SCAN–IT

The IAU Working Group for the

Preservation and Digitization of Photographic Plates

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Report from the Chair

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Dear Colleague,

Fate is not often kind, but just sometimes it can be unexpectedly helpful. Two years ago I started work on a project to examine evidence for the evolution of the Earth's ozone shield (see Page 6) using evidence recorded on historic stellar spectra. The project involves seeking out as many valid historic spectra as I can find, and provides travel funds for that purpose. Thus, I have not only had a cast-iron reason to visit as many observatories as I suppose useful for the research, but even the full support of travel funds. What better opportunity, then, to pack in my suitcase my PDPP Chair's Hat as well?

What did I expect to find in our sorry plate archives? Mostly I found chaos, some disarray, a great deal of dust, a little concern, and more than a little scepticism that the "old plates" could ever be worth the resources of professional staff. The following notes refer mainly to spectra*; I didn't pay so much attention to direct plates except in a general sense.

The story was almost universal: the plates exist, largely in their original storage scheme of ordering by R.A., and occasionally (e.g., at OHP) ordered by instrument. Except for the few (ROE, Lick, CfA), which are managed by a plate librarian or archivist, there is general neglect: returned boxes of plates unsorted, boxes of plates standing on or in other boxes of plates, no attempt to provide a correct environment, and everything sufficiently unhelpful that the statement that "no-one asks nowadays to look at the plates" is self-fulfilling. Locations varied; some archives (OHP, Lick, MWO, DAO, SAAO) were in rooms specially set aside, while others (Potsdam, ESO, KPNO) were merely in peripheral cupboards. The archives in rooms tended to have proper cabinets, while those in cupboards were stored in labelled boxes but arranged haphazardly. The older Potsdam spectra were in an attic with somewhat perilous access; the collections at SAAO (from the Cape and Radcliffe Observatories) were *upstairs* in a flat-roofed 2-storey building (!); the MWO plate vault is in an underground strong-room where the temperature and humidity are not very variable. The few supervised archives communicated a strong sense of the value of the historic material, but all the unsupervised archives were pretty dirty superficially, one of the worst being at Cambridge UK which retains a narrow, unloved room for its inherited plates. The Lick archive is up at the Observatory but in its own air-conditioned room.

Almost all archives included card catalogues that were intelligible. It was difficult to assess completeness, though it was clear that the ESO and KPNO archives are only fractionally complete (probably $< 50\%$) as a result of policies encouraging observers to keep their plates.

Some archives have had narrow escapes. The plate-store at OHP has been flooded. The Mount Stromlo plates were not damaged in the fire disaster because they had been dumped in a basement junk-room and the fire had jumped over that building. At the SAAO a number of the oldest plates have been spoiled by fungus caused by the high humidity and high ambient temperature. The Michigan collection you have already heard about in SCAN-IT 2; it has now been rescued by PARI. Plates from the Cape Observatory were amalgamated with the RGO collection in Cambridge, UK, but all have since suffered the curious fate of being over-protected: they are packed in crates, seemingly at random and certainly uncatalogued, in a warehouse in London. Worthy the astronomer who attempts to find what s/he needs!

The principal fresh activity that I came across in the professional domain was at Mount Wilson, where two part-time archivists are starting to create an on-line catalogue of all the spectra. There is more enthusiasm among the non-professionals; the Norman Lockyer Observatory in SW England is run for the benefit of public interest by a group of volunteers, some of them retirees from the Royal Greenwich Observatory, and their well-ordered archives and on-line descriptions and listings put the professional observatories to shame! Some of the plates lingering in Cambridge may be Lockyer's originals, and I am hoping to arrange their repatriation.

One positive aspect, however, is an awareness of the PDPP. Both Mount Stromlo and the SAAO asked me to report on what I found, whether there was a future for the material, and to suggest improvements that could be made. I hope other PDPP members can fill in some of the many gaps that I have had to leave, and will be able to add to this report in future Newsletters, or through our e-mail circular; you can subscribe to the e-mail circular by contacting me directly via e-mail (Elizabeth.Griffin@hia.nrc.ca).

Kind regards,

Elizabeth Griffin

*I have not yet visited the McDonald spectroscopic archive, now at Yerkes Observatory

Co-Editorial

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Owing to the apparent prominence of the "volunteer" gene in my makeup, I have the honor and pleasure to wear two hats within PDPP: the SCAN-IT Co-Editor's Hat and the PDPP Envoy Hat. It is while wearing the first hat that I am writing this SCAN-IT Co-Editorial.

Rather than an Editorial for this issue, our Chair has written a *Report from the Chair*, in which she covers many of the core issues with which we plate preservationists must deal. She describes some of the best and the worst situations regarding plate preservation efforts (or non-efforts!) that she has encountered on her travels while tracking down plates for her ozone-level work (see Page 2 for additional details). Her contribution on her ozone-level work is an example of "applied historical astronomy" (Hughes 2003; see Page 9). A better example of "relevance" to current times would be harder to find!

We hope - all of us! - that SCAN-IT will continue to contain additional examples of "applied historical astronomy" that have appeared in the recent astronomical literature. Your assistance will be very helpful in drawing our attention to recent work that might otherwise be missed. Those efforts should be ackknowledged and applauded so as to encourage the use of data from historical plates and to let the rest of us know that our work is bearing positive fruit. And there have been positive developments, the most recent one to come to my attention being the report here from our colleagues in Russia (see Page 10).

This issue marks the beginning of two new continuing sections of SCAN-IT, *What is the Value of Historic Astronomical Observations?* and *Technical Contributions*. Both sections will consist of original contributions submitted directly to SCAN-IT. The first will contain contributions in which astronomical results that made use of photographic plates are described. The second section, *Technical Contributions* will compliment the *Project Reports* section with content that relates primarily to the technological aspects of plate preservation and scanning. Your contributions are welcome in all areas of common interest. Please kindly submit the text of your contributions, in either plain-text or LaTex (preferred) format, to Elizabeth Griffin (Elizabeth.Griffin@hia.nrc.ca), SCAN-IT Editor, or to me (Co-Editor) at tlglhobs@comcast.net.

In addition to the welcome news from our Russian colleagues, the current issue of *Mercury*, the bi-monthly magazine of the Astronomical Society of the Pacific, features an article on PARI, the Pisgah Astronomical Research Institute, located in North Carolina USA. In addition to their research and educational goals, PARI has begun work toward creation of the North American Center for Astronomical Plate Preservation (NACAPP), to be housed and maintained at PARI. NACAPP's goals are to collect, preserve, and digitize astronomical plates and to "...make the results available via the Internet to researchers and students from around the world", according to Mike Castelaz, PARI Director of Astronomical Studies and Education and PDPP member. Information about PARI's preservation and digitization projects PARI's Web site is at http://www.pari.edu/p00_content_display00.asp?ID=59, and their home page is located at http://www.pari.edu.

The focus of the NACAPP initiative will be direct plates, and it will thus compliment the World Spectra Heritage (http://www.konkoly.hu/SVO/wsh.html), a not-for-profit corporation established to organize and operate the Spectroscopic Virtual Observatory (http://www.konkoly.hu/SVO/) based at the Dominion Astrophysical Observatory, Victoria, BC Canada. The SVO will be an international plate-scanning laboratory that will act to rescue, preserve, catalogue and digitize photographic spectra, and will create a database of ready-to-use spectra for use by worldwide researchers and educators. However, the SVO is not yet adeqautely funded, and searches for that are continuing; but GBs of scanned spectra are visible only on the horizon at this stage! The project is an IAU initiative through its *Working Group for Spectroscopic Data Archives*, a Division V Working Group. The SVO Project Manager is PDPP Chair, Elizabeth Griffin. See http://www.konkoly.hu/SVO/personnel.html for a complete list of the SVO Working Group members.

