SCAN–IT

The IAU Working Group for the

Preservation and Digitization of Photographic Plates

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The Case for Digitizing Plates

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Software

Editorial

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Welcome to another **SCAN-IT** Newsletter! Once again, we are bringing you a mixed bag: project reports and updates, discussions of the scientific requirements to be met when designing or selecting a scanner for digitizing plates, and some thoughts about the fate of unwanted or unreturned – even of returned! – plates. How can the community best organize itself to return plates to the home observatory when no-one there has a responsibility for receiving and sorting them? Is it better to wait until a "final home" is decided for each and every archive before shipping small personal collections? These may not be weighty matters, but they need well-researched answers nonetheless.

The Project grows

As the reports from the IAU and the AAS meetings indicate, the PDPP community is growing, both numerically and in its involvement in the management of its historic resource. That cannot but be a good thing. The hope is that organizations and individuals with really deep pockets will get to hear about how Astronomy is trying to save its heritage, and may be not unready to listen to our appeals. Already some acquaintances have mentioned hearing astronomers report on projects to digitize plates, and did I know? – so the word is spreading. This is really very encouraging.

Scientific Drivers

Most of the submitted articles concentrate on the *How* of digitizing observations; little coverage has been given so far to the *Why*, which is of course ultimately what drives the scanning efforts. It is high time to redress the balance, and we would like to encourage readers to collect two types of input: (a) references to results that were only achievable through an ability to access digitized photographic observations, and (b) a wish list of ideas for scientific topics that would benefit from – or only be possible through – such access, and submit them to the PARI listserver (**astro-plates@pari.edu**). The lists that are thus collected will form a valuable reference for anyone writing a proposal to digitize plates.

Recently when I needed to produce a list of scientific accomplishments that depended on accessing photographic data, I searched the ADS for combinations of the words "photographic –observations–digitize", and was pleasantly surprised to find a considerable number of examples, many of which were in the current year. Synopses of some of them fill up odd corners of this Newsletter. Researchers are quick to take advantage of new resources, and the publicity given of late to digitizing plates seems to be bearing rapid fruit. So please keep the reports and the ideas flowing in. In this issue, page 15 contains notes on two specific instances where access to plates helped solar-system research, while page 16 pleads the case for access to historical spectra in order to understand long-term Be-star phenomena.

PARI, a Center for North American Plates.

Do visit the PARI Website at **http://www.pari.edu**, and read about the amazing facilities there, and the plans to generate a large-scale plate archive and digitizing centre.

The Future of Astronomy's Past

Elizabeth Griffin

(Chair, IAU WG for the Preservation and Digitization of Photographic Plates)

The following article derives from a Discussion Meeting held during the IAU General Assembly in Sydney, 2003. Attended by about 40 people, the discussion touched on a variety of specific issues: a central repository for plates, recalling "personal" collections, on-line catalogues of archive contents, and buying versus building an appropriate type of scanner.

Astronomy has a Past. In about 3 million pieces, in fact. Photographic plates, in cabinets, drawers, boxes, shelves. Enveloped, labelled, protected. Evidence of events never to recur, of changes once witnessed and now eagerly sought to confirm or condemn a theory. Astrometry across a time-base of 60, 80, 100 years; asteroids on trajectories that may not after all collide with Earth; photometric changes of order half to one magnitude over a period of 20 years; surveys of the sky dating back to the 1920s or earlier (IVOA please note!); unique information regarding the evolution of the Earth's ozone.

Historic material is an invaluable complement to modern research, and to date most of our historic observations cannot be incorporated in research because the material is non-digital. The 40 or so people who attended the Round Table discussion last Tuesday were in no doubt about the crying need to rescue that mine of information before it deteriorates and is lost to perdition (or to an observatory trash-bin), nor in our ability to rise to that challenge. We took it as read that such steps, extensive and expensive as they might be, are an essential prerequisite both for the health of our science and for our credibility as guardians of its unique heritage.

Two sites have been identified as "area locations" for storing direct plates which an observatory no longer can or wishes to keep: Brussels Observatory in Europe, and PARI (North Carolina) for North American plates. Both sites will be furnished with high-speed scanners, and will operate digitizing programmes with instruments selected according to the inherent accuracy of the original material. Some observatories are already operating their own digitizing programmes, and may wish to deposit the scanned plates in an "area location" for long-term preservation.

Because spectra present a whole different set of requirements, they will be handled separately by the Spectroscopic Virtual Observatory (SVO), planned for the DAO (Canada). However, the SVO does not have the capacity to store plates indefinitely, and scanned material will also be sent to PARI.

What about ownership of the material and of the digital datasets? Presumably plate archives can be donated to a scanning operation, but the simplest formula is undoubtedly "long-term loan". And if we abide by the prevailing ethos for scientific data, all the products of the scanning labs will be free, just as other digital data are today free worldwide.

But don't leave it all to the people in the scanning labs. Theirs is a Herculean task. To proceed in orderly and rigorous fashion they need on-line inventories of the plate collections. Since we are organizing your digitizing for you, we welcome your help in putting the log-books or card catalogues on-line. Obviously it is important to adopt the same formats, and we can supply templates and instructions.

And what should you do about those “foreign” plates that have been lying in your office, measured or otherwise, for perhaps decades? Undoubtedly it would be better to return them to the observatory of origin while you can still exercise control over the matter; your post-retirement replacement or your executor will lack your knowledge and your plate-handling expertise. Actually the time for a major plate-recall is not yet ripe, as few observatories have plate archivists – though some do. Please contact Elizabeth.Griffin@nrc.gc.ca for possible information, and rest assured that your plates ARE wanted back. If the observatory had no log-book formalities, then please locate your own observing notes and send them, on-line.

There’s no denying that it will take resources – skilled, trained humans – to carry out digitizing programmes and manage the digital databases, and that means Money; the same commodity will be absorbed by plates in long-term storage. But the figures are orders of magnitude smaller than the cost of a new telescope or a space mission. Many an instrument is funded to solve just one question; historic data will be a resource for solving any number of questions. Specific scientific discoveries which historic data will enable may be hard to predict as many will be serendipitous, but the IVO faces exactly the same challenge, and many countries are willing to translate their faith there into investment.

Attitudes towards historic observations were still ambivalent at the Manchester GA, but a clear sense of purpose has now emerged - and the relevant technology has improved in the interim. As scientists we cannot afford NOT to carry this project through, and the time to begin is NOW. Yes, astronomy has a Past, but that Past can have an important Future for research, teaching and outreach and in the IVO.

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The Future of Astronomy’s Past – Nuts and Bolts

Elizabeth Griffin

This article derives from a Discussion Meeting held during the AAS Meeting in Atlanta, 2004. About 50 people attended. In its inception the meeting was to be a repeat of that held in Sydney but with all-American participation. In fact the meeting developed the plans beyond the point reached in Sydney by focussing on the details of several of the key issues, and taking up the matter of a central repository with the PARI personnel who were able to be present.

The IAU discussion meeting was continued and extended in Atlanta in January 2004, at a special session of the winter AAS meeting. While it addressed the same basic issues as in Sydney, the Atlanta meeting proceeded to the discussion of details – the suitability of PARI as a plate archiving centre, how to organize the acquisition of plates, the merits of various types of scanner, whether to scan by programme or upon demand, how to prepare catalogues of archive contents, and where to identify the kinds of funds that will be needed. There were also two major differences compared to Sydney: not only was this audience entirely North American, but the key personnel from PARI were present (and had fact sponsored the meeting). Despite – or because of – this decidedly domestic flavour, the meeting began to build models that could work for North America, creating at the same time a system, a template and a proof-of-concept that could support the creation of parallel systems elsewhere.

PARI is the repository-designate for north American plates. Its site was a former NASA and then Government satellite surveillance centre, and when it formed in 1997 the site still contained some extremely useful equipment and facilities. It sounds like the answer to our prayer – abundant climatized storage space (some 120,000 sq. ft), powerful networking capabilities and geological stability. PARI's only obvious drawback is its relative youth, but its sponsors are working hard to secure sufficient funding to guarantee its survival.

Whether it is wise policy to plan a single plate store for all the north American plates is a slightly contentious issue, given that nowhere can be guaranteed totally safe from climatological or human destruction, whatever the odds; in a sense nothing is "safe" unless or until *all* the information on the plates thus stored has been transferred digitally. However, the existing situation is even more worrying; one has only to reflect on the Mount Stromlo fire (which did not in fact destroy the plates, largely because they had been "dumped" in a basement junk room), earthquakes at CTIO and floods in Europe, to say nothing of human indifference, to realize that the real perils presently facing a number of archives are in fact substantially greater than anything of a totally unexpected nature that could randomly occur at PARI.

One indispensable pre-requisite for any archival work is an on-line catalogue of an archive's contents. Lack of such an asset is a frequent moan by those undertaking archival research, and was highlighted throughout SCAN-IT I. Access to the log books is of course essential in those cases, and usually they can be found. A few of the major observatories – notably Kitt Peak, CTIO and ESO – intended that observers should keep their plates and never return them, and there is no record of where any of those plates may now be. The meeting felt that it would be advantageous if the astronomers who had observatory plates in their possession could arrange *and supervise* the return of their plates before they retired. However, returning plates to unmanned plate vaults is not necessarily a good idea; it would surely be better to send them all to PARI, where they could be reunited with the respective parent archives in due course.

The meeting considered the costs involved in packing and transporting major collections of plates, in the light of recent experience in dealing with a relatively small subset (about 2,500) plates from Michigan. The cost clearly depends on the size of plate involved; large Schmidt plates should be wrapped separately, whereas smaller plates can be packed in batches of a few; however, the ROE has frequently transported 14×14-inch plates – perhaps as many as 8 or 10 at a time – by packing them into an original plate box along with pads of styrofoam and an outer box of similar material. Labour has to be provided, though need not be specialist (and could possibly be bargained from the host observatory in exchange for the "plates service" rendered), and packing materials – especially bubble-wrap – are not cheap. At all events, the original storage cabinets, many of which were custom-built, should be sent along with the plates.

PARI's interests lie both in providing a long-term plate-friendly location for astronomical plates and in establishing a large-scale scanning facility. PARI can operate on three different levels: (a) rescuing archives that are actively in danger, and digitizing them later, (b) acquiring archives for routine digitizing, and (c) providing long-term storage for archives which have already been digitized elsewhere. In fact PARI has already come to the rescue of part of the Michigan plate archive as a matter of urgency; the transference of others with equally empty futures at their home observatories is also under discussion. Wayne Osborn (U. Central Michigan) has also offered short-term storage on his home campus for crisis cases.

Anticipating a stable, long-term future for PARI, the meeting tried to specify the most practical and beneficial mode for digitizing the collections of plates which will make their final journey to PARI. Just which is the most appropriate, as opposed to the cheapest or the most rapid, method for scanning plates is a question which exercised the meeting longest, and one which has no obvious "best" solution as long as money is a controlling factor. There are divisions of opinion as to whether a commercial scanner can adequately capture effectively all of the information; sampling theory states that to ensure no loss of information the sampling size needs to be one-quarter of the effective resolution. To a large extent the properties of the scanner may depend upon the particular science to be pursued – whether the emphasis is to be on positional accuracy or on photometric fidelity. Ideally one must aim to capture the greatest detail so as to accommodate all possible future uses and users. The equipment should have a high degree of repeatability, and should use transmission rather than reflective optics in order to minimize scattered light. However, not all collections would merit the time (and hence cost) of scanning with a purpose-built instrument; even if the scanning step-size for astrometry is 5μ, a stellar image may well occupy a few tens of microns, and the edges are never perfectly sharp. Thus a commercial scanner, costing of the order of \$30K, may prove fully adequate for some plate collections. The solution may be to install several scanners operating in different modes. But at all costs we need to guard against the possible need to re-scan plates, even if it means storing, maintaining and migrating large databases of image files.

