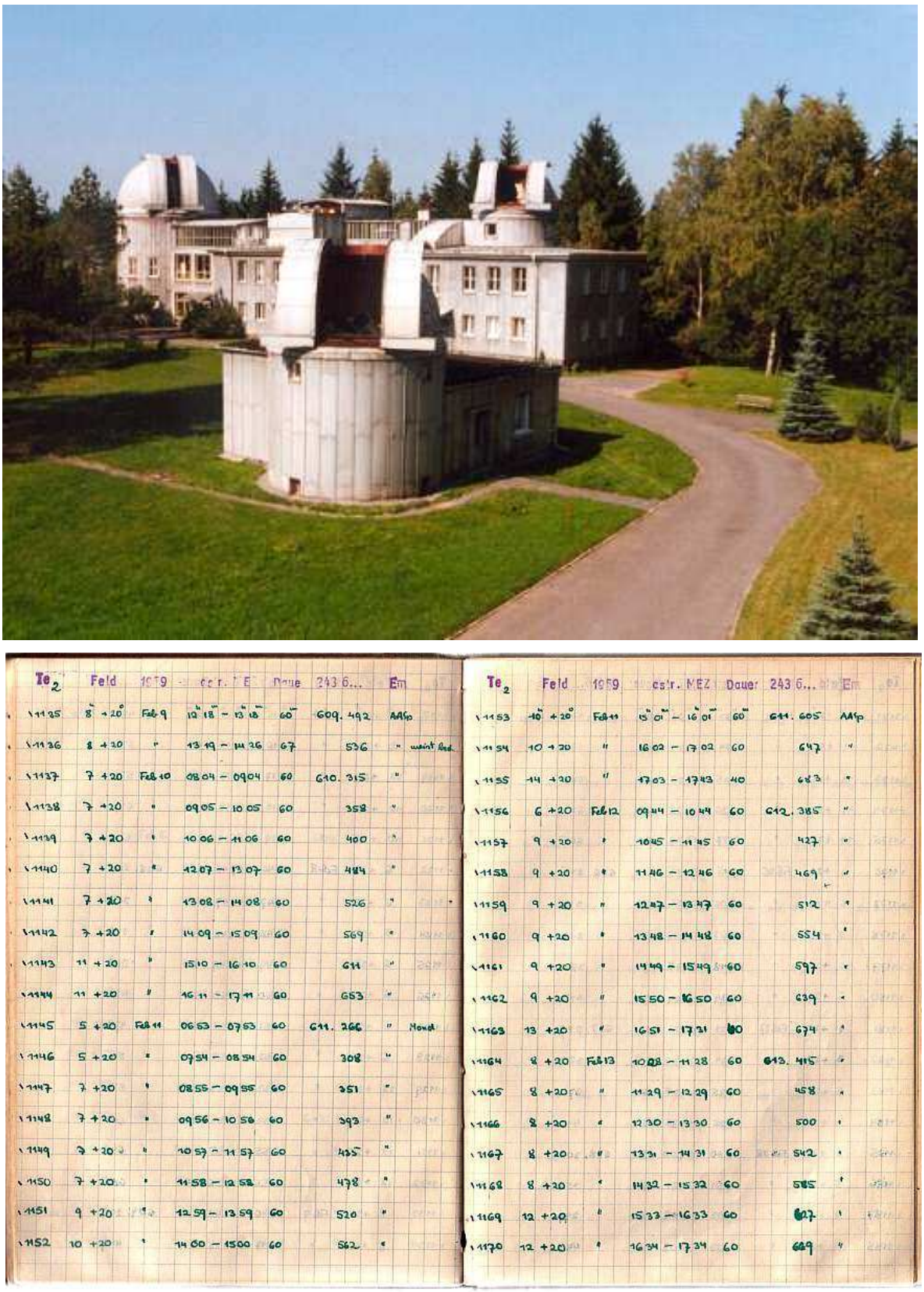

Te 2	Feld	1959	c s r. E	Dauer	243 6...	Em		Te 2	Feld	1959	c s r. MEZ	Dauer	243 6...	Em	
1135	8 +20°	Feb 9	12h18m – 13h18m	60m	609.492	AAfp		1153	10 +20°	Feb 11	15h01m – 16h01m	60m	611.605	AAfp	
1136	8 +20	"	13 19 – 14 26	67	536	"	wenig Bed.	1154	10 +20	"	16 02 – 17 02	60	647	"	
1137	7 +20	Feb 10	08 04 – 09 04	60	610.315	"		1155	14 +20	"	17 03 – 17 43	40	683	"	
1138	7 +20	"	09 05 – 10 05	60	358	"		1156	6 +20	Feb 12	09 44 – 10 44	60	612.385	"	
1139	7 +20	"	10 06 – 11 06	60	400	"		1157	9 +20	"	10 45 – 11 45	60	427	"	
1140	7 +20	"	12 07 – 13 07	60	484	"		1158	9 +20	"	11 46 – 12 46	60	469	"	
1141	7 +20	"	13 08 – 14 08	60	526	"		1159	9 +20	"	12 47 – 13 47	60	512	"	
1142	7 +20	"	14 09 – 15 09	60	569	"		1160	9 +20	"	13 48 – 14 48	60	554	"	
1143	11 +20	"	15 10 – 16 10	60	611	"		1161	9 +20	"	14 49 – 15 49	60	597	"	
1144	11 +20	"	16 11 – 17 11	60	653	"		1162	9 +20	"	15 50 – 16 50	60	639	"	
1145	5 +20	Feb 11	06 53 – 07 53	60	611.266	"	Mond	1163	13 +20	"	16 51 – 17 31	40	674	"	
1146	5 +20	"	07 54 – 08 54	60	308	"		1164	8 +20	Feb 13	10 28 – 11 28	60	613.415	"	
1147	7 +20	"	08 55 – 09 55	60	351	"		1165	8 +20	"	11 29 – 12 29	60	458	"	
1148	7 +20	"	09 56 – 10 56	60	393	"		1166	8 +20	"	12 30 – 13 30	60	500	"	
1149	7 +20	"	10 57 – 11 57	60	435	"		1167	8 +20	"	13 31 – 14 31	60	542	"	
1150	7 +20	"	11 58 – 12 58	60	478	"		1168	8 +20	"	14 32 – 15 32	60	585	"	
1151	9 +20	"	12 59 – 13 59	60	520	"		1169	12 +20	"	15 33 – 16 33	60	627	"	
1152	10 +20	"	14 00 – 15 00	60	562	"		1170	12 +20	"	16 34 – 17 34	60	669	"	

Figure 35.1: *Above: Sonneberg Observatory is a characteristic ensemble of buildings covered with aluminium sheet. Below: Log book of Tessar 2. (Photo: Peter Kroll, Sonneberg)*

