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Updates from FOTOSS: Highlights and Statistics from the OATo Photographic Plate Archive

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Abstract

This is a progress report of the on-going work that started with the activities related in [1]. First, we give an up-to-date account of the status of the FOTOSS[1] project, including preliminary informations on the number and characteristics of the digitized plate images; we then present a detailed explanation of the content and usage of the latest realization of the Master Plate Catalog (MPC), along with some general statistics based on the observations recorded in the MPC.

1 Plate archive status and outlook

FOTOSS is a project of the Astrophysical Observatory of Torino (OATo) in cooperation with the Shanghai Astronomical Observatory (SHAO) with the purpose of high-accurate digitization of the entire OATo's photographic plate archive for its scientific preservation and exploitation. In the first technical report dedicated to this project [1] we described the status of the OATo's plate archive, the aims of FOTOSS, and all the activities related to the shipment of the photographic plates from OATo to SHAO. In order to achieve this goal, the large majority of OATo's plates have now been inspected and catalogued, taking up from a previous endeavour started in the early 2000 and discontinued a few years later for lack of resources. A revised synopsis of the content of the current OATo's plate catalog is given in Table 1, which lists all the catalogued plates (see section 2 for more details) grouped by telescope used, plate dimension, and epoch of observation; this table supersedes Table 1 of [1]. Table 2 provides a summary of the physical status of the plates, rating them from high to low-grade. Large part of the plates are in good condition, whereas $\approx 2.5\%$ are affected by mild-to-severe emulsion degradation and $\approx 3.3\%$ have experienced some glass damage. The slow process of deterioration of silver-gelatine emulsion on glass support is known (see, e.g., www.canada.ca/en/conservation-institute/service/ and [2]); hence, proper measures for the care and storage of old photographic plates need to be taken (see, e.g., [3] and references

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

Telescope	*Characteristics*	*Number of Plates*	*Dimensions [cm]*	*Epochs*
OATo Telescopes				
Zeiss Astropgraph	Diameter 200 mm, focal 1140 mm	558	18x24	1925 - 1967
		2	20x20	1949
		430	16x16	1927 - 1987
		224	10x15	1929 - 1968
		2247	9x12	1952 - 1984
		35	9x9	1946 - 1983
		211	6x9	1929 - 1953
Morais Refractor	Diameter 380 mm, focal 6875 mm	274	20x20	1971 - 1995
		820	16x16	1973 - 1995
		89	9x12	1988 - 1989
REOSC Astrometric Reflector	Diameter 1050 mm, focal 9942 mm	429	16x16	1974 - 1996
		568	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 4000 mm, focal 4000 mm	968	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 1200 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 67/92 Reflector Asiago Observatory(PD), I	Diameter 920 mm, focal 2150 mm	69	20x20	1969 - 1993
Schmidt 40/50 Reflector Asiago Observatory(PD), I	Diameter 500 mm, focal 1250 mm	1	11$\varnothing$ (*)	1961
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 - 1996
Jewett Schmidt Telescope Harvard College Observatory Oak Ridge MA, USA	Diameter 600 mm, focal 2105 mm	77	20x25	1949
		33	20x20	1949
Schmidt 50/66/175 Uppsala South Canberra, Australia	Diameter 660 mm, focal 1750 mm	53	11x11	1980
Miscellanea				
Unknown		38	various	1950 - 1975

Table 1: Summary of the catalogued OATo's plates grouped by telescope, plate size and year of observation.
(*) this isn't a glass plate but a film of circular shape.

therein). In this regard, we note that a thought-out conservation plan of the OATo plates, even when their astronomical content has been secured by digitization, should be considered for two reasons: a) maintaining access to the original analog data until the evaluation of the digital images is fully completed; and b) historical/cultural interest of a qualified sample of the plates–with special focus on the most ancient and/or photographically captivating ones–which should be selected on the basis of objective criteria. Therefore, while the FOTOSS program is underway, we are addressing the issue of long-term preservation of these archival plates in view of their targeted usage.

Plate Status	**Number of Plates**	**Notes**
good emulsion	6100	100% good status
good emulsion $\geq 90\%$	646	good status between 90% and 100%
good emulsion $< 90\%$	167	good status less then 90%
emulsion with problems	179	detached, damaged, bad, deteriorated, spotted, yellowed
broken plate	245	broken, chipped, cracked

Table 2: Statistics of plate conservation status

1.1 Update on plates' digitization

A total of 7,275 plates were sent to China via air currier in two separate shipments, all of which arrived safely at destination. Technnical Note [1] ends by stating that the SHAO colleagues had completed digitizing the first shipment of plates and they were about to move on the second one.

Digitization of the first batch of plates took 6 months, as estimated, and they returned to OATo on March 8, 2022. The second batch of plates was in China 8 months due to a delay in the digitizing operations caused by an aggravation of the COVID-19 situation in Shanghai which forced the scanning staff to a period of lockdown. This batch returned to OATo on September 6, 2022. Figure 1 shows the 20 polyethylene plus the 2 small wooden crates containing all the scanned plates, after their return to OATo.

Together with each batch of plates, we received an external hard drive with the corresponding digitized data. The data consist of 7281[2] FITS files, with a total size of 1.9 TB. The original header of the FITS files contains only information about the format and size of the data (SIMPLE=T, BITPIX=16, NAXIS=2, NAXIS1, NAXIS2, DATE, BSCALE=1, BZERO=32768). The FITS keywords related to the observational data will be added as the images are processed.
The size of a single FITS file ranges from 111 MB (7680x7560 pixels) to 1017 MB (22400x23800 pixels) depending on plate size. Figure 2 shows the FITS images of two plates with different size. The visible border around the effective area of the plate is an effect of the

[2]The difference with the number of plates is due to a few double scans.