A scanning programme needs to be flexible, but with agreed priorities as to the order in which to scan (project versus demand), and quality control; not all plates should necessarily be scanned. When it comes to funding (and here the meeting had no easy solutions) it is the scientific potential of the photographic observations which is the most persuasive element. While future astronomers may well produce ideas for projects that the meeting was probably unable to anticipate, the literature already contains a wealth of superb results that prove beyond question how historic observations are indispensable to our science. Unquestionably. the more such observations are readily available to the community in scientifically-meaningful units the more they will be used to complement and enrich the interpretation of more modern observations. Understanding and implementing the plate calibrations is therefore the duty of the scanning project, and should be costed along with the handling and scanning of plates.

It is worth reflecting that a preservation and digitization programme such as this does not have to be funded and implemented in a single step. Creating a contents catalogue, recalling, sorting or shipping plates are invaluable but relatively inexpensive modules, and could (for instance) be financed through an extension to an existing NSF grant, or through funds earmarked for preserving heritage. It is also worth remembering that this scanning project is not open-ended; the plates have only to be digitized once.

Update on Plate Digitization Project at the Maria Mitchell Observatory

Vladimir Strelnitski (vladimir@altair.mmo.org)

Digitization of all of the 8,000+ plates of the Maria Mitchell Observatory's plate collection was finished in Nov 2002 (see Sky & Tel, March 2003 issue). For details, please visit our Website at `http://www.aas.org/%7Epboyce/mma/plates.htm`.

A preliminary version of the catalog of the plates is now online, and we have already had several orders for digitized images. We mail CDs with image files for a modest price to cover the technical and mailing expenses.

Three image files in TIFF format were burned on a CD for every 8×10-inch plate – the 65 MB overview scan of the whole plate with resolution of 840 ppi, and two high-resolution (2,500 ppi) scans (550 MB in sum) of the western and eastern halves of the plate, with some overlap. The higher resolution corresponds to about 10μ on the plate.

The approximate equatorial coordinates of each plate's centre are given in our online catalog. Unfortunately, we cannot guarantee that all the images have the same orientation (North up, East left), although we tried to orient the plates for scanning this way, using some traditional MMO observer's marks on the plates. Although we believe that at least the bulk of the plates were scanned with this orientation, our clients will have to check the orientation of the image and flip it, if necessary. These are wide FOV plates (10°), and, generally, it is easy to check the orientation of the image by identifying, with an appropriate sky map, a few bright stars.

We set up two student projects, in which the students worked with digitized plate images:

(1) An investigation of the photometric reliability of the copies, which demonstrated that, at least for stellar photometry, the digitized images are practically identical with the originals (BAAS, 33, 1322, 2001, Abstract 10.13). We conclude that the commercially available, customized AgfaScan 1500 scanner is definitely sufficient to the task.

(2) A study of the limiting stellar magnitudes of the plates as various astronomical emulsions were used over the years. This information will enter the new version of our online catalog.

A remarkable gradual increase of the limiting magnitude, obtained with the same exposure time, during the 7 decades covered by the measured plates (from the 1920's to 1980's) was revealed in the latter project. If the best plates with the early astronomical emulsions, Speedway, Presto, and HiSpeed, showed limiting magnitudes 14.4, 15.7, and 16.4, respectively, the limiting magnitude on the best plates with the post-1950's emulsions, 103a-O and IIa-O (some hypersensitized with N2), are 17.4 and 17.2, respectively. An interesting result is the revealed dramatic decrease of the *dispersion* of the limiting magnitudes from plate to plate with time. The dispersion gradually decreased from about 3.5 magnitudes in the 1920s to 1.5 magnitudes in the 1980s. We conclude that the dispersion of the limiting magnitudes was due not only to the dispersion of the conditions of observations, but also to the quality and homogeneity of the batches of plates, which appears to have been dramatically improving with time. The details of this project will be reported by its student author, Alia Davis, and myself at the upcoming AAS meeting in Atlanta.

Notes from the DDO, Canada

Tom Bolton (bolton@struve.astro.utoronto.ca)

Shortly after I wrote my contribution for SCAN-IT 1, we were able to get our PDS 110A into operation. So far we have scanned only a few dozen plates required for high priority projects. Since those plates were scanned, my associate, Dr. Mel Blake, has been working on the on the data processing pipeline. That has been necessary because he discovered a bug in the IRAF `dtoi` routine, which is set up to work with short integers only.

As I wrote in my last report, we were successfully retrieving and archiving old PDS scan files from 9-track magnetic tapes, converting them to FITS files and writing the FITS files on CD-ROMs. Shortly after I wrote that, our tape drive ate a tape and committed suicide. We were unable to make the necessary repairs, so we had to search for a used, but working, tape drive of the same model. That took some time, but we finally got one about a month ago. We hope we'll be able to finish reading our tapes before the warranty runs out on the replacement.

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Why Digitize Plates?

Catching the Final Helium Flash of an Expiring Star

As a star finally cools from a red giant to a white dwarf it can undergo a thermal pulse when its helium shell ignites. The star then expands rapidly and brightens, but the phase may be too short to be detected. However, three stars (of FG Sge types) have been observed to undergo this critical stage. Such observations provide a rare opportunity to view a stage of stellar evolution proceeding on a time-scale of only weeks. Two of the events captured on plates were respectively 100 and 85 years ago.

One of those stars, V605 Aquilae, brightened by nearly 5 magnitudes in 1917–1919, and subsequently exhibited cycles of fading and brightening. Much later it was identified as the central star in a planetary nebula. Studies of those marked spectral changes suggest that the fading is due to a thick cloud of dust, rather than to an intrinsic variation in the star. Similarities between the different manifestations of the evolution of V605 Aql and other cool objects provide indispensable clues linking the different events to common evolutionary states.

Reference: Clayton, G.C., De Marco, O., 1997, AJ, 114, 2679.

Status of the Digitization of the Archives of Plates of the Italian Astronomical Observatories and the Specola Vaticana*

C. Barbieri[1], *C. Blanco*[3], *B. Bucciarelli*[4], *R. Coluzzi*[5], *A. Di Paola*[5], *L. Lanteri*[4],
G. Li Causi[5], *E. Marilli*[3], *P. Massimino*[3], *S. Mottola*[7], *R. Nesci*[6], *A. Omizzolo*[2],
F. Pedichini[5], *F. Rampassi*[1], *C. Rossi*[6], *S. Sclavi*[6], *R. Stagni*[1], *M. Tsvetkov*[8], *R. Viotti*[6]

Abstract. A large-scale national project to digitize the archive of plates of the Italian astronomical observatories and of the Specola Vaticana started in 2002, following a pilot program funded by the University of Padova in 2001. Identical systems, composed of commercial scanners plus dedicated personal computers and acquisition software, were installed in all participating institutes. Two more elements: high-quality photometric sequences with the Campo Imperatore telescopes, and the distribution of the digitized information to all interested researchers via the Web, complete the project. This paper presents some of the activities carried out and results obtained.

1. Introduction

Highly valuable information is stored in the photographic archives of many Italian observatories and in the Specola Vaticana. Several plates date back to the end of the XIX Century. A proper digitization of this veritable treasury is of paramount importance, both for its preservation and for the fuller exploitation of its scientific content. We therefore started a large national program (see Paper I and Paper II).

Among the many potential scientific uses of the digitized files, we intend to pursue the following: search for past transits of asteroids and comets, for a better reconstruction of their orbital and physical evolution; discovery and inventory of high-proper-motion stars; time-history of variable stars in the Milky Way and in external galaxies, of AGNs and QSOs; inventory of novae and supernovae in external galaxies; spectral classification over wide fields.

2. The Photographic Archives Census

Table 1 gives an estimate of the number of plates in archives of the Italian institutes and the Specola Vaticana. The total is too many to be digitized in a reasonable amount of time. A visual inspection of the material is therefore in progress in order to select the best material according to the priorities set by our scientific interests.

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[3] INAF and University of Catania
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[7] DLR Berlin, Germany
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Note: A version of this paper is now in press in Baltic Astronomy

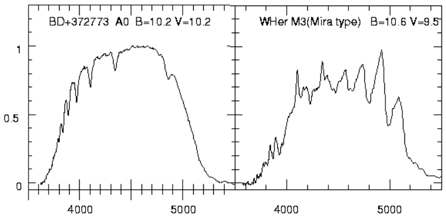

Figure 1: Spectral types of 10^{th} mag stars from an objective prism plate taken in 1972 with the Campo Imperatore S60

Table 1. Inventory of useful plates in the participating observatories

Archive	Type	Number of Plates	Dates
Italian observatories	Images	57500	1897-1998
	Spectra	26100	1951-1994
	Objective Prism	3100	1958-1998
Specola Vaticana	Images	8500	1894-1986
	Objective Prism	1326	1957-1986
	Polarimeter	30	1957-1986

The digital logbooks of direct imaging plates of all the Asiago telescopes, and of the objective prism spectra of the S67/92-cm and S40/50-cm telescopes are already on-line `(www.pd.astro.it/Asiago/)`. For the S67/92 telescope, an on-line query page is available (see `http://dipastro.pd.astro.it/ asiago/`), yielding data from the main fields of the catalogue, and a jpeg preview of the plates which have already been scanned. The query can be made by plate number, name or coordinates of the object. Use of these services by the international community is already very active. The logbooks in digital form from the other observatories are in advanced preparation, and should be completed before the end of 2003.

The Vatican archive is well preserved and ordered from the very first plate. The digitization of the logbooks is currently being done by the Bulgarian Academy of Sciences in Sofia.

3. The Hardware

Several commercial scanners with retro-illumination, resolutions of 1600×3200 dpi, format A3 or A4, output at 14 or 16 bits, have been purchased for Asiago, Padova, Catania and Rome. The same scanners are used by several other European institutes. The scanners are connected via USB2 or FireWire to dedicated PCs. Typical dimensions of the digitized files at 1600 dpi range from 70 MB for the 9×12-cm plates of the Asiago 122-cm telescope to 260 MB for the 20×20-cm Schmidt plates.

To store and distribute this large amount of data a NAS (Network Attached Storage) unit with capability of 0.5 to 1 Terabyte has been implemented in Campo Imperatore for NFS, FTP and Windows protocols. A second unit has been installed at Asiago Observatory.

The most serious limitation of the present hardware was encountered for fine-grained spectroscopic material. The resolution of 1600 dpi, coupled with the internally scattered light, is

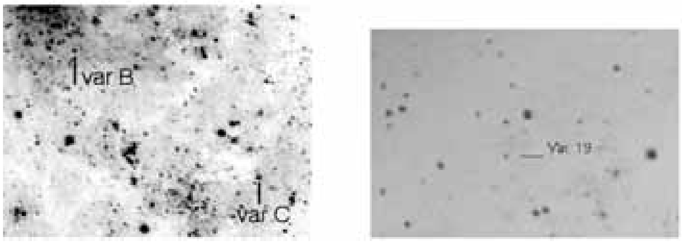

Figure 2: Variables in M33 (Hubble-Sandage, left) and in M31

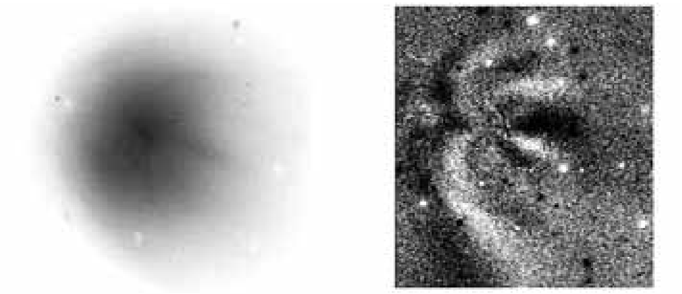

Figure 3: Comet Halley in 1910. Left: from a Vatican Astrograph plate. Right: from a Catania Astrograph plate, after a Sekanina-type filtering (courtesy G. Cremonese and R. Ligustri)

insufficient. However, for Schmidt objective-prism material and low-resolution spectra, useful work can still be done with the available equipment, as shown in Figure 1.

4. Plate Digitization

Data acquisition is performed via dedicated software that greatly enhances the ease of operation, working in a Windows operating system and providing as output a positive or negative FITS image, including a header. Typical digitization time for a S67 plate of 20×20 cm is 7 minutes.