35. Real and Virtual Heritage – The Plate Archive in Sonneberg – Digitisation, Preservation and Scientific Programme

Peter Kroll (Sonneberg, Germany)

Abstract

The real heritage of Sonneberg Observatory consists of several buildings with seven domes, a number of telescopes for photographic and photoelectric measurements, a plate archive – which is the second-largest in the world –, and a scientific library. While the instruments are today mainly used for public observing tours and to a limited degree for continuing sky patrol, the plate archive is systematically scanned in order to make the whole information stored in the emulsion of the plates accessible to the astronomical community and to allow the scientific study of all stars ever recorded. First pilot studies give a taste of what output can be expected from the digitized plate archive.

35.1 Brief History

Sonneberg Observatory was founded in 1925 by Cuno Hoffmeister as a municipal Observatory. In that time Hoffmeister was well-known yet for his works in variable star research. In close collaboration with the observatories in Bamberg and Berlin-Babelsberg he participated in a systematic photographic observational program, called sky-patrol, to monitor the stellar sky. In 1931, Sonneberg Observatory was affiliated to Berlin-Babelsberg Observatory.

After World-War Two the observatory became a member institute of the German Academy of Sciences. In the following decades the observatory grew significantly. Several new buildings were erected and new instruments were set up. The staff numbered up to 35.

