PRESERVING ASTRONOMY'S PHOTOGRAPHIC LEGACY
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The Astronomical Photographic Data Archive at the Pisgah Astronomical Research Institute

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Abstract.

Astronomical photographic data constitute an enormously important and, for the large part, unrepeatable resource for astronomical research. To answer the need for rescue, preservation and digitization of astronomical photographic data, the Astronomical Photographic Data Archive (APDA) was established at Pisgah Astronomical Research Institute (PARI). APDA is essential both for the health of astronomical science and for credibility of the current generation of astronomers as guardians of its unique heritage. The basic facility requirements met at PARI for APDA include: a secure area with controlled access; several thousand square feet of floor space with a solid foundation; a clean, dust-free environment with controlled humidity and temperature; protection from sunlight; office and lab space for high-resolution scanners and with internet access. APDA development is focused on collections in danger of disposal or extreme damage. Beyond this essential salvage effort, PARI is currently working to establish the physical archives environment, collection development plan, and standard finding aids for the archive. This essay describes the current set of collections, status for access, research resulting from the collections, and future direction of APDA.

1 Introduction

Understanding the physics of astronomical objects relies heavily on observations of change. Short-term changes can be studied through new observations, but what of changes that happen slowly over decades, sometimes almost imperceptibly, occasionally violently, often serendipitously? We can know nothing of those phenomena unless we can access observations taken over a long period of time, a process known as Time Domain Astrophysics.

Fortunately, astronomy has rich archives of observations spanning more than 130 years from the mid 1800s to the 1990s. These treasured observations are stored on photographic glass plates and film, estimated to total well over two million in North America. Unfortunately, this enormously important resource was in danger of being lost forever because there was no centralized collection point for this historic data.

In the fall of 2007, a group of 32 international scientists gathered at Pisgah Astronomical Research Institute (PARI) to develop a national plan for the preservation of astronomical photographic data (see Figure 1). They established the Astronomical Photographic Data Archive (APDA) at PARI. Housed in a highly-secure building on the PARI campus, APDA now includes collections from North America totaling more than 100,000 photographic plates and films.

Figure 1. Participants in the workshop on plate preservation held at PARI November 1–3, 2007.

Figure 2. Aerial view of the PARI campus. APDA is located in the building next to the radio telescope seen in the distance at the top right of the photo. For a sense of scale, the two 26-m radio telescopes are separated by 300 m.

The mission of APDA is to collect, restore, preserve and store astronomical photographic data that eventually can be accessed via the Internet by the global community of scientists, researchers and students.

PARI, dedicated to providing research and educational access to radio and optical astronomy for a broad cross-section of users, was founded in 1998. The former NASA Tracking Station campus includes more than 200 acres and is located in the half-million-acre Pisgah National Forest, near Asheville, North Carolina. Figure 2 is an aerial view of the PARI campus.

PARI is a natural home for APDA, offering physically secure and abundant environmentally controlled space. Specifications of the building at PARI for APDA include: 3,400 square feet of collection, lab, and office space, computer power conditioning control centers; an early warning fire detection and fire alarm system that is tied to a central system on the PARI campus; a local 235kw back-up generator; a solid foundation for the plate collection area and digitizing instruments; high speed internet access; and servers with 120 TB of storage media. Plate collections are maintained in original storage cabinets whenever possible. Those collections arriving without suitable storage are placed in appropriate storage containers, which may need to be built or purchased at significant expense

PARI provides the lab and office space for visitors using APDA and easy physical access to plates. Access to the plates themselves will be limited to staff and qualified researchers needing to access the plates for detailed measurements. All other access will be provided online. Researchers will be able to request digitization of specific plates needed for a specific research topic.

An astronomer, institution, or observatory with a plate collection may store their plates at APDA. The APDA staff requests information about the photographic plates such as the number of plates, epoch of exposures, exposure times, plate dimensions, plate emulsion type, observer, sky coverage, copies of logs, availability of storage cabinets, and copies of any original notes or comments. The APDA staff coordinates the shipment of the plates which includes the shipping schedule and costs to be shared by those sending the plates.

2 Collections and Operations of APDA

The current inventory of astronomical photographs includes more than 100,000 images from the Smithsonian Astrophysical Observatory (SAO), University of Michigan, Case Western Reserve University, Royal Observatory Edinburgh, Palomar Observatory, Kitt Peak National Observatory (KPNO), Cerro Tololo Inter-American Observatory (CTIO), and Harvard College Observatory. The photographic plate collection dates range from 1898 to 1993, beginning with the Harvard College Observatory Full Sky Survey and ending with the Warner and Swasey Kitt Peak Station QSO Survey. Table 1 summarizes the collections.