More recently, at Catania Observatory a new tool (AstroPlates) was developed by P. Massimino in Visual Basic 6. AstroPlates requires IDL 5.4 or later versions. It simultaneously generates FITS and jpeg files.

Tests have been performed on many different types of plates, both with images and spectra, to determine the spatial resolution of the scanners as well as their astrometric and photometric precision. The effective spatial resolution is 16 μ/pixel, sufficient for the greater part of the direct plates in our archives, as shown in Fig. 1. The present activity of digitization is concentrating on images and objective-prism plates, well distributed among the several telescopes in order to gain experience with the different problems. More than 1000 plates have already been scanned. Figures 2 and 3 give some examples of digitized images. Figure 4 gives an indication of the attainable photometric accuracy for 3C 345.

As is well known (Barbieri et al., 1977) since 1967 Asiago Observatory has carried out a large-scale survey of Quasar Variability. In the past many plates were acquired and reduced with traditional methods (essentially by eye). Now we intend to repeat this work on the digitized

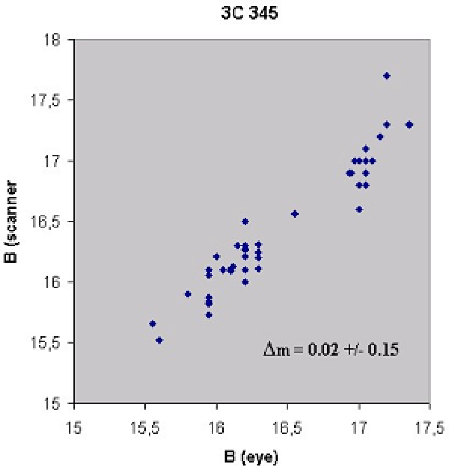

Figure 4: Comparison of digital vs. eye magnitudes for 3C 345

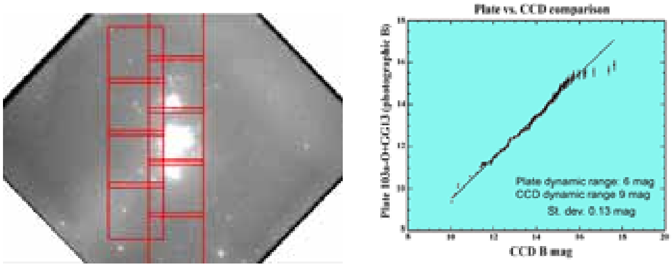

Figure 5: Left: CCD frames acquired in the M42 field. Right: CCD vs scanner B-photometry.

material using modern photometric techniques. Figure 4 shows that the digital data are in very good agreement with the traditional ones, whose intrinsic error is ±0.07 mag.

4.1. THE CCD PHOTOMETRIC PROGRAM

A crucial element of the national program is the acquisition of $BVRI$ sequences in selected fields, by means of the CCD camera of the Campo Imperatore Schmidt telescope; its field is approximately 1×1 sq. deg. Figure 5 gives an example in the Orion Nebula complex.

5. Future Plans

Our project aims to complete the digitization of the logbooks by the end of 2003, proceed with the digitization of selected fields of interest, define a common storage and retrieval system in order to make the FITS and jpeg files accessible to the general user through the Web, and start a call for proposals to the international community in order to digitize selectively those plates that give maximum scientific return.

The project calls for harmonization with the concept of the Virtual Observatory. We plan to coordinate our work with the Italian activities for the Datagrid and national Virtual Observatory (DRACO). As such, the use of the standards defined within the working groups of the International VO Alliance (IVOA) is envisaged, and we plan that our data will eventually be accessible to the community at large through the VO.

Acknowledgements. We acknowledge the support of S. Magrin, V. Mezzalira, A. Migliorini and G. Umbriaco (Dept. of Astronomy, UPd), E. Massone (Observatory of Torino), E. Catinoto (Catania Observatory).

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Barbieri, C., Omizzolo, A., Rampazzi, F. 2003, *Digitization of the Archive of Plates of the Asiago Observatory and of the Specola Vaticana*, Mem. SAI, 74, 430 (**Paper I**)
Barbieri , C., Blanco, C., Bucciarelli, B., Coluzzi, R., Di Paola, A., Lanteri, L., Li Causi, G.L, Marilli, E., Magrin, S., Nesci, R., Omizzolo, A., Rampazzi, F., Rossi, C., Stagni, R., Viotti, R. 2003, *Digitization of the Archives of Plates of the Italian Astronomical Observatories and of the Specola Vaticana*, Mem. SAIS, 3, 351 (**Paper II**)

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Why Digitize Plates?

Gamma-Ray Burster Investigations from Archived Plates

The conditions and mechanisms that trigger gamma-ray bursts (GRB) remain enigmatic, and are difficult to study statistically because of their unpredictability and their relatively low frequency of occurrence. There is evidence that some GRBs repeat their outbursts over time-scales of the order of tens of years.

Valuable information about GRBs can be gleaned by studying images of the pre-outburst positions. Deep plates in the digitized plate archives of the Royal Observatory Edinburgh (Scotland) and Sonneberg Observatory (Germany), can offer detections down to 23^{rd} magnitude, and are a particularly rich resource.

A long, historic archive can also provide insights concerning GRB recurrence through studies of recurrent optical afterglows. The position of the bright optical transient associated with a 9^{th}-magnitude GRB has also been investigated on Sonneberg Sky Patrol plates.

Reference: Hudec, R., Wenzel, W. 2001, Proceedings of the Fourth INTEGRAL Workshop, 423

Scanning the Solar Records at Mount Wilson

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A major grant was awarded by the NSF in early 2003 to Roger Ulrich (Principal Investigator) of the University of California (UCLA), to digitize the extensive collection of photographic white-light images of the Sun and Ca II and Hα spectroheliograms in the Mount Wilson solar archive. The collection dates back to 1893.

Roger reports that the project is going well so far, and that while it is not yet into full production several of the most essential steps are in hand. Raw scans have been made in test mode of one year of Ca II K images, and the team is now ready to commence the image extraction and conversion to single, fully identified files. Currently the reduction software is able to locate the sun's limb in those images; other necessary features (e.g. how to flatten the centre-to-limb gradient, or remove other unwanted image properties) are still under development. A scheme has been agreed concerning the form-based image distribution, but that aspect of the project is to come later.

Three people have been hired, to (a) manage the plates and carry out the scans, (b) identify the images and carry out a quality determination, and (c) begin the White Light Direct image analysis. An Eskographics Scanmate F14 scanner has been purchased, and appropriate scanning software has been installed. A 5-plate hanger assembly has been designed and fabricated, allowing 5 plates to be scanned simultaneously. Each scan provides up to 20 Ca II K images, and requires about 10 minutes of scanning time. All of the images from one plate are recorded into a single file, and UCLA-developed software is used to extract the sub-images from this composite file. Such a procedure is about ten times faster than anticipated, but requires a new step of sub-image identification.

The plates are also being re-packaged according to modern preservation standards. However, the repackaged plates cannot be returned to the present plate vault because they then occupy about a 50% larger volume, and the existing plate vault is practically full.

The logbook pages at the 150-foot tower have been recorded with a separate scanner. Those logbooks provide the fundamental database of the characteristics of each solar image; they are available on line as soon as they are scanned. The photographic sleeves housing the plates include a recording of the plate properties. If (as sometimes happens) the information on the plate sleeves differs from that in the logbooks, the differences are noted and the logbook information is adopted as being correct.

So far the data quality is very encouraging. There seem to be 12 bits of real data in the scans, and as long as the scanner is re-calibrated weekly its density range can be held such that it neither underflows nor overflows on the digitized images. The data are recorded as 16-bit TIFF images that can be read and converted to FITS files as necessary, and they can be conveniently displayed and studied using PHOTOSHOP. Things are not perfect: there is evidence of features in the "clear plate" that must have been introduced at the time the emulsion was deposited on the glass; there are also some grainy features that may indicate the onset of image decay. A set of movie reels, containing motion pictures of the solar Ca II K sun, was also found; unfortunately, some are in an advanced state of decay and will have to be disposed of since the data are not recoverable from that medium.

Royal Observatory Edinburgh
Update on Plate Library Holdings and Digitisation Programmes

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The Wide Field Astronomy Unit (WFAU), of the Institute for Astronomy of the University of Edinburgh and located at the Royal Observatory Edinburgh, operates the Plate Library and SuperCOSMOS, a fast, automatic microdensitometer. This note is an update reporting progress with the WFAU programmes described in *Royal Observatory Edinburgh – Plate Library Holdings and Digitisation Programmes*, which appeared in the previous issue of *SCAN-IT*.

Photography has now ceased at the UK Schmidt Telescope (UKST), located at the AAO in Australia. The Plate Library is the permanent archive for the exposures taken with the UKST. The final tally of exposures is ~19,000 (the last exposure is number 19408, but the sequence includes various test exposures). About 12,000 of those exposures were taken for individual research programmes rather than as part of surveys.

The digitisation programme of the SuperCOSMOS fast microdensitometer continues. The SuperCOSMOS Sky Survey (SSS) of the southern hemisphere is complete and available on-line. Scanning of glass copies of the POSS-II B_J and R in the north is in progress. 404 fields at high Galactic latitude, roughly corresponding to the area covered by the Sloan Digital Sky Survey, have been scanned. These data will be made publicly available in the next few months. Digitisation of the POSS-II B_J and R surveys should be completed during 2004. It is hoped to then start scanning POSS-II I and/or POSS-I E plates to provide additional colour and proper motion information, but the complete digitisation of these surveys will depend on funding and demand.

A new development is the SuperCOSMOS Science Archive (SSA). The SSA is a version of the SSS in which the object catalogues and other tables are stored in the relational database management system Microsoft SQL Server, rather than being held as simple files and accessed using locally-written software. The principal advantages of the SSA are that it provides faster and more flexible access to the data. For example, arbitrarily complex queries can be submitted using the standard database query language SQL. Currently only a small fraction of the SSS is available in the SSA, but it is planned to add the full dataset over the next few months. The SSA can be accessed at `http://thoth.roe.ac.uk/ssa`.

For further information on the surveys and for more general information on the WFAU, see `http://www.roe.ac.uk/wfau/`.

The Digitized First Byurakan Survey: Current Status

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Abstract

The Digitized First Byurakan Survey (DFBS) is a database of ~1900 FBS plates with low-dispersion spectra of ~20,000,000 objects brighter than 17.5 mag. It is the largest spectroscopic survey at high galactic latitudes, covering 17,000 sq. deg. It is a joint project of the Byurakan Astrophysical Observatory (BAO, Armenia), Universita di Roma La Sapienza (Italy), and Cornell University (USA). The FBS data were obtained with the Byurakan Observatory 1-m Schmidt telescope using a 1°.5 objective prism. The spectra allow us to select objects by spectral energy distribution (SED), broad absorption or emission lines, to classify them and to investigate them. At present all plates have been digitized with an EPSON Expression 1680 Pro scanner and stored on 85 DVDs. The astrometric solution process is active; spectral extraction and classification software, as well as wavelength and flux calibration, are being worked out. The FBS material will be available to the astronomical community through the Internet and on DVDs. A DFBS catalog will be created with all objects in it. New research projects based on the DFBS are possible.