What is the Value of Historic Astronomical Observations?

Part 1: Measurements of the Earth's Ozone

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Those of us who try to draw attention to the impending loss of so much of our international heritage of historic data face a curious dilemma. Unless we address the above question convincingly, it appears unlikely that the request will even be considered. Yet potential providers of huge sums to build futuristic telescopes to probe the unknown seem to be sufficiently satisfied with reasons such as, "because we don't know", or "because it's there". Why should our attempts to preserve and maintain access to what our predecessors thinkingly observed be obliged to answer the same question the hard way?

One reason appears to be a certain incredulity – not a disbelief that we can create and maintain the sort of databases we are speaking of, but disbelief that what they contain will add anything to existing knowledge. How can we convince fellow scientists that we are pursuing "applied historical astronomy", which Hughes (2003) deftly described as taking the results of our predecessors seriously in order to help push back today's frontiers? Those whose research involves variability with periods of more than a decade or two will have absolutely no doubt of the modern "value" of certain categories of historic data, but they are in a minority. Are there not other types of "valuable" research that need information from historic observations?

We know that the answer is Yes, and it is up to the PDPP to substantiate its claim fluently when asked, by offering a list of good examples. First, then, to build the list . . . . Where better than in this Newsletter? Let me start the ball rolling with a brief explanation of my own particular example: a search for evidence of the evolution of the Earth's ozone.

Researching the History of the Earth's Ozone

Ozone is the constituent of the Earth's atmosphere which blocks the harmful UV solar radiation, and is thus essential for the survival of every biological entity. It is created in a dynamic equilibrium by the action of sunlight on molecular O_2 in the stratosphere; most is formed above the tropics, from where winds subsequently transfer it polewards. Ever since a decrease in ozone abundance in Antarctic regions was first documented by Farman et al. (1985), dedicated instruments of increasing number, complexity and variety have been monitoring ozone, both locally – from ground-based equipment observing the solar spectrum – and globally from space. However, although the fact of the downturn in ozone abundance is incontrovertible, the rate of the decline, and to a large extent

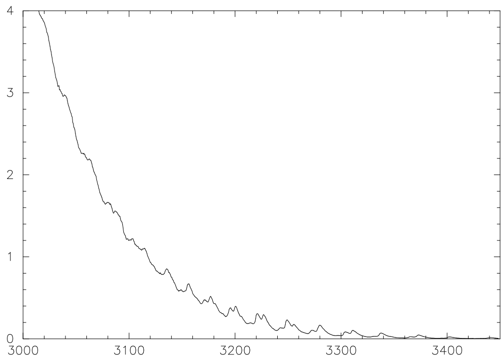

Figure 1: Lab. profile of ozone

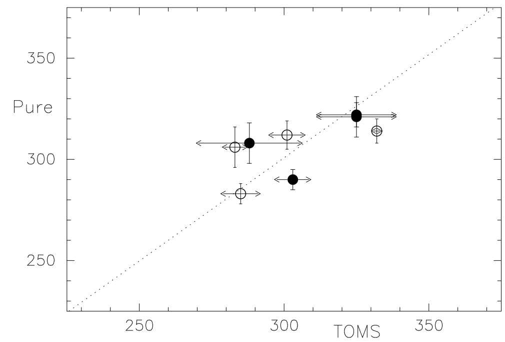

Figure 2: Stellar vs *TOMS* values

our predictions of its future behaviour, are based on the assumption that in the past UV was roughly constant, at something near the 1970s level. That the presence of chemicals such as chlorofluorocarbons in the stratosphere destroys ozone catalytically is equally incontrovertible, but because atmospheric scientists lack precise, methodical measurements of ozone abundances from the earlier decades they are unable to state unequivocally what fraction of the recent fall is due to anthropogenic causes.

One station, at Arosa (Switzerland), has recorded column ozone (called "total" ozone because it includes both stratospheric and tropospheric amounts) since 1926, but while a few others elsewhere operated similar equipment from time to time they were not fully independent of the Arosa data, nor was there more than one instrument at Arosa to guarantee the objectivity of its own data. Ground-based instruments examine the relative strengths of selected features of the Huggins ozone bands, which occur on the redward flank of the intense Hartley bands ($\sim \lambda$2400–3000 Å) (see Fig. 1); it is the latter which are responsible for the atmospheric cut-off near λ3000 Å. The technique is to compare the received intensity of sunlight within a band to that outside it, a technique better known in astronomy as Cambridge Narrow-Band spectrophotometry. The results at different altitudes of the sun are inter-compared, so one eliminates constants such as the absolute flux from the sun. However, owing to the extremely complex nature of the solar spectrum it is essential to position the bandpass filters very accurately since any drift will obviously affect the measurements substantially; the stability of the instruments, which work with direct sunlight, has always presented a significant challenge.

As G.M.B. Dobson, the pioneer of ozone monitoring, describes (Dobson 1968), as soon as routine measurements were begun in 1924/5, it was recognized that seasonal changes occur; the cycle has an amplitude of about 30% in mid-latitudes, up to 50% in the (ant)arctic circles but only about 10% in the tropics, and is explained by meridional circulations in each hemisphere. But total ozone can also fluctuate from day to day by as much as 10–15% as a result of local weather and associated changes in the temperature of the lower stratosphere; that is harder to model accurately. Not all weather events have a continent-wide impact, so intercomparing results may be inappropriate if stations are too distant.

During the early years instrumentation at Arosa was subject to changes and upgrades as new techniques were developed, and although there is no hard evidence of a bias in the early Arosa data it is important to establish their accuracy by reference to other sources, preferably using different methodology. Since the International Geophysical Year (1957-8), in which ozone research was a prominent focus, the number of ground-based ozone monitoring stations has burgeoned worldwide, latterly backed up by space-borne instruments, and both systematic and random errors can now largely be minimized – but that does not yield information on the past behaviour of ozone. One possible source – and it may be the only such – of historic records is astronomy's worldwide collection of photographic stellar spectra. Every ground-based spectroscopic observation of a celestial object extending shortwards to ∼3100 Å includes absorption by the atmospheric ozone in the line of sight, and can potentially furnish a measurement of the amount of total ozone above the observatory in question.

I have recently commenced an examination of as many spectrograms of hot stars taken in the UV as I could find, in as many plate archives as I could search; the general lack of on-line catalogues (see my grumbles in SCAN-IT 2!) has meant personal visits. However, since quartz optics are also essential because glass absorbs strongly below ∼3600 Å, the quantity of potential measurements is somewhat limited; Mount Stromlo and Haute Provence Observatories did not operate a suitable spectrograph, though others (Potsdam, Paris, Lick, Mount Wilson, Radcliffe ...) did do so. The objective is to digitize and analyse the plates with a technique that first had to be tested on more recent material whose results could be checked by other means.

