FOTOSS* Phase I: Chronicle of an Achievement

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Abstract

This document is a record of the key tasks and dedicated activities that ushered the start of FOTOSS, a project of the Torino Astrophysical Observatory (OATo) carried out in cooperation with the Shanghai Astronomical Observatory (SHAO). Its first objective is the high accurate digitization of the entire OATo's plate archive, with the ultimate goal of preserving century-old astronomical observations for their scientific exploitation.

1 Introduction

From the late 19th century and all the way through the early nineties, astronomers have registered their observations on glass photographic plates exposed at the focal plane of ground telescopes around the world. The images captured on these plates represent a unique record of the ever changing sky, allowing to explore the so called 'Time Domain Astronomy', which is aided if the information they contain is made electronically available. The task of systematic plate digitization requires sophisticated instrumentation, dedicated personnel, and can be very time consuming: this is one of the reasons which prevented astronomical observatories owning plate archives from fully realizing such a task. Another, more strategic, aspect is related to the amazing progress of digital sensors and space missions throughput experienced at the dawn of the 21th century. This phenomenon guided the main data reduction programs and fund allocation in a certain direction, somewhat overshadowing the role of historical data, which was relegated to a sort of low-impact, niche science.

Despite this trend, the scientific value of historical plates has been always recognized by the astronomical community worldwide; various efforts were put in place to foster international collaborations and gather different expertise which could help identify the main scientific drivers and find practical solutions for the exploitation of existing astronomical plate archives. Worth of mention, in this context, are the creation in 2001 of a IAU

*Valorizzazione scientifica dell'archivio di osservazioni **FOTO**grafiche del **S**ecolo **S**corso di patrimonio dell'OATo

working group on 'Preservation and Digitization of Photographic Plates' under Commssion B2 (PDPP, https://www.iau.org/science/scientific_bodies/working_groups/313/); the estabishment in 2007 of the Astronomical Photographic Data Archive (APDA) at the Pisgah Astronomical Research Institute (PARI, USA, [4]); the constitution in 2014 of a working group of the American Astronomical Society on Time Domain Astronomy (AAS, TDA, https://aas.org/comms/working-group-time-domain-astronomy-wgtda); the inauguration, in 2014, of AstroPLATE, a recurring international workshop on scientific use, digitization and preservation of astronomical photographic records (https://www.astroplate.cz); and the newly born NAROO digitization center in Meudon, Paris [13] (https://www.imcce.fr/recherche/equipes/pegase/naroo). During the years, many astronomical institutes have undertaken specific programs on their own archives, with different level of accomplishments and goals (to cite a few, [16],[19],[8],[5],[9],[15],[7]).

OATo's own equipment originally consisted of an old ASCORECORD measuring machine operated manually until the end of the '90s, when it was converted to an automatic and impersonal device (TOCAMM, [6]). TOCAMM was proven to be astrometrically stable at 0.5 micron level; however, the image acquisition process was extremely slow, and the control software designed to acquire small images around a pre-defined set of target objects as opposed to raster-scanning a whole plate area. Therefore, TOCAMM was considered unsuitable for a systematic digitization of the considerable in-house plate archive and later dismissed. In 2001, a pilot program of the University of Padova opened the opportunity for various italian institutions, including OATo, to test the validity of commercial scanners as plate digitizers, since they were easily accessible and reasonably fast ([2]). Some preliminary tests performed on a Umax Powerlook 1000 (2400x2400 dpi, 14 bit digital resolution) acquired by OATo showed that the astrometric stability was at the level of few micrometers, with sensible systematic errors in both the X and Y directions; it was decided then to use this scanner only for the generation of low-resolution image previews to complement the machine-readable plate database (see next section).

In the following years, common research interests in the field of astrometry between OATo and SHAO grew into a long-standing scientific collaboration agreement, which in 2019 was formally extended ("Agreement for Scientific Cooperation between Shanghai Astronomical Observatory and Osservatorio Astrofisico di Torino", Prot. N. 0000593 del 10/03/2021) to the use of a new fast plate digitizer owned by SHAO ([18]) for the full digitization of the OATo's plate archive. The realization of such a task had to confront with a series of scientific, technical, logistic, and bureaucratic issues; in the following, we try to give a full account of the story.

