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Josef Petzval (1807 – 1891) and the Early Development of Astrophotography

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The Beginnings of Photography

The first fifty years of photography are characterized by the search for suitable methods of obtaining the most stable and lifelike image. In 1839, on the basis of the ideas of Joseph Nicéphore Nièpce[1] (1765 – 1833), Louis Jacques Mandé Daguerre (1787 – 1851) made the first successful attempt to produce a photographic image (daguerreotype). The image was fixed on a silver-coated copper plate, which has been made photosensitive with jodide vapor; as developer mercury vapor was used. For photographing Daguerre used a simple achromatic landscape lens, developed by the French optician Charles Chevalier (1804 – 1859),[2] Alphonse Giroux built a wooden camera with this lens.[3]

In the same year, 1839, another process was announced which allowed prints to be made from paper negatives (calotype). From 1851 a new method gained acceptance in which a glass plate was coated with a light-sensitive layer immediately before exposure (collodion or wet plate process). This reduced the required expo-

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[1]Already in 1822 Nièpce in Châlon-sur Saone had photographed a house with a "camera obscura"; he used a silvered copper plate, which was photo-sensitized by a solution of bitumen and oil of lavender.

[2]Aperture of the objective lens 3,5″ = 8 cm, focal length 16″ = 36 cm. Already before photography was invented there existed lenses for the "camera obscura" in the 18th century for improving the quality of the images. For example William Hyde Wollaston (1766 – 1828) developed in 1812 a lens and improved the front diaphragm. These were the starting conditions for the development of photography.

[3]Cf. the camera with the signature of Alphonse Giroux in the Deutsches Museum (Inv. Nr. Z 5665.1).

sure time to a few seconds. The new medium quickly became established in many areas of application, including portrait photography, landscape and travel photography and news reporting. But until the invention of the gelatine dry plate process (1871), photography remained a complicated business which could only be carried out by specialists.

1 Petzval's Portrait Objective

At January 2, 1839 D. François J. Arago (1786–1853) published in the Academy of Sciences in Paris the invention of daguerreotype [2].[4] During this announcement Carl August Steinheil (1801–1870)[5] of Munich and Andreas von Ettingshausen (1796–1878) of Vienna were present besides others. The last one encouraged Josef Max Petzval, to calculate an improved objective.

Josef Max Petzval (1807–1891) was born in Spišska Béla, Hungary, now Slovakia [20]. He studied engineering at the University of Budapest, from 1835 to 1837 he was professor of mathematics, University of Budapest, since 1837 professor of mathematics in Vienna University. Petzval developed in 1840 a doublet system. The "Petzval-Objective" (aperture 1,5″ = 4 cm, focal length 3,4″ to 3,7″ = 8 cm) was a portrait objective, 22 times more light collecting than Daguerre's lens and avoided in addition some aberrations.[6] It had a short focal lens and at the same time a large field of view. It produced images which were sharp in the middle and became diffuse (out of focus) near the border, which was not disturbing in the case of portrait photography.

In January 1841, the optician Peter Wilhelm Friedrich Voigtländer (1812–1878) constructed with this objective a first camera made from pure metal [44], [41]. Due to the high luminous intensity the exposure time was reduced from 30 minutes to one or three minutes. The camera was presented to the Paris Academy of Sciences at March 15, 1841; the opinion of the experts way very positive:

> „Der von Hrn. Voigtländer in Wien construirte photographische Apparat, vermittelst dessen man Portraite erzielt, hat bereits von Seite der Akademie der Wissenschaften und der Aufmunterungsgesellschaft beifällige Aufnahme gefunden. Hr. Payen, Professor am königlichen Conservatorium der Künste und Gewerbe, hat in seinen neusten Vorlesungen diese sinnreiche Vorrichtung

[4] In 1831 Daguerre had discovered the sensitiveness to light of silver chloride, with which he had covered the silver plates. In 1835 he discovered that the photographes taken with it could be developed by mercury vapor. For fixing of the daguerreotypes fixing soda (sodium-thiosulphate) was used, an invention of John Herschel in 1819 in order to make exposed plates intensitive to light, cf. [16], here p. 230.