The Huggins ozone bands are comprised of a dozen or so broad dips, ∼20–25 Å wide, best seen in the interval ∼3050–3400 Å (see Fig. 1). The principal objective of the project was to extract total ozone from as many sites as possible, as early in time as possible. Although stellar spectroscopy was only in its infancy in the early 20th century, the identification of ozone as the great atmospheric absorber was in fact clinched through some early stellar work, first by Huggins and his wife (1890), then by Fowler & Strutt (1917) using low-dispersion prism spectra taken at Potsdam in 1904 and in Edinburgh in 1916. For precise results, however, one needs greater S/N than those early plates offer, so I have also borrowed scores of potentially useful material from US observatories dating from the 1930s. It is essential to select hot stars (early A or hotter), whose spectra are generally un-cluttered by stellar features in the UV.

For the "control" plates I selected 8 UV photographic spectra of Vega and Sirius taken during the currency of *TOMS* (http://toms.gsfc.nasa.gov/m7toms/nim7toms.html), the Total Ozone Measuring Satellite which recorded daily overpass data in 1° steps in longitude and 1°.25 in latitude between 1978–1993. The analysis entails determining the ratio of the equivalent widths of the stellar and the laboratory ozone features. Needless to say, that is easier said than done; a paper describing the work in some detail has recently been submitted to PASP. In the case of Sirius there is also one Goddard High Resolution Spectrograph (GHRS) spectrum available, and by dividing that into the ground-based spectra one can isolate the stellar ozone features. Although the GHRS exposure only extends redwards to λ3200 Å, it allows 5 ozone features to be studied by this "cleaning" method; it also provides a means of calculating some of the random errors. When one cannot so remove the stellar spectrum, one has to sketch in the ozone profile through the stellar features. The comparison between ground-based and satellite results is extremely encouraging (Fig. 2).

The next step is to apply the method to the more historic spectra. Some, especially the early coudé ones, are high quality and will support line-by-line analysis. But many of the early prism spectra have poor S/N, and as some lack comparison spectra it is difficult to be certain that the wavelength scale is correct. Nevertheless, such data are all that one has for 1916, 1920 ... and it is useful to have even a ball-park value for total ozone for those years. The natural variation of ozone is also a problem, and a future step will involve determining total ozone at a given site by analyzing every possible observation during a given period.

So far, this project has been funded by an Atmospheric Science foundation in Canada; the results are of considerable concern for the study of long-term ozone behaviour, and having developed a *modus operandi* I hope to continue it into the future as outlined. If all our archived observations were already in digital format the atmospheric scientists would have scoured them for this type of historic information long ago. But instead it has required a so-called "interdisciplinary scientist" (myself!) to act as a human link between the demand and the supply, and to do it the hard way (i.e. searching manually, borrowing and carrying plates to Canada and digitizing them myself); but it has allowed me to wear my PDPP Chair's Hat at the same time – see page 2, *Report from the Chair*, for a summary report on what I have found in various observatories.

The issues at stake here are of worldwide concern, and astronomy may help more than a little towards a broader understanding of the situation. This project can therefore argue convincingly for digitizing archives of historic stellar spectra.

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Project Reports

Efforts to Save Photographic Plates in Russia

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During the last few years, the Centre for Astronomical Data of the Institute of Astronomy of the Russian Academy of Sciences (CAD INASAN) has taken efforts to organize digitization of glass plate libraries of Russian astronomical observatories. The work is going on in the framework of the Russian Virtual Observatory (RVO) project and represents one of its main components for integration into the International Virtual Observatory. The most important task is the creation of a database of Russian telescope photographic plate observations, especially those obtained before World War II, which are of great value to investigators. Regretably, at present most of our astronomical observatories do not have the conditions necessary to safely maintain the plates. The only possibility to save these data is digitization.

It was decided, as a first stage of a project, to start digitization with the plates obtained in observatories of INASAN and of the Sternberg Astronomical Institute of Moscow State University (SAI MSU). These observatories have extensive glass libraries of sufficiently good quality to be included into a world net of electronic photoplate libraries.

The plate archives in question contain regions photographed for purposes of variable star investigations at SAI observatories. The archives contain more than 50,000 plates, making it an important collection in astronomy. It is planned to begin a large-scale project of scanning Sternberg Institute's plate collection in 2005. Two high-resolution Creo EverSmart Supreme scanners were acquired and installed by December, 2004. Currently, their photometric and astrometric properties are being tested. We plan to use these scanners to digitize the most important parts of the Sternberg Institute's plate stacks (about 22500 30x30 cm best-quality plates taken with the 40-cm, f=160cm, astrograph; almost 4000 plates of the highest historical interest, taken in Moscow with different objectives in 1895–1956; etc.). Some other series of plates will be scanned with two Epson scanners belonging to the Institute of Astronomy. We are currently trying to get more financial support for this project. The world astronomical community will be able to access the scans, but the particular procedure of the access is still to be determined, dependent on the funding (and thus hardware) available.

We also plan to scan the photographic archive of the 40-cm astrograph belonging to Zvenigorod Observatory of INASAN (about 4,500 plates).

The first stage of the project is to create a prototype digital database of the plate archives of the SAI and INASAN Zvenigorod Observatories, of the plate archives of all Russian astronomical observatories in a similar way, and to make digital copies of the plates taken by Russian astronomers during the course of many decades.

The general plan of the work includes:

1. Processing and digitizing the observation logs.
2. Making small-size scans of the plates available on-line.
3. Scanning all the plates; creation of a digital archive.

This work is part of an international project to create a distributed database of digitized plate libraries. The equipment is similar to that used by other comparable scanning projects in Germany and Bulgaria. The central organization of this international effort to digitize the plates is operated through the Information Center of the Institute of Astronomy, Sofia, Bulgaria, where the digitized images are being deposuted and maintained.

The central organization of this international effort to digitize plates is operated through the Information Center of the Institute of Astronomy in Sofia, Bulgaria, where the digitized images are being deposited and maintained.

Scanning Activities at Sonneberg Observatory

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Sonneberg Observatory, Germany

1. Background

The Sonneberg Plate Archive, with nearly 300,000 plates, covers almost eight decades. The plate archives in question contain regions photographed for the Sonneberg Field and Sky Patrols. The Field Patrol monitored 80 fields, selected along or near the northern Milky Way, with astrographs and a Schmidt camera at limiting magnitudes up to 18^m. The Sky Patrol (still) records the entire northern sky in two colors with 14 short-focus cameras at limiting magnitude of $\sim 14^m$. In 1997 plates were superseded by film.

Digital scanning started in 1990 with a line scanner (DIANA). A faster scanner (HISS) was developed in 1998 and was introduced during the THAPA meeting at Sonneberg Observatory in 1999. However, in subsequent years it proved too difficult to handle, and was finally discarded in 2002.

A private company (4π Systeme – Gesellschaft für Astronomie und Informationstechnologie mbH) started supporting our scanning operations in 2003 by donating relatively inexpensive new scanners and computer equipment. On January 1 2004 the company became the observatory manager, and is thus responsible for scientific and public activities.

2. Scanners and Software

Because so many of the astronomical community appear disinterested in the exploitation of their historical (though still extant) plate archives, it became increasingly likely that our applications for competitive financial support for scientific programs to include scanning the whole Plate Archive would fail. Our only solution was therefore to find inexpensive, fast and reliable scanners through private channels.

With the support of 4π Systeme we tested several different commercial flat-bed scanners. One of the most serious challenges was to find a scanner with a transparency unit big enough for at least the Sky Patrol plates (13×13 cm^2). We eventually found the HP Scanjet 7400c to be the most appropriate.

