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

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Abstract

A large-scale two-year project to digitize the archive of plates of the Italian Astronomical Observatories and of the Specola Vaticana has been started in 2002 with funds from the Ministry of the University and Research, following a pilot program funded by the University of Padova in 2001 (see Barbieri et al., 2002, Paper I). Identical systems, composed by a commercial scanner plus dedicated personal computers and acquisition software (developed initially at DLR Berlin) have been installed in all participating Institutes. Two more elements make up the total project: to provide high quality photometric sequences with the Campo Imperatore telescopes, to distribute the digitized information to all interested researchers via the international Web.

This paper presents some of the activities carried out and results obtained from August 2001 to March 2003.

Introduction

A great amount of highly valuable information is stored in the photographic archives of many Italian Observatories and in the Specola Vaticana, with plates dating back to the end of the XIXth Century. A proper digitization of this veritable treasury is therefore of paramount importance, both for the preservation of their volatile support and for the fuller exploitation of the scientific content (see e.g. Viotti et al., 1993, Griffin, 2001). Among the possible scientific objectives:

- previous transits of NEOs for a better reconstruction of their orbital evolution,
- high proper motion stars,
- variable stars in the Milky Way and external galaxies (e.g. the wealth of near-IR variables discovered by P. Maffei in the galactic plane, or the Hubble-Sandage variables in M31 and M33),
- spectral classification over wide fields,
- time history of QSOs

etc.

Following a pilot program funded by the University of Padova in 2001 (see Barbieri et al., 2002, Paper I), which gave several elements of knowledge and permitted to contact the National and International community, we have set up a collaboration among our six Institutions and have obtained national funds from the Ministry of the University and Research. We present here a report of activity covering the period from August 2001 to March 2003.

The photographic archives census

The photographic plate is a fragile and perishable support implying the risk, in time, to lose its entire information. It is necessary therefore to provide the means for an adequate conservation of this material, and for its repair where necessary and feasible.

While in Asiago the situation of conservation is at least acceptable, a preliminary examination of a random sample of plates in the other archives has revealed cases where the emulsion is detaching from its glass support, with consequent loss of part of the image data. Two examples of this deterioration found in the Specola Vaticana collection were presented in Paper I**.** Much more severe is the situation of the Catania archive, where some 80% of the original plates of the Carte du Ciel are probably lost for ever, and the only immediate sensible action that can be carried out is to start an inventory of the material, compile a digital logbook, and provide an envelope for each plate (at present, stored in wooden boxes with no protection), as will be detailed in the following. In Torino, the plates appear in good condition, but have no envelope. Therefore, a visual inspection of the archives is in progress, and if sufficient resources will be available, a reconditioning of the rooms and of the vaults will be carried out. The advice of experts will be sought in order to find ways to stop the deterioration of the emulsion, and if possible to restore its integrity.

1. ASIAGO

Table 1 – The Asiago photographic archive content (77928 plates)

Images	122 cm (9x12 cm)	1942 - 1997	nr. 9720
Spectra	Newtonian spectrographs of the 122 cm	1958 - 1991	nr. 3220
Spectra	Cassegrain spectrographs of the 122 cm	1951 - 1994	nr. 18584
Images	182 cm (12x20 cm)	1973 - 1989	nr. 3870
Spectra	182 cm	1973 - 1988	nr. 4301
Images	Schmidt S67/92 cm (20x20)	1966 - 1998	nr. 16729
Objective prism plates	Schmidt S67/92 cm (20x20)	1966 - 1998	nr. 1087
Images (films)	Schmidt S40/50 cm (10x10)	1958 - 1992	nr. 18411
Objective prism (films)	Schmidt S40/50 cm (10x10)	1958 - 1992	nr. 2006

In order to appreciate the potential scientific content of the archive, reference is made to **Fig. 1** , where the distribution over the sky of the Asiago S67/92 cm plates is plotted.

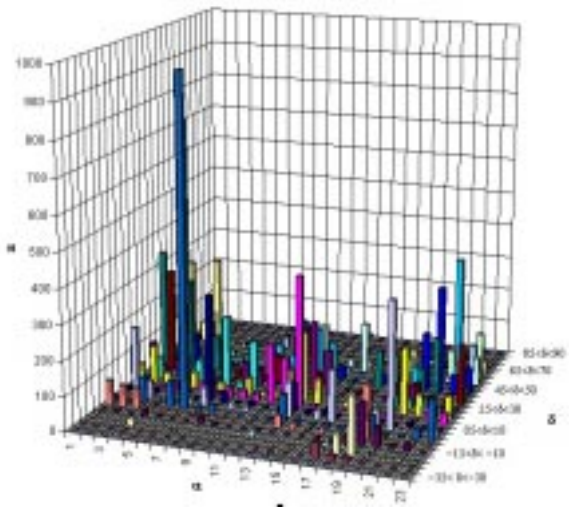

Fig. 1 – The distribution of plates of the Asiago S67/92cm. It is seen that some areas of sky have an high plate density, with the possibility to perform on them studies of statistical content.