The First Byurakan Survey (FBS)

The First Byurakan Survey was carried out by B.E. Markarian, V.A. Lipovetski and J.A. Stepanian in 1965–1980 with the Byurakan Observatory 102/132/213 cm (40/52/84) Schmidt telescope using 1°.5 prism (Markarian et al. 1989). 1874 Kodak IIAF, IIaF, IIF, and 103aF photographic plates in 1139 fields (4×4° each, the size being 16cm×16cm) were taken. FBS covers 17,000 sq. deg. of all the Northern sky and part of the Southern sky (Dec $> -5°$) at high galactic latitudes ($|b| > 15°$). In some regions it goes down to $|b| = 10°$. The limiting magnitude on different plates varies from 16.5 to 19.5 in V; however, for the majority it is 17.5 to 18 mag. The scale is 96.8/mm, the dispersion is 1800 Å/mm near Hγ and 2500 Å/mm near Hβ; the mean spectral resolution is about 50Å. Low-dispersion spectra cover the range 3400–6900 Å. Near 5300Å there is a sensitivity gap, dividing the spectra into red and blue parts. It is possible to compare the red and blue parts of the spectrum (easily separating red and blue objects), to follow the spectral energy distribution, to notice some emission and absorption lines (such as broad Balmer lines, molecular bands, He, [OIII] N1+N2 and [OII] lines, broad emission lines of QSOs and Seyferts, etc.), thus offering some understanding about the nature of the objects. The FBS is made up of zones (strips), each covering 4° in Dec and all R.A. except the Galactic-plane regions. In all there are 27 zones, which are named by their central Dec. The zones and the neighboring plates in RA overlap about 0°.1 (as the exact size of a plate is 4.1×4.1) thus making the whole area complete. Each FBS plate contains low-dispersion spectra of some 15,000–20,000 objects. There are about 20,000,000 objects in the whole survey.

The FBS was originally conducted to search for galaxies with UV excess (UVX). The discovery of 1515 UVX galaxies by Markarian and colleagues (later called Markarian galaxies) was the first and most important work based on the FBS plates (Markarian 1967; Mazzarella & Balzano 1986; Markarian et al. 1989). The study of Markarian galaxies enabled the discovery of many new Seyferts, the first spectral classification of that type of object, and the definition of starburst galaxies. The Markarian survey was also the first systematic survey for AGNs, and offered a new method of searching for AGNs.

The second part of the FBS was devoted to the discovery and investigation of blue (UVX) stellar objects (Abrahamian & Mickaelian 1996; Mickaelian 2000, and references therein). 1103 blue stellar objects were selected; they include the discovery of 42 new bright AGNs (Mickaelian et al. 2001). In addition the local density of QSOs and the completeness of the Bright Quasar Survey (BQS) (Schmidt & Green 1983) were re-estimated. The full catalog of FBS blue stellar objects is available at the CDS (Abrahamian et al. 1999). A survey for late-type stars on the FBS plates is being carried as well (Gigoyan et al. 2002 and references therein).

Optical identifications of 1577 IRAS point sources have been carried out on the basis of the FBS plates (Mickaelian 1995), 1178 of them being galaxies. The identification program contributed two samples of objects: BIS (Byurakan-IRAS Stars) (Mickaelian & Gigoyan 2001 and references therein), and BIG (Byurakan-IRAS Galaxies) (Mickaelian & Sargsyan 2003 and references therein).

The FBS has been especially efficient for searching for bright AGNs. Altogether 300 AGNs have been discovered in the above programs, as mentioned in the Catalog of QSOs and AGN (Veron-Cetty & Veron 2003). There are 3 catalogs at the CDS referring to objects discovered using the FBS: Markarian galaxies, FBS blue stellar objects, and Byurakan-IRAS Stars.

The Digitized First Byurakan Survey (DFBS)

Scanning of the FBS plates was started in June 2002 with an EPSON EXPRESSION 1680 Pro (A4 size) scanner. The plates were located on the scanner with the emulsion in contact with the scanner glass plate. Scanning was carried out in transparency (positive) mode controlled by a PC P-IV 1.5 GHz running under Windows-XP. An *ad hoc* program SCANFITS written by Stefano Mottola allows the resulting image to be written directly in FITS format in its header along with corresponding information about the plate. Automatic normalization of scanners does not work properly for astronomical plates. However, the scanner software options allow one to set manually the data density for the darkest and brightest areas of the image. A black paper sheet is used to cover one of the unexposed plate corners to allow a measure of the effective zero. We have scanned each plate by setting the lower limit on the black corner and the upper limit on one of the clean unexposed corners of the plate, taking care that in no case do the scanned values go outside the set numerical range. With those settings, the data numbers (DN) span the range 0 (dark) to 16383 (transparent). A 16-bit density range is available – the maximum for the gray-scale mode of this scanner. In practice the black corner counts are around 600 DN and the plate veil counts $\sim$14000.

The scanning resolution selected was 1600 dpi. The pixel size in this case is 15.875μ ($1''.542$), and the width of a spectrum occupies about 5 pixels. The length of an FBS spectrum is about 1.7mm, so we thus obtain 107 pixels along the wavelength scale, giving 32.7Å/pix dispersion on average.

The actual image size on the plates is 15×15 cm, so we have scanned this area with 9600×9600 pixels. The time for scanning one plate is about 10 minutes. We obtained a 175 MB file for each plate; 25 plates data could be stored on a 4.7-GB DVD. Table 1 gives basic data for the scanned FBS plates by zone.

Table 1: **The DFBS plate database**

Zone	Field	Plates	Area (sq.°)	Zone	Field	Plates	Area (sq.°)
+88.5	5	10	12.6	+35	55	96	849.6
+86	7	14	74.4	+31	55	101	851.6
+82	9	15	110.8	+27	56	106	842.8
+78	14	27	137.7	+23	61	100	900.8
+75	16	26	225.6	+19	60	108	909.2
+71	19	22	279.6	+15	58	108	897.6
+67	20	25	307.6	+11	62	109	959.6
+63	23	37	355.6	+7	65	99	970.0
+59	27	48	410.0	+3	68	99	1020.4
+55	31	52	474.8	−1	68	118	1022.0
+51	35	49	529.6	−5	67	100	1003.2
+47	45	64	678.4	−9	67	110	994.8
+43	57	88	836.4	−13	35	54	512.8
+39	54	89	840.4	All	1139	1874	17007.9

Data Reduction

Data reduction includes generating the plate solution (converting pixels to coordinates), wavelength calibration (converting pixels to wavelengths), and intensity and flux calibration (converting *DN* to *I* and *I* to flux).

A procedure for the plate solution (determination of the coordinate system) for the DFBS plates uses the *Tycho* catalog stars and IRAF. It is a manual process in a two-step procedure. The first requires the identification of a small number (about 20–25) of bright (<9 mag) stars from the *Tycho* catalogue. We assume the intensity peak in the red part of the spectrum as the star position (the centre of the circle at the red end). Then we overplot on the image the coordinates of the bright stars. A plate solution is then computed using the IRAF task CCMAP, and written in the FITS header. The second step is based on the first one and refines it. It uses all *Tycho* stars present in the field; the IRAF task CCFIND finds all those stars using the first plate solution, and then a second solution is computed and written in the FITS header as in the first step. A maximum possible accuracy is being achieved this way. At the end we attach the plate solution to the plate, and keywords are written in the FITS image header. We have actually 5 free parameters: x, y for the plate center (transformed into R.A. and Dec), rotation angle, and scales in x and y. The plate scale is 1.55 arcsec/pixel in the scanning direction and 1.54 arcsec/pixel along the CCD. The positional accuracy obtained is typically 1 pixel rms, quite sufficient for a safe object identification (recall that a spectrum is typically 5 pixels wide). The star identification and preparation of the input files requires about one hour. A cookbook with a detailed description of this procedure is available for users who ask for a plate that is not yet astrometrically calibrated.

To extract objects from the DFBS plates, we give their positions from the USNO catalog (Monet et al. 1996). This catalog-driven procedure is written as an IRAF script, including two simple FORTRAN programs for format conversion and checks. The list of all objects present in USNO-A2 down to the plate limit and included in the sky area is converted into pixel coordinates with the IRAF task CCTRAN. Then an image section of 21×150 pixels, including one well-exposed star, is selected and the spectrum is extracted with IRAF/APALL in interactive mode. This process allows us to derive the orientation of the spectra on the plate, and defines a template for subsequent automatic extractions. Finally, all spectra in the list are extracted automatically.

The wavelength calibration is rather tricky because no definite reference points exist on the spectra. We found that the red cutoff is rather sharp, so it can be used as a reference point but it is mildly sensitive to the brightness and spectral type of the object. For calibration, we use stars of intermediate brightness and types that have a definite red edge but are not overexposed. The sensitivity gap near 5300Å is used as well, as it is also more or less independent of object type and brightness. We use white dwarfs, subdwarfs, CVs, and QSOs with known redshift from the available catalogs which have broad Balmer, He, and some other (QSOs) lines. The reference points are λ(start) (3400Å), Hζ, Hϵ, Hδ, Hγ, He II 4686Å, Hβ, the "sensitivity gap" (5300Å), Hα, and λ(end) (6900Å). The calibration based on these points is sufficient for a coarse spectral classification. However, we plan to construct a good dispersion curve (and linearization), and after the extraction to transform all spectra into wavelengths. We derive a wavelength scale of 22 Å/pix at the blue edge, and about 60 Å/pix at the red edge, the mean being about 33 Å/pix. At Hγ, it is about 28.5 Å/pix. However, the spectral resolution is 1.5–2 times lower, as the photographic grains occupy 1.5–2 pixels.

The density calibration is made from the original data numbers (DN) according to the approximate formula $D = (V - B)/(T - B)$, where D is the (linear) density, V is the average DN value for the unexposed plate, B is for the black corner, and T is for a given pixel. The FBS plates do not have photometric calibration, so we cannot easily build a characteristic curve for each plate. However, we plan to use a typical curve for this type of emulsion to minimize the uncertainties and obtain the intensity (I) values. We have also made a number of trials to obtain an accurate sensitivity (response) curve for Kodak F-emulsion. Finally, we obtain the real SED for objects, and make a transformation for all spectra extracted. This will help significantly in the classification.

We also plan to make some rough photometric calibrations using photometric standards to facilitate a quick estimation of magnitudes from the FBS. It is estimated that up to 0.3 mag accuracy may be reached. However, we do not provide for photometric purposes; that should be done using the DSS database (e.g. data from the MAPS catalog, Cabanela et al. 2003). Plans for making multiband (UBVR) photometry are active. The estimated accuracy is 0.3 mag, though it will be 1.5–2 times lower for the V band, which falls near the sensitivity gap, as well as for the U (3660Å) for faint red objects, and R (6930Å) for faint blue objects, when the values will be near the background level (in fact, the R values will be systematically underestimated, as our spectra take only half of its bandwidth). To link our data to the MAPS (POSS) O (4050Å) and E (6450Å) magnitudes, we try to measure these values as well. In fact, these bands are better suited for our spectra, and they are being measured with higher accuracy.

Classification of the DFBS Spectra

We apply two different approaches. The first is based on creating template spectra for different types of object from available catalogs, and averaging their FBS spectra for each magnitude separately; the shape of the SED changes significantly from intrinsically bright to faint objects; for intermediate-type stars it is the same within reasonable limits. Then we search for similar objects (QSO, BLL, Sy, CV, WD, sd, M, C, etc.) among the FBS low-dispersion spectra. The success rate depends on the limits of given parameters: we can select either a small number of good candidates, thereby missing a fraction of all such objects, or a large number of candidates, thus picking up all objects of interest but including some contamination from other types. Thus a compromise should be made, depending on the given task. This method is good for a quick search for objects of interest.

The second approach is based on a numerical classification scheme for all FBS spectra. The classification principles are based on the relation between magnitude and width of the spectra (for separation into stellar and diffuse objects), SED, ratio of red to blue (color), length of the spectrum, presence or absence of broad spectral lines (absorption and emission), etc. The criteria of the classification scheme are worked out during the selection of blue stellar objects, red stars, and identification of IRAS sources. Our classification scheme will be linked to the general classification using standard objects of known types. This approach is good for working with all objects in the field.

The DFBS Catalog and Database

A catalog of all DFBS objects with positional, photometric and spectral information (some 20,000,000 objects) will be created after extraction of all objects from the plates. This will allow a quick access to DFBS without extraction of large 2-D images. It will be linked to most common databases (SIMBAD, NED, etc.) to make the work with objects easier. However, the complete DFBS database will contain all data on objects and their spectra. Many objects have two or more spectra from different FBS plates, so users can extract all of them for better understanding of their nature or to study variability, for instance. Both 2-D and 1-D spectra will be available. Each 1-D spectrum will be presented as a small table of 107 rows corresponding to recorded pixel data. The DFBS catalog, 1-D spectra and corresponding software will be written on DVDs (data for about 20 plates on each) and distributed to the main astronomical centres. The whole DFBS database will occupy some 100 DVDs.

