Telescope Bibliographies: an Essential Component of Archival Data Management and Operations

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ABSTRACT
Assessing the impact of astronomical facilities rests upon an evaluation of the scientific discoveries which their data have enabled. Telescope bibliographies, which link data products with the literature, provide a way to use bibliometrics as an impact measure for the underlying observations. In this paper we argue that the creation and maintenance of telescope bibliographies should be considered an integral part of an observatory’s operations. We review the existing tools, services, and workflows which support these curation activities, giving an estimate of the effort and expertise required to maintain an archive-based telescope bibliography.

Keywords: Bibliographic Databases, Telescope Bibliography, Publications, Bibliometrics.

1. INTRODUCTION
A well-established way to assess the scientific impact of an observational facility is the quantitative analysis of the studies published in the literature which have made use of the data taken by the facility. A requirement of such analysis is the creation of telescope bibliographies which annotate and link data products with the literature, thus providing a way to use bibliometrics as an impact measure for the underlying data. Creating such links and bibliographies is a complex task. It is a laborious process which involves specialists searching the literature for names, acronyms and identifiers, and then determining how observations were used in those publications, if at all. Depending on the circumstances, these specialists may be either librarians or archivists. For the sake of simplicity, we will refer to them as bibliography curators in the remainder of this paper.

The creation of such links represents more than just a useful way to generate metrics: doing science with archival data depends on being able to critically review prior studies and then locate the data used therein, a basic tenet behind the principle of scientific reproducibility. From the perspective of a research scientist, the data-literature connections provide a critical path to data discovery and access. Thus, by leveraging the efforts of librarians and archivists, we can make use of telescope bibliographies to support the scientific inquiry process.

The SAO/NASA Astrophysics Data System (ADS) provides services which support both activities described above: bibliography curators use the ADS’s search capabilities to discover and tag data products appearing in the literature, and the ADS harvests the data-paper links that have been generated by them to enable the discovery of data products from bibliographic records. Additionally, by integrating these bibliographies in its search capabilities, the ADS abstract service allows one to filter literature searches based on bibliographic groups, allowing for queries such as “give me all the papers about blazars that have HST and Chandra data.”

In this paper we review the existing and planned tools, services, and workflows which support the activities of a telescope bibliography curator. We then provide guidance on the effort and skills required to maintain a bibliography and conclude with a series of recommendations for projects considering these activities.

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2. ADS SERVICES

The ADS databases provide a search interface over bibliographic data covering the entire astronomical literature (1.9 million records), as well as a large portion of the physics and optics literature. As of this writing, the ADS database contains a total of over 9 million bibliographic records. These records are linked to a variety of resources, including astronomical objects, article-level citation metrics, and data products from a select number of archives. The ADS is being used on a daily basis by research scientists and librarians alike. Because of its completeness, it is considered the reference site for scholarly literature in astronomy and is being used by a growing number of astronomical institutions and projects all over the world to create and maintain bibliographies.

The ADS also maintains a full-text archive of current and historical publications covering the main astronomical literature (approximately 1 million documents) and several physics journals, which account for another million documents. Thanks to agreements between the ADS and the major publishers of astronomy and physics literature, this full-text archive now includes current content as it is being published, and this content is being indexed and made searchable through a single, unified interface, accessible from the ADSLabs full-text service. The search interface (shown in Figure 1) allows users to find all instances of particular words or phrases in the body of the articles indexed and returns, for each of the matching papers, a list of snippets of text highlighting the context in which the search terms were found. The project is planning to develop an API that can be used by collaborators to perform text-mining activities which will facilitate the creation and maintenance of bibliographic databases.

An analysis of the ADS search logs shows that the greatest use of the system comes from searches focusing on papers written by a particular author or on a particular topic. This search mode typically works well for

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*Figure 1. The ADS full-text search allows one to search for specific terms in the body of the full-text literature archive maintained by ADS. The service returns, for each of the matching papers, a list of “snippets” of text highlighting the context in which the search terms were found. A list of facets in the left column of the screen allows the user to further restrict the results by selecting additional bibliographic filters. In this case, we have constrained the results by restricting publication date range and requesting refereed papers only.*
researchers since the list of contributors and concepts covered in a study are summarized in the basic article metadata: authors, title, keywords, and abstract. However, the ability to search the full-text of these publications allows scientists and bibliographic curators to dig deeper and identify papers which mention particular entity names such as facilities, instruments, observations, proposals, or grant numbers. This provides an effective (as well as essential) way to generate a rich set of papers which mention facilities, instruments and data products generated from one or more projects. While the availability of a single full-text search interface greatly facilitates the process of finding potentially relevant papers, it is only the beginning of the bibliography curation process, which requires additional steps described in the following section.

