Astronomical Plate Archives: Past, Present, Future

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The Photographic Plate Archives

- The recording medium in astronomy (and not only astronomy) for recording images was photographic emulsion until about 1980, i.e. for about 100 years
- Hence all scientific Institutes involved in the past in imaging are expected to have archives of recorded images (as photographic negatives)

Photographic Negative Archives

- Astronomical
- Other sciences
- National and State Archives
- Musea
- Military
- Others

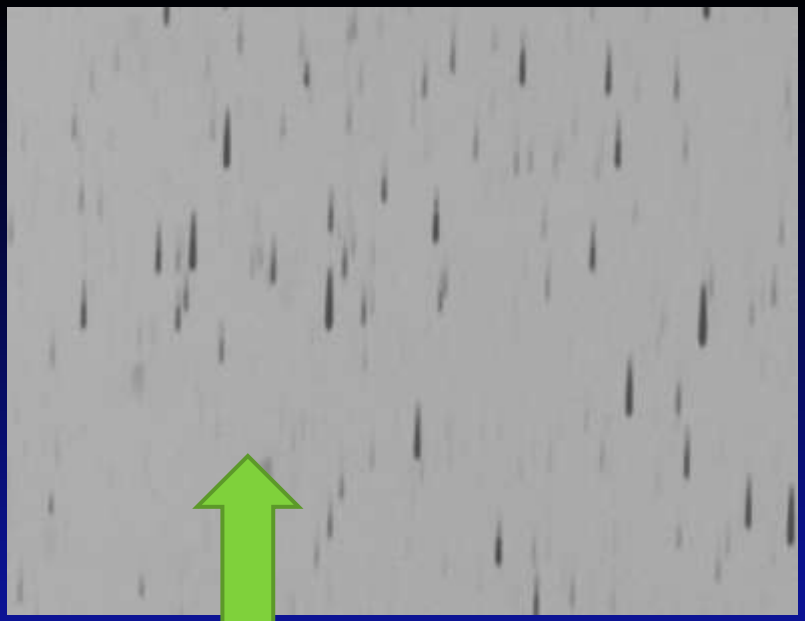
- Glass negatives
- Plastic negatives / planfilms
- Rollfilms-film strips

Astronomical Negatives (Glass & Film/Plastics)

- Direct images
- Low Dispersion Spectra
- Multiple images
- Spectra
- Special (such as images of screen of meteor radar)
- Stars / Night Sky Images (wide field)
- Stars and celestial objects (narrow field, from large telescopes)
- Meteor trailed images
- Planets
- Sun
- Moon
- Other targets

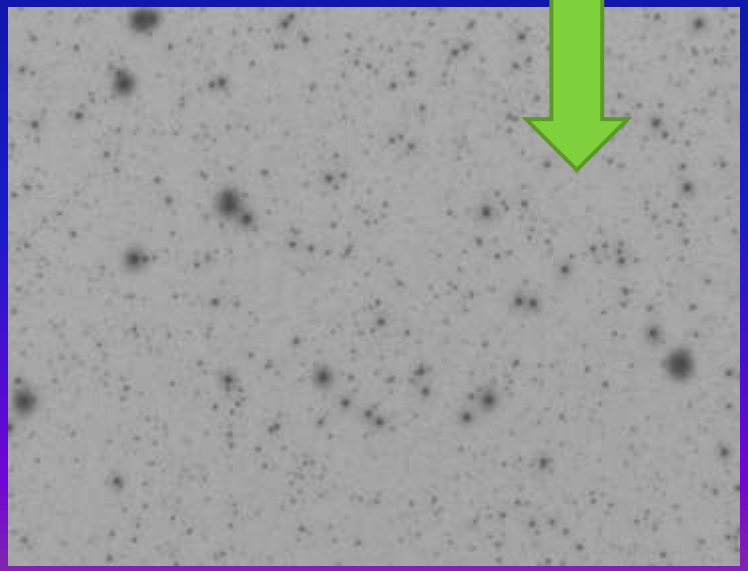
Various types of astronomical plates (digitised)

- wide-field >> 1 x 1 deg
- narrow field < 1 x 1 deg

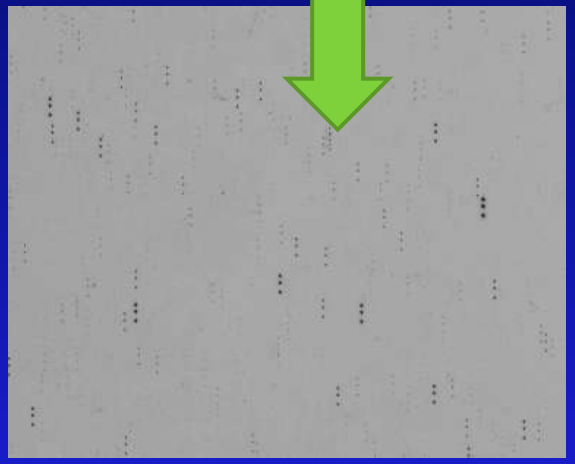


WF Spectral image

WF Direct Image

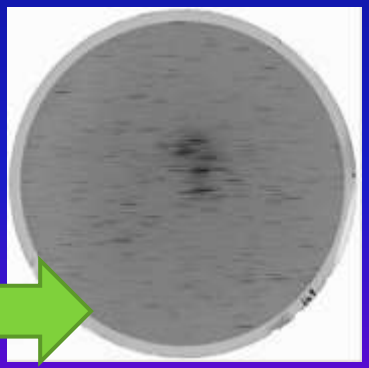


WF Multiple exposure



Sun

Solar system



HD spectrum, NF image

Personal visits to astronomical plate archives

- I have personally visited and evaluated the plates in more than 70 plate archives worldwide
- In numerous cases sad experience
- In few cases forbidden entry, then plates badly damaged
- In most cases plates not stored in proper conditions
- Many hidden (unknown before) plate collections found
- Mostly scientific valuable databases
- In numerous cases no contact person, no funding, no equipment

List/Catalogue of astronomical plate archives

- Complete list does not exist
- Many (~640 000) WF plates are included in WFPDB (Tsvetkov et al.)
- But this is not complete, in addition many NF images
- America archives list by Wayne et al., but, again, not complete
- Examples: numerous unknown archives found by us even at those Institutions where the management was not aware that they have plate archive
- Total numbers difficult to estimate, as at many archives they do not know how many plates they have. My recent estimate is > 10 mil. (glass & plastics, also solar, meteor and planetary negatives)

The largest plate archives (mostly glass)