A web page and user interface are in the process of being created. A preliminary site has been open at Universita di Roma La Sapienza (`http://astro1.phys.uniroma1.it/DFBS/fbs.htm`) since early 2003. A detailed description of the FBS and DFBS, instructions for making plate solution and extraction of objects, some example spectra, and the list of digitized plates are available. The list of all FBS plates (observational log) can be found in the Wide-Field Plate Database (WFPDB) at `http://draco.skyarchive.org/search_test/`.

The complete DFBS web page will be available at the end of 2004 in Byurakan, with mirror sites in Rome and Cornell University, as well as at the CDS. It will give access to full information on the FBS survey and DFBS, the catalog of objects, the database of 2-D and 1-D spectra, and classifications. A user interface will allow one to use the DFBS data together with the SDSS, MAPS, USNO and other databases, to extract spectra of any object present in the catalog, to compare the fields and data with corresponding ones from other surveys, etc. All this will create very efficient working with new (unknown) objects, especially for research in extragalactic objects.

DFBS will be a significant contributor to the Astrophysical Virtual Observatory, especially for its unique spectral information. There are plans to combine the DFBS with the Digitized Hamburg Quasar Survey as well (Engels 2002).

It is worth mentioning that FBS also initiated another large survey in Byurakan: the Second Byurakan Survey (SBS), with deeper limiting magnitude (19–19.5) but smaller area (~1000 sq. deg.) (Stepanian et al. 2003). The digitization of the SBS has been already started, and a similar database will be created as well.

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Solar-System Research and Photographic Observations

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1) QUAOAR is a Pluto sized Kuiper belt object. The discovery observations of QUAOAR where made in 2002, and allowed an orbit to be calculated. QUAOAR was then seen on a series of CCD images dating back to 1997. Armed with that orbit, the discovery team then went back to Kowals 1983 plates and found the object.... 20 years of arc guarantees that QUAOAR will not be lost, ever. In the words of the discovers,

"It was very hard to find Quaoar in these plates, we had to spend quite a it of time squinting through a magnifying glass to see it, but we have since digitized the images." Full details can be seen at `http://www.gps.caltech.edu/ chad/quaoar/precovery.html`.

2) S/1997 U1 and S/1997 U2 are two Uranian satellites, and were the first ground-based discovery of a Uranian satellite since Kuiper's 1948 discovery of Miranda. When we made this discovery we were quite hesitant: perhaps the object was actually a centaur; our 4 weeks of arc was not enough to decide. However, on the basis of our preliminary orbit we predicted the location of the satellites on Dale Cruikshank's plates from the 1980s – and eventually we found both satellites on those plates. We were then confident in our orbit, and announced the discovery.

These two cases – both typical of the way these things happen – convince us that many more discoveries of solar-system objects could be made and/or supported by scanning and/or cataloguing all the plate surveys that exist. We could have found QUAOAR and Sycorax 20 years ago if those plates had been scanned then. What else is waiting for us?

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Why Digitize Plates?

The Progenitor of SN 1987 A

Examination of historic observations of the region of Supernova 1987 A indicated that the progenitor star was a B3 Ia. It was not expected to become a supernova, and therefore it is important to learn as much as possible about its pre-supernova state in order to improve our understanding of the eruption.

Photometry of the object was carried out on a large sample of Harvard Plates spanning the period 1897–1947. No variability was detected in excess of $0^m.5$.

Reference: Plotkin, R.M., Clayton, G.C., 2002. Bull.AAS, 34, 1203

Understanding the Be Star Phemonenon

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Historical spectra have crucial relevance for our understanding of the Be star phenomenon. That subject bears directly on important questions about how circumstellar disks grow and develop, as well as on many related problems in hot stars of all kinds.

The newly-minted Be star δ Sco erupted in 2000, though it had been used as an MK standard and a photometric standard. Hα emission was apparently first noticed in the 1970s, although that date is questionable. δ Sco is also a spectroscopic binary with an eccentricity of 0.95, among the highest values known. Observations since its outburst have given us by far the most complete and continuous picture of the growth and evolution of a circumstellar disk, but we also need to know the spectroscopic and photometric behaviour as far back in time as we can go; history offers enormous potential in elucidating the nature of the binary orbit and of the disk. This and much more can be studied by re-examining the historical spectra.

There are nearly two dozen Yerkes spectrograms of the star; they covered the interval ∼1903–1909 as part of a survey to measure accurate stellar radial velocities; other sources extend the cover to 1978. As a by-product, many spectroscopic binaries and stars with “peculiar” spectra were found. Because δ Sco falls into both categories – and especially because its Be nature did not become apparent until nearly 100 hundred years later! – re-examination of those plates would be invaluable for evidence of any previous outbursts that may have gone unnoticed.

Emission in the higher Balmer lines may in fact have been visible on Yerkes plates taken in 1903. The velocities from those early plates were published in the same year, when two of the spectra appeared double-lined. In 1929 the velocities were re-published (along with additional ones), when they were curiously presented as “single line”; several were also revised. The Yerkes investigators clearly had reason to change their interpretation of what the plates showed. A fresh examination of the entire Yerkes series – as well as of series from other observatories – may show that the ”double lines” indicate weak central emission lines rather than a binary. Such a need for access to digitized historical spectra for study using modern techniques is most acute for understanding phenomena which develop and change over time scales of the order of a century. It is impossible to overstate the scientific value of such data.

One has only to point to the popular music industry for lessons on how to solve these problems. I can now listen to a re-issued “Blue Suede Shoes”, or Bruno Walter conducting a Brahms Symphony, first recorded fifty years ago. Surely we can do at least as well as Hollywood!

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A comment from Ejnar Hertzprung to Charles Worley in 1965 about double star data is equally applicable to the preservation and scanning of historical plates:

> “If we look back for a century or more and ask: What do we today appreciate mostly of the observations made then? the general answer will be: observations bound to time. They can, if missed, never be recovered. Of these observations, measures of double stars contribute a major part.”

(*Supplied by Thom Gandet (Lizard Hollow Observatory, Tucson, AZ, USA)*

Why Do We Need Sub-Micron Accuracy?

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1. Introduction

There is an ongoing debate about the best way to digitize photographic plates. Commercial scanners are appealing, with reasonable precision (a few microns) and low costs. Here we present results recently obtained with the StarScan granite-table measuring machine, showing that sub-micron precision and accuracy is really required for a "good job" in digitizing astrometric plates.

2. The AGK2 data

Between 1928 and 1931 the sky north of declination -5° was photographed on 1940 glass plates each covering over 5×5 degrees with 2 dedicated astrographs located in Bonn and Hamburg, Germany. The astrographs were of similar design; each had a 4-lens system with 0.15-m aperture and focal length of 2.0 meters, leading to a plate scale of 100 arcsec/mm. Data from both instruments were kept uniform. Two exposures of 3 and 10 minutes, respectively, were made on each plate. The plates were taken in a corner-in-centre pattern, so each area of sky was photographed on two plates. The emulsion used was fine grain and blue sensitive. Magnitude ranges for the measurable stars are from $B \sim 4$ to 12.

During the 1930s to 1950s, the measuring and reduction of the brighter stars was carried out by hand. The resulting catalog, called "Zweiter Katalog der Astronomischen Gesellschaft," (AGK2) was published in a series of volumes (Schorr & Kohlschutter, 1951, Vol. I), containing about 186,000 stars with positional accuracies of about 200 mas at the observational epoch. However, about 10 times more stars are measurable on the plates. Additionally, the inherent accuracies from the plate data for well-exposed images are at least as good as 100 mas; hence, if good reductions can be made and systematic errors can be handled, positions good to 50–70 mas (thanks to two exposures and the overlapping plate pattern) can be achieved. This combination of early epoch and high achievable positional accuracies makes the AGK2 plates a source of highly accurate proper motions (~ 1 mas/yr) for about 2 million stars.

The AGK2 plates were properly stored at Hamburg Observatory for the last 70 or so years and are still in excellent condition. In 2001, the Hamburg Observatory loaned all AGK2 plates to USNO for remeasurement.

3. StarScan measures

The USNO StarScan machine in Washington DC started to measure those plates in early 2002; measuring was completed by March, 2003. This machine has a large granite stage, 0.1-μ stage encoders, a temperature-controlled room and automatic plate clamping and rotation. All images on all plates are digitized in 2 orientations ("direct" and "reverse"), with 180° rotation between each. A CCD camera is used behind a Schneider telecentric lens. Stellar images on these fine-grain plates are as small as about 30 μ in diameter. Mapping by the telecentric lens is performed with a scaling of 1:1 onto 6.7 μ square pixels with a field of view of about 1300×1020 pixels, corresponding to 8.7×6.7 mm.

The machine is operated in step mode. A plate is digitized by moving the X and Y stages in steps of about 8 and 6 mm, respectively. At each location the stage comes to a stop and a short-exposure CCD image is taken together with a reading of the X,Y-stage encoders. There is no image smearing as with continually moving scanners. The cycle time is about 2 seconds; the digitization of a 200×200 mm plate takes about half an hour per orientation.

Two-dimensional Gaussians are fitted to the many images in each CCD frame, and care is taken to remove systematic errors arising from the lens system and measuring machine. All the following error estimates are per coordinate. The formal fit precision (1σ of the image profile fit) can be as good as 0.033 pixel = 0.22 μ. Because the model (Gaussian function) does not perfectly match the measured image profile, the derived fit precision value is likely to be worse than the actual errors of the centroid positions obtained. Extensive tests with a calibration dot plate (full measuring area of the X,Y stage) show a repeatability of the StarScan machine of $\sim$ 0.2 μ (Winter & Holdenried 2001).

The transformation of X,Y image centroid coordinates from the "direct" measure onto the "reverse" show a standard error of typically 0.5 μ when using the 300 or so brightest images per plate. That gives a measure precision of $0.5/\sqrt{2} = 0.35$ μ per measure, or 0.25 μ for the combined data of "direct" and "reverse". The residuals of the "direct−reverse" transformation also show remaining, uncalibrated effects from the footprint mapping, small magnitude equations and other distortions. From those we estimate an external accuracy of the StarScan measures of about 0.5 μ. With a plate scale of $100''$/mm that translates to 50 mas per coordinate for well-exposed stars.

4. External Results

Preliminary positions (α, δ) have been obtained for over 950,000 stars from a subset of 869 plates of the Hamburg zone data. Significant systematic errors as a function of magnitude, colour and X,Y-coordinates exist in the data (Zacharias et al. 2004). For well-exposed images, positional errors of $\sim$ 70 mas per star coordinate were already obtained with a somewhat crude modelling. With the $\sim$ 70 year epoch difference between that and the UCAC observations (see `http://ad.usno.navy.mil/ucac`), proper motions good to 1 mas/yr are obtained. AGK2 data for about 600,000 stars were included in the UCAC2 release. This is a factor of $\sim$ 2 better than previously best known (from AC2000 minus Tycho-2) for stars in that magnitude range, and comparable to the better Hipparcos stars!

5. Discussion and Conclusions

The above example clearly shows that sub-micron astrometric positions can be obtained from old photographic plates, as seen in an external reference frame (Hipparcos). Most of the error budget is still contained in modelling the measured X,Y image positions to coordinates on the sky. Without having X,Y measures better than what is "contained" in the photographic data these results would not have been possible. At least the AGK2 plates have the potential of about 0.5 to 1.0 μ positions, which can only be fully extracted with a digitization of the data on an accuracy level of or below 0.5 μ. To the knowledge of the authors there are only 2 machines worldwide which are capable of such accuracies: SuperCosmos in Edinburgh, and StarScan at USNO. All commercial scanners are not competitive by far.

In order to obtain best astrometric (and photometric) results from thin glass plates and photographic films the "flatness problem" has to be solved. Extensive tests at the StarScan machine have revealed that a vacuum suction system with an underlaying thick glass plate works perfectly. The emulsion-up surface remains unobstructed and can be measured just like a thick glass plate. A custom-made measuring machine, similar to StarScan, including options for film measuring, is currently planned for the Brussels Observatory for measuring astronomical and aerial photographic data to the accuracy level contained in the data (De Cuyper et al. 2003, 2004). The plans for StarScan are summarized in another contribution for this newsletter (Urban 2004).