Logbooks: The logbooks for direct imaging of all the Asiago telescopes and of the objective prism images of the S67/92-cm and S40/50-cm telescopes, are digitized and accessible on-line as PDF files in the Archive section of each instrument (www.pd.astro.it/Asiago/). The logbooks of spectroscopic observations (122-cm and 182-cm telescopes) will come in the near future.

2. TORINO

The photographic material resident at Torino Observatory consists of several thousand plates exposed at different telescopes during a period of about 70 years, as early as 1920 (see **Table 2**). This rich material has to be systematically inspected and suitably archived; a logbook listing some key information for each plate has to be produced.

Table 2 – The Torino photographic archive content (~6000 plates)

Images	Zeiss astrograph , 20 cm,	1923 - 1984 max 18x24	nr. 3000
Images	Morais refractor, 38 cm	1971 - 1980 max 20x20	nr. 1000
Images	REOSC reflector, 105 cm	1971 - 1994 max 16x16	nr. 1000
Images	GPO-ESO refractor, 40 cm	1978 – 1990 16x16	nr. 700
Images with off-site telescopes	(ESO-GPO, Cape Town, La Palma)		few hundreds

3. CATANIA

The Catania photographic archive is based essentially on direct image plates (see later for details about the solar data, which are not treated in this program). The plates considered for the digitization project are detailed in the **Table 3**.

Table 3 – Image plates in the Catania archive (~ 3000 plates)

Instrument and Period	Project	notes
33cm equatorial astrograph (Catania) (1897-1907)	Astrographic Catalogue + Carte du Ciel ~1600 plates (16x16cm)	1
33cm equatorial astrograph (Catania) (1910)	Halley comet 32 plates (16x16cm)	2
33cm equatorial astrograph (Catania) (1956-1964)	Fields of Catania astrographic zone ~100 plates (16x16cm)	3
S61/41 Schmidt Telescope (Mt. Etna) (1968-1992)	Direct images ~1200 plates (9x9cm)	4
33cm photographic objective (Mt. Etna) (1985-1992)	Direct images ~100 plates (16x16cm)	5
Vatican Observatory astrograph (1960)	Direct images ~30 plates (16x16cm)	6

Comments to the table:

1. About 1600 plates were made in the frame of historical contribution of the Catania Astrophysical Observatory to the project of the *Carte du Ciel*, from 1897 to 1907 in the assigned declination area from +47° to +54°. The plates of 16x16 cm size (60 arcsec/mm scale) were obtained with the 33 cm equatorial Steinheil in the old town station of Piazza Vaccarini (47m.s.l**,** long. $01^h\ 00^m\ 17^s$ lat. 37° 31' 43"). Some of the plates were broken or damaged due to frequent removals of observatory properties in such a long period. Most of the plates are in very bad state, and it is difficult to restore the old photographic emulsion for obtaining valuable scientific information. From a rough first analysis, it is estimated that only 200 plates are in acceptable condition for digitization.
2. A sample of about 30 plates in fair conditions of Halley's comet that were obtained in 1910. Some (but not all) of these plates have been reproduced in the Atlas of Comet Halley 1910 II (NASA, 1986)
3. From 1956 to 1964, with the same astrographic equatorial, in the framework of an international astrometric program to study high proper motion stars belonging to the astrographic zone of Catania for the *Carte du Ciel*, about 100 plates (16x16cm size) were obtained. The most part of these plates are in good state.
4. About 1200 plates of 9x9 cm size were obtained with the Schmidt S61/41 telescope at the M.G. Fracastoro station of Catania Astrophysical Observatory (Mt. Etna, 1725m.s.l., long. $00^h\ 59^m\ 55^s$, lat. 37° 41' 30") in the period from 1968 to 1992. The great part of plates are in good condition and ready to be digitized.
5. About 100 plates (16x16 cm size) were also obtained with the 33cm Steinheil objective by using the S61/41 telescope mounting at M.G. Fracastoro station from 1985 to 1992, and are all ready to be digitized.
6. A small group of about 30 plates, obtained at the Vatican Observatory astrograph around 1960, will be also digitized.

In addition to the plates considered in the table, Catania Astrophysical Observatory has collected a large number of plates of the Sun, all in generally good conditions:

- About 400 plates (6x9cm) in the continuum obtained with a 16-cm Mertz objective from 1907 to 1953.
- About 50 plates (13x18cm) in the continuum obtained with a portable spectrograph in the '40 and '50 years.
- About 3000 plates (6x9cm) in the K-line of CaII obtained with the spectroheliograph from 1963 to 1978 as a part of a program on solar patrol to which Catania Observatory participated.

In this first phase of the digitization program, we plan to make only some tests of scanning of these plates. We think that the systematic digitization of solar plates could be organized in the framework of a special program devoted to the general solar archive of Catania Astrophysical Observatory.

4. ROME MONTE PORZIO OBSERVATORY

Only the logbooks are available of the great amount of work produced with the S60/90 cm Schmidt telescope of Campo Imperatore Observatory from the early 1960s to the end of the 1970s. The plates themselves are scattered among different users, and difficult to recover.