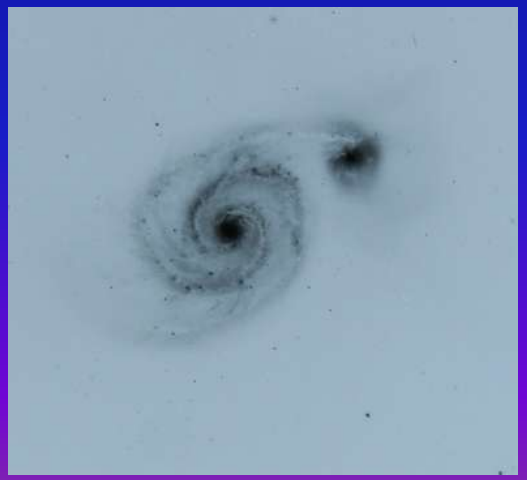
- HCO USA 500 000 plates
- Carnegie Pasadena USA 500 000 plates
- PARI USA 354 000 plates/negatives
- Sonneberg Germany 280 000 plates
- OHP France 250 000 plates
- Debrecen Hungary 200 000 plates (solar)
- Charlottesville VA USA 165 000 plates
- Swathmore Observatory PA USA 100 000 plates
- RGO UK 150 000 plates/negatives
- Ondrejov Observatory Czech Rep. 160 000 plates/negatives

Note some observatories not mentioned here have up to 1,5 mil. negatives on plastics/film (e.g. Table Mountain JPL Observatory, CA and Baker-Nunn archives in the US)

The astronomical plates taken by largest telescopes

- CFHT Hawaii USA, 3.6 m aperture
- UKSTU Siding Springs Australia 3.9 m aperture
- These telescopes were designed to work with plates
- Probably more

CFHT plates digitized by us by digital camera



New: Addition of satellite tracking data

- Astronomical photographic archives are not the only source of historical astronomical data
- Additional data are provided by photographic archives from satellite tracking cameras which contains huge number of wide field sky images >> 1 million with >> 1 billion star images and typically with very high time resolution down to 1 sec with reasonable magnitude limit of 14-16

Examples: large archives with satellite tracking data

Baker-Nunn camera networks negatives

- FOV 30 x 5 deg, lim mag 15, very dense sampling ~ few sec, >> 1 mil negatives, ~20 years coverage
- Very fast film camera with f/1 designed to detect very faint satellites Mirror 31 inch correcting lenses 20 inch. Exposures 0.2, 0.4, 0.8, 1.6 and 3.2 sec

2 networks (SAO and military), ~ 20 stations, ~ 1957-1977

B-N Films

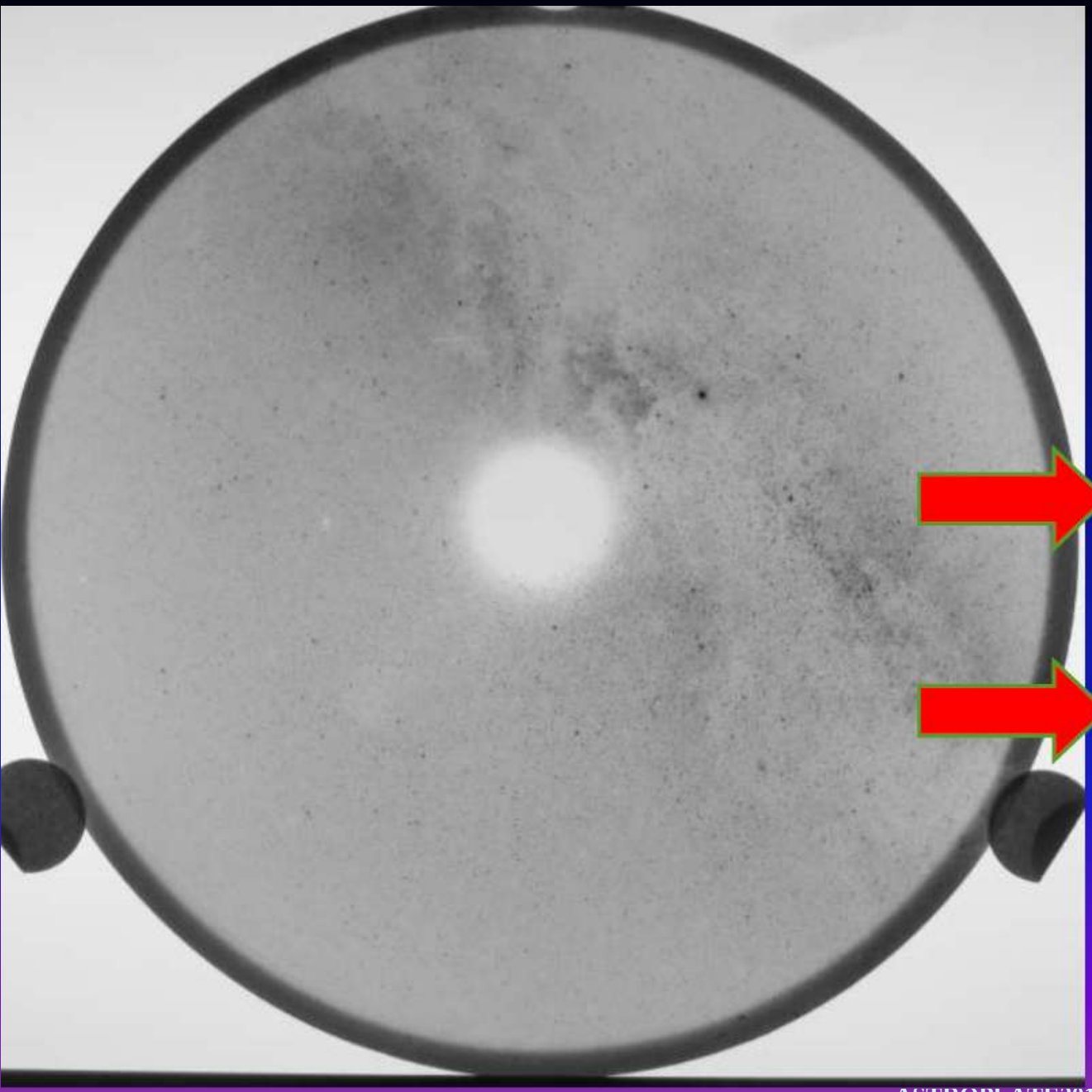
The films and the metadata/documentation found in several US state archives

21 boxes with B-N films recovered in Washington DC, SI, about 0.5 mil frames
Much more (>> 10 milion) probably exist somewhere