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StarScan Measuring Machine of the U.S. Naval Observatory

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A summary of the StarScan measuring machine was provided in the initial SCAN-IT newsletter. Briefly, the machine – located at USNO Washington, DC – is designed for high-precision astrometry. Plates as large as 24×24 cm can be measured; accuracies in positions of images of better than 0.5μ are routine. The machine was originally built in the 1970s, but was modified in the late 1990s to take advantage of faster computing and better, cheaper optics.

The initial program of the modified system was to re-measure the AGK2 plates, exposed about 1930 and containing data from stars from about magnitude 5–12.5 north of -5 °. The measuring was completed in June of 2003. Since that time, the USNO has been working on obtaining the plates exposed at Hamburg Observatory (Germany) and Black Birch Astronomical Observatory (New Zealand) around ICRF objects. These plates, totalling about 3500, are currently located in Hamburg, but shipment to Washington DC has begun. It is expected that the measurements will begin in 2004 and will take about 1.5 years to complete.

The D4A Digitizer

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Abstract

The aim of the pilot project "Digital Access to Aero- and Astrophotographic Archives – D4A", financed by the Belgian Federal Science Policy Office (Project I2/AE/103), is to preserve the historic scientific information contained in the aerial photographic archives of the National Geographical Institute and the Royal Museum of Central Africa, and in the astrophotographic plate archive of the Royal Observatory of Belgium. In collaboration with the astronomical institutes of the Vrije Universiteit Brussel and the Universiteit Antwerpen, and AGFA-Gevaert, a world-leader in photographic matters, the goal is to acquire the necessary know-how, hardware and software to digitize the information contained in the photographic plates, as well as the associated meta-data. The project sets out to offer the results to the public and to make them directly useable for scientific research through the modern technology of the information society. A digital catalogue is under construction, as also is an air-bearing digitizer of high geometric and radiometric resolution and precision. This digitizer will be housed in a temperature and humidity stabilised clean room with an adjacent archive room.

1. Introduction

Digitizing a photographic image can be done "on the fly", using a digital detector moving with constant speed in one direction with respect to the photographic plate, i.e. scanning, or "on the step", using a digital detector at rest with respect to the photographic plate.

The digital detector, a CCD or a Complementary Metal Oxide Semiconductor-based camera, can have only one pixel (zero-dimensional), a row of pixels (one-dimensional), or an array of pixels (two-dimensional).

For most astronomical applications, overlapping digital sub-images can be used. Bright stars in the overlaps are used to tie up the whole image and to transform the measured X and Y positions on the image into celestial α and δ coordinates. Aerial photographs need to be digitized as raster images, requiring an accurate stepping with an exact number of pixel sizes in both the X and Y directions. The digital image can be stored as a tiled file containing the individual footprints as sub-images. The accuracy of the photographs depends on the type of emulsion used, the type of substrate (glass plate or polyester film), the optical quality of the instrument used, the exposure time, etc. Astrophotographic images can have a density range of 5 (i.e. a grey scale or density ranging from 1 to 100,000) and sub-micron stellar position accuracy.

2. Commercial Scanners

Commercial colour scanners normally use three one-dimensional CCD rows for simultaneously creating on the fly a red, green and blue (RGB) digital image. Each CCD row usually has an adjacent row that is covered up. At the end of each integration or exposure the electrons created by the incident light falling on the exposed rows are quickly clocked to the adjacent blacked row and read out by clocking them into the ADU (Analogue to Digital Unit) converter at the end of the row. As the detector moves at constant speed in one direction during the integration, a part of the image that is captured by an individual pixel also falls on it during the next integration, while the time the light coming from a point of the original image is projected on a pixel also varies. Hence, the way traditional scanners work means some of the finer details of the image are smeared out over the neighbouring pixels, creating a soft-looking digital image. In certain photogrammetric scanners (like the PS of ZI) it is possible to reduce the integration time and the neighbour overlap by creating a dead time between the integration intervals in order to produce a "hard(er)" image. Most commercial scanners also apply an image "sharpening" filter in order to make edges look sharper. The level of detail in astro- and aerial photographic plates requires a very high optical resolution and precision to produce high geometric and radiometric accuracy in the digital copy, and precludes the use of commercial scanners for the digital archiving process.

3, The D4A Digitizer

The D4A project will develop a two-dimensional plate digitizer that will operate on the step in order to create a precise digital optical copy of the original image. A photographic image is made up of an irregular distribution of developed grains of varying sizes, whereas a digital image consists of equally spaced and sized square or rectangular pixels. In order to capture the level of accuracy of the analogue photographic images as closely as possible, a digital detector is needed with at least a 10-bit ADU read-out and a pixel size of about 5μ (De Cuyper, 2002). The huge number of exposures requires the use of an electronic shutter. We will mount the digital camera above the plate, perpendicular to its surface, and use an air-bearing open-frame XY table to allow us to position the plate with a geometric accuracy of some ten nanometers. A two-sided 1:1 telecentric lens will be used to ensure that, if the original image is not perfectly flat, the introduced error will only slightly enlarge the projected image of a point source, while keeping it isotropic and without displacing it. The part of the footprint of the telecentric objective that is used will be limited to its central area where the distortion is less than a pre-defined maximum. In this way an "optical" contact copy of the original image onto the digital detector will be achieved. In order to be able to reach and maintain a high geometric and radiometric accuracy, the digitizer will be placed in a climatized clean room, at a temperature of $18°C \pm 0.1°C$ (1σ) and a relative humidity (RH) of $50\% \pm 1\%$ (1σ).

The D4A digitizer will be able to digitize photographic greyscale and colour images and spectra on glass plates and polyester film sheets as well as on film rolls, to an extremely high level of precision. (See also the notes on SuperCosmos, N.C. Hambley et al. 1998, and on StarScan, L. Winter and E. Holdenried, 2001). The photographic plates will be put emulsion side up in a square plate-holder with an opening of the same dimensions. Through the use of pneumatic cylinders, the plate-holder is pushed up to bring the outer edge of the emulsion in contact with an equally-sized counter-pressure plate, in order to place the top of the emulsion layer in the focal plane of the digital camera. For thin glass plates (Schmidt plates, etc.) and film sheets or rolls the plate-holder contains a supporting glass with a groove on the sides. The thin plate or film is kept flat by pumping away the air between it and the supporting glass plate after the counter-pressure plate is engaged. The illumination will be in transmission mode, using a diffuse light source. In order to allow the digitization of colour images an RGB filter wheel will be placed in the light path. A neutral-density filter wheel is used to regulate the light intensity as a function of the density level of the photographic image.

In order to automate the digitization process in the most stable possible conditions, a film roll transport system mounted on two opposite sides of the inner open airbearing frame will automatically spool the film roll to put the next image above the plate holder, while next to the granite table a turntable and a plate holder stack will be designed, operated by two pneumatic arms to exchange plates or film sheets.

4. Climatized Archive Room

Photographic plates contain a distribution of (silver) grains embedded in a gelatine layer fixed on a glass plate or polyester sheet. They are very sensitive to changes in temperature, relative humidity and chemicals, and are at great risk of degradation through chemical reactions from fingerprints, humidity causing destructive fungi, and so on. Most photographic collections are stored in conditions that are far from ideal. In order to assure the lifetime of its astrophotographic plates, the Royal Observatory is constructing a climatized room that will be kept at 18°C and 50% RH and is large enough to become an international plate archive centre.

5. Benchmark

The most important quality parameter of a measuring machine is its geometrical stability. Hence the benchmark procedure has to include a very simple test, which measures the stability of the machine: A target (for example, one dot on a dot plate) is moved into the centre of the field of view of the digital camera and a number of pictures are taken, while the XY-table is held on that position under servo. Analysing the images, in fact centering the dot and measuring its position with respect to the digital detector, will reveal thermal movements, jitter and mechanical noise in the system. In addition we get an estimate of the centering error of the dot. This tests "static" repeatability, as the position of the XY-table is not being changed.

The next important test is the dynamic repeatability. The machine is moved in a repeated pattern and a different point of the dot plate is put in the centre of the field of view each time the position changes. After the whole plate area has been covered, we start again with the first point. The better the machine can go back to the same position after one pattern has been covered, the better its dynamic repeatability. It is useful if the test includes at least two points that will make a back and forth motion possible, so as to get a measure of the bi-directional repeatability as well. A minimal pattern consists of nine points: the centre, corners, and mid-points between the corners of a square that covers most of the measuring area of the XY-table.

The last and very conclusive test of any XY-table is the measurement of a calibration plate with known accuracy. This would be a measurement of geometrically very precise chrome dots on glass plate. The measurement determines the metric accuracy of the machine as compared to normal (i.e. with the geometric dot plate). Another way to do this test is to use a calibration laser. Both results should be compared to give the best understanding of the behaviour of the machine. The systematic errors found can then be corrected by tabulating them into the positioning software of the XY-table.

6. Testing

This project will also study in detail the technique of first making an analogue copy on roll film, allowing unattended all-time scanning, and the photochemical cleaning of plates containing fungi or ageing deteriorations, in order to determine the introduced geometric and radiometric deformations and hence their applicability for this scanning project.

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Why Digitize Plates?

Light Variations in Young Stars

T Tauri stars are young objects in the late stages of formation. Short-term changes are well known, and are keenly studied since they can indicate activity of unusual significance. Evidence of associated accretion and dispersal of the parent material can contribute vital information about the mechanisms of star formation, particularly in regard to the condensation of planets. The time-scales are well within the compass of most plate archives, so researchers have been delving back in time in order to quantify the evidence that can be gleaned. Our understanding is further heightened when historic optical data are combined with modern multi-wavelength observations.

The T Tau star KH 15D was recently found to exhibit eclipses though none was reported previously. Measurements of plates taken between 1909–1988 confirmed that the deep eclipses observed today did not occur in the first half of the 20^{th} century. This sudden onset of eclipses can best be explained if KH 15D has a proto-planetary disk that is seen nearly edge-on. The observations may therefore be signalling the actual formation of planets around a young star.

Variations in other T Tau stars were ongoing throughout last century, and consist of fluctuations of 2–3 magnitudes of differing time-scales, with (in some cases) much shorter flickering as well. On the other hand, T Tauri itself showed such light fluctuations prior to 1917, when they ceased abruptly and have not re-started.

The precise nature of the variations and their lack of periodicity in T Tau suggest variable extinction along the line of sight that has now cleared away. However, although part of the fluctuations in all T Tau stars may be attributable to such extrinsic causes, the lack of comparable variability in the vast majority of other stars indicates intrinsic causes too. Much more archival work is required in order to sift and analyse the intrinsic causes and their implications for stellar and planetary formation. These recent studies have made use of only the Harvard archive. There can be no doubt that many more examples are waiting to be unearthed elsewhere.

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A High-Speed, High-Precision Scanner for the Harvard Archive

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1. Introduction

At Harvard College Observatory (HCO), we have been investigating the requirements for a high speed, digitizing platform for the large collection of photographic plates (~600,000) that were collected between 1882–1989. This paper details some of the results of that investigation.

2. Archival Requirements (Film to Digital Pixel)

One of the first questions to arise when setting requirements for scanning a photographic plate for archival purposes is, "What size pixels are needed to capture all of the information on the plate?" There is a general awareness that photographic emulsions contain silver halide crystals that become chemically activated by photons, allowing them to turn into silver when developed. What is less well known is that, as the crystalline grains are developed, they turn into silver filaments. Page 391 of *The Theory of the Photographic Process* (James 1977) explains how "a very small silver halide grain can be developed to yield only one filament per grain; a large grain commonly forms a mass of many filaments that roughly resembles a wad of steel wool in structure." Figure 1 shows a very high magnification microphotograph of developed silver filaments. Figure 2 shows two stages in their development, to illustrate how the grain grows from a small crystal to a large filament, while Figure 3 shows that different halides form similar but different filamentary tangles (James 1977, p. 376).