5. ROME UNIVERSITY

There are no proprietary plates. A collaboration has been activated with the Bjurakan Observatory to digitize the objective prism plates of the Armenian Survey, in particular those obtained by Dr. Markarian. A scanner Epson 1640 XL, optical resolution 1600x1600 14 bit, has been moved from Rome to Bjurakan to proceed with the scanning.

6. VATICAN OBSERVATORY

Table 4 – The content of the Specola Vaticana archive (9815 plates)

33cm photographic doublet (1894-1953)	Carte du Ciel : 540 plates Astrographic Catalogue : 1148 plates
40cm Zeiss Refractor quadruplet (1935-1974)	Direct images: 380 plates (30x30cm) Direct images+spectra: 3111 plates (18x24cm) Direct images: 1245 plates (13x18cm)
60 cm Zeiss Reflector (1935-1974)	Direct images: 924 plates (9x12cm) Direct images: 145 plates (7x9cm) Direct images: 172 plates (6x9cm)
65 cm Schmidt Telescope (1957-1986)	Direct images : 794 plates (20x20cm) Spectra : 1326 plates (20x20cm) Polarimeter : 30 plates (20x20cm)

We are planning to do a systematic scanning of the entire archive of the Carte du Ciel (540 plates): these plates are in a very good state of conservation (for every plate there is a detailed description of the characteristics of the plate, the plate constants to do astrometry, and every information concerning exposure time and weather conditions). An electronic catalogue of the logbooks of these plates is in preparation.

At the Vatican Observatory there is also the fundamental Spectral Atlas of the elements (A. Gatterer, J. Junkes, E. Salpeter, 1937, 1942). We are studying the possibility to scan the plates of the spectra, and to publish the images of this Atlas in pdf format.

Digitization of the plates

1 Activity in Padova-Asiago

Two scanners (Epson 1640 XL, A3 format, optical resolution 1600x1600 dpi, 14 bit) have been bought by the Department of Astronomy, one for the Asiago station and one for Padova (a third scanner UMAX Powerlook 1100, A4 format, optical resolution 1200x2400 dpi, is available in Asiago; it has been tested and proved of good quality, but at the moment is not used for this project). The same model of scanner is used by DLR in Berlin, an Institute with which we have underway a fruitful exchange of experiences (in particular for the ADAS survey of asteroids, see http://dipastro.pd.astro.it/adas/). Dr. S. Mottola of DLR has written and installed in our computers a series of programs that greatly enhance the ease of data acquisition, working in the Windows operating system and providing as output a negative or positive FITS image (with customizable header), that can be directly analyzed with IRAF, MIDAS or IDL.

Both scanners have been connected to identical dedicated PCs, with 1 GB of RAM, 40 GB of hard disk and DVD/CD writer. The approximate dimensions of the digitized files at 1600 dpi are: Schmidt plates (20x20 cm) 260 MB, 122 cm plates (9x12 cm) 70 MB, 182 cm plates (20x12 cm)

150 MB. The size of the files obviously poses a serious problem, both for storage and for distribution. We are for the moment saving the files to DVDs of 4.7 GB each, but this can only work as a backup, a dedicated system being necessary for the future.

Tests have been performed on 30 different types of plates, both with images and spectra, to determine the effective spatial resolution of the scanner. The result is 16 micron/px, which is sufficient for the plates used in imaging but not quite so for the spectroscopic material (see **Fig. 2**).

Fig. 2 – Detail of the spectrum of α Bootis obtained in 1951 with the prism spectrograph A, camera IV, of the 122cm telescope. A close inspection reveals that the digitized image has lost some of the resolution present in the original material.

A search was made to find more suitable scanners on the market; we were well impressed by the IMACON Flextight 2848, but its price is too high for our present budget.

Therefore the present activity of digitization is concentrated on images, well distributed among the several telescopes in order to gain experience with the different problems; at present, the total of scanned plates is about 750, so distributed:

- The digitization of **all available M33 plates has been completed**, namely 150 plates taken with the S 67/92 cm, 10 plates with the 122 cm, 70 plates with the 182 cm (see **Fig. 3** and **Fig. 4**).
- The digitization of the **M31** plates is under way. Already done: 30 plates taken with the S67/92, 10 plates with the 122 cm, 230 plates with the 182 cm (see **Fig. 5**).
- The digitization of **QSO** plates has been started. So far, three QSOs have been considered: 3C 345, 3C 232, Ton 1542. For 3C 345, we have digitized 49 plates from S67/92 cm, 36 plates from 122 cm, 12 plates from 182cm telescope. For the other two objects only a preliminary search in the plates archive has been done with a total of 5 plates for 3C 232 and of 6 plates for Ton 1542.
- The digitation of about 50 S 67/92 cm plates of the **Pleiades** and of **NGC 7000**, was performed by Milcho Tsvetkov (Bulgarian Academy of Science), while in Asiago in the frame of a collaboration with the Sofia Sky Archive Data Center (see **Fig. 6**).