As a consequence of German reunification the observatory became part of the Thüringer Landessternwarte Tautenburg next to Jena. However, the Ministry of Science of Thuringia decided to close the observatory within a period of three years. The observatory was closed in 1995 for nine months. Town and district of Sonneberg founded an association (so-called *Zweckverband*) to keep the observatory operational. The staff was reduced to five persons. After a few years it became more and more difficult to continue this construction.

In 2004 the observatory was handed over to a private company, 4π Systeme GmbH, of astronomy and information technology – a spin-off enterprise originating from the observatory. The company is obliged to continue observations and scientific work and to preserve the buildings, domes, and instruments. An astronomy museum founded in 1997 is operated by the association *Freunde der Sternwarte Sonneberg e. V.*.

35.2 The Real Heritage of Sonneberg Observatory

From the historic point of view the real physical heritage of Sonneberg Observatory consists of four parts: observatory buildings, astronomical instruments, plate archive and scientific library.

35.2.1 Observatory Buildings

Sonneberg Observatory is situated on top of the small hill *Erbisbühl* at 640 m above sea level on the southern rim of the Thuringian forest. The very first building, erected in 1925, was comparably small with a 5-m dome. Later, a number of wooden barracks with movable roof were set up in order to host several telescopes. Today, all these wooden buildings do not exist any more.

The first building was extended by a number of rooms and a lecture hall. In the 1950ies three dome buildings with three to four laboratory and office rooms were built. In 1960 the new main building with basement, two floors, a 8-m and 5-m dome and a movable roof for the sky patrol was erected. In the 1970ies, a separate workshop building was built.

In the late 1970ies all buildings were covered with aluminium sheet for isolation and to protect them from rainy weather. This layer gives the observatory a very characteristic appearance (Fig. 35.1 above, p. 310). Since 1994, the observatory as an ensemble of buildings is officially listed as a historic monument.

35.2.2 Astronomical Instruments

Two photographic programme have been conducted (see Bräuer et al., 1999):

1. The *Field Patrol* has monitored about 80 fields along or near the northern Milky Way (fields in higher galactic latitudes were added later) mainly with two astrographs (400/1950 and 400/1600 mm) at limiting magnitudes up to 17^{m}. A Schmidt camera (500/700/1720 mm) with a limiting magnitude of 18^{m} was mostly used for monitoring of open star clusters.
2. The *Sky Patrol* (see Fig. 35.2, p. 313) was recording the entire sky northern to $\delta \sim -30°$ in two colors (photographic (ca. B) and photovisual (ca. V)) at a limiting magnitude of 15^{m}(B) and 14^{m}(V) with 14 cameras (55/250 mm) on two mountings. The Sky Patrol is still running with 7 cameras. Due to increasing light pollution by the nearby town of Sonneberg the patrol was restricted to fields northern to $\delta \sim -10°$ in the late 1980ies.

Two Cassegrain telescopes (600/1800/4500 mm and 600/7500 mm) have been used for photoelectric multicolor measurements of variable stars. In the 1990ies, the telescopes were equipped with CCD cameras. Today, the second telescope is used for public observations. One dome of the observatory hosts a historic refractor (135/1800 mm) which was heavily used by Hoffmeister in the past, and which is today the main instrument for public guiding tours.

Table 35.1: *Principal series of Sonneberg plate archive*

Series	Instrument	Plate (mm)	Field (°)	mag_{limit}	Total	Scanned
SC	Schmidt 500/700/1720	130×130	3.4×3.4	18 (B)	8700	5200
GA/GB/GC	Astrographs 400/x	300×300	10×10	17 (B)	20300	5100
A,F	Astrographs 170/x	200×200	8×8	16 (B)	14200	0
E	Ernostar 135/240	160×160	30×30	13 (B)	22800	15000
Te	Tessars 55/250	130×130	26×26	14 (B) 13 (V)	160000	160000
others (ca.)				10...16	70000	25000
total (ca.)					296000	210000

35.2.3 Plate Archive

All plates taken at Sonneberg Observatory are stored in two protected rooms (Fig. 35.3, p. 314). The plates of each field are collected in card boxes with up to 20 plates, separated by chemically neutral paper sheets. Each box is labeled with the coordinates of the recorded field and the period of time when the plates were taken. The storage conditions in the rooms are kept at 40% to 50% relative humidity and temperatures of about 18°C to 23°C.