B-N Example Images

Data suitable for wide-field studies, OT searches, fast variablity

Up to 100 000 stars per 1 full frame



Super-Schmidt Baker Camera

About 100 000 films

Limiting magnitude 15, very sharp images

FOV 55 degrees

1950-1960

Very dense (20 minutes) sampling

Now deposited at PARI, NC

In Space: Gemini and Skylab UV spectra experiments

Original negatives are at PARI, NC

History: evaluation of archival plates by eye estimation

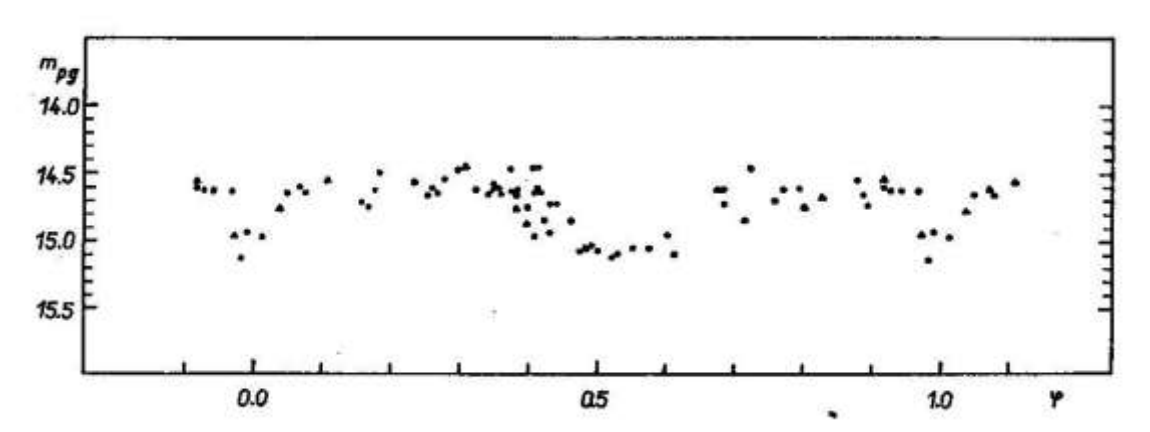
Eye estimation can however still yields valuable results:

Experienced person can provide measurements with precision analogous to plate photometers and CCD scanning

The method is quick and suitable for evaluation of on many plates where digitization is less effective

Comparison of eye estimation by very experienced person with plate photometer - HZ Her inactive state, Sonneberg Observatory astrograph plates

eye



photometer

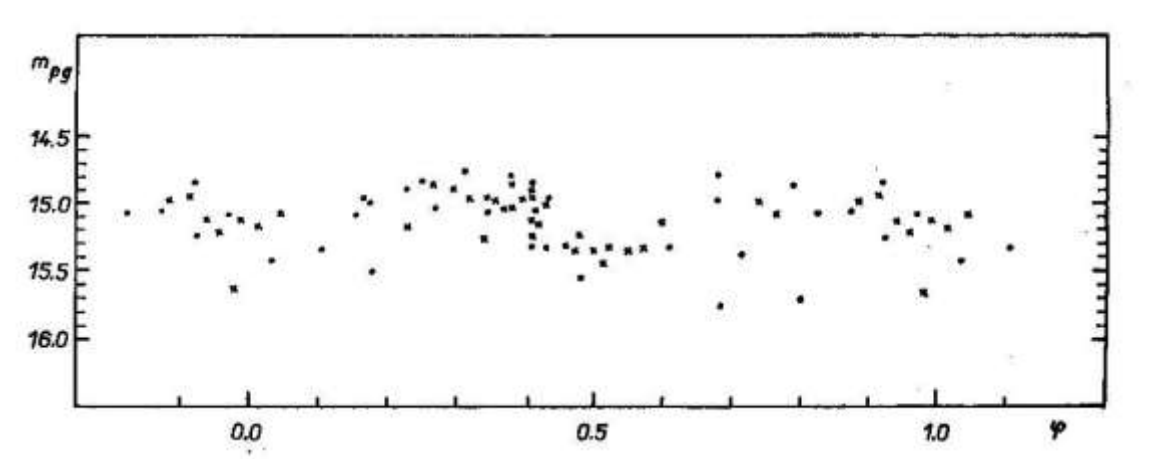
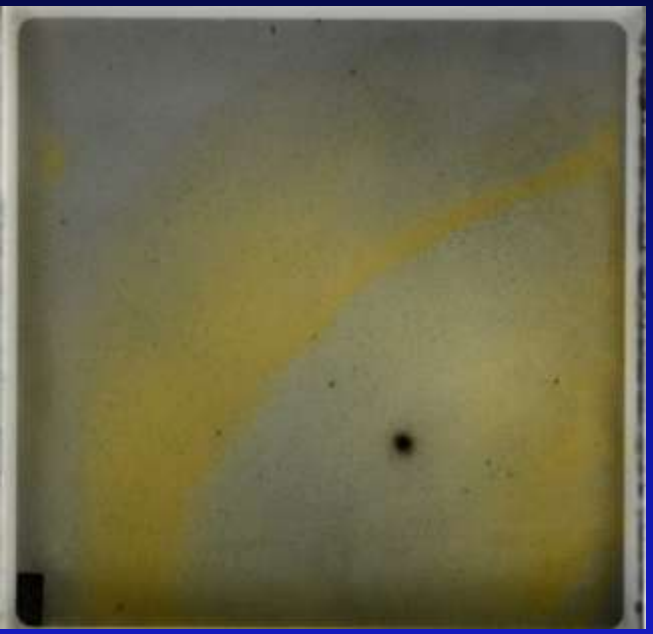
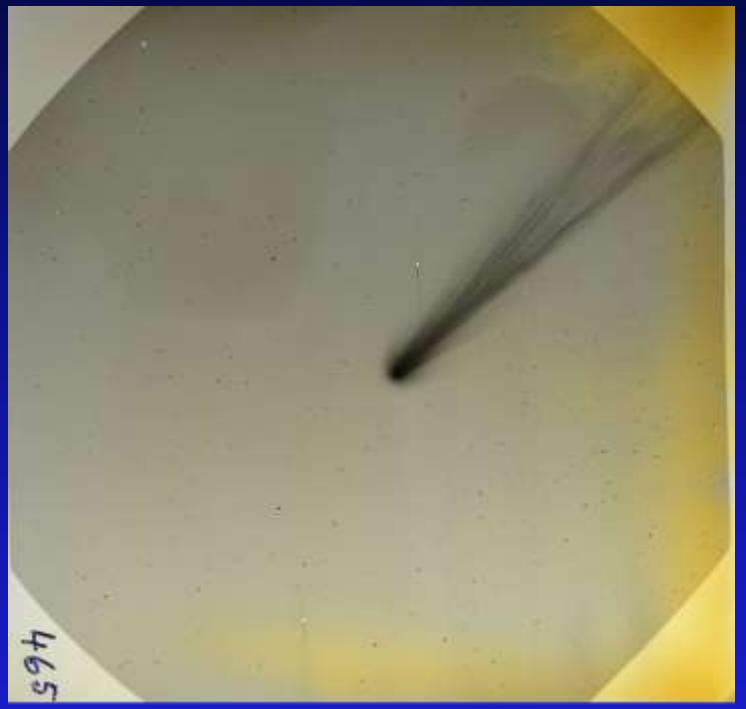


Plate informatics/Metadata

- Observing logs and books
- In hand written form
- Some fraction transferred to files: absolutely necessary step
- Plate searches by computers
- Searchable www forms
- Goal is to find plates which include the object of interest (or given sky position)
- Problem: in numerous cases were the observing logs lost and/or moved to library and/or attic with only little chance to find them

Damages to plates: need to digitize fast





Gold disease and damage by humidity
Collaboration with IChT Prague in recovery damaged plates

The main degradation types

- Golden desease
- Released emulsion

- Mold – especially at observatories around the mediteran coast
- *In addition to that, totally damaged plates mostly due to water exposure*

Are glass plates and/or films reliable medium for data storage?