Figure 1: Left panel: 13 boxes containing the plates of the first batch. Right panel: 9 boxes containing the plates of the second batch.

scanning method which uses a mosaic technique[3], and must be removed. More details of the digitization equipment and scanning process will be given in a future report dedicated to the processing of the digital data.

2 The Master Plate Catalog (MPC)

The first direct output of the activity of collecting informations from the plates and the observational material associated with them is the contruction of what we name Master Plate Catalog (MPC), a plate database that serves as repository of all the relevant data, which can be efficiently queried to extract informations on the recorded observations. The database in its present form consists of 7337 photographic plates[4] (see also Table 1), of

[3]The images have been obtained by two different digitizing devices, one with a camera sensor of 1400x1400 pixels (s1) and the other with a camera sensor of 1280x1080 pixels (s2). Since a plate is much larger than the camera, the device takes multiple exposures of the plate at different positions, each exposure having the size (in pixels) of the camera used. Once all the images have been recorded, they are assembled into a single image of the whole plate. The pixel size of an image from s1 is 1400xm by 1400xn and the pixels size of an image from s2 is 1280xm by 1080xn, where m and n are the number of single photos taken along the the two image axes.

[4]The full photographic archive includes several hundred spectral images not considered here. Moreover, a considerable set of plates are relative to the OATo observing program of visual double stars: of these,

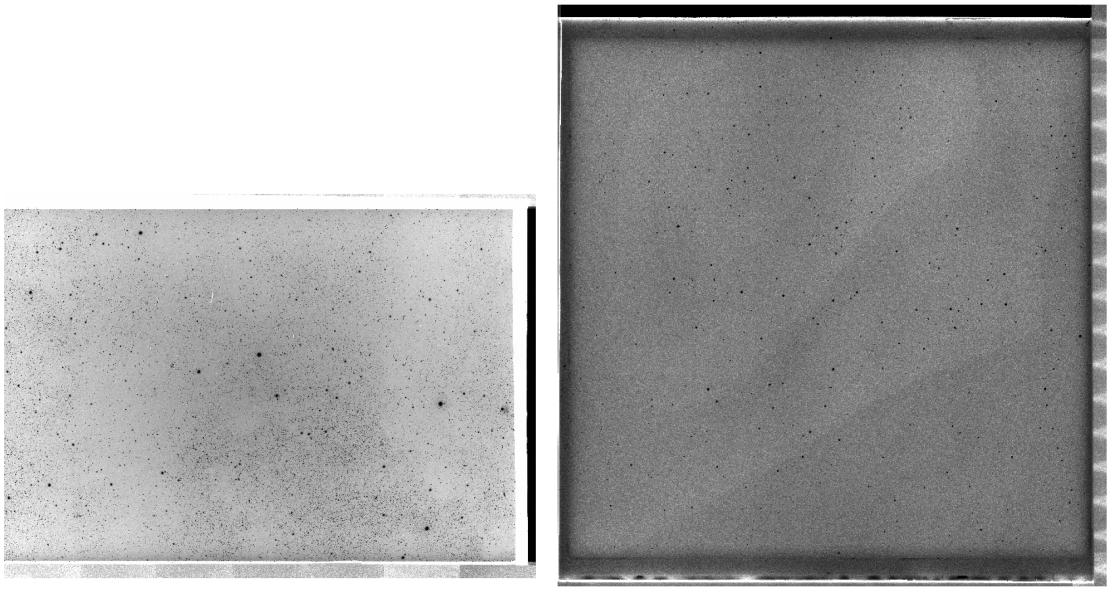


Figure 2: Left panel: 7680x7560 pixels FITS image of a 9x12 cm plate. Right panel: 22400x23800 pixels FITS image of a 24x24 cm plate.

which 7275 have been digitized as part of the FOTOSS project[5]. The final format of the MPC is an ASCII csv file made of 11725 rows and 22 columns. The fields of the MPC are listed in Table 3 and described in detail in Section 2.1.
All the informations concerning the exposures have been transcribed from the observing logbooks, the envelopes where the plates were stored, or directly from the glass plates. Moreover, a preview image in JPEG format is supplied for each plate. For plates catalogued before 2018 ($ID1 <= 5551$), the preview images have been obtained by means of a commercial scanner (600 dpi resolution), whereas for the newly catalogued ones, preview images were taken with a digital camera (24.3 Mpx resolution) after positioning the plate on a backlighting table. For this second set of plates we provide also the photo of the plate envelope, when present [6].

We note that the number of catalog records does not match the number of actual plates due to the method of ingestion in the MPC of a number of plates with multiple exposures of the same object or with multiple objects[7]. Plates corresponding to a single exposure

only a subset (200) related to potentially more interesting targets took part in this phase of the digitization program, and the remaining plates (<1300) are not included in the current MPC. Finally, a limited number of assorted plates, many of which of uncertain origin/content have not been addressed at this stage.

[5]62 catalogued plates have not been digitized because we deemed them unusable.

[6]We also took photos for a subset of the plates catalogued before 2018 for which the original image had been lost.

