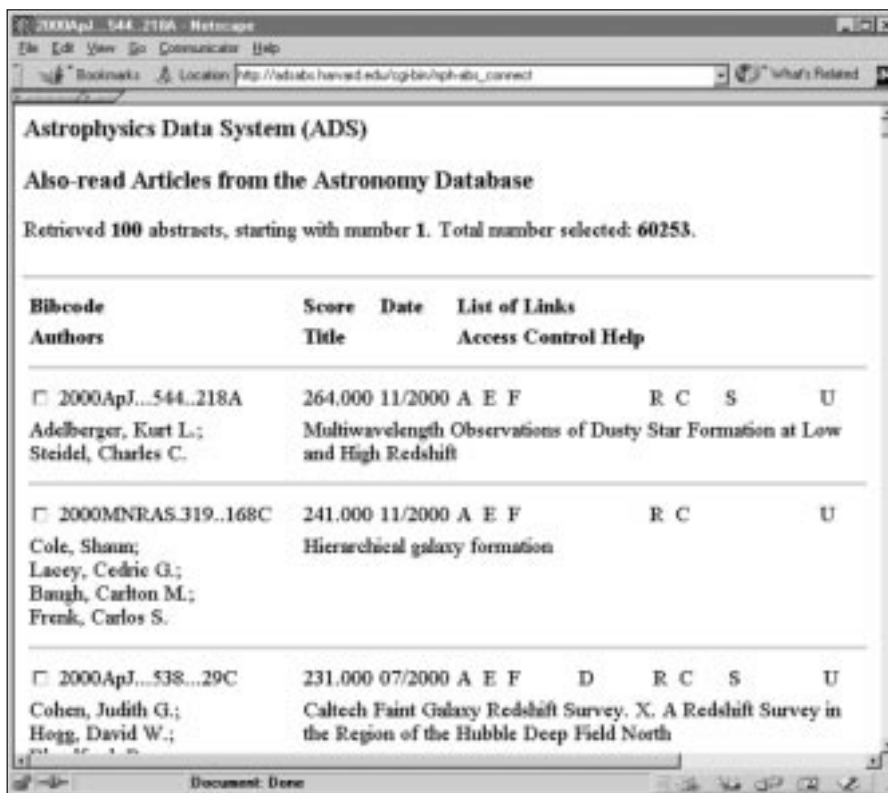


Figure 10.
Sample of brief records for “Also-Read” articles



who read all or selected articles in the group (see Figure 10).

Applications and Implications

The NASA Astrophysics Data System: Astronomy offers numerous features, functionalities, and content that facilitate efficient access to the literature of astronomy. Indeed, it has become standard practice for online astronomical journals to include a link to ADS for each article and for the cited references of these articles to include an ADS link as well. All of the major features and functionalities found in the Astronomy service are available within other ADS abstract databases, providing value-added access to the literature of related disciplines. The Astrophysics Data System not only permits users to customize the format and display of records, but also enables them to control the parameters of the search process to meet their individual needs. In recognition of the inherent difficulties of free-text searching, the system offers automatic searching of author name variants and synonymous search terms. By providing access to citing articles, it allows users to identify records that are bibliographically related. Through its “Also-Read” feature, it offers users direct access to the collective insights of a user community with similar interests. While some ADS features are common to other databases, functionalities such as synonym searching, citation indexing, and collaborative filtering are atypical. In view of their significant benefit, designers of next-generation databases and services should consider incorporating these features and functionalities into future bibliographic and digital information systems. Users of current Web-based online public access catalogs and electronic journal collections would welcome such enhancements.

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NASA Astrophysics Data System Mirror Sites

The ADS bibliographic services are now available from several sites worldwide:

- Beijing Astronomical Observatory, Beijing, China.
- Centre de Données Astronomiques de Strasbourg, France.
- European Southern Observatory, Garching, Germany.
- Institute of Astronomy of the Russian Academy of Sciences, Moscow, Russia.
- Harvard-Smithsonian Center for Astrophysics, Cambridge, USA.
- Inter-University Centre for Astronomy and Astrophysics, Pune, India.

- National Astronomical Observatory, Tokyo, Japan.
- Observatório Nacional, Rio de Janeiro, Brazil.
- Pontificia Universidad Católica, Santiago, Chile.
- University of Nottingham, United Kingdom.

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