[5] [27] In the Deutsches Museum exists a Steinheil Camera of the year 1839, Inv.-Nr. Z 5665.3

[6] Especially the Petzval portrait objectivess were free from chromatic aberration since 1858. The absence of spherical aberration was reached by diaphragmation. Because the sine condition, introduced by Ernst Abbe, was not fulfilled, there existed still a strong image field curvature.

in Anwendung gebracht. Die Portraite wurden von Kennern bewundert, und es ist anerkannt worden, daß man bisher noch keinen solchen Grad der Vollkommenheit erreicht hat. Übrigens hatte schon Daguerre, ein in diesem Fach gewiß competenter Richter, das nämliche Urtheil hierüber geäußert."[7]

From the first camera only a few copies are preserved. One is in the Technical Museum in Vienna, one in the Deutsches Museum in Munich.[8] The camera was successful despite of its relatively high price; in ten years 8000 pieces were sold by the firm Voigtländer, which moved from Vienna to Braunschweig in 1849.

During his further optical calculations Petzval found in 1843 an important condition for the correction of aberrations: The later so-called "Petzval sum" must be equal zero, if an optical system, which is free from astigmatism, is displaying flat objects without image field curvature. In 1846 Petzval improved the luminous intensity of his lens by a factor of 2.3 with his new construction.

Soon the Petzval portrait objective was imitated, because it was not protected by patents, for example the so-called German objectives appeared.[9] Abroad especially known from 1866 on were the portrait objectives of John Henry Dallmeyer in London, a son-in-law of the well-known optical firm A. Ross.[10] An overview concerning photographical objectives can be found in the publications of Moritz von Rohr [38], [39], [40] and [12].

OBJECTIVE	Aperture ratio	Field of view	Optical planes
Portrait	until 1 : 2.5	large	6 or 8
Universal	1 : 4.5 bis 1 : 9	at least 50°	4 to 6
Landscape-	1 : 12	...	...
Wide angle	1 : 18	...	max. 4

[7]Beilage Nr. 192 zur Allgemeinen Zeitung, Augsburg 1841; according to COURRIER FRANÇAIS, April 12, and MONITEUR, May 13, 1841.

[8]Deutsches Museum, Inv.-Nr. Z 5665.2, Voigtländer Camera, 1841. Deutsches Museum, Inv.-Nr. 47378, Voigtländer Camera, around 1850.

[9]German objectives: Optische Industrienstalt, vormals E. Busch in Rathenow (1 : 4, focal length 200 mm, angle 25°, 1850, Inv.-Nr. 63126, C. Dietler in Vienna, Hermagis or Suter in Basel. Adolph Hugo Steinheil invented in 1866 the aplanatic lens (f/6 bis f/8), in order to avoid the distortion of landscape objectives. The objective consisted of two symmetrical arranged, cemented lenses with a diaphragm in the middle. The spherical aberration and the distortion were completely avoided, the astigmatism only partly. The Dallmeyer "rapid rectilinear" was constructed is a similar way. Aplanats were used as well as universal objectives (portrait aplanat, 1872) as well as low-intensity wide angle objectives. Steinheil corrected the astigmatism in addition and thus introduced the antiplanet in 1881. Voigtländer did not acquire a German patent (No. 5761) before June 25, 1879. In 1885 there existed a modified Voigtländer portrait objective where the flint and crown glass lens were changed in the back (1 : $1\frac{1}{6}$, angle 50°).

[10]John Henry Dallmeyer in London, triplet 1 : 10,6, angle 62°, 1860, Inv.-Nr. 5160 oder Inv.-Nr. 60526. Further producers of portrait objectives: Darlot & Jamin, A. Claudet, Gase & Chardonnet (1 : 8,5, 70°, 1862, Inv.-Nr. 59287), Lavrance and Auzoux in Paris, H. D. Taylor in America: Cooke portrait lens, 1893.

More than half a century after Petzval's invention his idea of construction was still highly appreciated:[11]

> „Die Petzval'schen Portraitobjective sind so vorzüglich, dass sie noch heute [um 1900] als Portraitobjective ihren Platz behauptet haben: sie sind zu Tausenden verbreitet und wenn man von einem Portraitobjective schlechthin spricht, so ist in der Regel ein solches von Petzval'scher Construction gemeint"[12]

2 Beginnings of Astrophotography

Shortly after the invention of astrophotography in 1839 astronomical applications were tried, for example the photography of the Moon, the Sun and of some bright fixed stars, cf. [37], [42], [5], [50]. John Herschel (1792–1871) detected the importance of photography for the faint nebulae. He addressed himself to the new technique and started with experiments. The astrophotography had only a few advantages in the beginning. The American photo pioneer George Philipps Bond (1825–1865) succeded to measure the distance of the double stars (Mizar and Alcor) in 1857 more precise that F. G. W. von Struve's (1753–1864) famous measurement with the help of a micrometer [14].