2 Consistency of the OATo's plate collection

OATo's plate assortment contains observations made with different telescopes, of both Torino Observatory and other national and international observatories, related to research activities of the local astronomers covering a time span of more than 70 years, precisely from 1925 to 1996. The main observation programs were devoted to minor bodies of the

Solar System, visual binaries, open clusters, astrometry of radiosources, parallaxes of a few stars of astrophysical interest, some stellar variability, and comet studies. Principal benefits of a full digitization and reduction of this material are foreseen in the dynamics of Solar Sytem bodies and from the analysis of special fields, while a deeper exploitation could be made possible by opening the calibrated plate database to the astronomical community.

Starting in 2003, thanks also to some financial support from Regione Piemonte [11], OATo began a systematic survey of its photographic material, which involved the following actions: a) assess the conservation status of the plates, b) take measures to improve their preservation, c) classify them one by one, and d) create a machine-readable plate database containing all the relevant informations from the observation logbooks and plate envelopes, as well as from the notes written on the plate glass, deemed to be preserved. Part of this routine activity, as mentioned in the Introduction, was the generation of a low-resolution (600 dpi) image of each plate by means of a commercial scanner, for visual inspection purposes. A detailed account of the protocol that was adopted for the requalification of the OATo's archive can be found in [3], (`https://www.anms.it/upload/rivistefiles/104.PDF`). This work, which was carried out intermittently – due essentially to lack of adequate resources – until 2008, resulted in 3131 plates cleaned, catalogued and ingested in an ACCESS database; a choice, the latter, dictated by reasons of compatbility with a specialized software developed by CSI-Regione Piemonte for the archival of standard photographic material (`http://www.regione.piemonte.it/guaw/htmpl/intro.html`), no longer in use..

In 2018, with the help of an Erasums student from Moldavia, Ana Vrancean, we picked up the work left in 2008 with the purpose of checking the integrity of the plate data, and relative scan images, then performed some statistics on the various entries of the online catalog [17]. However, a substantial number of plates were still unaccounted for, and the actual consistency of the full archive was finally determined during the demanding preparatory activities started in April 2021, preluding to the shipment of 7275 OATo's plates to Shanghai, where the digitization phase began in the late fall of 2021, and is currently underway. Of the plates we did not ship, a small number was either deemed of too poor quality or calibration tests, while 1205 plates belong to a visual double and multiple star observation campaign conducted at OATo with the REOSC telescope between 1976 and 1987. The latter was a program mainly based on a list of targets from the Aitken Double Star Catalogue (ADS, [1]) and the Washington Double Star Catalog (WDS, maintained by the US Naval Observatory [10]), aimed at measuring the double separation and position angle. Given the peculiarity of the exposure technique used for many of the plates (the so-called 'metodo delle tracce', [14]) and that all these measurements have been published in the astronomical literature, we decided to digitize a selected subset of observations of known or candidate physical binaries which could benefit from an astrometric re-reduction for an improved estimation of their orbital parameters.

Table 1 gives a summary of telescope characteristics, plate size, and epochs of the up-to-date OATo's archive consisting of 8543 plates[1] . For about 6% of them we could not

[1]The number refers to direct focus images; OATo owns also a (limited) number of photographic spectra, which are not considered here

determine the exact epoch of observation, or at which telescope they were exposed; in the summary table, these are listed as 'miscellanea'.

3 Goals and workplan for a digital archive

Before sending the plates to SHAO, we had to make sure that all the information relative to each and every plate was registered. So, we resumed the activities discontinued around 2008 (see previous section) and defined a strategy of operation. The status of the archive was very inhomogeneous: less than half plates had been properly recorded, and the remaining were either in their original envelopes or with no envelopes at all. Thanks to the past efforts, all the information available for the recorded plates was stored in the ACCESS catalog; they had been cleaned, scanned at 600 dpi resolution, put in high-density polyethylene sleeves and stored in paper envelopes reporting their catalog number. On the other hand, a large portion of the more recent plates was still to be classified. So, we retrieved the polyethylene and paper envelopes left over from the earlier work, and acquired additional ones from a specialized company (`https://www.fototeca.it`), plus other specific material such as cotton and latex gloves for plate handling, and kapton tape that we used to make provisional repairs of cracked or partially damaged plates deemed useful for digitization. In order to collect all the available plate data and possibly retrieve missing information, we consulted the observation logbooks kept in the OATo historical archive, and also contacted OATo retired employees who had been involved in the observational activities.