APDA also holds collections of 250 spectra of various dispersions from CTIO, ESO, KPNO, Mount Mégantic, and Mt. Palomar. And, APDA has 220 direct and objective prism plates from AAT, Cental Michigan University, Mauna Kea, Mt. Palomar (5-m, 48-inch Schmidt, and 18-inch Schmidt), Tonantzintla, and the USNOFS (40-inch). Collections are either donated to APDA, or put on long term loan.

Table 1. Major Astronomical Photographic Data Collections Housed in APDA

Collection	Telescope	Number of Plates	Years
Cerro Tololo Observatory	24-inch f/3.5 Curtis Schmidt	6,500 direct and objective prism	1968-86
University of Michigan	37.5-inch f/19 reflector	20,000 spectra	1911-63
Warner & Swasey Observ.	24/36-inch f/3.5 Burrell Schmidt	22,000 direct and objective prism	1944-92
Prairie Meteor Network	16 150-mm f.l. f/6.3 wide-field cameras	11,000 films	1964-75
Harvard Meteor Project	Two 12-inch f/0.8 Baker Superschmidts	30,000 molded films	1953-68

Acquisition of a collection usually begins with an institution contacting APDA expressing the need to relocate the astronomical photographic plates. In other cases, an astronomer may become aware of a neglected, but valuable, plate collection which requires a safe space and a place where the collection can be accessed. In either case, the APDA staff will discuss the means for transportation, and formalize the collection transfer with a written agreement. APDA requests the plate collection's cabinets, log books, and any other catalog information that will facilitate the development of an on-line catalog of the collection.

When a collection arrives at PARI, each plate number is compared to the accompanying catalog information for consistency and accuracy. When the comparison is complete, the collection catalog is converted to electronic form and published on the APDA website.[1] The publication is in spreadsheet format and can be downloaded in searchable form. The information in a collection catalog spreadsheet includes, where applicable and available: plate number; prism type; observation date; observer initials; plate center (or collection origin defined) coordinates; UT start time; hour angle; local start time; exposure time; single or multiple exposures; emulsion; hypersensitization; filter; plate temperature; telescope information; focus; east or west of pier; plate holder number; spectrograph resolution, and program name.

A researcher may sort through the on-line catalog according to their own criteria. When ready, APDA is contacted and a quick scan is made of the plate the researcher is interested in studying. The researcher may also visit PARI and peruse the plate collection first hand. Currently, digitization occurs on demand. However, as part of a new citizen science project initiated at PARI, APDA is

[1] `http://www.pari.edu/library`

scanning a series of objective prism plates. The citizen science project is called Stellar Classification Online – Public Exploration (SCOPE).[2]

With SCOPE, scanned images of the objective prism plates are available through a user-friendly Web interface designed for classification of stars as a citizen science program. The objective prism plates are those originally used to compile the Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars, Vol. 1-5 (Houk & Cowley 1975; Houk 1978; Houk 1982; Houk & Smith-Moore 1988; Houk & Swift 1999), sometimes referred to as the Michigan Blue Survey (see, for example, Sowell et al. 2007). About 161,000 stars were classified by N. Houk who, when she retired, moved a portion of her plate collection to APDA.

In this collection of nearly 3,000 plates, there are about a half million stars that have not been classified. Because Dr. Houk's collection has so much data, no single person could classify all of the stars within a lifetime. This is a perfect scenario for a world-wide distributed computer-based citizen science project, which was built in 2008 and launched in January 2009 (Castelaz et al. 2009). Dr. Houk's plates are being scanned and uploaded to SCOPE for the world to contribute to her life's work. As a result, citizen scientists are creating a digital library of new stellar data as they use SCOPE.

The data in SCOPE consists of jpeg images of Dr. Houk's photographic plates. An off-the-shelf transmission scanner digitizes the plates. After a plate has been scanned and loaded into SCOPE, citizen scientists use a JAVA applet to choose a star and compare that star's spectrum to one in a library of 119 standard stars. The standard spectral types are from the Library of Stellar Spectra by Jacoby, Hunter, & Christian (1984). When the citizen scientist has decided on the class of star, their classification is submitted to a database. The data is sorted by star and classifications are compared and statistically analyzed for consistency from user to user.