The first cometary photo was received by the English photographer William Usherwood in 1858 with his portrait objective of short focal lens of 2,4 m ([29], here p. 138–139). Comet Donati showed up on Usherwood's plate in between seven seconds with head and long tail, whereas George Philipps Bond could get only the haed of the comet with his 15″ = 38 cm refractor. The next successful photographs of comets were not taken before the 1880s (Fig. 1).

The majority of astronomers did not appreciate the new technology of photography, because the result did not reach at all the possibilities and accuracy of visual observations. In addition the procedure of photography was much too complicated for most astronomers without technical and chemical know-how. Only a stepwise simplification of the procedure increased the hope of implementation of astro-photography as a new observing method. The still existing problem – after the invention of the portrait objective – was the material for taking the photographs:

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[11]The portrait objectives are spherical, astigmatic and corrected in respect to image field smoothing. The universal objectives (the spherical corrected triplet of Dallmeyer, beginning of 1860s) and in addition the wide angle objectives (doublet of Th. Ross, the spherical lens of C. C. Harrison and J. Schnitzer) should neither show image field curvature nor distortion. The landscape objectives (Th. Grubb) are not free of distortion.

[12][19], here chapter 7, p. 113.

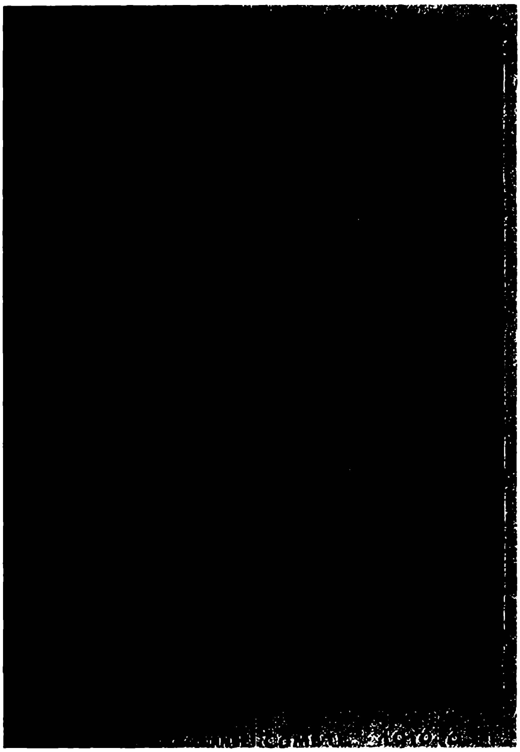

Fig. 1 Comet Brooks, Paris, Obsevatioire Flammarion de Juvisy, 1910.
Dans le champ des étoiles. Les photographes et le ciel 1850–2000, Paris, Adagp 2000, p. 84, Fig. 89c, cf. p. 142.

- the daguerreotype, which was improved more and more,[13] allowed only reversed images and no copies.

[13]The photosensitivity of the plates was increased in 1840 by a halogen coating over the silver iodide plate: the method of bromide vapor as accelerator ("quickstuff") was invented by John Frederick Goddard in London. Thus portrait photos were possible in one instead of eight minutes. Hippolyte Louis Fizeau succeded in 1840 to introduce a second improvement, when he coloured and preserved the ready daguerreotype in a bath of gold chloride, in a solution of gold in nitric acid and hydrochloric acid (aqua regia).

An important disadvantage of daguerreotypes was the instability in respect to light. Thus the valuable originals had to be stored in a case ("Union-Case", 1845). A further improvement goes back to the nephew of J. N. Nièpce, Claude Félix Abel Nièpce de Saint-Victor (1805–1870), who replaced the metallic plate in 1847 by a glass plate and used a white-of-egg layer as carrier for the photosensitive silver salts.