3. LINKING DATA AND LITERATURE

Linking observational metadata with the scientific literature begins with gathering a rich set of keywords and stop words. Curators gather as many terms as they can that describe a given project with the assistance of project scientists. In the case of the SAO Sub-Millimeter Array (SMA) project, the curators would compile a list of keywords ranging from “Pu’u Poli’ahu” on “Mauna Kea” in “Hawaii” to the “Radio Telescope Data Center” archive or even “SMA correlator.” Typically, curators cast their net out wide and use the exhaustive list of keywords to scan the full-text of the journal literature for any mentions of authors, affiliation, facilities, data, techniques or anything else particular to the project of interest. Stop words can be used contextually to counteract and filter the false hits that would accompany the broader keyword search. As an example, since SMA is an acronym used in physics to refer to Shape Memory Alloys, a curator may use the term “alloy” as a stop word to exclude a text snippet containing both “SMA” and “alloy.”

Armed with an exhaustive list of keywords and stop words, the curator would use a semi-automated search and discovery tool which typically relies on the ADS to discover papers containing relevant content. A few such systems exist today: FUSE, developed by the European Southern Observatory; NRAOPapers, developed by NRAO and currently being used by its librarians; and the Chandra bibliographic archive. In a systematic fashion, the curator would create subsets of journal metadata, typically for a date range or by certain journal titles, using the ADS search interface. Metadata from the ADS, and occasionally the publishers, is ingested into the system, searched against the compiled list of keywords and stopwords, and filtered results are outputted to a triage zone.

Over time, the curator can advance to a point where he/she can spot an article in the triage zone that for instance mentions the SMA but only in reference. It is in this area that the curator weeds out or keeps articles based on careful deduction, assistance of a project scientist or ultimately by contacting the authors for further clarification. The standards for citing observational metadata are largely loose and authors often provide vague clues that the curator must catch to accurately tag the work. For example, authors could make the claim that they used submillimeter array data in their study but could be referencing a similar project such as ALMA.

Once the curator has determined that an article belongs in the project collection or bibliography, a record is formed from metadata pulled from the ADS and associated metadata is tied to the record by creating additional annotations (“tagging”). This activity allows a curator to enrich the basic bibliographic metadata with items of interest to his or her project. This may include the proposal cycle under which observational data was obtained, number of antennas used in the study, frequencies used, etc. The driving force behind this activity is to learn from current science programs such as the SMA and develop better programs for future science activities. Ultimately, the projects use the metrics that result from the latter curatorial activities to review, assess and benchmark projects.

4. A VALUE-ADDED CURATION LIFECYCLE

While the main goal of an archivist or librarian who engages in the creation of a bibliography is to provide a rich set of relevant statistics to management, the information collected can be repurposed for a variety of uses that go beyond its original intended purpose. For instance, a facility director might be primarily interested in generating metrics to include in annual reports to funding agencies, whereas a peer-review panel or time allocation committee will look at the track record of individual observers before awarding additional telescope time. Archive scientists will find the bibliography useful in understanding how data are first published and
AstroExplorer is a prototype application which connects observations, objects, and the literature. This screenshot shows a list of Chandra observations (right pane), the publication where the first observation was cited and the objects mentioned in that publication. The left pane displays data facets, which can be used to further filter the data products.

whether they are re-used, while research scientists will benefit from discovering connections between papers and data as well as identifying multi-wavelength studies.

In support of discovery, the ADS has long provided, as part of its search interface, a set of filters which allow users to restrict results by a limited number of bibliographic groups maintained by the respective set of curators. This is done by having ADS periodically retrieve the list of identifiers from the online bibliographies maintained by the curators from collaborating institutions and projects. For example, the Chandra bibliographic group is updated on a regular basis by the Chandra archive group, and the list of papers appearing in it is pulled from the Chandra archive every week-end. A similar workflow applies to the papers belonging to all the bibliographic groups supported in ADS, which are listed in Table 1.

Observational metadata, astronomical objects and related publications are things that go well together, and interesting applications can be built when the connections between them are harvested, modeled, and indexed. AstroExplorer$^*$ is a prototype application developed by ADS and the VAO that helps explore, search, bookmark, share, and work with assets of importance to astronomers$^2$. It harvests and indexes metadata about, and connections between, papers, data, and astronomical objects. The application (shown in Figure 2) is built upon a semantic database which incorporates linked resources curated by a number of different archives, specifically: publications in the ADS; astronomical objects at Centre de Donnes astronomiques de Strasbourg (CDS); and observational metadata from a selected set of telescope bibliographies (currently Chandra and several MAST missions). This type of application is made possible by a close collaboration between curators at the participating data centers and the AstroExplorer developers, and currently requires an enhanced level of data sharing between them.