Given the project timeline, we needed to accomplish the task of recording the plates in a swift yet rigorous way, and we decided that the best way to make preview images was to retro-illuminate the plate and take a photo with a digital camera. For the camera we used a SONY ILCE-6000, 24.3 Mpx resolution, already owned by OATo, and for retro-illumination we bought a light table 36x43cm produced by O.D.L di Dugaria Luca & C. Snc, and commercialized by City MED on the MEPA (Electronic Marketplace for the Public Administration) platform. We still needed to come up with a stable device to hold the camera while shooting pictures, so we decided to employ an available camera stand, where we lodged the light table, latching the camera at an adjustable distance on top of it. Once the intrumental setup was in order, we started the routine work of plate recording (see Fig. 1); at the same time we worked on the population of the online catalog, as detailed below.

3.1 The plate catalog

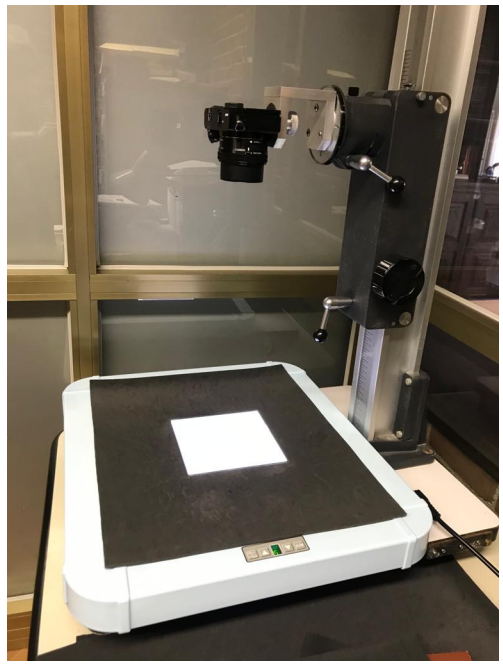
The plate catalog is a full inventory of the OATo plate archive in the form of an ASCII file that can be used to make queries on astronomical objects, sky areas, or other relevant data concerning a particular plate exposure. Each record (one per plate, but see the caveats in the itemized list) contains the following entries:

- Catalog number: unique number in ascending order

Telescope	*Characteristics*	*Number of Plates*	*Dimensions*	*Epochs*
OATo Telescopes				
Zeiss Astropgraph	Diameter 200 mm, focal 1140 mm	517	18x24	1925 - 1942
		416	16x16	1927 - 1987
		162	10x15	1929 - 1968
		2207	9x12	1953 - 1984
		40	9x9	1946 - 1983
		53	6x9	1948 - 1953
Morais Refractor	Diameter 380 mm, focal 6875 mm	274	20x20	1971 - 1994
		817	16x16	1946 - 1995
		89	9x12	1988 - 1989
REOSC Astrometric Reflector	Diameter 1050 mm, focal 9942 mm	744	16x16	1974 - 1996
		1347	9x12	1973 - 1993
		8	9x10	1984
Merz Equatorial refractor	Diameter 300 mm, focal 4500 mm	2	18x24	1929 - 1930
Other Telescopes				
GPO Astrograph ESO, Chile	Diameter 400 mm, focal 4000 mm	969	16x16	1981 - 1992
Zeiss Astrogrpaph Cote d'Azur Observatory, Nice, FR	Diameter 400 mm, focal 2000 mm	52	16x16	1986
Astrographic Telescope Royal Observatory Cape Town, Sudafrica	Diameter 330 mm, focal 3438 mm	26	16x16	1937 - 1989
G.D. Cassini Telescope Loiano Observatory (BO), I	Diameter 1524 mm, focal 12000 mm	9	24x24	1988 - 1990
		4	16x16	1988
		8	9x12	1988 - 1990
Galileo Telescope Asiago Observatory (PD), I	Diameter 1220 mm, focal 6000 mm	7	9x12	1962 - 1965
Schmidt 670/920 Reflector Asiago Observatory(PD), I	Diameter 670/920 mm, focal 2150 mm	63	20x20	1969 - 1993
Schmidt quasi-Cassegrain Reflector Catania Astrophysical Observatory, I	Diameter 410/610 mm, focal 1190/6000 mm	1	16x16	1983
		67	9x9	1980 - 1983
Jacobus Kaptein Telescope Roque de los Muchachos La Palma, Canary Islands	Diameter 1000 mm, focal 15000 mm	27	20x25	1993
Jewett Schmidt Telescope Harvard College Observatory Oak Ridge MA, USA	Diameter 600 mm, focal 2105 mm	77	20x25	1949
		33	20x20	1949
Miscellanea				
Ucertain		524	various	1926 - 1985