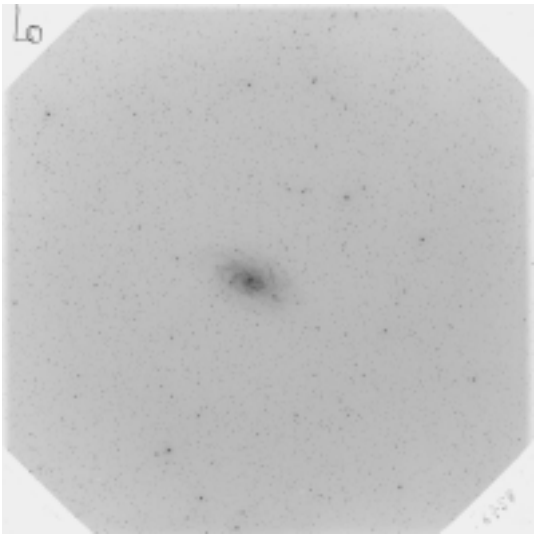

Fig. 3 – Full size Schmidt 67/92 plate of M33 (no. 6758, scanned file 12000x12000px at 1600 dpi). South is bottom right, East bottom left.

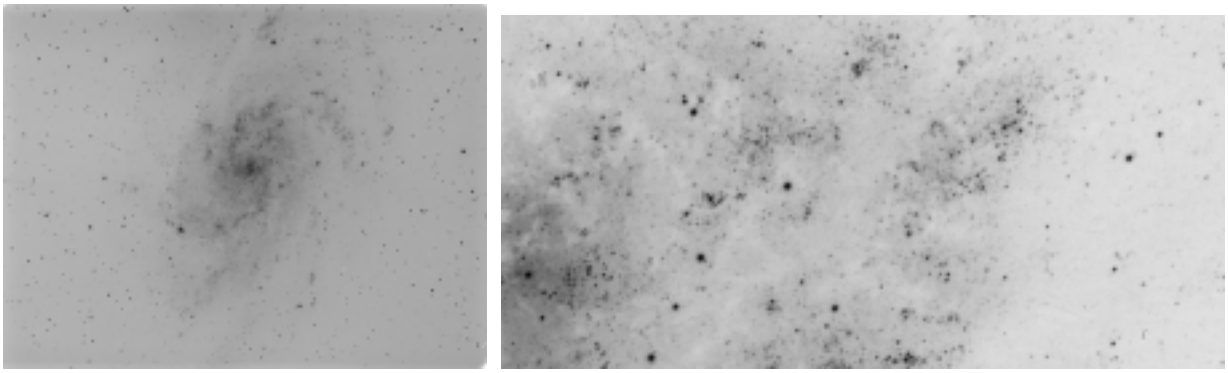

Fig. 4 – Left: M33 plate from the 122cm telescope. Right: detail of M33 from the 182cm telescope.

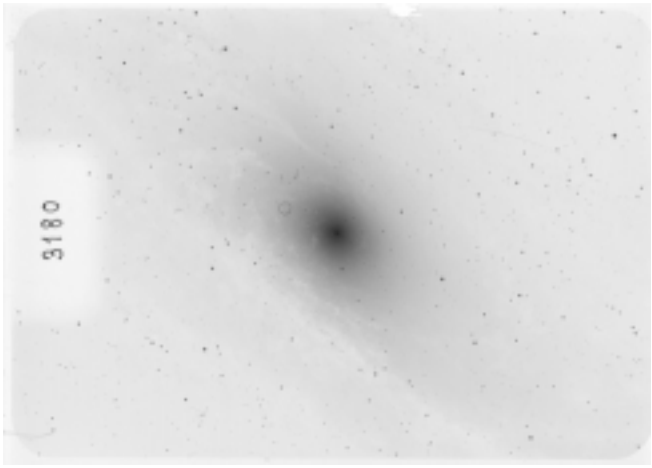

Fig. 5 – M31 plate from the 182 cm telescope archive. The small circle near the nucleus is a nova marked on the emulsion by Leonida Rosino

To evaluate the photometric capability of the output digital files, in Paper I we examined with the IRAF-DAOPHOT package the Selected Area 57, using for comparison the photometric data given by A. Purgathofer (1969), and adjusting some of the parameters to the photographic plate and to the scale of our Schmidt telescope. A better check was made on the plates of 3C 345.

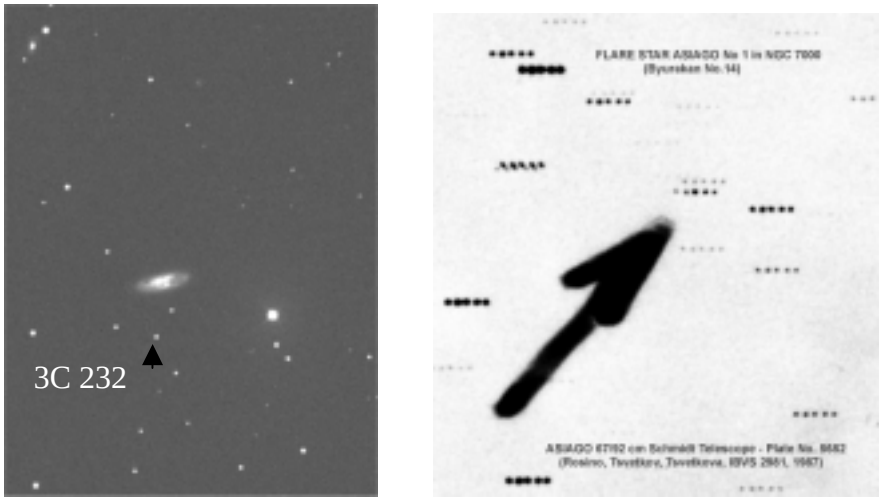

Fig. 6 – *Left*: Image of the QSO 3C 232 and of the nearby galaxy NGC 3067. *Right*: Flare star in NGC 7000 from a S67/90 plate scanned by Milcho Tsvetkov in Asiago.