[7]A multi-exposure consists in moving the telescope pointing by small steps to obtain a sequence of exposures of the same field slightly shifted from one another; in many cases the start and end of each exposure was indicated on the plate envelope and/or in the observation log. The not so common multi-object instance occurs when the same plate is multi-exposed by pointing to different target fields: it was

Name	Type	Unit	Description
ID1	int		Catalogue identification number
ID1_index	char		Catalogue identification number index
Plate_number	char		Plate identification number
multiobject	char		Number of fields
multiexposure	char		Number of exposures
Plate_Status	char		Quality of the plate
Object	char		Name of the observed object
Obj_type	char		Type of the observed object
RA_ICRS	float	deg	Right Ascension (International Celestial Reference System)
Dec_ICRS	float	deg	Declination (International Celestial Reference System)
UT_start	char	hh:mm:ss	UT time of the start of exposure
UT_end	char	hh:mm:ss	UT time of the end of exposure
Emulsion	char		Name of the photographic emulsion
Filter	char		Filter type used during the observation
Epoch_int	int		Epoch of the observation in integer format
Observer_name	char		Observer name
Temperature	float	Celsius	Air temperature
Telescope	char		Telescope name
Plate_size	char	cmxcm	Plate format
Exposure_time	float	sec	Exposure time
Notes	char		Observer and miscellaneous notes
Image_file	char		Name of the JPG image file

Table 3: MPC field names, variable types and units, and short description

of a single object are assigned a single record of the MPC, while plates with multiple exposures and/or multiple objects may correspond to several records depending on the number of exposures and/or objects [8]. In this respect it must be warned that there is an inconsistency between the first part of the catalog, produced before 2018, and the second one added successively. The first 3130 plates of the MPC have catalog numbers (ID1) in the range [1, 5551], corresponding to 5545 records, because different consecutive ID1 have been assigned to multiple exposures or multiple objects on a single plate. On the other hand, the successive 4207 plates cover the ID1 range [5552, 9759], corresponding to 6180 records, because multiple exposures or multiple objects on the same plate have the same ID1 but correspond to different records[9]. We are presently running some quality control tests on the catalog to verify data integrity and resolve possible inconsistences still present. After that, we intend to make the MPC available on-line together with all the JPEG previews of the plates.

a practice used to economize on glass-supported photographic emulsions, very expensive at the time.

[8]Multiple records referred to a single plate have been generated only when distinct data for each multiple exposure/object were available.

[9]We note here that a few catalog numbers (ID1) are missing, i.e.: 50, 83, 251, 307, 311, 4250, 7524. It is possible that in a future revision of the catalog this inconsistency will be removed.

2.1 Detailed description of MPC fields

In this subsection each field of the MPC is described in detail.

1. **ID1:** catalogue identification number. It is a progressive number ranging from 1 to 9759. As anticipated in Section 2, in the range [1, 5551] several consecutive ID1 values can be associated with the same plate when multiple exposures and/or objects are recorded on it. Otherwise, in the range [5552, 9759] each plate is associated to a unique ID1 value that can be repeated on several consecutive records when multiple exposures and/or objects are recorded on the plate.

2. **ID1_index:** this field has been added in order to distinguish multiple records associated to the same plate (see Section 2). The field value can be a letter in the set [a, b, c, d, e, f, g, h, i, l, m]. For example, a plate recording 3 different exposures has 3 records associated with it, each one flagged with the letter a, b and c respectively. The field is empty when the plate is associated to a single record.

3. **Plate_number:** plate identification number. It is the original plate identifier, as written on the glass plate. It can be made of numbers, letters and other characters (e.g. 872; 4-370a; P96). The field is empty when the information is missing.

4. **multiobject:** string defining whether the plate contains a single object (1/1) or multiple objects (from 1/N to N/N for N objects). When distinct data for each of the multiple objects are not available, the total number of objects is reported. The field is empty when the information is missing.

5. **multiexposure:** string indicating whether on the plate is recorded a single exposure (1/1) or multiple exposures (from 1/N to N/N for N exposures) of the same target object. When distinct data for each of the multiple exposures are not available the total number of exposures is reported. The field is empty when the information is missing.

6. **Plate_Status:** descriptive string defining the conservation status of the plate. It describes the status of the emulsion (e.g. good emulsion, good emulsion 90%, detached emulsion) and/or the status of the glass (e.g. broken, chipped, cracked).

7. **Object:** Name of the observed object. The naming of the astronomical objects follows the rules introduced by the International Astronomical Union (IAU)[10]. In particular, minor planets names are from the catalog published by the Minor Planet Center of the International Astronomical Union (IAU)[11]; comet names are from the 1995 IAU designation[12]; double stars have designations from several different cata-

[10] `https://www.iau.org/public/themes/naming/`
[11] `https://www.minorplanetcenter.net/iau/lists/MPNames.html`
[12] `https://minorplanetcenter.net/iau/lists/CometResolution.html`

logs[13]; star clusters and galaxies are named from the New General Catalogue (NGC) or the Messier catalog (M) or the Index Catalog (IC) or the Trumpler R. J. (Tr) list, or using their common/historical name; radiosource names are in the form `QSO BHHMM+/-DDD` The field is empty when the information is missing.

8. **Obj_type:** Type of the observed object. The catalog reports 16 types of objects identified by the following acronyms: minor planet (MP), planet (P), comet (C), star (S), double star (DS), radiosource (QSO), open cluster (OC), globular cluster (GC), galaxy (GAL), nebula (N), planetary nebula (PN), artificial satellite (SAT), search for object (R), calibration (CAL), miscellanea (M), unknown (U).

9. **RA:** Right Ascension (as reported by the observer) in degrees[14]. The field is empty when the information is missing.