Yes and No

Yes - if carefully stored, the plates will hardly degradate over next 100 years or even more. But for astronomical plates, this is mostly not the case

But - there is a danger that the plates can be almost completely destroyed e.g . by water, as shown by floods in Prague in summer 2002 (200 000 centrally stored archeological photographic plates very seriously affected and badly damaged)

More recent: HCO plate stacks flooded (60 000 plates damaged)

Bologna

Unproperly stored
Many badly damaged by water

Historical value
Bologna tower telescope 1st MMT in the world

Plate Digitization

- Why to digitize the plates?
- The photographic emulsions can be damaged
- To enable evaluation by dedicated software and powerful computers
- The access to the info in the plates is otherwise very difficult
- What positional accuracy is needed?
- What resolution (pixelsize in microns) is needed?

Plate Digitization II

- Very high astrometric positional accuracy 0.1 microns or 0.1 arcsec only with custom made scanners, very expensive
- Most applications do not need such high accuracy
- Most plates are NOT astrometric or have intrinsic astrometric inaccuracy > 0.5 arcsec hence no need for very accurate astrometric machine
- Even the CdC plates intrinsic inaccuracy 0.3 arcsec
- Pixelsize: emulsion 5 microns, Sonneberg 25 microns. Smaller pixelsize = very large size of image files = more difficult to store, to acces, and to evaluate

Plate Digitization: 3 technologies – Cost and Time Factor

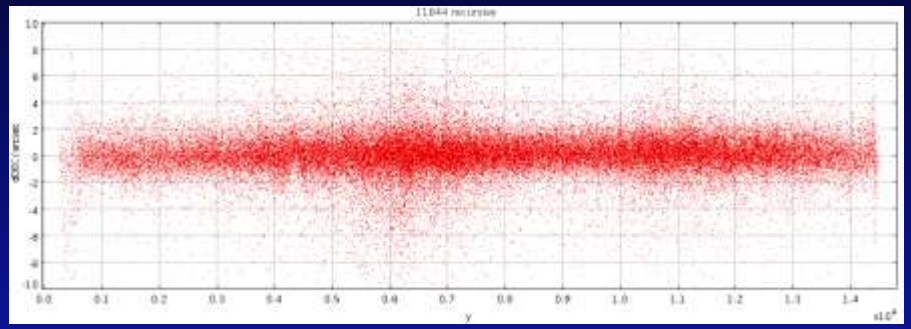
- Dedicated custom made accurate scanner - very expensive, difficult to move, 1 plate > 100 Euro
- Commercial flatbed scanners – moderately expensive, 1 plate >> 10 Euro
- Digital camera - inexpensive, fast – 1 plate < 0,5 Euro
- Very rough estimates, cost of purchasing instrumentation not included

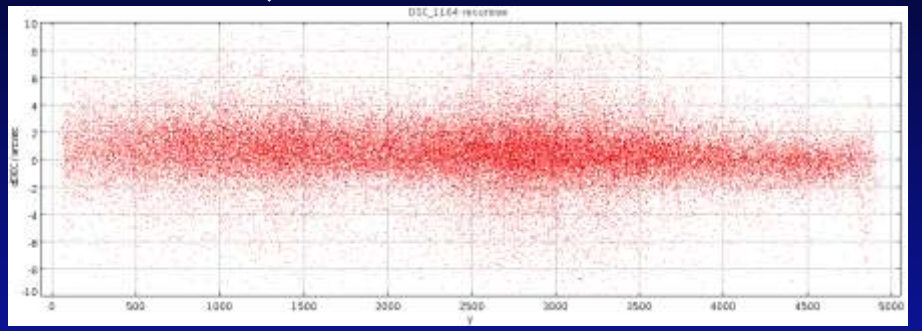
Comparing Digital Camera vs Scanner

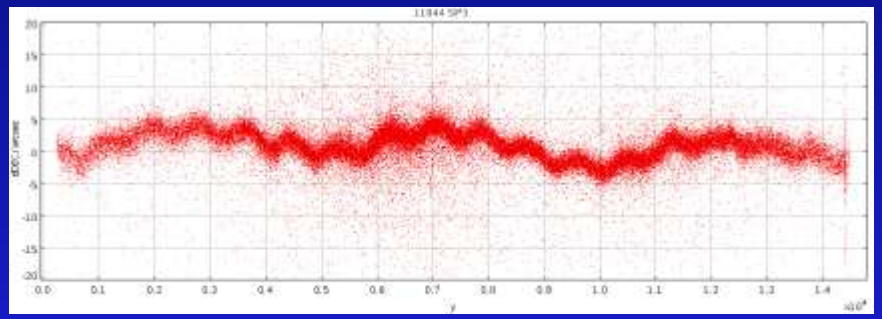
Digital Camera

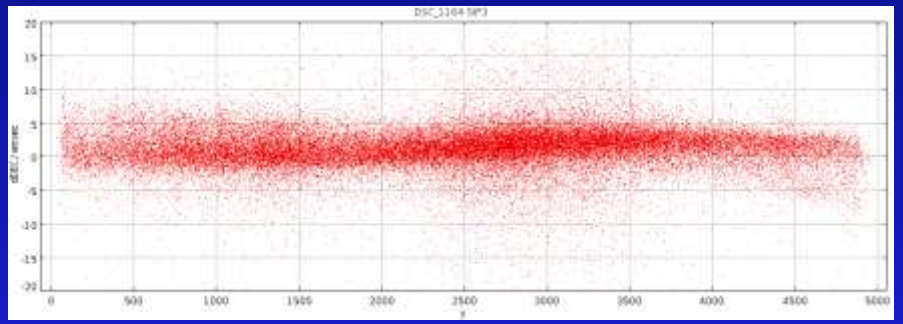
- Very fast (2 sec/plate)
- Very low-cost scanning
- No waves caused by irregular movement
- Easy transportable
- Satisfactory resolution for small and medium sized plates (5-20 microns)
- Need to apply automated algorithms for lens distorsion and edge cutting - solved

Comparing Camera vs. Scanner (the residual plots)









Scaner **Camera**

Bamberg Southern Sky Survey Plate NZ 11844

Comparison of the three methods

Table 2. The standard deviations for measured coordinates of double star components.
N is number of plates used for comparison.