3 Education and Research uses of APDA

APDA is important to time domain astrophysics, but PARI has also found that APDA is an important part of its research and education programs. The Duke University Talent Identification Program Summer Field Study in Astronomy at PARI engages 30 high school students from around the U.S. in astronomical research. Teams of three students spend two intense weeks resident at PARI, using PARI's resources, investigating areas of study that include stellar evolution. Several teams select APDA and the objective prism plate collection as part of their work.

Individual high school students conduct their senior research projects at PARI. One student scanned the Omicron Ceti spectra in the Michigan Spectrograph collection and built a light curve of emission and absorption features. Another student used the objective prism plate collection to classify stars in open clusters as part of an open star cluster stellar census. The open cluster star census was continued by summer undergraduate research students. The un-

[2] `http://scope.pari.edu`

dergraduates presented their work at American Astronomical Society Meetings (McGurk & Castelaz 2006; Aubrey & Castelaz 2007).

In addition to student research, other research by PARI astronomers using APDA include a spectral analysis of Eta Carinae for the period 1968-1972 (Cline, Barker, & Castelaz 2008). Gaps in the observation of spectra of Eta Car occurred in 1970 and 1975 when two occurrences of the 5.5-year cycle of brightness and spectral variations were expected. Two objective prism photographic plates (Houk & Cowley 1975) of Eta Car were found in APDA. One plate (IN emulsion + RG1 filter) was taken on 1968 July 4 UT. The other plate (IIa-O emulsion) was taken on 1972 March 12 UT. While these plates were taken between the predicted 5.5-year cyclic events of 1970 and 1975, and therefore represent the usual emission-line spectra, the spectrum of Eta Car was extracted from each plate and presented. Absorption components attributed to P Cygni profile were measured and the average velocity was found to be -461 km/sec.

The most recent investigation by PARI astronomers is the digitization of a series of spectrograms of Nova Cygni 1920 in the University of Michigan-Ann Arbor Spectral Plate collection (Cline, Castelaz, & Barker 2009). The plates have a dispersion of 40 Å/mm and were taken from 23 August 1920 to 4 October 1920. Nova Cygni 1920 (Denning 1920) was one of the brightest and fastest galactic novae observed, increasing in brightness nearly 13.5 magnitudes and then declining 3 magnitudes in 16 days. Velocities of emission and absorption lines were re-measured on each of 45 spectroscopic plates. The spectra were scanned with a transmission scanner that has a resolution of 0.23 Å/pixel. Each scanned image includes a titanium comparison lamp spectrum along with the nova spectrum for wavelength calibration. In addition, the interstellar H and K lines are easily detected and used as one method to measure the velocities of the nova's H and K lines. The spectra were presented, and the line profiles in terms of the possibility of early formation of emission knots was discussed.

4 APDA Support Instrumentation

APDA has several machines that allow astronomers to measure the positions and magnitudes of stars on plates. Classic machines include a Grant Line Measuring Comparator, a Becker Iris Diaphram Photometer, and a radial velocity measuring engine.

APDA can scan individual plates with a MicroTek 4800 dpi transparency scanner. This scanner is controlled with a PC with two dual-core Xeon 3 Ghz processors, 16 GigaBytes of RAM, a local 250 GigaByte Hard drive, a 2 Gigabit fiber optic Local Area Network, and a data hard drive with 120 TB of storage.

APDA also possesses two high-precision microdensitometers, GAMMA I and GAMMA II, that were built for NASA and the Space Telescope Science Institute (STScI). GAMMA I and GAMMA II were donated to PARI for APDA by STScI in 2008 and are expected to be fully operational by 2010. These microdensitometers were used by a team of scientists to develop the Guide Star Catalog and Digitized Sky Survey projects that guide and direct the Hubble Space Telescope. EMC Corporation has donated a networked storage system and software that can store and analyze the more than 120 terabytes of research data that can be expected from scans with GAMMA I and II. The donations

to date by PARI, STScI and EMC have allowed the APDA to begin work on digitization. Funding is now needed to ensure that this can continue.

5 Plate Preservation Workshop Recommendations and APDA

Thirty two astronomers and archivists participated in the Workshop on a National Plan for Preserving Astronomical Photographic Data held at Pisgah Astronomical Research Institute on 1–3 November 2007. The workshop resulted in the official establishment of APDA and the creation of Time Domain Astrophysics.