10. **Dec:** Declination (as reported by the observer) in degrees[14]. The field is empty when the information is missing.

11. **UT_start:** start time of the observation in Universal Time (UT) in the format hh:mm:ss[15]. The field is empty when the information is missing.

12. **UT_end:** end time of the observation in Universal Time (UT) in the format hh:mm:ss[15]. The field is empty when the information is missing.

13. **Emulsion:** Name of the photographic emulsion. The field is empty when the information is missing.

14. **Filter:** Filter type used during the observation. The field is empty when the information is missing.

15. **Epoch_int:** Epoch of the observation represented as an integer number (yyyymmdd). The field has value 0 when the information is missing.

16. **Observer_name:** name of the observer. The majority of the observers are astronomers who have worked or still work at OATo. For few observers only the initials of the name are reported as their identity could not be traced. The field is empty when the information is missing.

17. **Temperature:** air temperature at the time of observation expressed in Celsius degrees. The field is empty when the information is missing.

[13] see `http://www.astro.gsu.edu/wds/Webtextfiles/wdsnewref.txt` for a list of acronyms and relative references. There are several double stars identified by the unknown acronyms TR or TRA. For some of them the field `Object` reports also the Index Catalogue of Visual Double Stars (IDS) designation.

[14] The coordinates have been transformed from the original ones provided in the format RA_hours, RA_minutes, Dec_degrees, Dec_minutes, maintaing only significant decimal digits

[15] In few occasions, the observer reported Sidereal Time (ST) instead of Universal Time (UT); in such cases, we transformed ST into UT and only retained the latter in the MPC for sake of conciseness and data uniformity

18. **Telescope:** name of the telescope. The catalogue reports observations acquired by the 4 OATo telescopes (Zeiss, Morais, REOSC, Merz), and by 11 telescopes located in others sites. The telescopes and their characteristics are listed in Table 1. The field is empty when the information is missing.

19. **Plate_size:** plate format in $cm \times cm$. The different plate formats are listed in Table 1.

20. **Exposure_time:** exposure time in seconds. When the original exposure time is expressed in hours or minutes it has been converted to seconds. The field is empty when the information is missing.

21. **Notes:** this field reports all the annotations made by the observer during the night. They may relate, for example, to atmospheric conditions, characteristics and physical parameters of the observed object, the state of the instrumentation, the epoch of the coordinates, the adopted measure of time. In some cases this field has been used to add some useful information acquired during the construction of the catalog. The field is empty when the information is missing.

22. **Image_file:** name of the JPG image file reproducing the plate. The JPG file names of the plates with $ID1 \leq 5551$ have the format "$ID1$"-"$Plate_number$".jpg[16], the JPG file names of the plates with $ID1 \geq 5552$ have the format "DSC_number"_"$ID1$"_"$Plate_number$"_"L".JPG[17].

In all fields the character "?" indicates an uncertain, incomplete or missing information; the character "&" has the function of separator of multiple information.

3 General statistics from the MPC

We are now able to produce some descriptive statistics of the OATo's photographic archive gathered solely from the MPC catalog. In the following, we present some tables and graphs summarizing the astronomical content of the archived plates and highlight some characteristics of the recorded observations with an historical perspective. Finally, we give an example of how on-line access to the MPC can be exploited for the search of old observational records of a specific celestial object.

First of all, we looked at the sky distribution of plate centers in equatorial coordinates (RA, Dec), as depicted in Figure 3. Besides the visible galactic plane traced by observations of open clusters, the bulk of positions are clustered around the ecliptic; in fact, $\approx 70\%$ of the observed objects belong to the Solar System (minor planets, planets and comets). This can be also seen in the histogram of Figure 4, which plots the number of plates per object

[16]The images recently redone with the digital camera have a trailing L ("$ID1$"_"$Plate_number$"_"L".jpg) which stay for Lastra (Plate).

[17]DSC_number is the number of the image assigned by the digital camera. The trailing L stands for Lastra (Plate).

type: 54% of the plates contain images of minor planets; the second observed object type is *Comet* (C, 9%), whereas the third observed targets are double stars (DS, 7%). Solar system objects constitutes 66% of the archive, galactic sources 21%, and extragalactic sources 6%. The remaining 7% are calibration, miscellanea or unknown type.