	N	mean	ADS 8002 A		ADS 8002 B	
		σ	σ_X [μm]	σ_Y [μm]	σ_X [μm]	σ_Y [μm]
"Fantasy"	25	0.81	0.77	0.83	0.97	0.66
"Ascorecord"	25	1.57	1.34	1.72	1.29	1.95
"Fantasy"	36	0.84	0.81	0.82	1.06	0.68
Scanner (by I. Izmailov)	36	2.95	1.88	3.72	2.57	3.65
"Fantasy"	30	0.77	0.67	0.75	1.00	0.64
Scanner (by S. Kalinin)	30	1.80	1.51	1.56	2.61	1.49
"Fantasy"	40	1.03	1.00	1.11	1.19	0.83
MDD (presented method)	40	1.02	1.03	0.95	1.07	1.01

If we adopt the accuracy of the "Fantasy" as a unit of one, the relative accuracies of other methods of measurement are the following:

"Ascorecord"	1.94
Scanner (by I. Izmailov)	3.51
Scanner (by S. Kalinin)	2.33
"Fantasy"	1.00
MDD	0.99

Grosheva et al., 2012

Scanner Microtek Scan Maker i900
Fantasy – high quality dedicated plate measurement machine
MDD – Canon digital camera

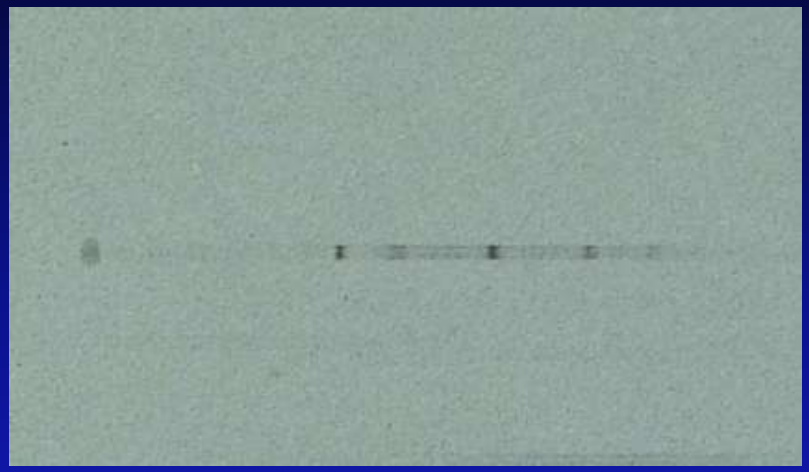
Digitization: current status

- Custom scanner ~ 325000 plates digitized
- Slow, very expensive
- Commercial scanners ~ 350000 plates digitized slow, moderately expensive
- Digital camera ~ 50000 plates digitized
- Very fast (1200 plates/day), very inexpensive

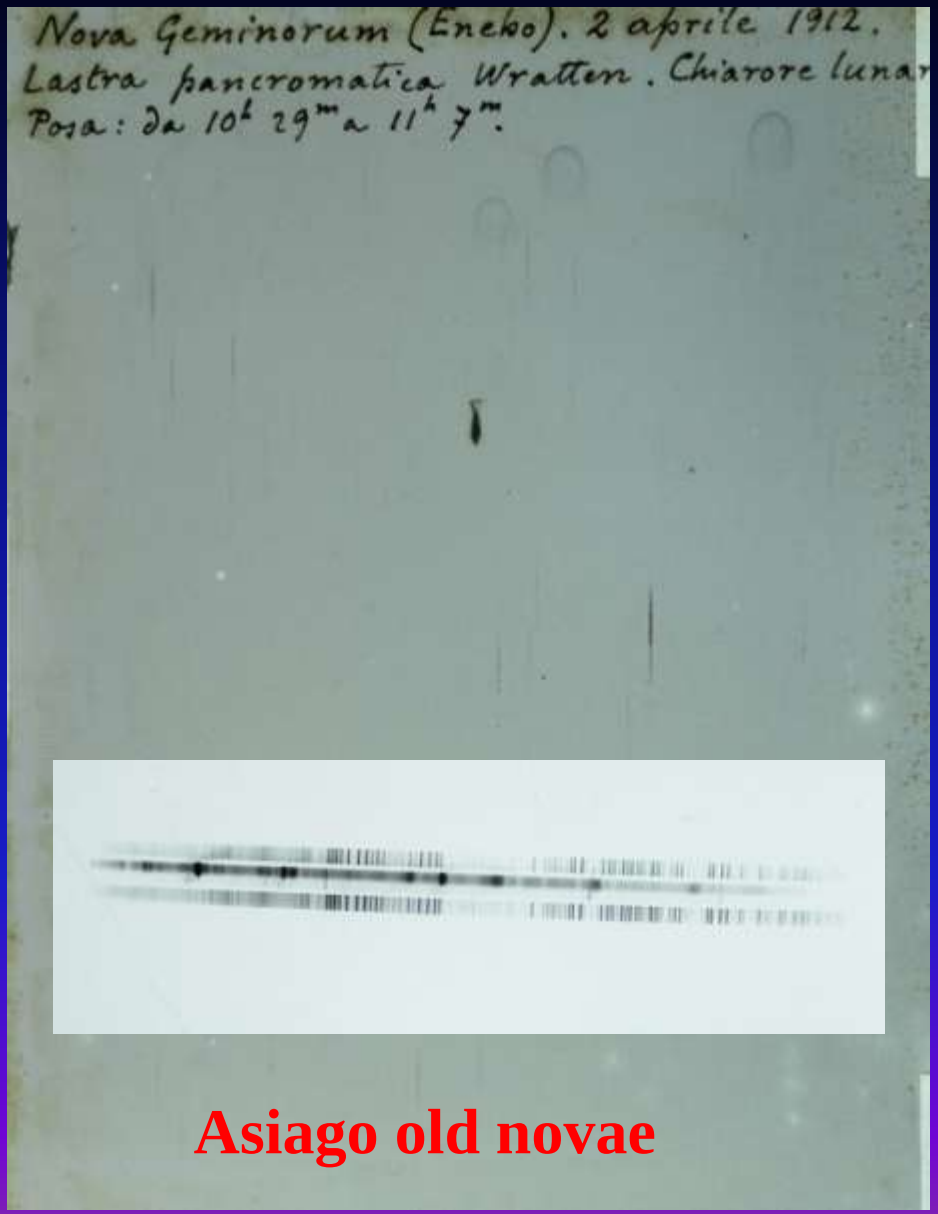
Plate Archives visited and (partly) digitized by us (digital camera)