Table 1: Summary of OATo's archive plates and telescope characteristics

(a) Plates are inspected



(b) Each plate is retro-illuminated and recorded on camera

Figure 1: Cataloguing plates at OATo

- Plate number: the number of the plate written on the glass, and/or the original plate envelope
- Plate size: the size of the plate in cm
- Multi-exposure[2]: when applicable, with relative information available, the plate record is split in multiple records, one per exposure, and this entry reads 'N/M' where N is the N-th of M total exposures
- Multi-object[3]: when applicable, with relative information available, the plate record is split in multiple records, one per target object, and this entry reads 'N/M' where N is the N-th of M total target objects
- Plate coordinates: the coordinates of the center of the plate or of the target object
- Plate epoch: the observation epoch

[2]This is a common situation, consisting in moving the telescope pointing by small steps to obtain multiple exposures of the same field slightly shifted from one another; in many cases the start and end of each exposure was recorded by the observer on the plate envelope and/or in the observation log.

[3]There are some, not frequent, occurences in which the same plate was used for imaging more than one field, to economize on glass photographic plates, very expensive at the time. In practice, the final image is a superposition of different sky areas.

- Target Object: the IAU standard name of the target object
- Telescope: the name of the telescope at which the plate was exposed (the list of telescopes and their optical characteristics are given in a separate table)
- Observer(s): The name of the astronomers who conducted the observation
- Exposure length: the exposure time in hh:mm:ss
- Exposure start: the start time of the exposure in UT
- Exposure end: the end time of the exposure in UT
- Emulsion Type: the type of emulsion (the list of emulsion types and characteeristics is given in a separate table)
- Dome Temperature: the temperature as reported by the observer (in degrees Celsius)
- Plate/Emulsion status: the actual conditon of the plate/emulsion (good, sufficient, poor, cracked, detached,)
- Additional comments: any relevant comment on the exposure as reported by the observer
- JPEG image name: the filename of the preview image

When the relevant information is not available, its corresponding field is left blank. The catalog is near completion and will be accessible from the OATo website; a full account of the catalog content and relevant statistics shall be presented in an upcoming report ([12]).

4 The export to China and the 'snag' of cultural heritage

As it turned out after consulting with the head of INAF Libraries and Historical Archives Service (A. Gasperini, e-mail of March 15, 2021), in order to send the plates to China we would need a formal authorization of the Italian Ministry of Cultural Heritage, on the premise that such plates were subject to the rules applied to "fotografie, con relativi negativi e matrici ... la cui produzione risalga ad oltre 25 anni" and to "beni e ... strumenti di interesse per la storia della scienza e della tecnica aventi più di cinquanta anni" (D.Lgs. 22 January 2004, n. 42, Art. 11, comma 1, letters f) and h)). In our opinion, such interpretation was improper, or at least questionable, for the following reasons.