In Paper 1 we had also checked the astrometric precision of the S67/92 digitized plates, using the coordinates of the SA 57 stars provided by USNO-A2.0 (http://www.nofs.navy.mil/, epoch 1955.287490) to check the equatorial coordinates. By a second order interpolation algorithm (Bertini, 2001) the following standard deviation were derived: St. Dev . in RA = 0".41, St. Dev. in Dec = 0".62. We considered those results extremely encouraging, so we have extended the tests, with better astrometric programs, to other star fields at the center and in the corners of the plate; up to now, the tests have been limited to subfields of 1500x1500 px, with approximately 150 USNO stars per field, finding a St. Dev. in both coordinates of about 0”35.

2 Activity in Torino

Systematic plate inspection and inventory, complemented by the creation of an on-line logbook of the complete OATo plate archive, is starting. In parallel, selected plates will be measured with a scanner already available at OAto (Microtek Artixscan 1100, 1000x2000 dpi, optical density 3.9, 14-bit resolution). **Fig. 7** shows a plate taken in the direction of the Orion Nebula in 1930 with the Zeiss astrograph.

As part of a research program dealing with the realization of the optical link to the quasi-inertial radio reference frame, more than 300 plates obtained around 1990 with the REOSC and Morais telescopes have already been digitized using TOCAMM (an original ASCORECORD measuring machine, automatized by OATo and currently hosted by Cagliari Observatory), which has proved to be astrometrically stable at the 0.5 micron level (Lattanzi et al., 2001).

This material, along with some selected older plates digitized with higher resolution available scanners, will be used in order to assess the astrometric ad photometric accuracy attainable with the in-house scanner, and at the same time characterize the quality of the plate material at hand. For this purpose, specialized reduction software has to be set-up.

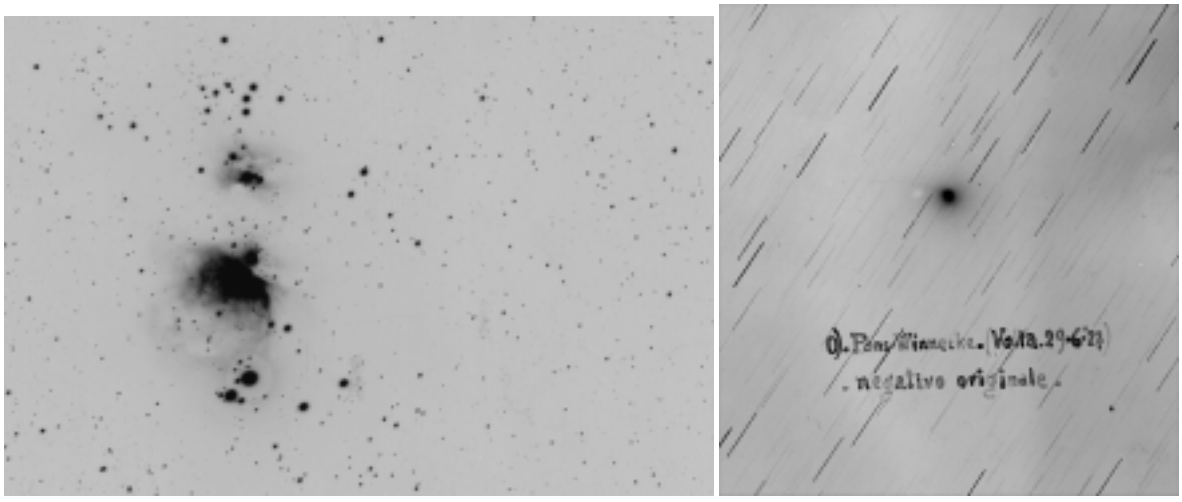

Fig. 7 – *Left*: M42, a plate obtained in 1930 with the Zeiss Astrograph at Torino Observatory. *Right*: comet Pons-Winnecke taken ta Pino Torinese by Volta (June 29, 1927)

3 Activity In Rome University

The Rome University team has taken up the task of digitization of the objective prism material, given their long-standing interest on these arguments (see Cassatella et al., 1973, 1975). The tests initially started on the Byurakan plates with an equipment similar to that used in Padova, showed promises of a good scientific return; therefore a deeper analysis was performed on a plate taken with the Schmidt telescope of Campo Imperatore (observer F.Smriglio, 7/7/1972, log number

N.696, emulsion 103aO+GG13, dispersion 340A/mm at Hγ) in order to check the accuracy of spectral classification with IRAF packages applied to spectra from plates. Our procedure includes several steps:

1- plate solution, to assign the celestial coordinates to every object present in the plate (accuracy of the calculated positions about 2 arcsec).