- ~50 plate astronomical archives visited and partly digitized by us in US, Mexico, Europe, and China,
- ~ 50 000 plate scans obtained, including
- Italian speciality: very numerous spectra of historical novae. Never investigated by computers! Asiago, Merate, Catania, Loiano
- 2 archives fully digitized by us (Tuorla Finland, 11 000 plates) and UNAM Mexico 2000 plates. One partly (Hewitt UK, 2000 plates)
- For more details see our poster

Nova Geminorum 1912 Catania Observatory



Italian observatories have collections of ~thousands of spectra of old novae some up to 100 years back in history (eg Catania, Loiano, Asiago, Merate). These old records were never evaluated by computers



Asiago old novae

Examples of archives digitized by digital camera

- Tuorla Observatory Finland plate collection fully digitized by us in March 2017 (11 000 plates in just 1 week)
- Hewitt 2000 plates/2 days
- UNAM Mexico CdC 2000 plates/2 days

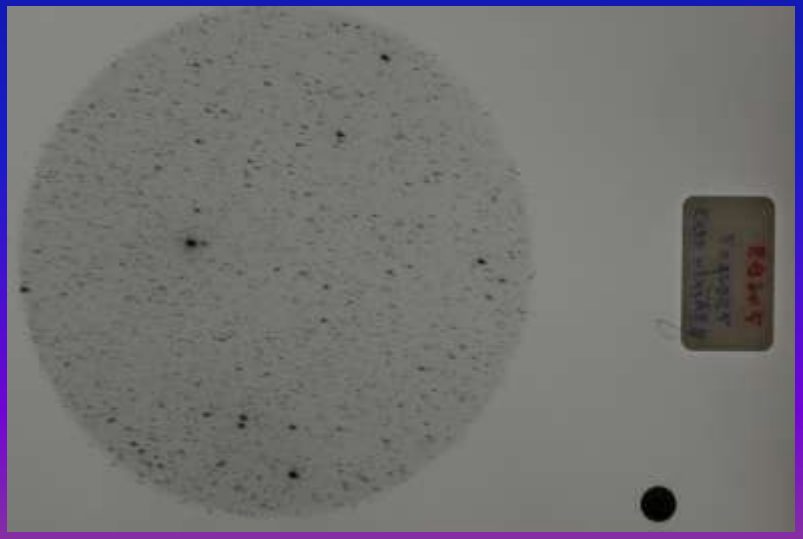
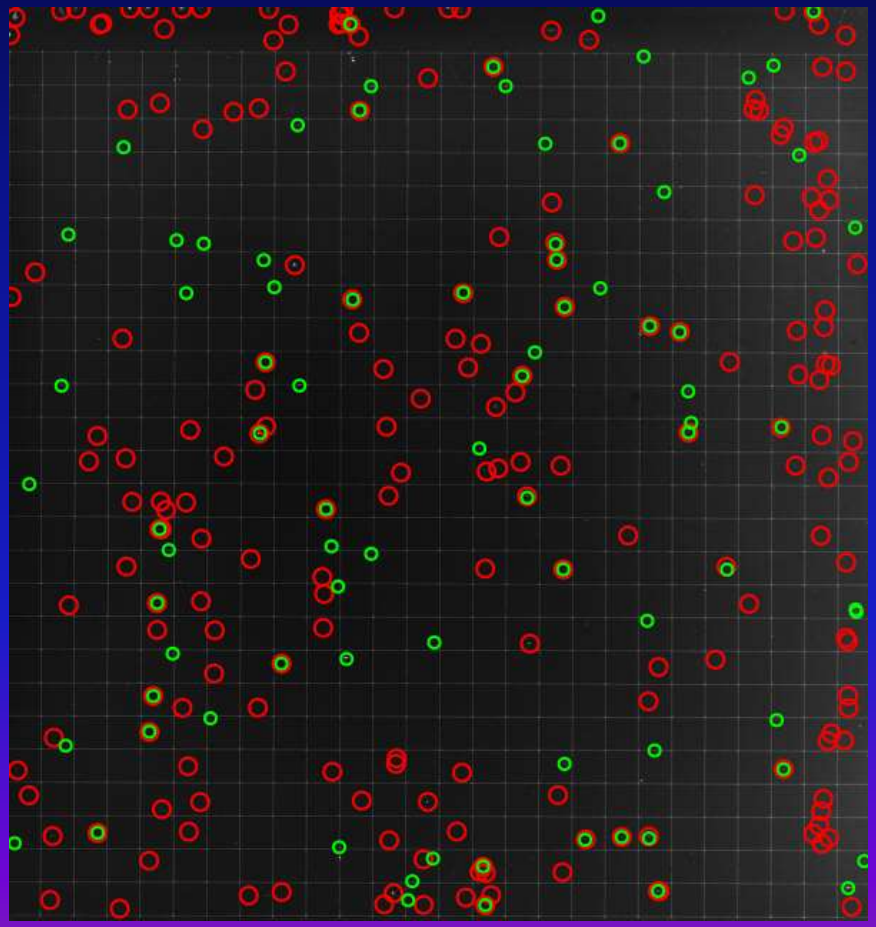


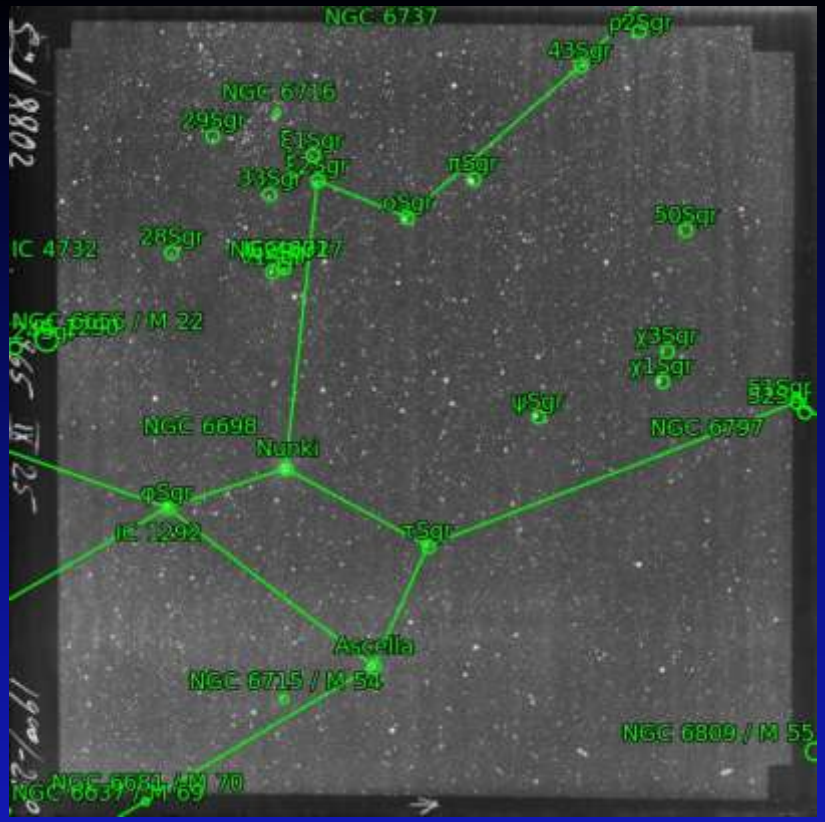
Figure 1. Dr René Hudec (at rear) and Lukás Hudec photographing the plates in November.