During that investigation it turned out that such scanners are relatively powerful and accurate according to their basic hardware and low-level software, but the accompanying graphical user interfaces always scale these abilities down to a somewhat confusing "magic" software claiming to do something and to know everything – but nobody really knows what. In particular, the data depth was often limited to 8 bits. We then discovered a sophisticated software named VueScan, which is able to handle dozens of different commercial scanners in a clear and understandable way. One great advantage of VueScan is its capability to handle the scanner's internally-produced 16-bit images. The genuine HP software inevitably yields images only 8 bits deep. The HP 7400c is also equipped with an illumination unit and a frame mask for exactly 13×13 cm^2 size samples. The time for scanning one of the Sky Patrol plates is about 7 minutes, for a physical resolution of 20μ.

After tests, 4π Systeme purchased four of HP scanners (plus one spare scanner) and associated computers. Each computer has a hard disk of 40 GB. A single scan produces 72 MB of raw data (6000 × 6000 pixels × 2 bytes). There is also another computer with a 200 GB disk and a DVD+R writer. Before writing to DVD the raw data files are gzip-ped, decreasing the data volume to about 45 to 50 MB per scan. Thus, one DVD contains ∼90–95 scans.

3. Logging, Archiving, and Accessing the Data

During a scan the operator manually fills in a log on each of the four scanners, recording a unique scan number, plate number, field designation, box number, scan date and operator's name. Although that increases the data management effort we decided to distinguish scan IDs from plate numbers since it can happen (fortunately very rarely) that a plate number is wrongly written on the glass plate. In such cases we now have only to change the relation between scan ID and plate number.

The DVDs are archived in jewel cases upright on wand shelves. As of March 1 2005 ∼133,000 Sky Patrol plates have been scanned this way, leading to a total of about 1,400 DVDs, or 6.5 TB of compressed raw data.

In parallel to the archiving on DVD, all images are heavily JPEG (8 bit) compressed and stored on hard disk. The compressed files are ∼2.5–3 MB size. We plan to make these files available over the Internet at www.sonobs.de. The raw data are available on request for collaborations, or can be purchased.

4. Manpower and Management

Since April 2003 the manpower for the scanning operations has consisted of instructed helpers, volunteers and pupils. During one week the scanners are used for ∼50–60 hours, digitizing nearly 1,500 plates. If the availability of this relatively affordable manpower holds, we can continue in that mode until the whole archive is scanned. However, much depends on conditions beyond our control, such as the structure of the national labour market.

Regular test scans are made with the same plates in order to check the stability and accuracy of each scanner.

5. Problems and Outlook

We estimate that all the Sky Patrol plates and films that measure 13×13 cm^2 will be digitized by mid-2005. The Schmidt plates with the same dimensions can easily be scanned afterwards. With slightly different frame masks it is possible to scan smaller plates of 6×6 cm^2 up to 9×12 cm^2, which may employ us until the end of 2005.

The large Ernostar and astrograph plates of 16×16 cm^2 up to 30×30 cm^2 require bigger, and thus more expensive, scanners.

While the plate scanning can be managed with instructed assistants, the data management needs skilled experts. That part of the work can only be made step by step as the resources of the company allow. Good progress was recently achieved by implementing a robust algorithm to derive the World Coordinate System (WCS) for each scanned plate.

Results from NSF Support on Grant ATM-0236682 – Digitization of Ca K Images in the Mt. Wilson Archive

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This project will provide a digital database of 70 years of Ca K images within the next 18 months. At that time we will begin the digitization of the direct images, the "white light" series. The present status is given in the Web page at:

`http://www.astro.ucla.edu/~ulrich/MW_SPADP/`

There are currently 11,751 images spanning the interval 1915 to 1940 available for study. These are not yet corrected for vignetting and photographic response but they do have their centers and radii determined and are in a standard fits format. As an aid to image selection, we also provide a complete set of thumbnail images linked to intermediate size jpg versions of the images. An example of the thumbnail pages is shown in Figure 1.

We anticipate that the digitization project and the synoptic program of magnetic and velocity observations for which this proposal requests funding will allow a continuous record of rotation rate as a function of latitude over a period of 90 years. There are also some analogue magnetogram data in the form of photographs of oscilloscope traces taken by Babcock (1955) and Babcock and Babcock (1963). Original photographic films from this program are available to us and can be scanned using facilities of the photographic archive project.

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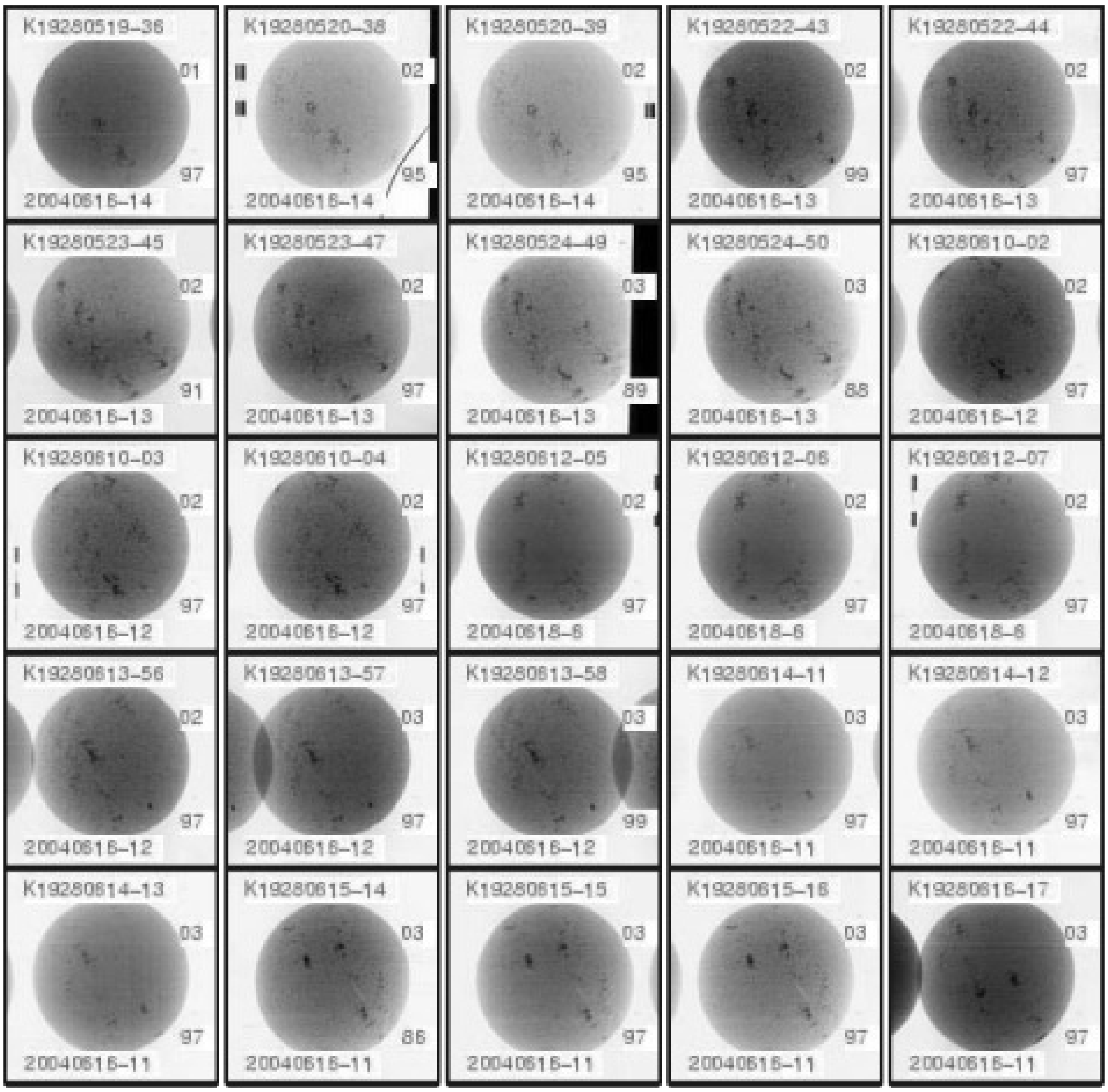

Figure 1: Sample of the thumbnail page. Each image is linked to a larger but still reduced size version of the image.