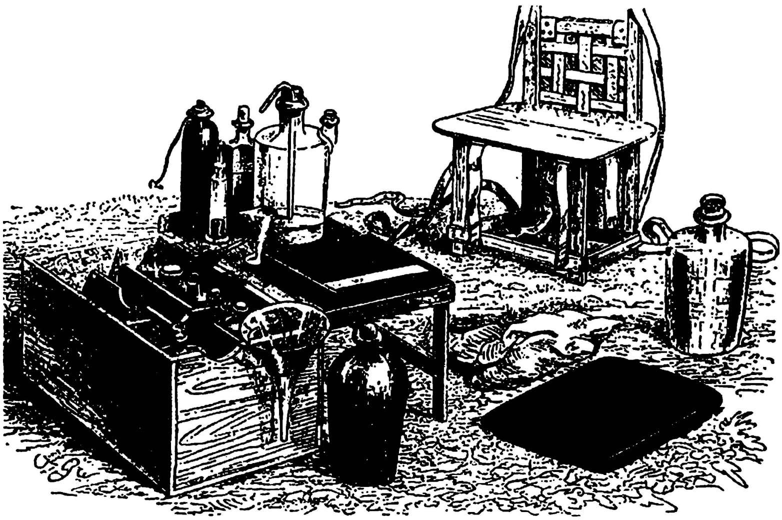

Fig. 2 Collodion or wet plate process (1851), introduced by Frederick Scott-Archer (1813–1857). Kruse, Georg: Das Licht macht Bilder, München, Ehrenwirth 1967, p. 123.

- the negative-positive-procedure, announced in January 31, 1839 by William H. Fox Talbot (1800–1877), called calotype,[14] needed long exposure times.

One step forward was the invention of wet collodion plates by Frederick Scott-Archer (1813–1887) in 1851 (Fig. 2). This was a more sensible procedure; thus the exposure times could be reduced to 15 seconds during bright sunshine. This caused around 1860 the suppression of daguerreotype and caloptype. The new procedure was based on sensibilisation of glass plates, which were made light sensitive with silver salts by using collodion.[15] After some experiments one decided in 1874 to use the new collodion process for photographing the Venus transit [47], [48]. But this new method did not give good results; in 1882 for the next Venus

[14]The patent for the calotype was given in February 2, 1841. With this procedure the exposed plate was intensified by development; that means, only a few atoms are reduced to silver by direct light influence, most of the atoms by the development. Talbot used the "Photogenic Drawing Box" of Ackerman & Co. in London as camera. An improvement of the calotype procedure from Louis-Désiré Blanquart-Evrard who used for the prints of the glass negative albumin paper (white-of-egg paper) instead of salt paper in 1850. This salt paper is finer and less faded. In 1851 Gustave LeGray proposed in addition to wax the paper before sensitizing. This increased the durability of the negative but made the details less clear (ambrotype).

[15][3] Collodion is a viscous solution consisting out of gun-cotton (nitrocellulose) in alcohol and ether with an admixture of iodine and bromine potassium. Collodion was used as binding agent of the photosensitive layer consisting out of iodide of silver and argentic bromide. The plates had to be exposed very early after the sensibilization still in wet condition. In 1853 Adolph Martin used tin plates instead of glass (ferrotype, tintype) in the USA.

transit the Berlin astronomer Arthur Auwers (1838 – 1915) advised against the use of photography.

Real success was not reachable before the invention of dry plates. In 1871 Richard Leach Maddox in London used for the first time a gelatine emulsion instead of collodion.[16] Already in 1873 John Burgess in London offered ready dry plates for selling. Charles Bennett in London detected in 1878 that gelatine emulsions get fully developed by heating, i.e. that the sensitivity is increasing [11]. Thus the exposure times could be reduced to one tenth of the wet collodion plates. The wet plates disappeared completely within of some years. At once factories for the production of dry plates were erected; in 1880 the first dry plate of George Eastman (KODAK) in Rochester, New York, appeared. In 1887 in addition the celluloid film was invented, but astronomers prefered the glass plates.

Thus in the 1880s the photography could finally assert as resource for the research (Fig. 3). On one side the camera had reached an acceptable weight, on the other side

Fig. 3 Photo laboratory for the development of dry plates.
Konkoly-Thege, Nicolaus von: Practische Anleitung zur Himmelsphotographie, Halle an der Saale, Wilhelm Knapp 1887, p. 116.

[16]Maddox used an emulsion out of gelatine, silver salt and bromine (or cadmium bromide). In 1874 Richard Kenneth in London sold drained gelatine emulsion ("pellicle").

sensitivity of the photographic plates allowed to save more information, i.e. to observe fainter objects than with the naked eye. This feature of the photographic emulsion, the summing up of the intensity of light should be demonstrated with an example: In 1893 the astronomer Max Wolf (1863–1932) photographed three times the constellation of Cygnus with different exposure times:

after one hour exposure time	52.000 stars
after three hours exposure time	108.000 stars
after thirteen hours exposure time	197.000 stars

The photographic plates had two additional advantages, first to preserve the condition of the sky for later investigations in plate archives and to analyse with high ease in the laboratory. Naturally a much higher measuring accuracy could be reached in the laboratory than during the night using the micrometer.