Each exposure is recorded in manually written log books (Fig. 35.1 below, p. 310), containing instrument name, plate number, date and time of begin and end of exposure, Julian day, emulsion type, field name oder coordinates of plate center, sky condition, and remarks. A subset of these parameters (civil date, Julian day, field name, instrument name, plate number) are also written at the upper and lower edges of every plate for clear identification and practical use.

A rough overview of the content of the plate archive gives the following table 35.1, p. 312. For details see Bräuer et al (1999).

35.2.4 Library

The library of Sonneberg Observatory consists of three parts: books (text books on astronomy, mathematics, physics; monographs, conference proceedings, etc.), periodicals, and publications series of other institutes and of astronomical organizations.

The publication series which were collected on the basis of mutual interchange of publications between about 150 astronomical institutes world-wide are probably the most valuable content of this library since periodicals and books are available in other libraries too but others institutes' publications are often not. From the observatory first days on all incoming literature was scanned for publications about variable stars – the main field of research. All these notes were collected on file cards forming the BCVS (Bibliographic Catalogue on Variable Stars). In the 1980ies these data were keypunched and sent to CDS in Strasbourg, France. Today the catalogue is available online (see Rössiger & Bräuer, 1994).

The scanning of the literature has stopped in the early 1990ies since more and more necessary periodicals and proceedings could not be acquired any more. In parallel, CDS is scanning all new literature anyway and offers this in the internet. Nevertheless, one great advantage of the file cards of the BCVS is the locally accessibility of about

Figure 35.2: *Instrumentation of Sky Patrol (image taken in the 1960ies) (Photo: Peter Kroll, Sonneberg)*

95% of the papers listed therein. In particular, papers from before around 1950 which are not yet available in the internet can be found physically in the library. Of course, this situation will change in the future making this collection more and more obsolete – from the point of view of information science.

35.3 The Virtual Heritage of Sonneberg Observatory

In parallel to the real heritage as being physically present a digital heritage has emerged in the recent years. The process of digitization has started in the early 1980ies and is still going on. Formally speaking, the photometric information in the plates of the archive is stored since the exposure took place, however only with the help of the digitization this heritage can be made accessible in a systematic way and to broad community. Coming from the buzz words around virtual observatories, telescope, archives etc. we propose to call this heritage a virtual one.

35.3.1 Log-book Data

When observing with the photographic instruments the observer writes manually all exposure data in a log-book. Each record contains instrument name, plate number, date and time of start and end of exposure, Julian day, emulsion type, field name or coordinates of plate center, weather conditions, and remarks. A subset of this information is also carefully written on the emulsion side along the upper and lower edge of each plate for identification: civil date, Julian day (plus fraction) of mid of exposure, field name, instrument name, and plate number. In the early 1980s keypunching of the log books has started. In that time, the date were stored on tape cassettes, later on floppy disks, and finally on hard disks. Currently, about 90% of the data are stored in a dBase database. This database is under migration to a modern database system with internet access.

35.3.2 Digital Plate Archive

Long before the systematic scanning of the plates was started, they were carefully cleaned. This became necessary since the plates were frequently used over decades by visual inspection for variable stars. Each investigator had to handle plate by plate, taken them out of the box, inspecting the field of interest under a microscope, and finally putting the pile of plates back to the box. By this way, many finger prints, dust grains and other impurements were found on the glass side of the plates. A few plates also show on the glass side written remarks and small frames around stars left over from the discoverers of variable stars.

The process of cleaning the plates was accomplished by checking the plate identification data against the log-book database. By this way it turned out that about 3%

Figure 35.3: *Sonneberg Plate Archive (Photo: Peter Kroll, Sonneberg)*

of all plates display some kind of erroneous identification data.

In order to get experience several experiments with different commercial and dedicated scanners have been carried out in the 1990ies. About 5,000 plates were scanned in this way. The systematic scanning of all plates started in spring, 2003. After a number of unsuccessful applications to get grants from the Deutsche Forschungsgemeinschaft or from the Ministry of Science of the state of Thuringia, the 4pi Systeme company took the investment to purchase five commercial flatbed scanners.