Status of Platescan Activities at USNO (Washington)

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In summer 2004 Sean Urban left the Astrometry Department at USNO to become the Chief of the Astronomical Almanac Office. Supervision of the StarScan project was delegated to Norbert Zacharias. Gary Wycoff took over from Sean Urban the duties of principal operator of the plate measurements and archiving process. Bill Hartkopf, Brian Mason, and Ted Rafferty are thanked for loading plates onto StarScan.

In April 2004 measurements of all relevant AGK2 plates, including all repeat measures, were completed. Final reductions of the 721 Bonn and 1208 Hamburg Zone plates of the AGK2 project are still in progress. The data will be included in the upcoming UCAC3 catalog.

By September 2004 all remaining plates from the Hamburg Zone Astrograph (ZA) and the USNO Twin Astrograph (BY = Black Birch, New Zealand project, yellow lens) were shipped from Hamburg Observatory to USNO Washington DC. Almost all the plates are 6.3 mm thick, microflat. The ZA plates are 24 by 24 cm while the BY plates are 20 by 25 cm. A single plate has a mass of almost 1 kg. A total of about 3000 plates were shipped in 2 sessions (March and September) using the same 8 crates each time. All plates were packed by Marion and Norbert Zacharias with great support by the Hamburg Observatory and USNO staff. The director, Professor Schmitt is thanked for the long term loan of the ZA plates owned by the Hamburg Bergedorf Observatory to USNO. All the ZA plates were taken by the late Professor Christian de Vegt and his astrometry group at Bergedorf. Most of these ZA and BY plates were measured at Bergedorf either manually or with the HAM-2 machine (Lars Winter), however only a fraction of the plate area could be targeted. The StarScan measures will be a complete digitization with 0.5 micrometer accuracy for astrometric reductions.

Most of these plates were taken in fields around radio stars and quasars for the Radio-Optical Link (ROL) project. Due to the large field of view (about 6 by 6 degrees) about 50% of the entire sky is imaged on these plates taken between about 1977 and 1995, with a scale of 100 arcsec/mm and a limiting magnitude of about V=14. Most fields have a 4-fold coverage and the expected mean positional errors for well exposed stars is expected to be about 50 mas per coordinate.

The ROL plate measuring began in May 2004. A preliminary set of approximately 230 Hamburg Zone plates (ROLZA) were measured during the period from early May 2004 through mid June 2004. The first set of Black Birch plates (ROLBB), also numbering around 230, were measured during the period from mid June 2004 through late July 2004. Measurement of the ROLZA plates resumed in late July 2004 and, since then (through the present date), around 650 have been measured for a total of approximately

880 ROLZA plates. The grand total of ROLZA and ROLBB plates measured since May 2004 up to early February 2005 is around 1110.

The availability of 8x DVD writers allowed us to save the raw pixel data from the StarScan measures since late August 2004. In the past the fit parameters of all detected objects were recorded while the raw data were lost. Each plate is measured in 2 orientations ("direct" and "reverse") and produces 3 GB of compressed pixel data which fit onto a single DVD. We sometimes measure a dozen plates per day and raw pixel data backup with a 1x or 2x DVD was not an option. Fortunately this has changed. We don't expect any better astrometry from any kind of reprocessing of the archived pixel data in the future. The main reason to save the pixel data is to be able to get to "problem cases" if needed. Typically double stars (blended images) are problem cases. In the past the philosophy was to just put that plate on the machine again and re-measure, which was almost as fast as the data retrieval from tapes or 1x DVDs would have been. Now we face the fact that we won't have a StarScan machine forever (see below) and we also run out of space to store plates. The plan now is to keep a pixel data archive on DVDs and relocate measured plates into the PARI archive.

During the last few months, StarScan has experienced down time lasting over a month due to several hardware related problems. A key instrumentation person, Ted Rafferty retired early in 2005 and it is getting harder to maintain the equipment. The new lead person for StarScan hardware is now Gary Wieder (USNO instrument shop) and for software issues Greg Hennessy continues to be invaluable. We hope to finish measuring all remaining about 2000 ROL plates within 2 years.

Technical Contributions

The D4A Digitiser

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Summary

The D4A (Digital Access to Aerial- and Astro-photographic Archives) project aims to acquire the necessary know-how, hardware and software to digitise the astro-photographic collections of the Royal Observatory of Belgium and the aerial-photographic collections of the National Geographic Institute and the Royal Museum of Central Africa, in collaboration with AGFA-Gevaert.

The D4A digitiser under construction consists of a granite based Aerotech ABL 3600 open-frame air-bearing X-Y positioning system, with custom built hardware to mount glass plates, film sheets and film rolls. The optical sub-system consists of a C-Cam Technologies Complementary Metal Oxide Semiconductor (CMOS) camera mounted to a Schneider telecentric Xenoplan lens and will be illuminated by a computer controlled LED. The maximum scanning area is 350×350 mm with a speed of 6 plates (240×240 mm) per hour. A first benchmark of a prototype ABL 3600 was carried out and the proposed illumination system tested as detailed below.

1. Introduction

The D4A Digitiser project, as described by De Cuyper, Winter & Vanommeslaeghe (2004), is progressing toward completion. The Aerotech ABL 3600 X-Y table including supporting sub-systems was ordered in September 2004. We are finalising the drawings right now and expect the machine to arrive in Brussels around May 2005. The air-conditioned clean-room is being prepared at the Royal Observatory of Belgium (Brussels) and will be ready by the time the machine arrives.

We finished most of the preliminary tests of the CMOS camera and illumination. We are building a thermoelectrically cooled version of the BCi4 CMOS camera in cooperation with C-Cam Technologies to improve the signal-to-noise ratio of the camera still further as well as the geometric stability.

A geometric benchmark was carried out in Pittsburgh in the Aerotech plant to check the behaviour of the ABL 3600 X-Y positioning table. To test the illumination sub-system of the Digitiser in connection with the telecentric lens and the CMOS camera, a test assembly of all necessary components was performed in Hamburg and a variety of light-sources checked.

2. Description of the Digitiser

The D4A digitiser will consist of a granite based Aerotech ABL 3600 open frame, air bearing X-Y positioning system, with an automatic plate-holder assembly suitable for mounting glass plates and film sheets up to 350×250 mm). Extended with an automatic film roll transport system and a plate tray handling and storage assembly with plate rotator, the Digitiser will be able to process nearly all known transparent photographic material.

A cooled CMOS camera from C-Cam Technologies (using a 12-bit ADC) is mounted to a Schneider Xenoplan telecentric 1:1 lens. This optical sub-system will be illuminated by a light-source with a very bright LED (lifetime $>$ 50,000 h) that is computer controlled through a precision power-supply for adjusting the exposure of each individual sub-image. The D4A digitiser is intended to measure astronomical (up to 350×350 mm) as well as aerial (up to 240×240 mm) photographs at a rate of at least 6 plates per hour.