All these advantages led to experiments, to record the sky systematically. Early astronomical photograpohs are made by David Gill (1843–1914), who photographed with a 6 cm Dallmeyer portrait lens[17] in the Cape observatory in South Africa from 1879 to 1907. He published with Jacobus Cornelius Kapteyn (1851–1922) in Groningen in 1896/1900 a first photographic survey. Also Benjamin Apthorp Gould (1824–1896) took in 1870–84 photographs of double stars and clusters in the southern sky at Cordoba Observatory, Argentina [24]. Later, in 1910, the Harvard observatory in Oak Ridge/Mass. possessed a 40 cm Petzval lens (focal lens 2.21 m) at the Metcalf refractor.

In 1887 an international cooperation on the occasion of the astrophotographic congress in Paris was started in order to cartograph the sky photographically. In the framework of this CARTE DU CIEL project, initiated by the brothers Henry in Paris, Edward Charles Pickering (1846–1919) of the Harvard University in Cambridge/Mass. accepted to photograph the southern sky. From 1890 the photographs were taken in Arequipa, Peru, with a 24″ = 61 cm “Bruce” doublet astrograph (a Petzval objective, focal ratio 1 : 5.6).

3 Photography of Nebulae

Not only stars were photographed. Especially photography was successful in the field of recording faint objects like nebulae. Just at the turn of the century, around 1900, there was an increasing interest in these objects. Thus astrophotography had a rapid progress ([49], [28], [21], here p. 206–261, [31], [51], [25], [46], [15]). In this context two great pioneers in this field are to be mentioned:

[17][22] Dallmeyer portrait lens: d = 6,3 cm, f : 4, 1882, later d = 15,2 cm.

Max Wolf (1836–1932) in Heidelberg and his friend Edward Emerson Barnard (1857–1923), who was active since 1895 at Yerkes Observatory, later at Lick Observatory.

The first recordings of faint nebulae turned out from the 1880s. Some astronomers in England, France, Hungary· and America photographed in combination with reflectors. One tried photographically to recognize the different structure of spiral nebulae and gaseous nebulae; this was a task where photography was clearly superior compared to the eye, as well as in respect to the fineness of structure as well as in respect to the number of discoveries. In an article of 1891 the advantages of short focal length portrait lenses were compared to long focal length refractors:

> „Wir wollen den für die photographische Himmelskarte gewählten Normalrefraktor, von 33 cm Öffnung und 343 cm Brennweite, vergleichen mit einem kleinen von mir benutzten Doppelobjektiv, nämlich einem Portraitobjektiv von Hermagis von 5,8 cm Öffnung und 20 cm Brennweite. Wenn wir Fixsterne photographieren, so hängt – bei im übrigen gleichen Bedingungen – die Helligkeit des Bildes allein von der Oberfläche der Öffnung der benutzten Linse ab, weil wir es mit einem Lichtpunkt zu thun haben. Hierbei wäre also der grosse Refraktor 32mal der kleinen Portraitlinse überlegen. Mit anderen Worten: Wenn wit mit der Portraitlinse ebenso schwache Sterne photographieren wollen, als wir mit dem 33 cm-Refraktor in einer Stunde erhalten, so müssen wir etwa 32 Stunden exponieren. [...] Ganz anders liegen die Verhältnisse bei Objekten, die ausgedehnte Bilder auf die Platte liefern, wie Nebelflecke, Kometen, Planeten, Meteore u.s.w. [...] Bei verdoppelter Brennweite der Linse bedeckt das Bild die vierfache Fläche auf der photographischen Platte und ein Punkt der Platte erhält nur den vierten Teil Licht. Es ist also in diesem Fall die Lichtstärke eines Objektivs gegeben durch das Quadrat des Bruches: Objektivdurchmesser durch Brennweite. [...] Wenn wir photographische Eindrücke von denselben schwachen Nebelflecken bekommen wollen, die wir mit der kleinen Portraitlinse in einer Stunde erhalten, so müssen wir mit dem grossen Refraktor 8 Stunden exponieren.“[18]

Wolf's first successful photograph of the sky was taken at September 24, 1887. He recognized that a photograph of the sky is oeconomically only possible with a large field of view of the objective. Instead of photography with refractors Max Wolf introduced in 1888 the portrait objectives in astronomy which have a high luminuous intensity and have a short focal length. His collection covered the apertures of 6 cm to 15 cm.[19] Max Wolf's collection of portrait objectives (Fig. 4):

[18] [52], here p. 107.