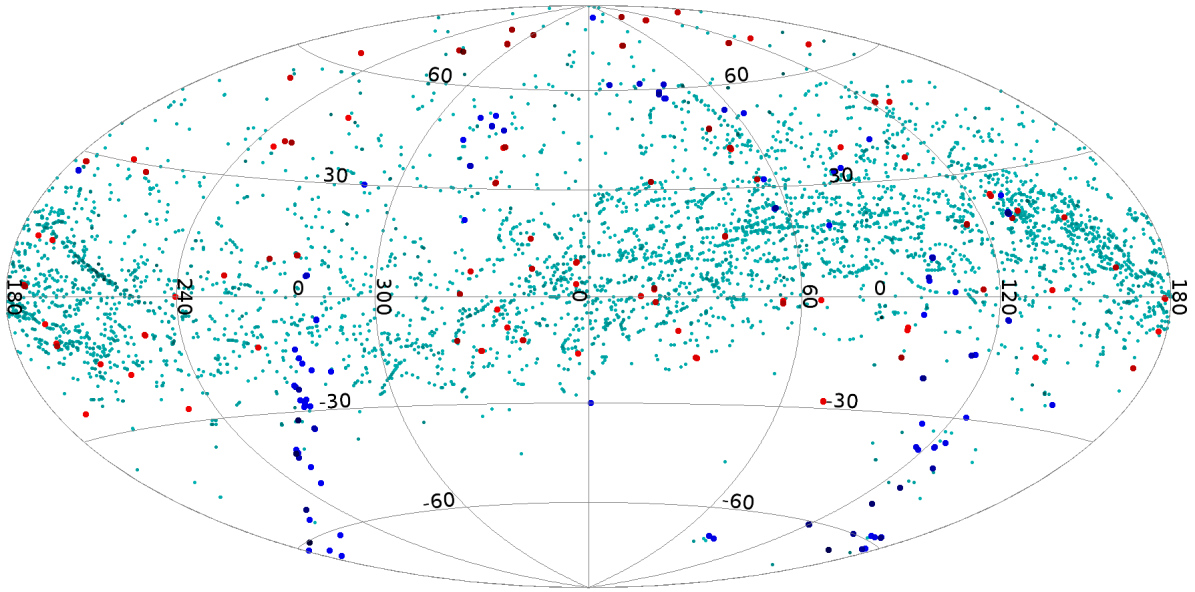


Figure 3: Distribution of plate centers in equatorial coordinates (Aitoff map projection). Red and blue dots show the positions of radio-sources (QSO) and open clusters (OC), respectively.

The bar chart in Figure 5 shows the relative usage of the different telescopes in terms of number of plates produced: 80% of the plates have been taken with the OATo telescopes, 63% of which with the Zeiss telescope alone (50% of the total). The remaining 20% of plates come from non-OATo telescopes, both Italian and international (see Table 1), 67% of which being from the ESO-GPO telescope (13% of the total). After the 3 OATo's telescopes representing the bulk of plate production, next in line comes the GPO-ESO telescope at La Silla, Chile, where OATo's astronomers carried out intensive observing campaigns in the '80s and early '90s. Another way of looking at OATo plates' production in time is illustrated by the pie charts of Figure 6, where the plates are grouped by epoch ranges, with colours corresponding to the number of plates taken by a specific telescope in that epoch interval.

The top four panels of Figure 7 show the distribution of the observed types of objects for each of the four main telescopes (Zeiss, Morais, REOSC, GPO-ESO); the bottom panel groups all the other telescopes. It can be noted how the minor planet and comet campaigns initiated at the Zeiss–the oldest OATo's telescope–were continued at the Morais–the second oldest telescope–and that the latter was dedicated to a QSO astrometric program conducted jointly with the REOSC telescope, which started operating in the early '80s; we also note that the ESO-GPO telescope was employed for the observation of a few southern targets

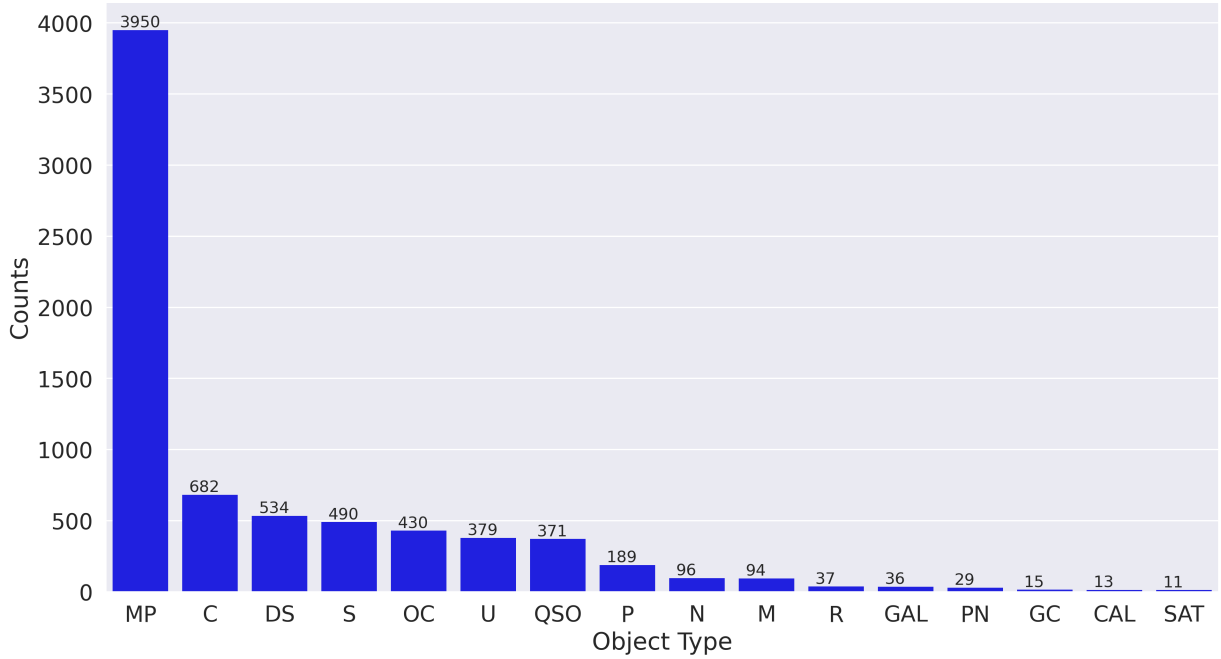


Figure 4: Histogram of the observed types of objects.

of the OATo QSO program (see also the sky map of Figure 3), as well as for a program dedicated to open clusters, besides the long-standing OATo's campaigns on Solar System objects and double stars. We also looked at the apportionment of the exposure times in the whole catalog, as illustrated in Figure 8, while Figure 9 reports the mean exposure times per object type, pointing out that the longest exposures ($>$ 1 hour) were mainly dedicated to the search of minor planets and comets. Finally, Table 4 shows the extraction of selected fields from the MPC using `topcat`, obtained by searching for observations of minor planet *(168) Sibylla* listed in the field `Object`. The query retrieved 2 plates with 2 exposures each, dated 1969. The quality of the plates can be inspected by opening the JPEG preview images linked to the MPC records.