Participants in the Workshop adopted a number of recommendations. Some were directed towards the astronomical community, some towards those involved in archiving photographic material and several specifically to PARI regarding the establishment and conduct of APDA. One was a general recommendation that "PARI's Astronomical Photographic Data Archive (APDA) should be developed as an astronomical photographic data repository."

PARI has supported several actions connected to the recommendations to the general community. Specifically, PARI staff collaborated with the census of plates, participated in the special AAS Special session on Archival Data and Time Domain Astronomy, and assisted in the preparation of both an article in *Physics Today* on archiving plates and a position paper for the current decadal survey. PARI has agreed to be a collection point for orphan plates.

In developing ADPA, PARI has followed those recommendations for operating plate archiving centers. Web-accessible catalogs of the plates are being prepared. APDA has developed a standard letter of agreement that covers the deposit of archival astronomical photographic images at PARI by a depositor.[3] APDA has kept the plate collections it has received separated by origin, and each collection is easily accessible. Complete electronic catalogs of each collection are made available online and downloadable.

There were seven recommendations directed toward PARI with the aim of advancing the development of its plate archiving activities. A number have been implemented. The recommendations are reproduced below followed by PARI's response to date.

Recommendation 1. Given its available physical space and support facilities, PARI's Astronomical Photographic Data Archive (APDA) should be developed as an astronomical photographic data repository.

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[3] The two parties agree that: the items are described that are to be deposited at PARI; the depositor can state whether they want to retain ownership of the materials, or transfer ownership to PARI upon delivery at the PARI campus. The agreement asks the depositor to estimate value of the collection. The depositor can also explicitly state in the agreement whether PARI should return one or more of the items to the depositor upon receipt of a request to do so, with costs and methods of shipping of returning items the responsibility of the depositor. The depositor grants permission for the deposited items to be made available for scientific and/or historical use by qualified investigators at the PARI campus. PARI agrees that items will not be loaned or taken off-site without the depositor's permission. PARI also agrees that depositor will be credited when its items are used in scientific or other publications. Finally, PARI agrees to exercise due care in storing the items with the condition that PARI is not responsible for damage or loss through calamities, shipping or routine research use.

Recommendation 2. PARI should carry out a study of what will be needed to operate APDA in a professional manner. This would include personnel (e.g., an archivist) and the financial resources.

Recommendation 3. PARI should consider forming an advisory group charged with providing advice on photographic archiving issues.

Recommendation 4. PARI should work on establishing an endowment for plate archiving.

Recommendation 5. In order to attract funding, a priority for PARI should be to have some demonstrated uses of the plates it has in astronomical research.

Recommendation 6. To increase the plate archive's visibility to the astronomical community, PARI's website should have a direct link from the main PARI page to the plate archive portion.

Recommendation 7. PARI is encouraged to organize regular meetings at which the progress of plate archiving can be assessed.

Recommendation 1 is identical to one made to the astronomical community and, as described in this essay, PARI has done its part to make APDA a major archive for astronomical photographic data. Recommendations 2, 4, and 5 essentially deal with ensuring adequate funding for APDA, and PARI is actively addressing this issue. Grant proposals to national preservation programs are being prepared; research being done with APDA plates by students and staff astronomers continues to be an important part of the strategy for securing funding. PARI has considered forming an advisory committee as suggested in Recommendation 3, but the general feeling (including of a significant fraction of those at the Workshop) is that it may be too early for this. Recommendation 6 resulted from the observation by the Workshop participants that it was not easy to locate information on APDA and its plate holdings on the PARI website; PARI has since modified its home page to include a link to APDA. Finally, in response to Recommendation 7, PARI has plans to establish a series of annual workshops focusing on time domain astrophysics, but accomplishing this goal is partly dependent on securing funding.

6 Summary

APDA has become the home to extremely important archived data that might not otherwise survive or be accessible. More collections are anticipated, and expansion to 10,000 square feet of floor space is possible. Even though the plate collections will be preserved, the realization that 21st century astronomy demands an on-line, virtual observatory workplace is motivation for APDA to proceed with digitization of all plates in all stored collections. To this end, APDA plans to re-calibrate the GAMMA I machine for this purpose, and begin the precise digitization process. The future of APDA depends on the foresight of astronomers who understand the importance of preserving their science and heritage.

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