[19] [56] Here one finds a list of the 16 objectives with the apertures and makers, additional two Bruce refractor objectives.

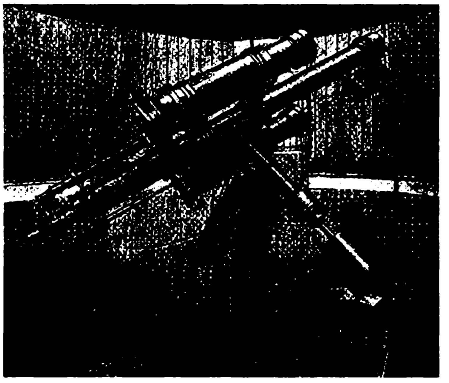

Fig. 4 Max Wolf's (1863 – 1932) portrait objectives.
Photo Landessternwarte Heidelberg-Königstuhl.

- Two objectives d = 6″ = 15 cm made by Voigtländer, which Wolf combined in 1892 with a 6″ guiding telescope,
- A Pauly aplanat (Zeiss) d = 6″ = 15 cm,
- A Kranz aplanat d = 5″ = 12.7 cm,
- Four objectives with d = 4″ = 10 cm: two Pauly aplanates and a Millet-Petzval and a Voigtländer-Euryscope, a d = 8 cm Geiger-Petzval,
- Six objectives of d = 6 cm: Steinheil aplanat, Zeiss planar, Zeiss anastigmat, two Pauly-Petzvals, a Pauly-Unar, a Hermagis-Petzval.

The large field of view of the portrait objectives was especially suitable for photography of nebulae. Due to the high luminous intensity of these lenses from the time of the wet collodion plate photography a considerable diminution of the exposure time was possible. Wolf was able to detect many new nebulae. He recorded the plates with a camera of aperture ratio of 1 : 5. For example he detected on a plate of March 24, 1892, which was exposed for 96 minutes, 130 nebulae in a circle of 1 degree. At the pole he even detected 1528 nebulae.

„Bei der Anwendung der Doppelobjektive von grossem Oeffnungsverhältnis auf die Himmelsphotographie zur Aufsuchung schwacher ausgedehnter Nebelmassen am Himmel [...] zu einer grösseren Anzahl Aufnahmen gelangt, war ich überrascht, wie ungemein zahlreich allenthalben am Himmel die planetarischen und kleinen Nebelflecken zu finden waren. [...] Gleichzeitig war aus den ersten Versuchen ersichtlich, dass sich diese schwachen Nebel, von denen ja das Auge am Fernrohr nur verschwindende und vorübergehend erhaschbare Eindrücke erhält, sich auf der Platte mit grosser Sicherheit einstellen und messen liessen. Andererseits war das wesentliche ihrer Gestalt unmittelbar zu erkennen und zu beschreiben.“[20]

[20][55], here p. 111 – 112.

These photographs of nebulae inspired Max Wolf for a new classification of nebulae – 100 years after Herschel. Wolf started with the nomenclature of Wilhelm and John Herschel which he completed. In 1909 he developed a scheme where he distinguished on photographic plates 23 types of nebulae (from a to w, from the globular to the spiral nebulae), cf. Fig. 5. [Die Klassifizierung] „wird daher rein beschreibend werden müssen, ohne irgend welche Rücksicht auf eine Hypothese über die Entshehung der Nebel oder die Beschaffenheit des Spektrums.“[21] Wolf deplored that he could not carry out a classification according to the spectra because at that time only about 150 spectra were known; but in Harvard observatory this was tried for the bright nebulae.[22] Wolf expressed his intention,

> „auf photographischem Wege und mit einfachen Messwerkzeugen die vielen unbekannten Nebel zu katalogisieren und sie kurz zu beschreiben. In dieser oder ganz ähnlicher Weise soll nach und nach eine Grundlage für einen photographischen Nebelkatalog und damit für die Erkenntnis unseres Weltsystems so wichtige Statistik geschaffen werden. Wie wichtige diese Katalogisirung ist, geht auch aus den angeführten Beispielen so recht anschaulich hervor. ... [Es] stellt sich daher das Verhältnis von neuentdeckten zu bekannten Nebelflecken wie 132 zu 3. Mit anderen Worten, es wären bisher – vor Anwendung der Photographie mit den kurzbrennweitigen Linsen – nur zwei Prozent der leicht zu photographirenden Nebelflecken katalogisirt.“[23]