Plate_number	multiobject	multiexposure	Plate_Status	Object	Epoch_int	Telescope	Plate_size	Exposure_time	image_file
153	1/1	1/2	good emulsion	(168) Sibylla	19691005	Zeiss	9x12	600.0	DSC02016_5739_153_L.JPG
153	1/1	2/2	good emulsion	(168) Sibylla	19691005	Zeiss	9x12	600.0	DSC02016_5739_153_L.JPG
171	1/1	1/2	good emulsion	(168) Sibylla	19691010	Zeiss	9x12	600.0	DSC02059_5757_171_L.JPG
171	1/1	2/2	good emulsion	(168) Sibylla	19691010	Zeiss	9x12	600.0	DSC02059_5757_171_L.JPG

Table 4: Example of data extraction from the MPC

4 Conclusions and future work

We have given a detailed account of the construction and usage of the Master Plate Catalog (MPC), an ASCII csv file containing all the observational informations retrieved from the

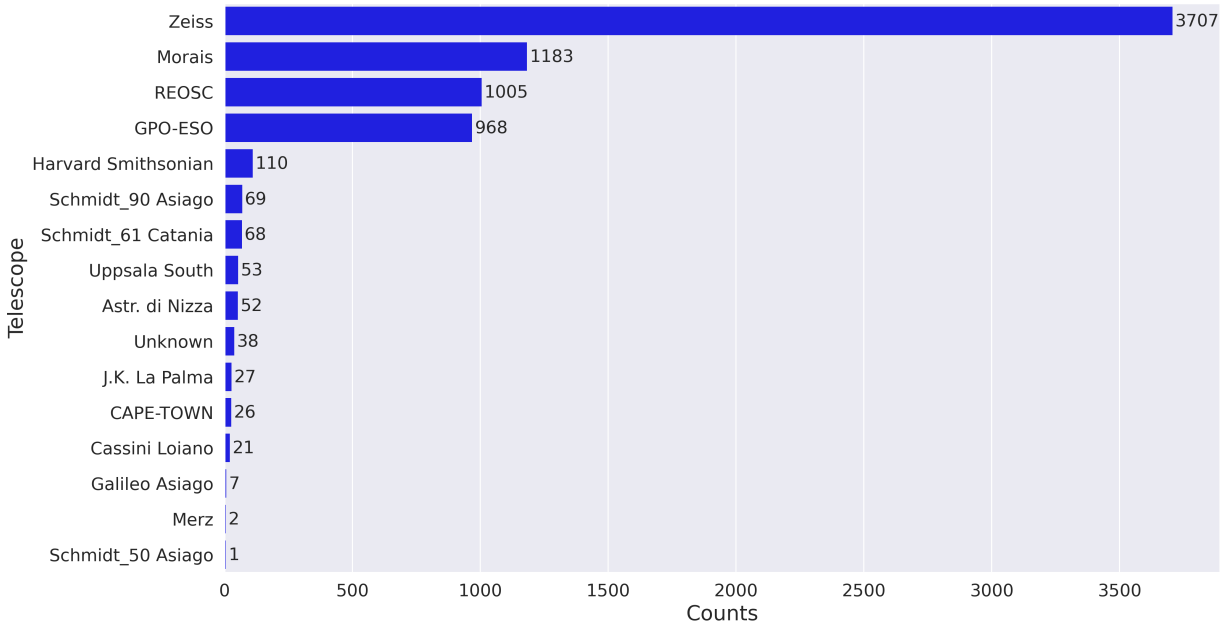


Figure 5: Histogram of the number of plates per telescope.

OATo's plate archive in its present status. The FOTOSS digitization program has successfully achieved its first goal, i.e., the high-accurate digitization of 7275 plates, producing fits images for a total of 1.9 Terabytes of data. The next steps will deal with the processing of the digitized images, which will finally allow to gauge the quality of the data at hand in view of their scientific usage. The upcoming online version of the MPC, along with all the plate preview images, will be advertised on the INAF-OATo website.

5 Acknowledgments

Matteo Tivan, as partial fullfilment of the academic activity 'Alternanza Scuola Lavoro' directed to high-school students, helped checking the MPC integrity and homogenize the 'Object' field according to IAU standard nomenclatures. We thank G. Massone for his advices for the recovery/resolution of missing/unclear data toward the construction of the MPC.