2- identification of objects of known spectral class and extraction of their spectra. In its turn, also this point includes several steps: linearization of the photometric plate response, automatic selection of the plate sections containing the individual spectra of the chosen objects (about 200x50 pixels), extraction of the individual spectra, wavelength calibration and normalization to the local continuum (if necessary for a better visualization of the spectral lines)
3- extraction of the spectra of unknown objects and classification by comparison with the previous ones.

We extracted several spectra and made crosschecks on already classified objects, obtaining very satisfactory results. Some final spectra are shown in **Fig. 8**, where the ordinates represent the sky subtracted intensities normalized to the maximum flux. Note that the emissions of the Hydrogen Balmer lines are clearly detectable in the spectrum of the Mira type star.

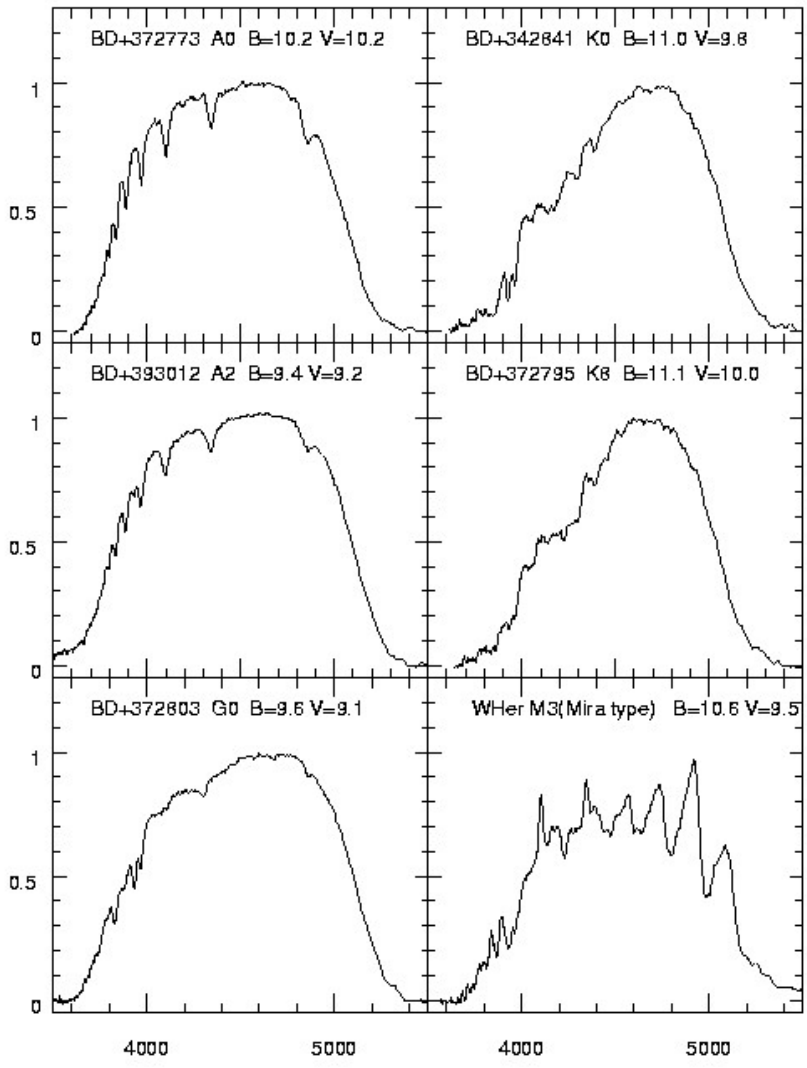

Fig. 8 – Examples of digital scans of a Campo Imperatore objective prism plate

Given this very encouraging results, a second scanner is being bought to be placed in Asiago Observatory, as a further station entirely dedicated to the objective prism plates.

To get an indication of the photometric results possible on short focal length telescopes, we scanned a plate of the 40/61/121 Schmidt camera of the Catania Observatory, using an EPSON 1680 Pro(A4 format): the plate is n.239, 103aO Kodak emulsion + GG13 (blue) filter, including M16 and M17 near the galactic plane. We transformed the plate transparency, given by the scanner, into photographic density, and then into flux assuming a standard density-intensity relation,as no sensitometric spots are available for this plate. Aperture photometry was then performed with IRAF/apphot of 60 stars belonging to a photoelectric sequence of the Guide Star Catalogue included in the field. A comparison of our instrumental photographic magnitudes with the GSC2 ones is plotted in **Fig. 9**. Note that the fainter stars of the sequence are close to the plate limit. The best fit linear relation shown has slope 0.85, close to the ideal value of 1.00 and the rms deviation is 0.14 mag, fairly satisfactory for our combination of emulsion and focal length.

We confirm therefore that sufficiently accurate photometry can be done on the digitized images, for instance to look for variable stars. As a result, a third scanner has already been bought and put in operation at Perugia University, in order to scan the large amount of Asiago S67/92 plates taken by P. Maffei for the search of variable stars (of which many in the near IR) and stored there. Several plates have already been scanned (Prof M. Busso, private communication).