By participating in this joint curation effort and linking data products to records in the ADS, bibliography curators can take advantage of the curated metadata and metrics that the ADS provides for all records in

$^*$http://adslabs.org/semantic
Figure 3. AstroExplorer uses the ADS metrics API to compute metrics related to single observations or a set of observations based on the list of papers linked to them. The metrics currently supported by ADS fall in three categories: papers published, citations and downloads (usage). For each categories ADS provides various averages, normalizations and breakdowns in refereed vs. non-refereed. A set of popular indices and their change over time is also provided.

The use-cases above provide some examples of the synergy that we gain from working in a collaborative fashion. The results of a curation effort shared between the ADS, the Astrophysics archives and institutional libraries are clearly greater than the sum of their parts and are at the heart of the curation lifecycle that our community enjoys.

5. BEST PRACTICES

While the post-publication curation efforts outlined above are essential to maintaining a complete bibliography, much effort can be saved by moving some of this curation activities up-front, during the publication process. There are very good reasons to do so: authors of a publication know best which data set was used for that
publication, and what software (including versioning). The principle of research reproducibility prescribes that
the reader should be able to reproduce results, given a precise description of the data set(s) and software used.
Ideally, all this information should be included in the publication metadata during the manuscript preparation
process. In order for this to happen consistently and habitually, a practice of data citation will have to be
introduced that will be as simple as citing a paper.

The archive where the data are hosted would be responsible for making data citable in the first place and for
providing authors with instructions on how to incorporate data citations in their publications. A good example
of an archive that provides detailed guidelines on how to create citable data sets, together with policies on how
to cite these data sets is the Planetary Data System§ (PDS). Another example is the system adopted by the
Astronomy Data Centers Executive Committee (ADEC) and the AAS journals¶. Examples of repositories
where software archived are the Astrophysics Source Code Library∥ and the Astrophysics Software Database¶.

Is having a clear recipe for data citation enough? Will authors adopt this practice on a voluntary basis
and will it become as habitual as writing an abstract? Our experience is that this is not the case. Accomazzi
concludes that “unfortunately the adoption and use of dataset identifiers in the [astrophysics] literature has not
been a success story,” and the situation in the planetary sciences does not seem to be much different. Realistically,
data citation will become common practice only after we develop a set of editorial and curatorial tools to go
along with the policies and standards which support this effort. The publishers will have to promote the use of
tools to facilitate the authoring process and a form of citation verification during the editing process. Archives
and projects will have to provide user-friendly options to support identification, self-archiving, persistency, and
branding. As with all things that need a level of effort, every party involved will want to know what’s in it for
them. Everybody involved will agree that furthering science is a lofty goal, but this may not provide enough
motivation for people to perform additional chores during the publication process. Luckily there is an effect
that can be easily translated into the currency of the publication process: citations. It has been shown¶ that
publications which are linked to the associated data products result in higher citation rates. For authors this
means that if they facilitate linking their paper to data and software, this will likely result in more citations.
For publishers, higher citation rates get translated immediately into higher impact factors. Links and citations
enhance a papers discoverability, which is beneficial for every party involved.

The other side of the equation is discoverability. Citing data and software is one thing, being able to find
those citations and then being able to follow links to the cited products is another. Knowing that a search for
such citations will be exhaustive is essential for the process of compiling instrument bibliographies. Although
powerful, full-text search alone is not sufficiently reliable for tracking the use of identifiers (such as data set
identifiers and grant numbers). For example, using the full-text search on the AGU website to find citations of
PDS data set identifiers results in many false positives, which you only find out after opening the full article
text, a time intensive process in itself. The full-text search provided in ADS Labs provides a better solution in
the sense that search results are shown in context through snippets of text and regular expressions can be used
to select and further filter results. However, as efficient and clever as search can be, it is no replacement for
old-fashioned curation.

6. EFFORT REQUIRED

The curation of links between the literature and items of value to management and the community is by far the
most time consuming aspect of maintaining a telescope bibliography. However, before the curation even takes
place, the proper IT infrastructure needs to be in place together with the necessary buy-in from management, to
ensure that the bibliography receives suitable priority. The bibliography curators must have access to a System
& Database Administrator to assist with high level technical support. Once a proper infrastructure has been
set-up, a minimal percentage of time is required from the Administrator over the course of a year and assistance
is requested on an infrequent basis. This position is typically already part of the organizations or project’s overall
IT support, but an appropriate amount of time should be budgeted and dedicated specifically to this task.