Comparing the undeveloped crystal sizes of the film to the pixel sizes of a CCD imager is not a good way to understand the information content that can exist in the exposed and developed emulsion. To understand the granularity of the information captured on film requires a more complex analysis. Kriss (1988) and Kriss et al. (1989) quantify it thus: "Traditionally, film-based systems have been defined in terms of resolution or modulation transfer function (MTF). The problem is then to equate a film MTF to an effective equivalent number of square pixels as would be on a CCD imaging sensor. The one dimensional MTF for a sensor is given by $\mathrm{MTF}(\nu) = \sin(\pi D\nu)/\pi D\nu$. If we normalize the measured film MTF and the ideal sensor MTF at the 50% point as shown in Figure 4, we can relate the size of the imaging aperture of size D to the 50% response frequency ν_0 by the equation $\pi D \nu_0 = 1.9$. Using that result and the measured MTF values for film, the effective pixel aperture D can be calculated for each film. Table 1 shows the effective pixel size for common film speeds." This matches well with the common knowledge that "faster" films are grainier. Old astrophotographs are not well characterized to the ISO scale, but from this analysis it would seem that a pixel size in the 10–11μ region should capture the information on even the best of the old plates. Experimental work with plates from POSS II has also indicated that scanning pixel sizes of 15μ and below capture the information on modern plates (Laider, Lasker & Postman 1992).

3. Photodensity Requirements

The requirements for photodensity measurements are another consideration in the scanner design. The smallest star image on a plate will be of the order of 25–30μ. That size also usually represents the limiting magnitude recorded on the film. Studies have shown that, for the PSS plates, the star diameter increases linearly by about 25μ per magnitude over about a

Figure 1: Filament of silver.

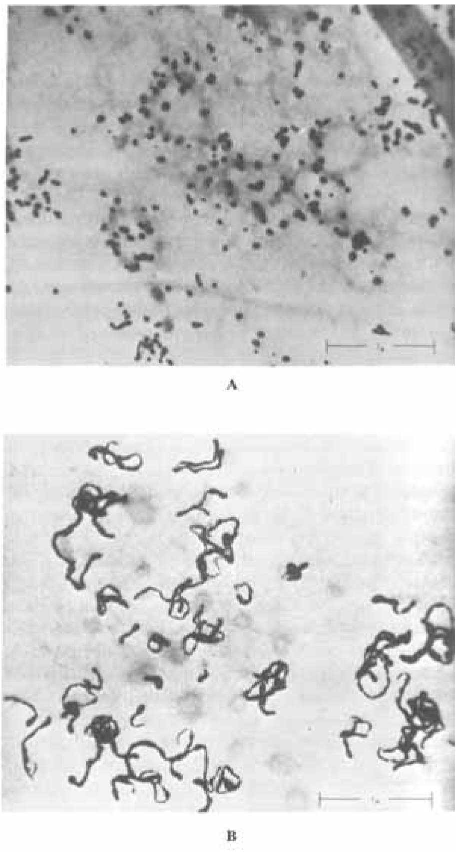

Figure 2. Grains during development. Top: early stage; bottom: later stage

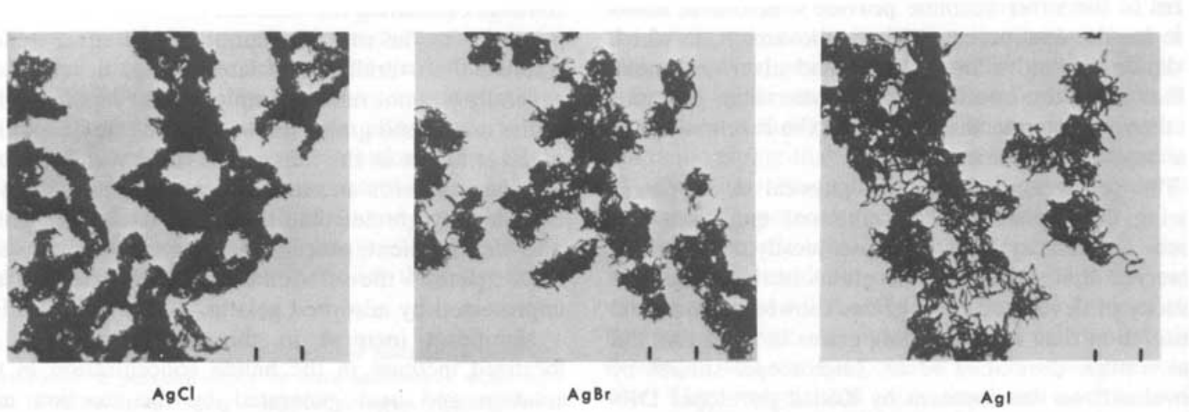

Figure 3: Different halides have somewhat different filament growth patterns. Left to right: AgCl, AgBr, AgI

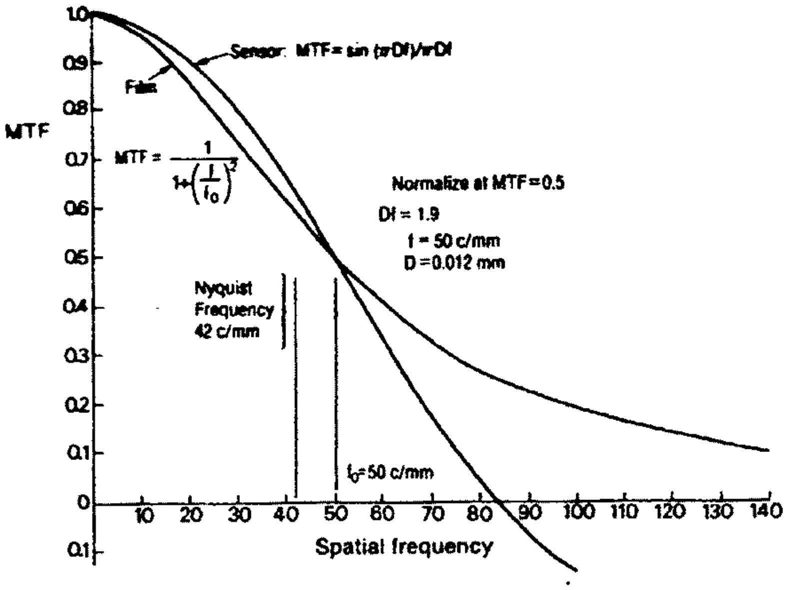

Figure 4: A method to calculate the effective pixel size that can be associated with photographic film when a frame transfer device with square pixels is assumed as the sensor model. The curve shown for film is based on a theoretical model and does not represent a particular film

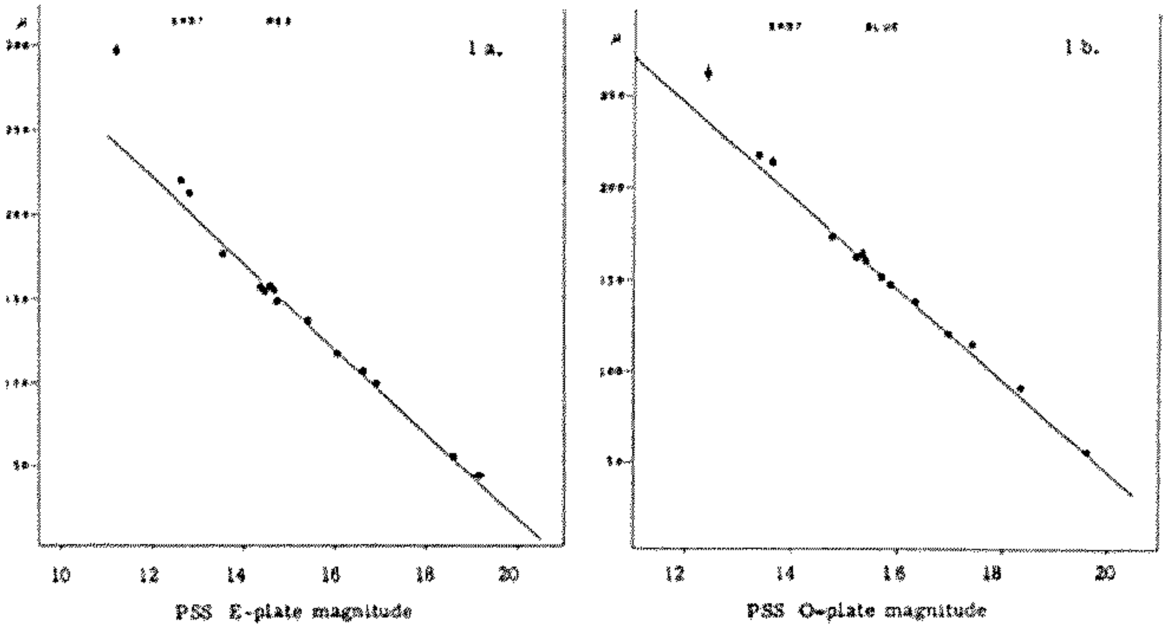

Figure 5: Star Diameter *vs* magnitude

Table 2: Film Equivalent Pixel Sizes

ISO Speed	Pixel Size
100	12μ
200	14μ
400	19μ
1000	26μ

10-magnitude range (Figure 5) (Klinglesmith, 1983). With 10–11μ pixels, there will be at least 2 pixels per diameter of a limiting-magnitude star image, which satisfies the Raleigh criterion for sampling information reliably. For our scanner design we will use cameras that digitize to 12 bits. That precision is the best available in high-speed (5–10 FPS) cameras, and it matches well with the truly achievable dynamic range of the CCD chips. Some commercial scanners have 14–16 bit A/D converters, but with pixel sizes in the 4–5μ region and full well capacities of 65Ke for the linear array pixel each A/D step may consist of a single electron, and electrical noise in the system is likely to be many hundreds of A/D units. For a more detailed discussion of the realities of scanner specifications, see `http://www.scantips.com/basic14b.html`.

Because our plates are negative sky images, the background is really determined by the relatively clear emulsion areas. Histograms of digitized plates show that this "background" is generally a Gaussian distribution over about a third of the digitization range at the white end. The whitest part will consist of blemishes and scratches in the emulsion that allow the brightest transmission through the glass plate alone. The emulsion itself and random developed grains provide the rest of the "white" sky background. For the scanner it will be imperative to pay close attention to the gray flat-fielding, particularly in the region of 2/3 towards the white. Much work has been done on using the immediately local background on the plates to identify star images that are close to the background level, because there is often a large variation in background across the plate owing to localized differences in developing and fixing solution action, residual chemicals, and collected dirt and dust from decades of storage.

4. Astrometric Requirements

Astrometric measurements are based on an accurate grid for measuring star positions. The primary ruler is the CCD chip itself. There are three potential chip types to consider: a linear array, a TDI array, and an area array.

A linear array is used in most commercial flatbed scanners. The pixels are aligned to the X dimension and imaged with a lens to cover all or part of the flatbed area in that dimension. Since the array is only one pixel deep it must be moved in the Y direction each pixel time to capture the data; the line integration time (~8–10μsec) adds up, and it must take 10–20 minutes to scan an 8×10-inch plate at high resolution. The linear array is usually moved by a stepper motor that drives the scan head down one or more steel rods. The accuracy that can be achieved with this arrangement is in the range ± 7–20μ, and is of the order of a pixel or two in both X and Y directions because of the tolerances of the screw and the wander in the rod and slider. This kind of system is an open loop system where the accuracy must come from the mechanical components.

An area CCD array speeds up the scanning by having pixels over an area that includes both X and Y dimensions. The ATMEL sensor that we are considering using, for example, is a 4K×4K CCD with pixels 11μ square. That chip provides a square grid that is 45mm on a side. An X–Y table is used to move this two dimensional "ruler" around the scanning area, making an effective 11-μ grid across the entire plate. Air bearing, linear motor table movements can have a step precision of ~20–100nm and local sub-micron absolute accuracy, which is of the order of 0.1 pixel or less. However, to achieve that level of accuracy the table servo system needs time to settle into the desired position to 0.1 pixel, which it does through feedback from the table encoders, and in all that takes from about 100ms for a very short move to about 400ms for a move of 25mm. The table settling time and the size of the array determine the scan time for this type of scanner. Positional information from the table and the chip plus the photodensity information allows interpolation of the centroid of a star image to about 1–2μ precision even though the measuring "pixel" grid is 11μ. Moreover, achieving that level of accuracy and precision is not inexpensive. Capable tables will today cost $60–180K, depending on specification..