Special software is being developed for handling the 18 GByte/h data rate with on-line processing and storage of all images. The goal is to provide astrometrically and photometrically calibrated digital images with overlayed identified stars. The extracted information will be stored in a database. The digital images will be compressed lossless in order to reduce the storage size and time.

3. Benchmark

The geometric benchmark carried out in Pittsburgh at the Aerotech plant was intended to measure the stability of the ABL 3600 air bearing X-Y table. This open frame system performed very well and we decided to use it as the base for our Digitiser.

The ABL 3600 was fitted with a cross beam above the moving stages. A small Z-stage was mounted to this beam to allow focusing of the CCD camera. The Z-stage carried the geometric benchmark assembly, which consisted of a microscope objective and an Electrim EDC2000S CCD camera. Thus the camera was focused by changing the distance between the microscope objective and the plate mounted on the inner frame of the ABL 3600.

To carry out the benchmark, we used a glass plate with a grid of tiny chromium dots on its upper surface (i.e. the surface facing the microscope objective). This geometric grid glass plate was mounted in a sturdy aluminium plate-holder in the centre of the inner frame of the ABL 3600. The X and Y frames of the ABL 3600 are open and the granite table that they are moving on also has a central opening so the light of the illumination can pass through it (open-frame construction). To obtain flat illumination, we used a diffuser between the halogen lamp and the geometric grid glass plate.

The ABL3600 uses Heidenhain ZERODUR glass scales for the positioning of the X-Y table. These determine the positioning accuracy of the Digitiser, while the centering error of the chromium dots in the field of view of the digital camera is dominated by the Poisson noise of the bright background illumination, as we are measuring black dots on a white background. It was possible to centre to a precision $< 0.1\ \mu$m; the repeatability found for this benchmark was $< 0.09\ \mu$m. Owing to the temperature change in the room we could only verify that the ABL3600 prototype would meet our requirements, but were unable to determine a reliable measuring accuracy. As the D4A Digitiser will be located in a temperature (18 C $\pm$0.1 K) and humidity (50 % RH $\pm$1 % RH) stabilised clean-room built by Becker Reinraumtechnik, the final accuracy of the X-Y table will be better than 0.1 μm. That corresponds to the proposed sub-micron accuracy for digitising astrometric plates (Zacharias et al. 2004) and for reassembling the individual overlapping foot-prints into one (aerial) image.

4. Illumination Experiments

To determine the optical quality of the telecentric lens, the CMOS camera and the light-source, an existing test assembly (Winter 1999) was modified. By illuminating the photographic plate or film with a highly diffuse light-source a good mapping of the plate's density scale onto the CMOS camera's intensities is obtained. As the measurement itself is carried out in transmission, the intensity of the measured light is proportional to the transmission. Hence the density of the plate has to be calculated from this. For the whole optical system a photometric benchmark was designed so that the machine can be checked at all times for correct photometric performance.

It is well known that halogen lamps are not very stable, and have a very moderate mean time before failure (MTBF), typically 2000–4000 hours, and in order to avoid problems caused by changing the light 'bulb', we choose to illuminate the photographic plate with a high-power light emitting diode (LED) that has a very stable light output depending only on the stability of the supplied current and with an MTBF of ~50,000 hours.

The influence the illumination has on the digitised image is shown in Figs. 1 and 2. Fig. 1 was taken with a very diffuse illumination, while Fig. 2 was taken with light that had a high percentage of parallel light. Note that the scratches on the emulsion show up only in the latter case, while all the details of the astronomical image are the same in both. A more detailed analysis shows that the grain noise is doubled in Fig. 2 compared to Fig. 1. Obviously we need a very diffuse illumination for our Digitiser.

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Zacharias, N. & Urban, S. 2004, SCAN-IT, 2, 24

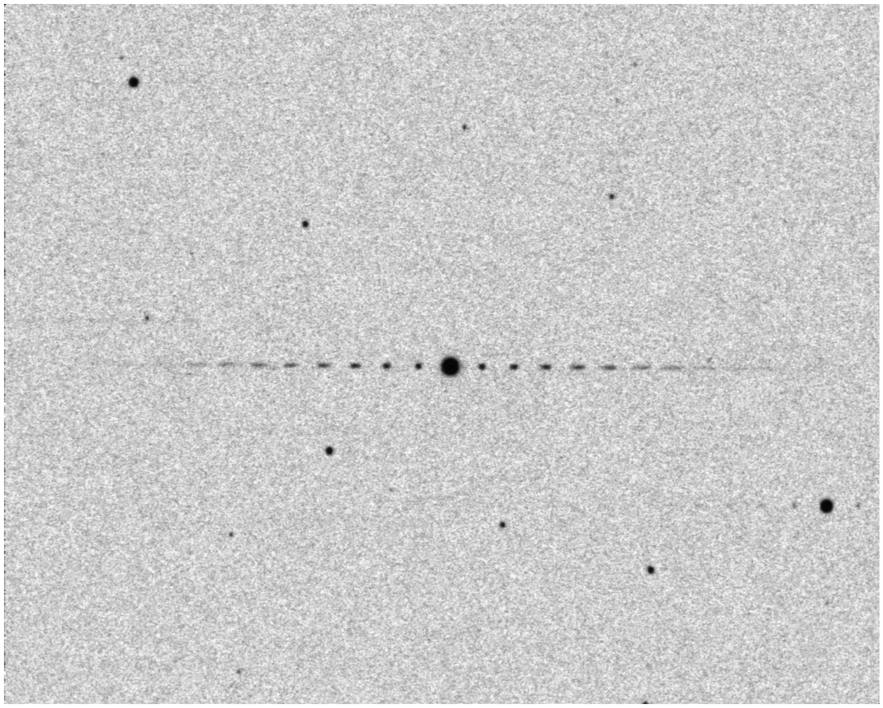

Figure 1: Diffuse illumination. Note the upper left corner underneath the medium bright star shows an empty field.

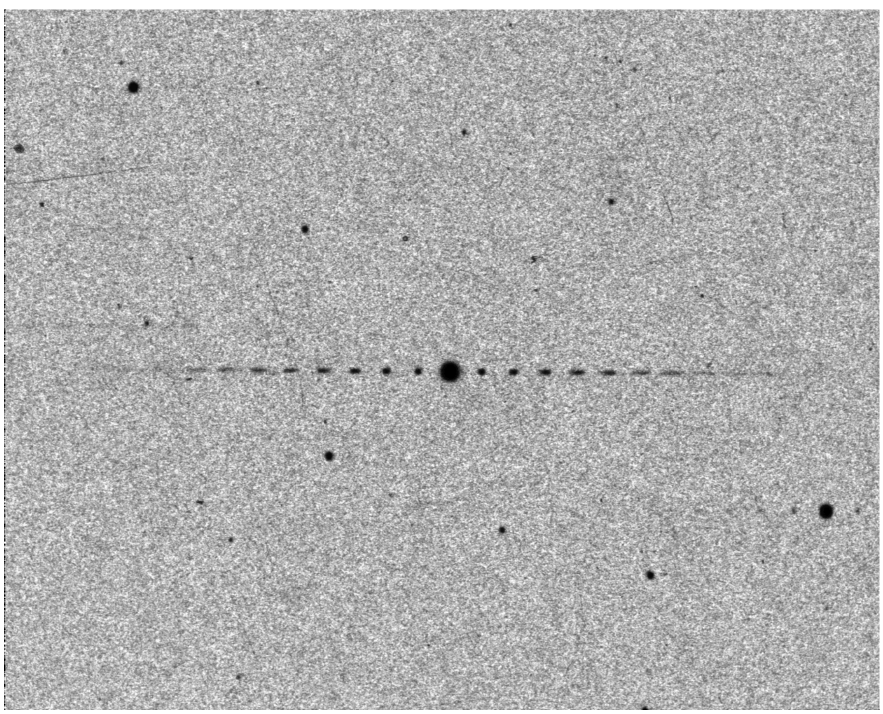

Figure 2: Diffuse and parallel illumination. Note the scratch in the upper left corner that is uncovered by the parallel light. A lot of star-like images now appear everywhere, and are caused by dust particles on the surface of the photographic emulsion.