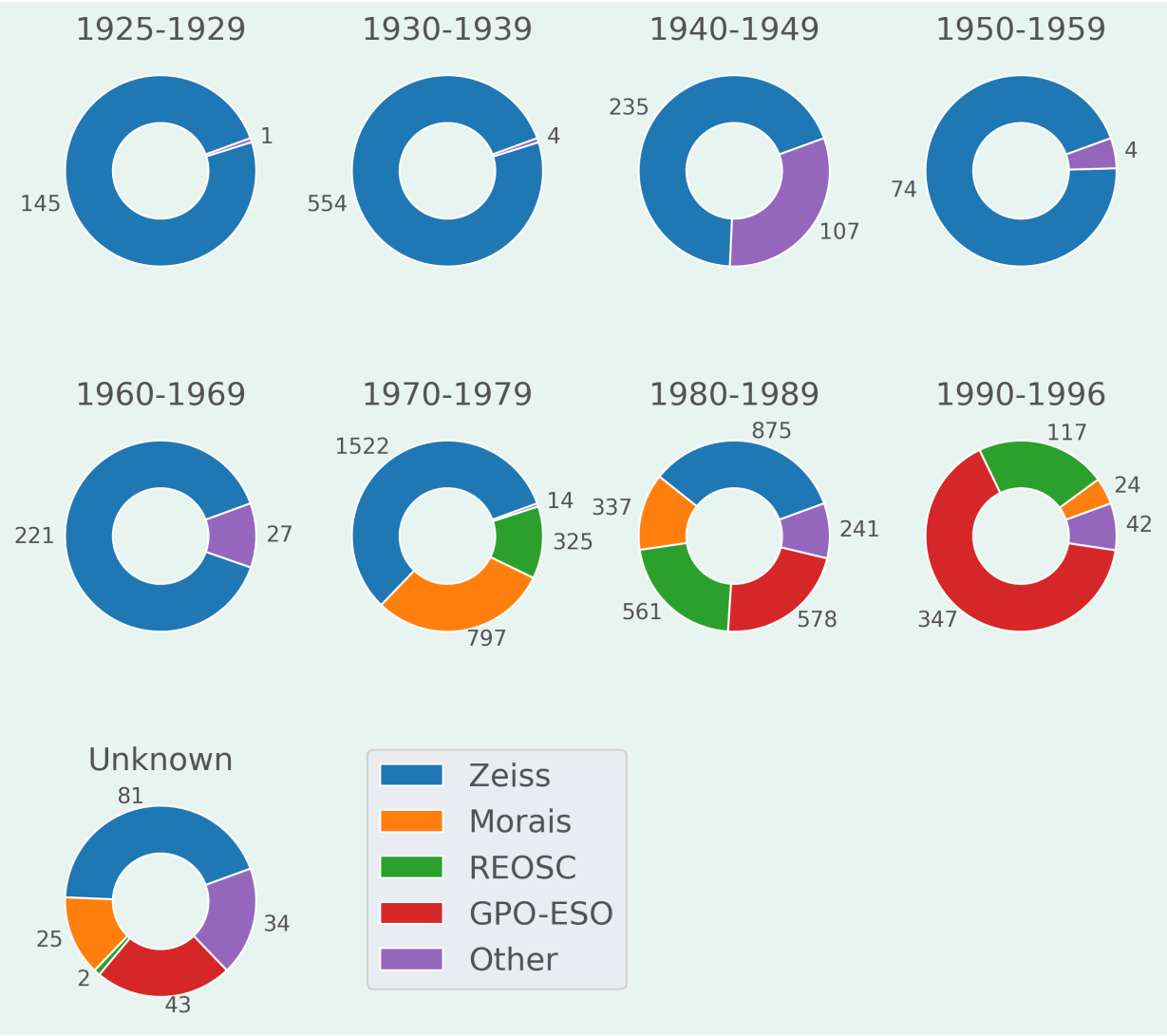


Figure 6: Pie charts showing which telescopes have been used in different ranges of epoch and the correspondent number of plates. The label *Other* groups all the non-OATo telescopes except ESO-GPO. The bottom-left pie-chart groups plates of unknown epoch.