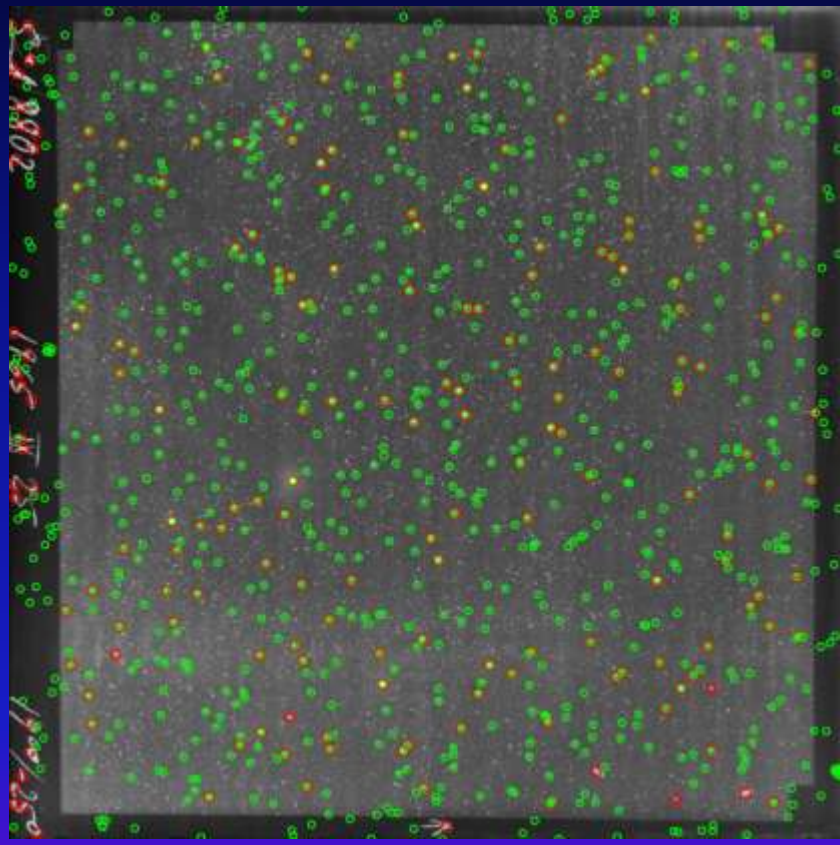
Carte du Ciel Mexico Plates astrometry (digital camera)



- Center (RA, Dec): (178.349, -11.387)
- Center (RA, hms): 11h 53m 23.650s
- Center (Dec, dms): -11° 23' 12.371"
- Size: 1.79 x 2.01 deg
- Radius: 1.345 deg
- Pixel scale: 1.96 arcsec/pixel

Astrometry Tests (digital camera)





The typical internal astrometric accuracy of astrometric CdC plates is 0.2 to 0.3 arcsec but note that the accuracy depends on seeing conditions

- Center (RA, Dec): (286.397, -25.253)
- Center (RA, dms): 19h 05m 35.395
- Center (Dec, dms): -25° 15' 09.472"
- Size: 14.9 x 14.7 deg
- Radius: 10.416 deg
- Pixel scale: 10.8 arcsec/pixel

We have for non astrometric plate 0.3 arcsec so it is obvious that the technique we use is accurate enough, not adding any significant error

Automated pipelines to evaluate digitized plate data/large scanning projects

- APPLAUSE (Germany Hamburg, Bamberg, Potsdam) 72314 plates so far

https://www.plate-archive.org/applause/

- DASCH HCO USA 324 908 plates so far, affected by flooding few years ago (scanner lost), now all flooded plates (60000) recovered and (now) fast scanning 100000/year, 400/day … but 8 FTE staff

http://dasch.rc.fas.harvard.edu

Others major scanning efforts

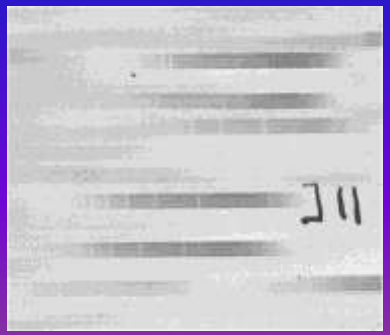
- Other major digitization efforts with no pipeline: China 29 000 plates, data delivered to Chinese VO, Sonneberg 250 000 plates
- High quality superprecise plate digitizer developed and installed at the ROB Brussel some 10 years ago but no details about number of plates digitized
- Large Italian plate scanning project led by Prof. Cesare Barbieri was interrupted and closed.

Creating Astronomical Plate Centers

- Storing plates which would be otherwise destroyed
- Creating centres with large number of plates and excellent equipment
- Europe: UDAPAC, no success
- USA: PARI, success, already > 600 000 plates
- China: collecting 40000 plates from China to one place

PARI – US Initiative for North American Plates
PARI Institute, NC private funding

Recently about 354 000 plates there, plans for more



?

Past

Glass Plates

Recent

DVDs

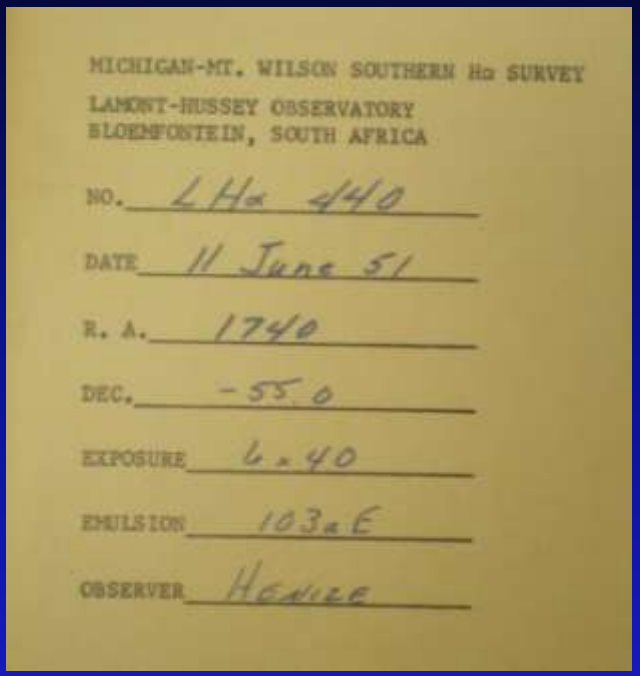
Future

?