Digital Aperture Photometry of Saturated Star Images

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In recent studies of the active late-type star CF Octantis (Innis et al, 2004a, 2004b) we analysed digitised plate images (both from a flat-bed scanner and a commercial digital camera) from the Bamberg Sky Patrol Archive. We used a standard photometry package in IRAF[1] (designed for CCD photometry) to analyse the digitised images, which had been converted to photo-positives. We were able to find satisfactory transformations from plate magnitudes to catalogued magnitudes, even though the stellar images were saturated in the cores. As is well known, iris photometry of such images is based on a relationship between magnitude and image diameter, but a referee's enquiry about how this worked for aperture photometry prompted the study reported here.

King (1971), Kormendy (1973) and Racine (1996) showed that the flux profile of a bright star can be traced out for several degrees from the central peak. We digitised the flux profile of King (1971), as a first approximation to the profiles expected for the Bamberg plates. The left panel of Figure 1 shows a series of such profiles, on a semi-log scale (x-axis in arc seconds), representing a range of ∼4 magnitudes. The right panel shows these same profiles, but now with a common saturation limit imposed, plotted on a linear scale with the x-axis now in 5.25 arc sec pixels to match the resolution of our digital scans. These can be considered as a series of synthetic stellar flux profiles that would be recorded on a given plate. As can be seen, for this saturation flux level, the saturation radius varies from around 2 to 12 pixels. We chose this as we found, from the plates, that this approximately matched the observed radii of saturation of stars with B magnitudes ranging from ∼13 to ∼8.

Figure 2 shows a comparison between the profile derived from King's data (solid line) and one obtained from a Bamberg plate. The observed profile is sky subtracted, and the synthetic profile (one taken from the right panel of Fig. 1) is a reasonable match. Our aim was not to derive an accurate representation of the flux profile for a Bamberg plate, but to see if the known stellar flux profile gave some insight why aperture photometry would be successful.

Aperture photometry of 19 stars (with B magnitudes from ∼13 to ∼9) was performed for 90 plates. The mean magnitudes are shown as open circles in Fig. 3, plotted against Tycho-2 B_T magnitude. The vertical axis has an arbitrary offset (the photometry zero point) which has been adjusted to give reasonable agreement near B_T=12. Also shown is a 1:1 gradient line (solid line with + signs) for comparison. The aperture photometry is reasonably linear for the fainter stars, but quickly falls off with increasing brightness.

[1]IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

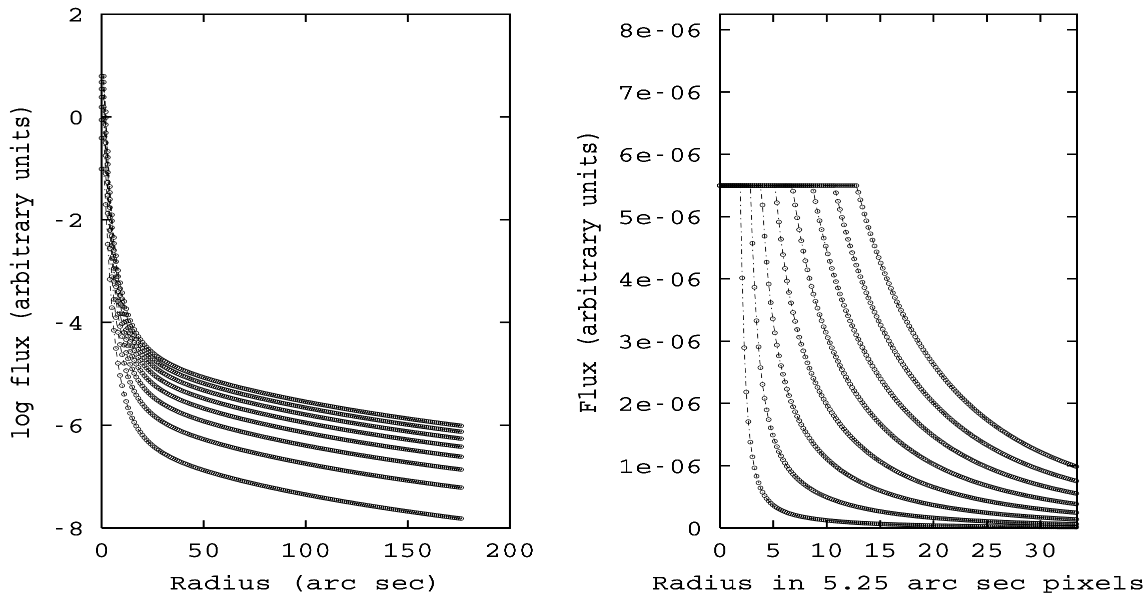

Figure 1: Digitized flux profiles of the Bamberg Sky Patrol Archive plate images. The left panel represents a range of ∼4 magnitudes. The right panel shows the same profiles with a common saturation limit imposed.

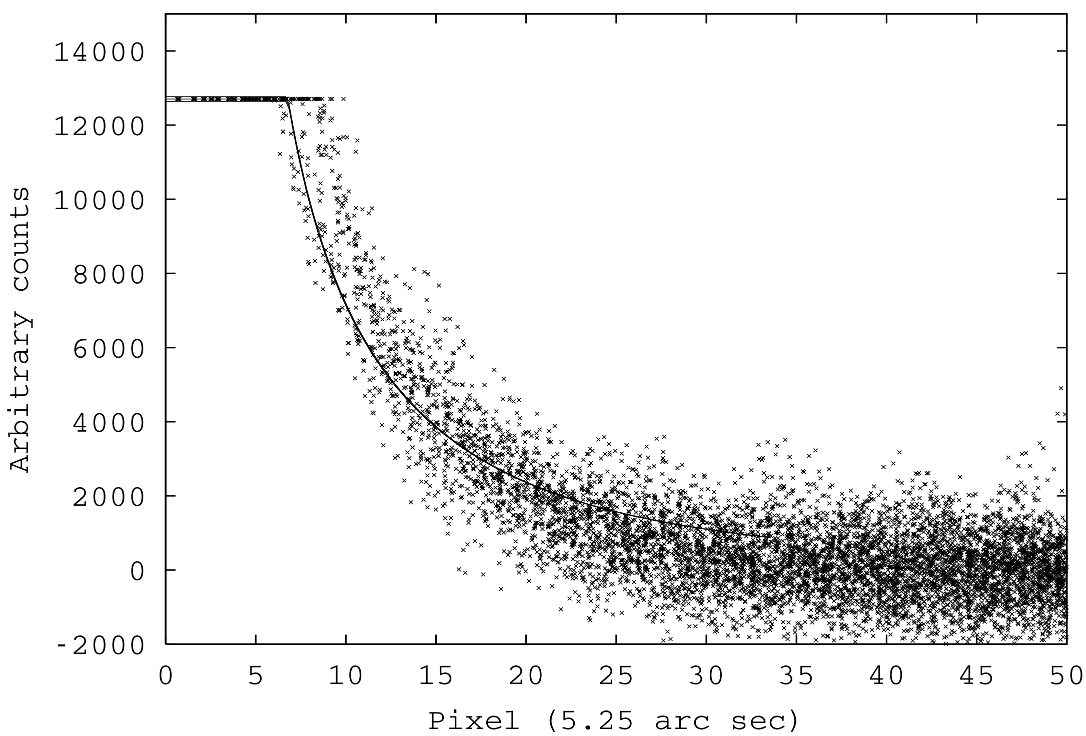

Figure 2: Comparison between a profile derived from King's data (solid line) and one from a Bamberg plate.