Just exactly as it is now done with CCD cameras, before the advent of digital sensors, astronomers have employed photosensitive emulsion on glass support to record images of the sky at the telescope's focal plane with the scope of making advancements in observational astronomy. Therefore, the function of these photographic plates was, and still is, scientific;

the fact that, technically, they can be named *photographs* does not make them equivalent to *pictures*, i.e., images whose fruition is finalized to the act of viewing them. Moreover, in all these years, OATo's plates have never been treated as historic material, they are not part of an official archive nor they have ever been assigned an inventory number; in fact, their conservation and storage have been practically consigned to the initiative and care of those OATo astronomers appreciating the potential scientific value of such old plates. For these reasons, we believe the plates should not be subject to restrictions based on their potential interest as cultural heritage until their primary function – that of storing scientific data – would be fully accomplished, i.e., their digitization.

However, our point of view was not considered as viable, so we took on the additional tasks involved in obtaining the authorization papers and handling the export procedures.

When we contacted the 'Soprintendenza Archeologia Belle Arti e Paesaggio' of Torino (`http://www.sabap-to.beniculturali.it`) about the authorizations, we tried to clarify whether it was appropriate in our case to apply the restricitons mentioned above. After a few iterations, in particular with the head of 'Ufficio Mostre' Dr. Rocchietti, and the head of 'Ufficio Esportazioni' Dr. Moratti, we agreed that, given the peculiar nature and instrumental function of the material in question, the decision of making it subject to cultural heritage regulations was an unnecessary excess of zeal on OATo's part. However, the formally correct procedure would have been for the Soprintendenza to come to OATo for an inspection of the plates, and then make an official decision. This could not happen quickly, especially due to the contingency of COVID-19 emergency. Therefore, to expedite things in the interest of the project (which had a specific timeline dictated by the expenditure of funds allocated for the digitization task by SHAO), we agreed to adopt the following compromise: We would treat strictly as historical heritage only the ~ 800 plates older than 50 years, requiring as such an authorization granted by the Ministry in Rome; whereas the export of the remaining ~ 7000 plates – not labeled as 'historical' because going back to less than 50 years – would have been approved directly by the regional superintendence, with a faster procedure.

Having reached this decision, we split the shipment in two tranches: first the plates more recent than 50 years, then the 'historical' ones. Working in strict contact with the Soprintendenza, we produced all the necessary documents for the authorizations, including an all-risk insurance policy to cover the plates transportation and permanence abroad.

The shipment part was also rather laborious, since, according to cultural heritage regulations, it needed to be handled as 'temporary export'. This entailed another bureaucratic step, i.e., the issuing of a 'carnet ATA' by the Chamber of Commerce of Torino (`https://www.to.camcom.it/carnet-ata`). This document was to accompany the plates in the phase of custom clearance and inspection, particularly critical for a temporary export. Despite the enormous efforts involved, we were able to accomplish all these tasks in sync with the organization of the two shipments.

Figure 2: Customized boxes with different lodging separators

4.1 Plates packaging operations and shipments schedule

As plate containers, we used boxes of high-density polyethylene (measuring 60L40W42.5H cm), especially customized by a Chinese company (`http://seaman8188.com`) and shipped to OATo by our chinese colleagues. As shown in Fig. 2, they came with internal separators of different sizes made of high-density rubber to help organizing plate stockage, plus plenty of foam sheets which we positioned in between the plates for shockproof protection. The process of packaging was laborious and meticolous, as we had to be able to keep track of each single plate shipped by association with its catalog number, while devising the best strategy of placing plates of different sizes in the same box, which would optimize the use of space.

For the first shipment, we managed to send 5503 plates stored in 13 boxes, weighing in total 475 kilograms (see Fig. 3); they left OATo on July 22, landed in Shanghai with two separate flights, one arriving August 14 the other August 18, and whre delivered at destination (Sheshan station, about 70Km from Shanghai Observatory, where the scanning machine is housed), on September 3! The delay was a combination of air carrier issues and the somewhat lenghty custom procedures applying to temporary exports, especially in these pandemic times. We had entrusted the shipment to SOCISEC S.r.l. (`https://www.retelogistica.eu`), a logistic company based in Battipaglia, SA, (recommended by our administration), who was certainly professional and helpful but, in our opinion, not very experienced with temporary exports.