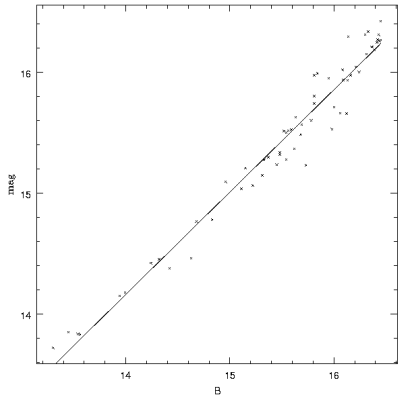

Fig. 9 The photometric linearization of a Catania Schmidt plate

4 Activity at the Specola Vaticana

A scanner identical to those in Padova-Asiago has been installed in Castelgandolfo. About 300 Schmidt plates (almost all objective-prism) have been digitized. No reduction work has been done so far.

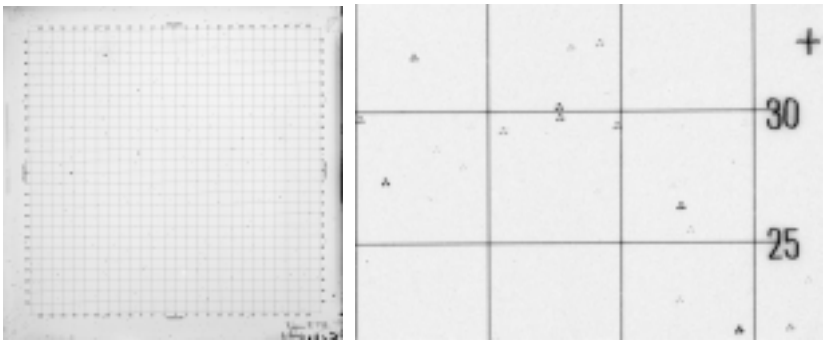

Fig. 10 – A typical Carte du Ciel plate taken at the Vatican Observatory. *Right*: detail of the multiple exposure

5 Activity in Monte Porzio

The Rome Observatory has already started the calibration work on a sample of plates that have been selected from the archive of the Asiago 67/90 Schmidt telescope. Observations are carried out at the 60/90 Schmidt telescope of the Campo Imperatore Observatory equipped with the 2048x2048 thinned and back illuminated CCD camera (ROSI) and a standard Johnson filters set.
The aim of this work is to produce an algorithm to be used to linearize fluxes from the digitized plates, or to create a pipeline to directly modify the data files. The final solution will depend on which will make it easier for the final user to extract scientific information from the archive.
A conversion to the standard Johnson filter set will also be attempted to homogenize actual measurements and data from the historical archive.
It is our goal to produce a long term light curve of the variables found in the test plates.
Simultaneously, we work side by side with the Asiago and Vatican teams to help in scanning their archives.
A system for data storage and quick distribution over the Internet (NAS: Network Attached Storage) has been bought and implemented in Campo Imperatore. It accepts NFS, FTP and Windows protocols. The present capability is 540 GB, in configuration RAID5 without hot spare, and it can be expanded to 1 TB.

6 Activity in Catania

At Catania Observatory, the activity program is still in a phase of organization. A scanner Epson 1680 Pro, A4 format, with performances similar to that used in Padova, has been bought in March this year, with a dedicated high quality PC (512 K RAM, two 80 GB hard disks and DVD writer for a first storage in optical disks of scanned images). The tests on this new scanner for the best digitization of the plates, and the selection of the material to be digitized from Catania archive have begun. A detailed electronic logbook of the plates is in compilation.

In the meantime, by using an available AGFA ARCUS II back-illuminated scanner, some tests have been already made on the old (1910) plates of Halley's comet, and on more recent plates obtained at the M.G. Fracastoro station with the same 33cm objective. The plates have been scanned at 8-bit gray levels, with a resolution of 600 dpi, and saved in .jpg format (see **Fig. 11** and **Fig. 12**).

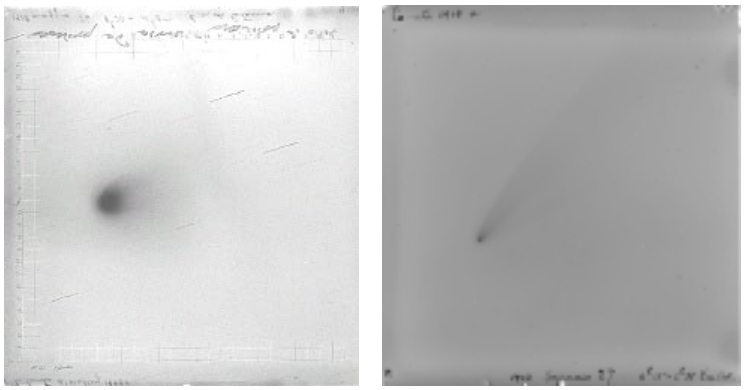

Fig. 11 - *Left*: digitized plate (16cmx16cm, 60 arcsec/mm scale) of Halley1909c comet head (26/5/1910, 1.5 h exposure, 0.3 A.U. distance from earth). *Right*: image of comet 1910a (27/1/1910), both obtained with the 33 cm astrograph of the Catania Observatory.