4 Photography of the Milky Way and of Dark Clouds

Besides nebulae Max Wolf photographed also regions of the Milky Way and discovered large luminous and dark clouds in Orion, Cygnus und Auriga.[24]

Already since a long time astronomers discussed the „holes in the sky“, the dark regions in the Milky Way, which could be interpreted due to unregular distribution of the stars or due to clouds which darken the light of the stars behind. From 1890 the photographs of Wolf, Barnard and the Jesuit father John W. J. A. Stein (1871 – 1951) provided hints to dust and dark clouds between the stars and in the Milky Way, especially in Cygnus and Scorpio. Barnard photographed the Milky

[21][59], here p. 109; Tafel V: Nebel-Typen.

[22][33] Here four groups of nebulae were distinguished: irregular nebulae, gaseous nebulae (diffuse nebulae, planetary nebulae, nebulous stars), "white nebulae" and globular clusters with continuous spectra (small roundish nebulae, spiral nebulae and globular clusters) and irregular clusters.

[23][55], here p. 125 – 126.

[24]Wolf called a nebula North America Nebula due to its form and commemorating Barnard. Wolf gave a lecture about his results in the field of nebula research in 1907 during the meeting of the "Deutsche Naturforscher und Ärzte". Later two illustrated books about nebulae were published: [23], [58].