We started preparing for the second shipment of 1772 plates (consisting of 746 historical plates plus the remaining more recent ones) right after the summer holidays, even though the final authorization from the Ministry arrived only at the end of October. The shipment included 7 of the high-density polyethylene boxes plus 2 small wooden boxes (see Fig. 4), wheighing in total 240 kilograms, that we entrusted again to SOCISEC. This time they chose DHL as carrier, hoping that the whole process of transit, custom clearance, and

(a) Preparations of 1st shipment

(b) 1st shipment ready to leave OATo

(c) 1st shipment at destination

(d) Box opening at destination

Figure 3: Shipment of 5503 OATo's photographic plates

delivery would be faster. The plates left OATo on November 11 and arrived in China on November 19, but were delivered at destinaton ony on December 23! The custom clearance in Shanghai took significantly longer this time because DHL would not handle directly the temporary import, and SOCISEC couldn't find an agent in China who would take charge of the job; so, we had to hand it over to a local broker contacted by our chinese colleagues, and probably some glitch intervened, slowing down the process. We believe that some inspection went on during custom attendance, but our colleagues report that the plates arrived in good condition both with the first and second shipment: we finally declared successfully concluded our enterprise.

5 What's next

As we write this note, our colleagues have completed digitizing the first shipment of plates, moving on to the second one. The boxes are handled one by one, and each plate is put back in it original position in the box, right after scanning. Fig. 5 shows some phases of

(a) 2nd shipment ready to leave OATo

(b) 2nd shipment at destination

(c) 2nd shipment at destination

(d) Box opening at destination

Figure 4: Shipment of 1772 OATo's photographic plates

plate handling and cleaning at SHAO.

In the next steps of the FOTOSS project, which will address image processing and calibration, we plan to set up a few targeted pilot experiments to evaluate both the astrometric and photometric performances of different kind of plate material, using the latest Gaia catalog as reference.

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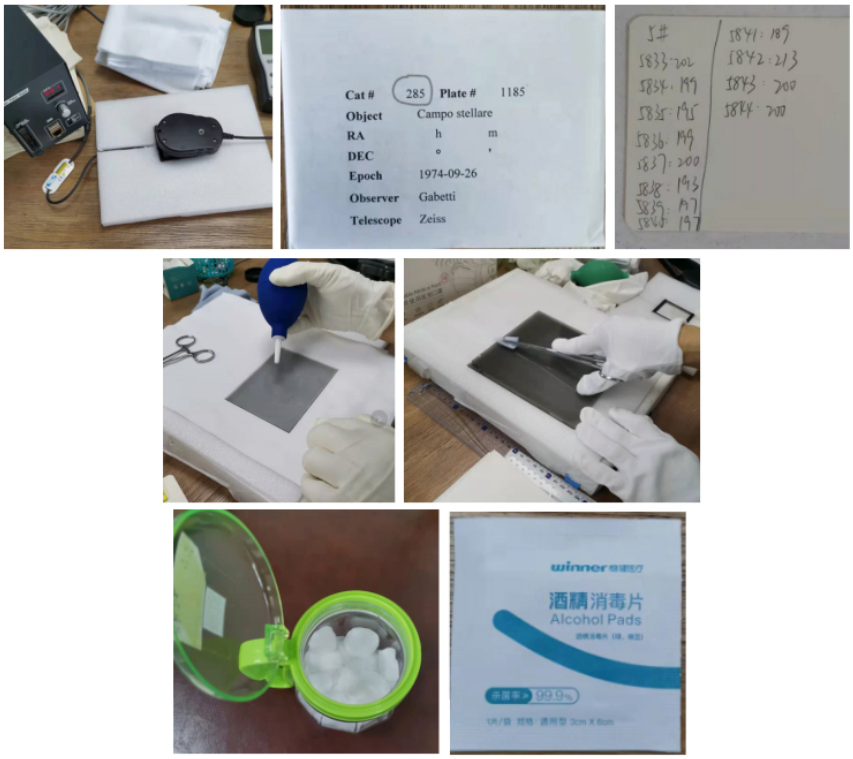

Figure 5: Plate preparation for scanning at SHAO

CISEC); Camera di Commercio di Torino.

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