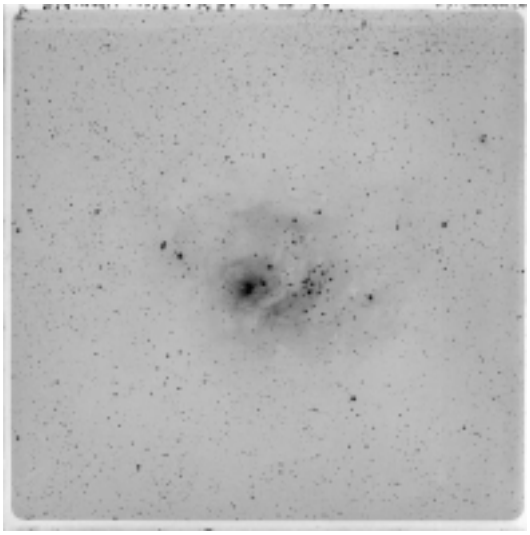

Fig. 12 - Digitization of a plate of the M8 nebula obtained the 22/6/1987 with the 33cm telescope (16cmx16cm, 60 arcsec/mm scale) of the Catania Observatory.

This material will now be re-scanned with the new scanner at 16 bit per pixel

Inspection and these attempt of scanning the ancient plates of the astrographic catalogue and of *Carte du Ciel* have given ample evidence of the strong damage they suffered by funguses and moulds. A preliminary analysis of some plates in better-than-average conditions, whose digitized images are shown in **Fig. 13**, indicates that even the restoration of a partial number of the old photographic plates in the archive can give valuable scientific information. In this framework, besides some attempts to restore these plates made by technicians of Catania Observatory, a collaboration with the Institute of Plant Pathology of Catania University, to explore in detail the damaged photographic emulsions, has been undertaken.

So a convenient and sure collocation of the old plates of the Catania archive and, if possible, their restoration, is a main and urgent problem.

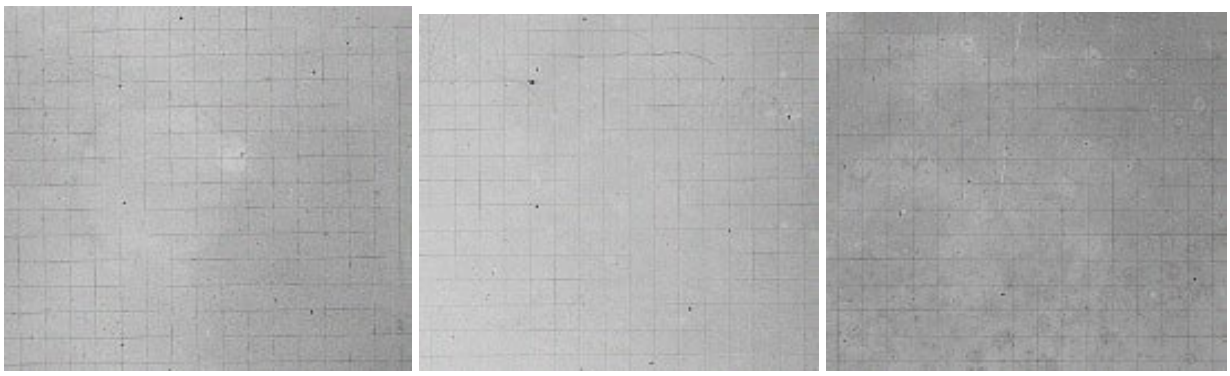

Fig. 13 - Images of three plates obtained in summer of 1896 (plate center scanned at 8 bit with 1200 dpi resolution). Damages of different level in the emulsion are evident.

On-line consultation

In the site of the Asiago Observatory (http://www.pd.astro.it/Asiago/) we have implemented a section dedicated to archives, where the already digitized logbooks are available in PDF format. Notice that a logbook of the S67/92 plates was already available through Strasbourg with the code VI/90 (http://vizier.u-strasbg.fr/cats/VI.htx). This archive was developed by Dr. Milcho Tsvetkov, Bulgarian Acad. of Science.

For the S67/92 telescope, an on-line query page is under development (see http://dipastro.pd.astro.it/~asiago/), yielding data from the main fields of the catalogue, a .jpg preview of the plate and the form to request the FITS file via FTP. The query can be made by plate number, name of object or coordinates. It is currently being discussed whether to provide also the downloadable FITS file of each plate, e.g. by duplicating the system in Campo Imperatore.

Future plans

We briefly sketch our plans:

- complete the digitization of the log-books by the end of Y2003
- confirm with further tests the astrometric and photometric accuracy of the digitized plates
- digitize some 2000 plates well distributed among the several telescopes;
- define a common storage system, in order to make the digital files accessible to the general user through the web for a quick view;
- start a call for proposals to the International community, in order to selectively digitize those plates that give a maximum scientific return.

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