Plate Archives: Astronomy & History & Detective stories

- Investigations in astronomical plate archives are closely related to history of astronomy especially in cases of special extended plate projects
- Not obvious question: which professor, which scientific goal is related to the particular archive?
- Are there related historical publications?
- In some cases, almost detective investigations e.g. searches for measurement logs for Henize archive and searches for negatives in (huge) state archives

Karl Henize Mt Wilson-Michigan Southern Sky Hα Survey


MICHIGAN-MT. WILSON SOUTHERN Hα SURVEY
LAMONT-HUSSEY OBSERVATORY
BLOEMFONTEIN, SOUTH AFRICA

NO. L Hα 440

DATE 11 June 51

R. A. 1740

DEC. -55.0

EXPOSURE 6.40

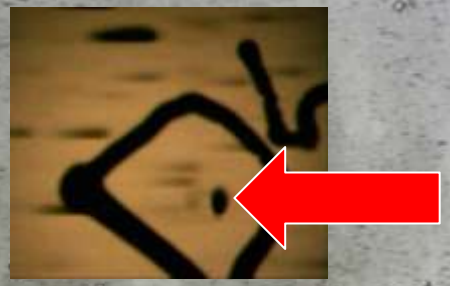
EMULSION 103a E

OBSERVER Henize

Professor of Astronomy, later NASA Astronaut

290 high quality plates 15 x 15 inches taken in 1950-1952 in South Africa by dedicated telescope by Karl Henize (for his Dissertation)
Found and Now deposited at PARI, NC
Bit where are the measurements logs?

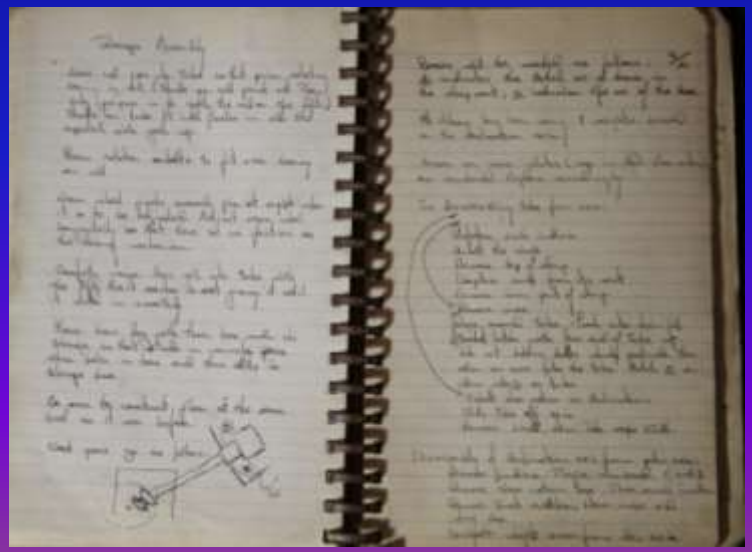
Example of emission object found



Southern Hα Mt Wilson Michigan Survey Plate

Many spectral surveys in the US …. Can be used for many HEA tasks e.g. serches for highly redshifted OAs of GRBs

Treasure hunting with Astronaut Henize family



Henize measurements logs recovered and digitized at Hazy center in Washington DC in Sept 2012

Important for ESA Gaia RP/BP - LDS

Recovering Henize telescope, Africa observatory, and prism

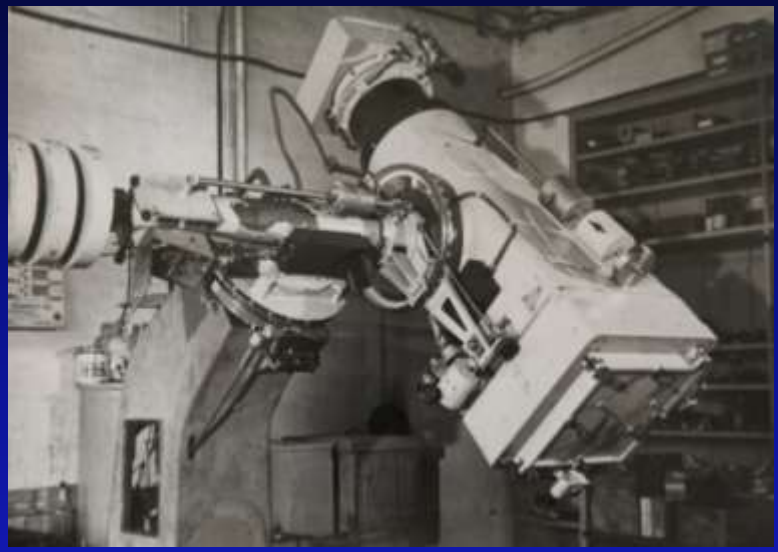


Photo courtesy: Henize family

Main problems I

- In contrast to e.g. government photographic archives and museums, the astronomical photographic archives (1) have severe lack of funding (2) are not properly stored
- While government archives have funding for cleaning, re-jacketing and restauration of negatives, nothing like this is available in most astronomical archives
- Some of them are badly damaged, most stored in not proper conditions

Main Problems II

- Very difficult to get the funding to digitize and evaluate the plates
- Most of funding proposals rejected as "old stuff" or "not a basic science"
- Problems at plate archives: difficult communication, no contact person, difficult access to plate logs, no funding, difficult or no access to plates (even to large archives)

ASTROPLATE conferences

- ASTROPLATE I Held in Prague March 2014
- Talks online http://astroplate.cz
- e-Proceedings online
- ASTROPLATE II Prague March 2016
- e-Proceedings online NEW!!!
- ASTROPLATE III Bamberg March 2019
- ASTROPLATEIV Prague (TBC) March 2021

Conclusions

- Astronomical Plate Archives represent valuable extended (> 10 milion) data source
- Recent digitization and evolution of dedicated software enables evaluation by computers, for the first time. But limited, lack of funding.
- Storage of negatives in numerous archives is not optimal
- Except few examples, very limited or no funding
- Fast (<10 sec) and inexpensive (~0.25 $) plate digitization technique developed and tested able to convert glass plates to computer files effectively
- Satellite Tracking Photographic data additional source of valuable information … >> 3 million frames, large FOV, very dense sampling.
- In general: Interface astronomy/history/culture/chemistry: very difficult to get funding for that

The End