The TDI sensor fits into the picture somewhere between a linear array and an area array. It is a linear array with a CCD at each X pixel location that extends in the Y direction and allows the CCD clock to move the integrated charge for the pixel down the CCD in lock-step with the moving image. This arrangement allows the plate to move during the integration time, thus speeding up the scan. The speed up of such an arrangement is directly related to the number of CCD stages orthogonal to each pixel, and is typically in the range 64–128 times. These sensors are often used for surveillance cameras in moving planes, satellites, or conveyer-belt inspection equipment. The major problem with using them for photometric and astrometric work is that the final integrated pixel contains smeared information from areas above and below the actual desired pixel region because the image is moving even as integration is occurring. It is also difficult to synchronize the exact location of the table with the pixel location on the image.

5. Plate Sizes and Speed of Scans

Harvard's plate collection consists largely of two plate sizes: 14×17 inches (~35,000 plates) and 8×10 inches (~400,000 plates). Our proposed scanner needs to have a working capacity large enough to handle the large plates. That working capacity also allows the alternative loading of two of the smaller plates, and the proposed table configuration optionally allows scanning of both plates simultaneously, by incorporating two cameras. In order to make the human handling of the plates the limiting factor in scanning the collection, we set the goal that it should take no more than ~30 seconds of table movement to capture a plate digitally. If the overall plate-handling process, which can be effectively pipelined for many activities, takes ~1 minute per plate, then it is feasible to scan the entire Harvard collection over a period of about three years by running a single-shift operation.

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Why Digitize Plates?

Long-Term Astrometry and Photometry of Globular Clusters

Access to well-maintained archives of direct plates is proving invaluable for studies of globular star clusters. Astrometric measurements of stars observed decades apart allow one to reject accurately the cluster non-members to an unprecedented degree of completion.

When such pure segregation of the cluster stars becomes possible, as in a recent investigation of the M4, involving measurements dating back to 1896, the detailed properties of the cluster could be examined properly for the first time.

The study revealed a reddening gradient across the cluster; when that was removed the colour-magnitude diagram was even more tightly defined. Cluster membership of previously suspected variables was also confirmed, and new variables were identified. A new measurement of the space velocity demonstrated that the cluster has a curiously small component out of the plane.

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Photometric Variability in 3C 273?

Ever since a tentative light-curve for the discrete radio source 3C 273 was published in 1963, when its identity as the first so-called quasi-stellar object (quasar) was established, interest has focussed on the reality of a possible periodic element in that photometry. Should 3C 273 prove to have a component of periodic variability, that would argue strongly for the source of the quasar energy residing in a single massive object.

942 photometric measurements of 3C 273 were collated from 12 different plate archives spanning 93 years from 1887–1980. Data were selected from the same source where feasible to ensure homogeneity, and all measurements were reduced to the same system in order to avoid spurious systematic effects. While strictly period modes of variation for 3C 273 could not be established in the 93-year span investigated, some segments of the light curve certainly suggested non-random fluctuations. 3C 273 seems to define a class of quasars that have an energy release on a time-scale of 10–20 years. Our understanding will only be improved by regular monitoring in conjunction with the historic data.

Reference: Angione, R.J., Smith, H.J., 1985. AJ, 90, 2474

The Plate Measuring Machine of the US Naval Observatory

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The USNO Plate Measuring Machine (PMM) has been idle for about a year, and that there are no plans to scan more plates. Given the USNO budget, the future of PMM is in doubt. Were external proposals for scanning to appear, they would need to include funding.

Speaking off the record, I believe that the USNO would be open to proposals to give, or indefinitely loan, the PMM to institutions that could accept the "as is, where is" terms that USNO would require.

The machine is not yet due for retirement; the granite, air bearings, lasers, and mechanical components have life, but the 386-based control computer is well beyond its design lifetime and would definitely need replacing.

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Why Digitize Plates?

The Mass of the Well-known Bright Star Procyon

For decades the bright standard Procyon (α CMi), a visual binary with period of about 40 years, presented a long-standing problem for astrometrists and theorists, since the mass of its F5 IV-V primary has failed to agree with that derived from astrometric orbit. The disagreement of 0.25 $M_\odot$, or 16%, five times the quoted uncertainty of ± 0.05 $M_\odot$, has constituted a serious embarrassment to stellar evolution theory. On the one hand, it was baffling that theory should disagree with observation by such a devastating margin, while on the other, if that was the actual size of the discrepancies for one of the brightest and best-observed systems then the disagreement did not augur well for measurements of all the fainter binaries.

The astrometric mass was recently redetermined from measurements of over 250 direct plates spanning 83 years, coupled with modern coronographic and *HST* measurements. The new value agrees with the evolution calculations to well within the stated uncertainties of ± 0.037 $M_\odot$. The redetermined parallax is also significantly smaller than that measured by *Hipparcos.*

On the basis of the photographic astrometry, a major long-standing discrepancy between theory and observation has at last been resolved. The physical parameters of the binary have now been determined to a precision that can be expected of modern technology. (However, the discordance between the new value for the parallax and that recorded in the *Hipparcos* Catalogue has not yet been fully explained).

Reference: Girard, T.M., et al., 2000, AJ, 119, 2428

Notes from the Harvard Plates Archivist

Alison Doane (adoane@cfa.edu)

Our experience with commercial flatbed scanners has taught us that they have merit in defined, circumscribed situations. At present, most of the middle of the flatbed-scanner market has gone out of business. The UMAX PowerLook 3000 ($5,000 US) stopped being produced several months after ours was purchased. The Agfa scanner used by Maria Mitchell Observatory is no longer produced. If you wish to purchase a mid-range scanner, we would encourage you to investigate the Tekgraf TDS 1130 and the creo IQsmart series. The Tekgraf is sold in the UK as the Fuji FineScan 2750XL. Both of these scanners sell for approximately $14,000 US, with an additional $2,500 per year for a service contract.

Although we experienced many months of technical problems with our UMAX, those problems have been solved for the present, and the scanner performs a valuable service to the plate stacks. Scientists are able to scan small, discrete areas around the star they are studying – just enough to include some comparison stars – and can then put many such images on an ftp site. They then process these images using IRAF, sometimes with impressive results. We have found a recent surge of interest among young postdocs and graduate students in studying our plates in this manner; prior to the purchase of our scanner our youngest visitors were in their mid-forties.

From a preservation perspective, any increased use of old archived data serves as an important protective device in warding off threats to close down the archive. Therefore, from a political perspective, a commercial flatbed scanner can function as a preservation device.

Having made this positive statement for commercial flatbed scanners, we would like to state some negatives. They are designed for the commercial market which is primarily concerned with colour images; hence the engineering behind commercial scanners has thrown a great deal of effort into improving the sophistication of colour reproduction. This sophistication is actually an impediment when scanning plates in grayscale mode, as we are doing with the Harvard plates. It inflates the price of the scanner unnecessarily, and also makes the software unnecessarily slow and complex. If your goal is to scan the entire plates and not discrete portions of plates, time becomes a large factor – optimistically, one could complete a single grayscale 1200 dpi 14-bit scan of an 8×10-inch plate in 20 minutes. At 3000 dpi, the time is more than doubled. The emphasis upon colour design can also lead to ongoing failures with the scanner hardware that disrupt production.

From the perspective of digitizing a large archive of black-and-white negatives, it is best to use a scanner whose engineering has focused upon speed, positional accuracy, and robustness. No such scanner exists, which is why our present thrust is toward seeking funds to produce a custom designed scanner.

CORRESPONDENCE

How can we organize a general recall of scattered plates?

Sue Tritton (sbt@roe.ac.uk or ukstu@roe.ac.uk) writes:

Regarding the question of a general recall of plates, I think this is now URGENT. If you think of the major plate archives, many no longer have anyone looking after them.

In the Plate Library here in Edinburgh we have various photographic plates "dumped" on us by astronomers (mostly no longer active in research) "for safe keeping". Some of these I can identify as having an obvious home (e.g. ESO, AAO, etc.) – but in many other cases, although I can identify the original telescope I would not know what to do with the plates. Those plates are effectively "useless" in Edinburgh but could be valuable if in a suitable archive and properly catalogued. I am worried that when (for example) vacated rooms are cleared in preparation for new staff at an institute, any plates that happen to be stored there may just be thrown out rather than returned to the correct places.

I am also having great difficulty in persuading astronomers who admit to having UKST plates which they no longer want or use to return them – even though I send them suitable containers and, in some cases, agree to pay the shipping costs!

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Why Digitize Plates?

New Phenomena in Stellar Variability Patterns

The Sonneberg plate archive – a collection of some 270,000 plates dating back to 1926 – is in process of being digitized. 300 stars, chosen more or less randomly in the Orion/Taurus/Auriga region, were examined for variability on 500 plates taken between 1960 and 1966.

The results were surprising: significantly more than 50% of the stars investigated proved to be variable. Some are irregular variables, some have cyclic variations with periods of 1000 days or more and amplitudes of several $0^m.1$; others brighten and fade slowly over decades with amplitudes of a few $0^m.01$.

A considerable fraction of stars declared photometric constants in the *Hipparcos* Catalogue are in fact variable on a long time-scale.

The existence of long-period, large-amplitude variability in stars was predicted long ago by Schwarzschild, but has never before been established observationally.

Given the random nature of the sample, it is highly likely that research in other plate archives will substantiate and add to these results, once the data can be mined digitally.

Reference: Kroll P., Vogt N., Bräuer H-J., Splittgerber E., 2000, AGM, 17.CT02

The TOPCAT Catalogue Browser

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TOPCAT is a catalogue browser for viewing and editing astronomical catalogues and similar tabular datasets. It is driven from an easy-to-use graphical user interface and includes the following features:

- view and edit the table data using a scrollable browser,
- view and edit the metadata for the whole table or for individual columns,
- re-order or delete columns,
- compute new columns from algebraic expressions involving existing columns,
- sort rows on the values in a given column,
- select subsets according to various criteria,
- generate scatter-plots, optionally distinguishing different subsets,
- calculate statistics on each column for some or all rows,
- output a modified table in the original or a different format.

Additional functionality is provided by being able to launch other programs for analysing tabular data, such as Mirage (`http://www.bell-labs.com/project/mirage/`) from within TOPCAT. Catalogues in a variety of formats can accessed, including FITS tables and the new VOTable format developed for the Virtual Observatory. Hence TOPCAT can inter-operate with other packages which read FITS tables, such as CURSA (see SCAN-IT, no. **1**, October 2002, p22 and `http://www.starlink.rl.ac.uk/cursa/`).

TOPCAT is provided by the Starlink Project in the UK (`http://star-www.rl.ac.uk/`). It is a new package and is being actively developed. It is written in Java and hence is inherently portable. Further information about TOPCAT, including how to obtain a copy, is available from its home page at URL `http://www.star.bristol.ac.uk/~mbt/topcat/`.

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Why Digitize Plates?

Historic Outburts in an X-ray Binary

X-ray binaries are a relatively newly-discovered class, so we have little information about the time-scales of any variability. Photographic magnitudes to $\pm\ 0^m.5$ of the X-ray binary A 0538-66 were therefore measured on 91 plates from the Harvard archive. Data of this nature enable researchers to investigate modulations in the periodicity of cyclic events.

The presence of a suspected 16.651-day periodicity in x-rays was fully confirmed. But while 10 outbursts of at least 1 magnitude occurred within 3.3 days of ephemeris maximum, the majority of plates close to ephemeris maximum did *not* show a significant brightening of the star. The on–off behaviour seen in recent years was therefore operating during the earlier epochs too.

Reference: Brock, K.L., Clayton, G.C., Wollman, E.R., 2002. BAAS, 34, 1201.