§ http://pds.nasa.gov
¶ http://ascl.net
∥ http://www1.astrophysik.uni-kiel.de/asd/
A software developer is required in order to install, customize and enhance applications supporting the curation efforts, as well as to facilitate the dissemination and exchange of the resulting work. Preferably, the system that is ultimately developed is web-based, so that it can both ingest and exchange metadata with other systems, such as the ADS and VO archives, using web-based protocols like OAI-PMH and TAP. Ideally, the developer will be familiar with the entire web-based technology stack (HTTP, XML, XSLT, Ajax), modern programming languages (python, Java), and database technologies in use in astronomy (SQL, ADQL). Development time can be reduced by collaborating with groups that have already created applications to manage telescope bibliographies, including ESO’s suite of software (Telbib and FUSE), STScI’s MAST bibliographic database, and the Chandra Data Archive bibliographic database. The Software Developer time can range from a fraction of an FTE to a full FTE, with the latter ultimately improving the quality of the bibliography. Embedding the developer with the curators, and allowing for interaction with project scientists, is highly recommended and leads to a higher quality end-product.

As mentioned earlier, curating a telescope bibliography can be time intensive, depending on the degree of text mining involved and the amount of communication needed with scientists to evaluate items for inclusion. The amount of effort can range from a fraction of an FTE for smaller projects to possibly 2 FTE for a bigger organization with multiple projects. While the overall FTE count may be small, the actual number of people involved in the curation effort is often larger, with each person contributing his or her particular skills. For instance, an organization such as ESO has two people part-time responsible for its bibliography, with one performing the more advanced curation, mining the literature, matching items to criteria, tagging, and the other doing macro level curation through the use of scripts, advanced database queries, as well as the development and maintenance of software tools. In the ESO scenario, the FTEs are embedded in the library, which has elevated the library within the organization. The model is different for the Chandra Bibliography, where the 1 FTE curator’s title is Archive Specialist instead of Librarian. The effort is shared among a group of Archive Specialists who are also tasked with other archive operations duties. In addition, part of a position is also heavily involved with the development of the bibliography system used for curation and dissemination.

7. RECOMMENDATIONS

It should be pretty clear by now that we consider it essential for a new project or archival initiative to include in its plans the task to create and maintain a comprehensive bibliography. It has been encouraging for us to see this happen more and more often, as projects realize the value of linking data and literature. However, only in few cases is the curation effort as thorough as it can be: as we have argued in the previous sections, the amount of time and effort involved in creating deep links between individual observations, instruments, observing proposals, and the literature can vary widely and requires much more than just coming up with a list of papers related to the telescope. If one of the goals is to enable discovery and re-use of the data products stored in an archive, then make sure to budget for a robust curation process. Our first recommendation is therefore: make sure to include the cost of creating and maintaining a comprehensive bibliography in your operations from the start, and don’t underestimate its potential cost and impact.

An archive manager should also plan to use the bibliography to provide meaningful statistics about the use of data products to management and scientists involved in evaluating system operations. Our advice to the curators is to collect as much metadata as possible in the creation of the bibliography and to be prepared to have to compute statistics that haven’t been used yet or answer questions that haven’t been thought of yet. For example, Rots et al. have recently proposed using fraction of observing time published and archival usage as metrics which are less observatory-specific than the typical ones (e.g. number of publications or citations per data product). As we see more and more studies analyze data from different observatories, it may become reasonable and necessary some day to estimate the impact of each individual observation as a fraction of the papers’ total impact. The more detailed the bibliography is, the easier it will be for the curator to compute (or estimate) these metrics. Our second recommendation is: collect as much metadata as you can as part of the curation process, because you will need it some day.

As most of our curators are well aware, there are great benefits in promoting practices which facilitate the identification in the research literature of items of interest to them such as scientific artifacts (object names, data products), technical configurations (instruments, software), and administrative aspects (supporting grants,
proposal ids). There have been some attempts to standardize the names of the relevant entities (e.g. object names abide by a well-established nomenclature) and to provide ways for authors to properly identify them during the manuscript creation process. While these efforts have seen mixed results, we feel it is everybody’s responsibility to try to improve the situation. A new archival system which plans to distribute data products to the public should provide guidance to its users on how the data products are named and how they should be referenced in the literature. Similar requirements should apply to acknowledging observing programs and grants which enabled the creation and analysis of the observations. Our third recommendation is: **provide clear instructions and requirements to archive users which promote the current best practices for citing data, software, funding sources, facilities, etc.**