These scanner of HP Scanjet 7400c type are fast enough, reliable, and easily operated. In order to achieve the complete data output of 16 bit, the scanners are operated by the universal scan software VueScan. Four scanners were operated in parallel with a total throughput of 25 plates per hour. The resolution of 20μm per pixel is a compromise between photographic grain size (about 15μm), scan speed, and data volume. One sky patrol plate of size 130 mm $\times$ 130 mm yields an image of 6k $\times$ 6k pixels of 2 bytes each, thus 72 MB in total of raw data stored in files of TIFF type. By gzip-ing these files are lossless compressed to about 45 to 50 MB. After this compression up to 90...95 scan files are then stored on DVDs. Up to the present all sky patrol plates of this size have been scanned. Two of these scanners are still used to scan the older sky patrol plates of smaller sizes.

The whole-sale scanning was accompanied by a permanent assessment of the photometric and astrometric properties of the scanners. While the photometric stability is satisfying, the positional accuracy appears too

poor for sophisticated astrometric studies. But owing to the relatively small plate scale of 830″/mm astrometric investigations are not feasible anyway.

For scanning the Schmidt plates of the same size but with a scale of 120″/mm astrometric investigations can be taken in consideration. For this reason, a better scanner had to be procured. A good opportunity was raised by the offer of the Maria Mitchell Observatory, Mass., USA, to sell their AgfaScan T5000 sacnner which was formerly used for scanning their plate archive (see Strelnitski & Davis, 2004). Although this scanner has several drawbacks (for the highest resolution the plates can only be scanned in two swathes) it was purchased in August 2006 and ready for operation in May 2007. Since then all the 8800 Schmidt plates have been digitized.

In order to digitize the large astrograph plates a bigger flat-bed scanner was purchased in autumn 2007. This scanner of Microtek ScanMaker 9800 XL type is able to scan a full 300 mm × 300 mm plate with 2 bytes per pixel and 20 μm resolution within about 20 minutes. Up to now, about 8000 plates have been digitized with it.

To sum up, the current virtual heritage of Sonneberg Observatory comprises about 12 TB data stored on 2600 DVDs. Scanning the whole plate archive will probably be achieved in 2011 with a total of 20 TB.

35.4 Utilizing the Virtual Heritage

The digitization of the plates does not end in itself. In the contrary, only by digitization the full astronomical content of information – so far hidden in the emulsion – can be raised.

In the recent years several studies of stellar variability based on digital data have been conducted:

- **Long-term variability** While the discovery of variable star by traditional visual inspection of photographic plates can reveal changes between two plates of at least 0.3 mag only, the analysis of stellar photometric data automatically measured on scanned plates allows to decrease the detection limit to below 0.1 mag. In particular, long trends over years in photometric variability with small amplitude can be detected only in this way. A pilot study by Vogt et al. (2004) based on scanned Sonneberg plates revealed several new types of long-term variability: cycles of about 20 years length with 0.1 to 0.4 mag amplitude, and annual trends of 0.002 to 0.005 mag with increasing or decreasing slope.
- **Variability of solar-like stars** Fröhlich et al. (2006) have studied the photometry of the solar-like star HK Lacertae on about 2000 scanned Sonneberg plates. The results were in good agreement with high-precision photoelectric data. The data from the plates yielded a prolongation of the light-curve into past by two decades. Although rather noisy, the data could be used to detect the rotational period of the star, and even a new long-term cycle was derived.
- **Variability of host stars of extra-solar planets** An interesting application of the scanned plates arises from the long-term study of stars at which extra-solar planets have been detected. Originally in order to check if the eclipse light-curve (amplitude 0.017 mag only) of the planet HD 209458B could be measured Richter (unpublished) has visually estimated the photometry of the host star HD 209458A on all available plates (ca. 2500). The eclipse light-curve could not be revealed, but the stars shows several phases of irregular variability with an amplitude up to 0.4 mag.

The whole-sale investigation of the scanned plates has still to be conducted. The above mentioned project show the potential of a systematic investigation of virtually all stars recorded in the plates. Certainly, there is a great number of suspicious objects and unknown phenomena still to be discovered.

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