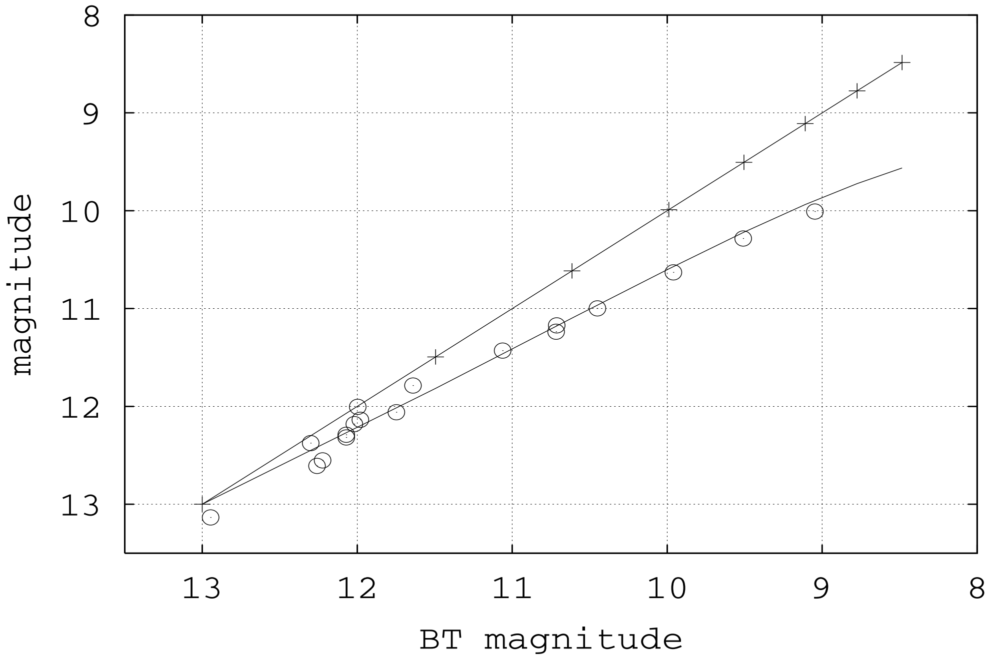

Figure 3: Mean magnitudes derived from aperture photometry of 90 plates (open circles) plotted against Tycho-2 B_T magnitude (+ signs).

We performed 'aperture photometry' for the saturated, synthetic stellar profiles shown in the right panel of Fig. 1. The solid line in Fig. 3 shows these results. We adjusted the zero-point so that the aperture magnitude of a synthetic profile, of a given radius of saturation, matched the plate magnitude found for an observed profile of comparable radius of saturation. The agreement between the aperture magnitudes measured for the stars on the Bamberg plates and those derived from the synthetic profiles is quite good, and suggests that the profile determined by King (1971) is a reasonable match to the profiles on the Bamberg plates. We found it straightforward to derive satisfactory transformations from plate magnitudes, derived from aperture photometry of photo-positive plate scans, to catalogued magnitudes (Innis et al, 2004b).

We intend in the near future to better determine the shape of the stellar flux profile recorded on the Bamberg plates. However, it seems clear that standard astronomical aperture photometry techniques, in the main developed for CCD data, can be satisfactorily applied to photo-positive images of digitised plates.

A more complete account of this work has been submitted to *The Observatory*.

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Harvard College Observatory Digitizer Project

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In the last year we have made significant progress toward developing the infrastructure that will allow the digitization of the Harvard Plate Stacks. Our proposal to NSF for a project to build a high-speed digitizer was accepted and funding was in place in July of 2004. Since the inception of the project, we have been working very hard to get all of the detailed system design work done to allow us to purchase or manufacture all of the components needed to build the proposed machine.

We were exceptionally fortunate to have a special, not commercially available, camera donated to the project. This camera is built around a 4k by 4k CCD that is capable of capturing about 7 frames per second with 12-bit digitization. The CCD has 11μ pixels, and the particular CCD that we received is of very high quality with only a very small number of defective pixels and no column or row defects.

The camera came without lens or shutter so we had to find a way to develop that functionality. We are using a 1:1 double telecentric lens with very low distortion; specifications are less than .01 distortion over a 60mm circular area. This will image a ~ 45 mm square area on the plate with a resolution of 2309 pixels per inch. The camera has a narrow bandpass filter centered in the green placed in front of the CCD. A plate will be strobe-illuminated by very bright green LEDs in a specially designed light distribution system. This gives the function of a shutter mechanism.

We have ordered an air-bearing X-Y table with linear motors from Aerotech Corporation. This table will allow rapid movement of the plate beneath the camera, which is held in a fixed position. The fixture holding the plate is designed to be modular to accommodate different plate sizes. It will support the plates so that they can be illuminated from below, held with the emulsion face up and at focus. The fixture is also designed to facilitate easy loading and unloading of the plates.

We have engaged a team of 5 students at Worcester Polytechnic Institute (WPI) to help with the mechanical design of this fixture as a major qualifying project of their senior year. The design is well underway and we expect that the core fixture will be constructed at WPI as part of their project. The first two fixture modules will allow us to digitize either a single 14 x 17 inch plate or two 8 x 10 inch plates. We are estimating that a scan of one 14 x 17 inch plate or two 8 x 10 inch plates will take on the order of a minute for the digitizing process, with additional time needed to load and unload the plates.

Because each plate varies considerably in dimension, we have been challenged to find a method of securing the plate within the fixture. The fixture must accommodate variations in nominal thickness, in uniformity of thickness across the plate, in dimensions per side, and consequent squareness of the plate. Many plates also have been repaired by sandwiching the broken portions within one or two clear glass plates, held together with tape around the edges. We need our plate fixture to hold plates in a way that supports them from sagging, holds them securely while accelerating and stopping quickly, and that keeps the whole working area of the plate clear for back illumination. While we have what we believe are good solutions to these problems, only time and some real experience will tell the whole story.

We have accomplished a large-scale reorganization of the physical layout of the collection to allow in-house digitization on the bottom floor of the Stacks. The Stacks now contains a specially-constructed area to isolate the scanning process from plate cleaning and preparation. Because of the unusual design of the building, it has been a challenge to design the digitizing system in a way that will allow the X-Y table to come into the area through a 4-foot square window. After much examination, we determined that this window was the largest opening available for access into the building.

As of this writing, we have the camera in our possession, the table is on order and our expectation is that all of the parts of the system will be available to start integration and testing in April or May of 2005.