As discussed earlier in this paper, you will not be the first one to create a telescope bibliography. Neither will you be the first one to be tempted to start from scratch and build on the expertise of your local programmers, archivists and librarians. While this is an entirely reasonable way to get the job done, it has the unfortunate effect of further splintering the number of existing bibliographic management systems in use in astronomy today. As mentioned in section 2, there is a growing number of products in use today for this purpose, and as more projects participate in this effort, it would be desirable to have at least one general-purpose system which supports the basic functionality outlined above: search, save, review, annotate. With the introduction of the comprehensive full-text search capabilities in the ADS, there is no reason why a bibliography system cannot be developed as a web-based application which sits on top of the ADS search engine, relies on the ADS user accounts, and which connects to the observational database of each participating data archive through a proper driver or plug-in. Such system does not yet exist but we hope that it will in the not too-distant future, and should be built through a collaborative software development process. Our final recommendation is thus: **do not reinvent the wheel but rather work with us in building a general-purpose, web-based, modular curatorial ecosystem that will benefit the entire community.**

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Table 1. The ADS Astronomy and Astrophysics Abstract Service provides a bibliographic group filter, which gives the user the ability to have the results of a query limited to a set of papers which belong to one of the bibliographic groups defined below. The level of curation, update frequency, and completeness of such groups varies widely, and ADS makes no statement about their overall accuracy. The groups that provide an enhanced level of curation by providing links to data product are identified in the description column.

| Group Name | Group Description and Policies |
|------------|-------------------------------|
| ARI        | Papers written by researchers at the Astronomisches Rechen-Institut in Heidelberg. |
| CfA        | Papers written by researchers at the Center for Astrophysics (CfA) in Cambridge, MA. |
| CFHT       | Papers written by researchers at the Canada-France-Hawaii Telescope (CFHT), HI. |
| Chandra    | Articles that are related to the Chandra X-ray Observatory, including articles on Chandra-related theory, software, calibration, instruments, etc. Those articles that present specific Chandra observations are linked to the data in the Chandra Data Archive on which they are based. The database is maintained by the Chandra Data Archive. |
| ESO/Lib    | This group contains approximately 10,000 books in the ESO Astronomy Library. |
| ESO/Telescopes | Refereed articles using ESO data. All papers using data from Paranal (VLT, VLTI, VISTA, VST) or Chajnantor facilities (ESO observing time of APEX or ALMA) as well as La Silla papers since publication year 2000 reference the program IDs from which the data originated. They are linked to the corresponding data products located in the ESO Science Archive. The database is maintained by the ESO Library. |
| Gemini     | Articles concerning observations made at the Gemini Observatory. |
| Helioseismology | Articles about Helioseismology provided by the Global Oscillation Network Group (GONG). |
| HST        | Refereed articles using Hubble Space Telescope data, generated by the Multimission Archive at STScI. Note: matching HST proposal IDs to published papers is an on-going project and never completely up to date. All articles are linked to the data on which they are based. |
| ISO        | Articles pertaining to the Infrared Space Observatory. |
| IUE        | Refereed articles using International Ultraviolet Explorer data, generated by the Multimission Archive at STScI. Note: matching IUE proposal IDs to published papers is an on-going project and never completely up to date. About 70% of the articles are linked to the data on which they are based. |
| Keck       | Papers written about observations made at the W.M. Keck Observatory. |
| Leiden     | Papers written by researchers at the Leiden Observatory. |
| LPI        | Articles from the complete Lunar and Planetary Institute (LPI) bibliography, from approximately 1975 to 1994. These are typically papers about planetary astronomy. |
| NCSA/ADIL  | Articles contained in the Astronomy Digital Image Library (ADIL) at the National Center for Supercomputing Applications (NCSA). |
| NOAO       | Papers using National Optical Astronomy Observatory (KPNO and/or CTIO) observations, maintained by the NOAO librarian. |
| NRAO       | Articles related to observations from the National Radio Astronomy Observatory, maintained by the NRAO librarian. |
| PhysEd     | Articles from journals related to education in physics and engineering. |
| ROSAT      | Articles about ROSAT experiments and/or ROSAT data. |
| SDO        | Papers related to the Solar Dynamics Observatory project. |
| Spitzer    | Articles about the Spitzer Space Telescope data, instruments, and articles that provide predictions or models of Spitzer results. |
| Subaru     | Papers about data taken with the Subaru Telescope. |
| SMA        | Papers about the Smithsonian Astrophysical Observatory’s Submillimeter Array. |
| USNO       | Papers written by researchers at the United States Naval Observatory. |
| VSGC       | Papers about variable stars in globular clusters. |
| XMM        | Papers about XMM-Newton Telescope observations. |