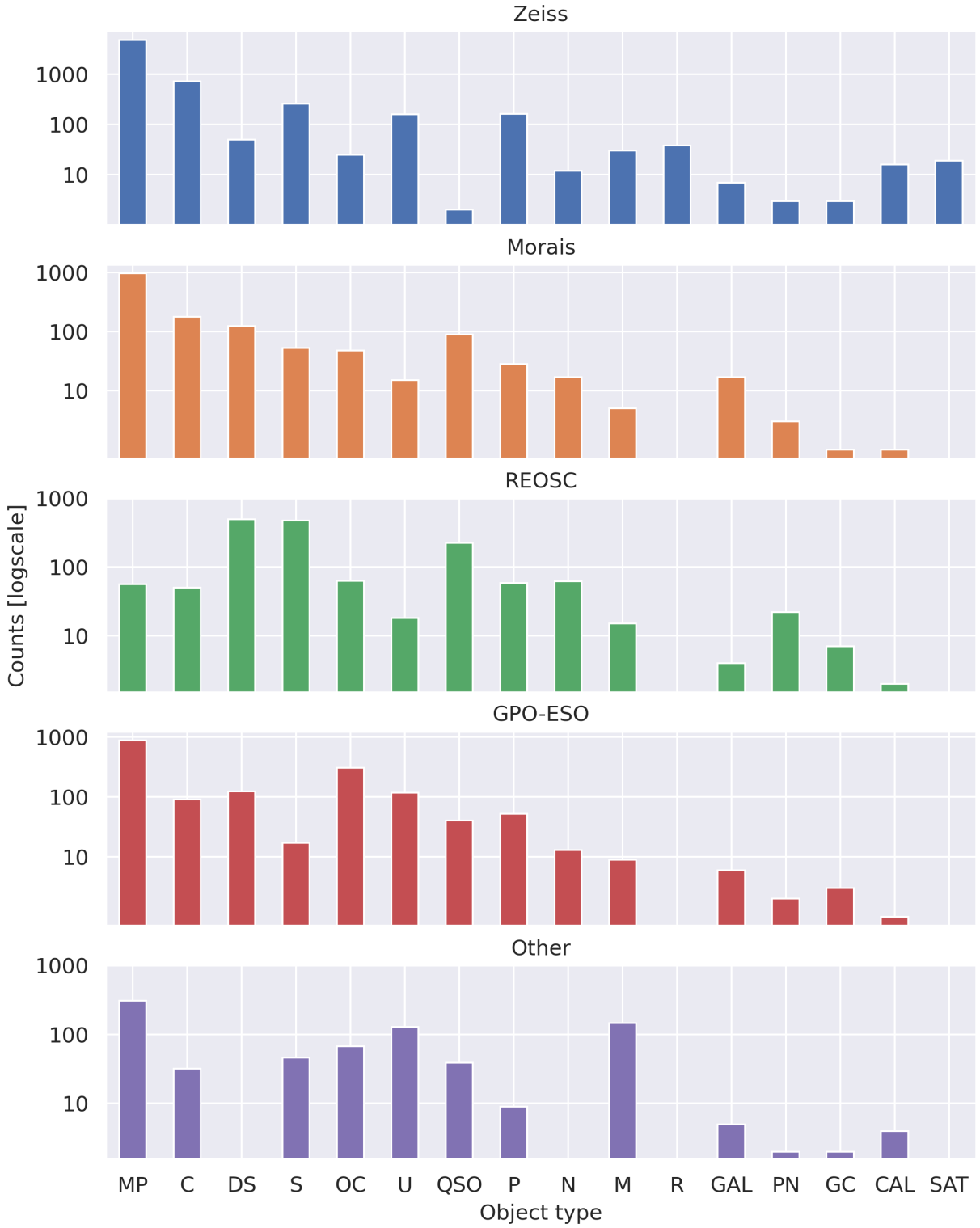


Figure 7: Histograms of the type of objects observed by the main four telescopes (top 4 panels). The bottom panel groups others non-OATo telescopes (*Other*).

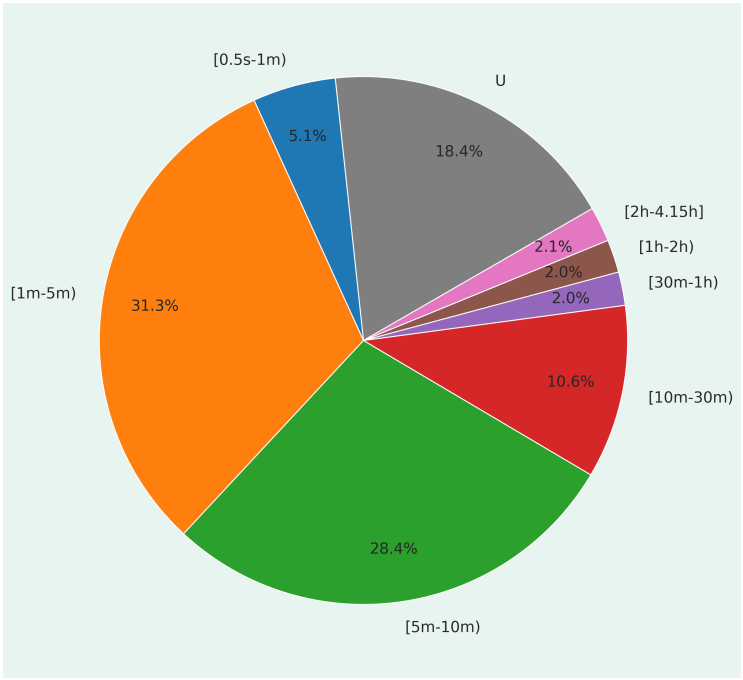


Figure 8: Pie chart showing the distribution of exposure times in the MPC. Exposure times are grouped in bins of non-uniform width (external labels); U stands for unknown exposure time. The internal labels show the percentage of exposures for each bin.

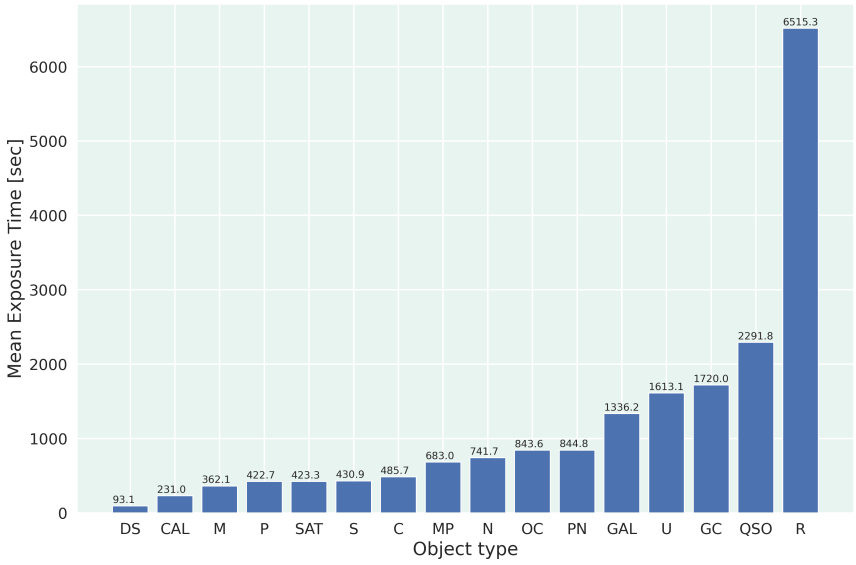


Figure 9: Bar plot showing the mean exposure time in seconds for the different types of object.

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