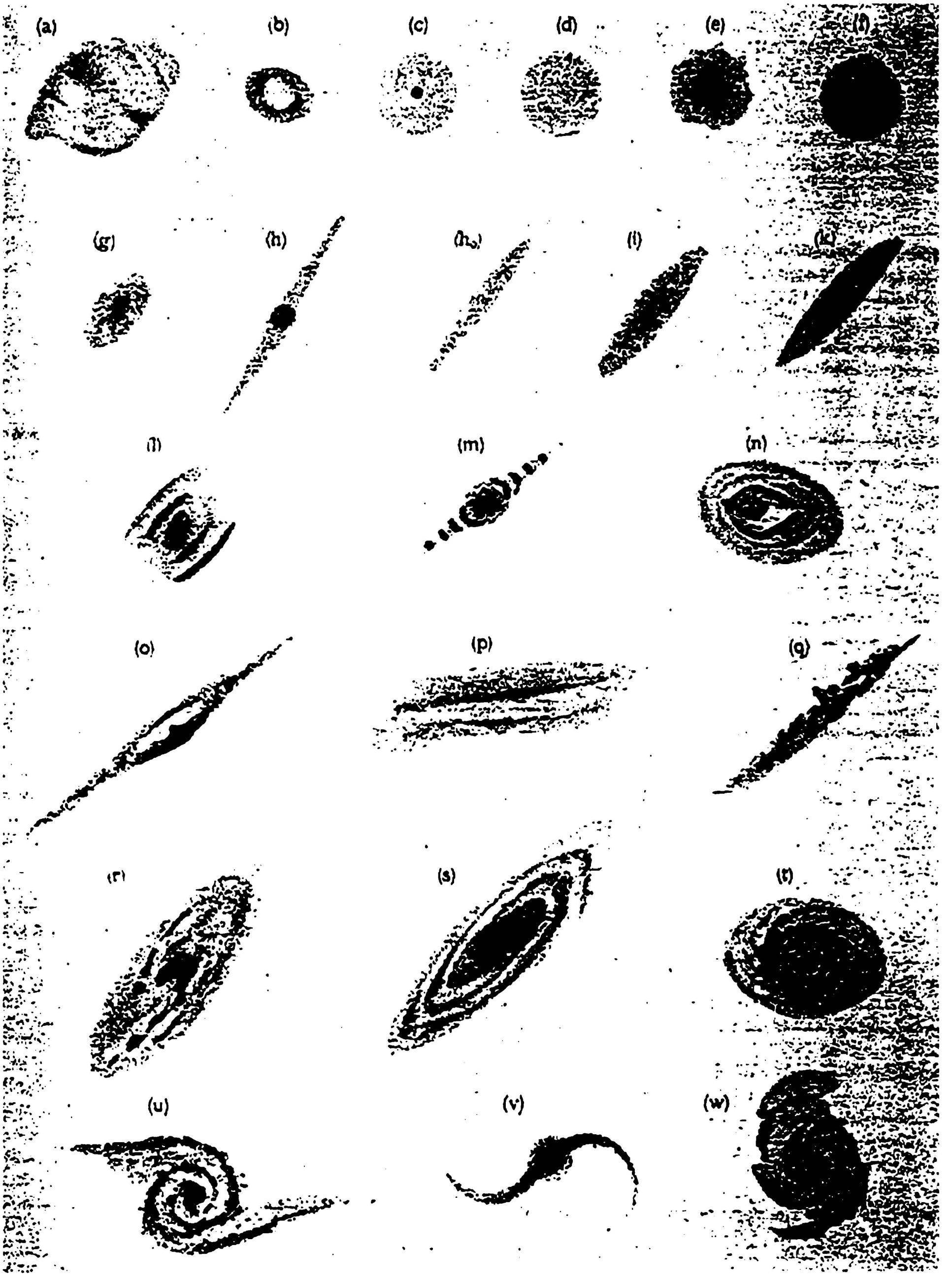

Fig. 5 Classification of nebulae, Max Wolf (1909).
[59], Bildstelle Deutsches Museum 49864.

Way from 1889 with a Willard-Petzval camera (doublet, d = 6″ = 15 cm) and with other portrait objectives up to 10″ = 25 cm aperture and pointed out in 1907 the absorption features in Taurus and in the Coal Sack.[25]

The existence of interstellar dust with absorbing effect became evident ([9], here p. 13). In 1919 Barnard compiled a catalogue of dark clouds in the Milky Way. "I do not think it is necessary to urge the fact that there are obscuring masses of matter in space. This had been quite definitely proved by my former papers on this subject."[26] But it was still not clear how trong the absorption is and if the dust in clouds is compressed or equally distributed in the cosmos. In 1923 Max Wolf ascertained on his photographies position and dimensions of the dark clouds by the help of star counting. Thus he could determine the absorption caused by the dark clouds. In his "Wolf diagrams" the magnitude as x axis and the corresponding number of stars in the magnitude interval $m - \frac{1}{2}$ und $m + \frac{1}{2}$ as y axis is marked. With this diagram the absorption effect of the cloud and the distance of the cloud can be estimated ([61], [13]).

With the help of these dark structures Wolf devoted himself to another astronomical problem around 1900. There were hints that the spiral nebulae are stellar systems, but the determination of the distance was really difficult. Max Wolf tried on the basis of his photographs an interesting estimation for the distance using elongated and transversal caves in comparison to a cave in the Orion nebula.[27]

5 Discovery of New Objects

The astrophotography proved true also by the discovery of new objects. For example Eugen von Gothard (1857–1909) in Herény, Hungary, discovered in 1886 the central star of the ring nebula in Lyra on a photographic plate (taken with a 26 cm reflector). Three examples for the successful application of portrait objectives should be mentioned in the following (Fig. 6):

1. Barnard was the first who discovered a new comet by photographic means in 1892 [4]. Thus he opened a new field for photography.
2. Already December 23, 1891, Max Wolf succeeded with a first discovery of a asteroid by photographic means, which he named after his American donator "Brucia" (323) [53]. Now the discoveries of asteroids increased strongly: from 322 before the use of photography to four times as much during 50

[25] [8], here p. 221, [6], [7], Bruce Photographic Observatory of the Yerkes Observatory, Barnard's Bruce Telescope: 1904, optics Brashear, two photographic doublets, 1:5 and 1:8, focal length 50″ = 128 cm, an objective prism made by Zeiss, in addition a 5″ guiding telescope.

[26] [10], here p. 1.

[27] [60] Wolf's parallaxe of Nova Persei was 0.01″ Campbell's was 0.008″ = 500 LJ. Wolf's result was rather good in comparison to others of his time.

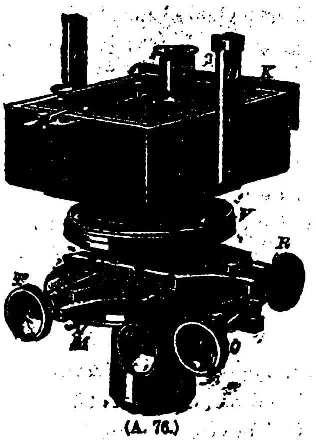

Fig. 6 Eugen von Gothard's (1857–1909) portrait cameras, Szombathely-Herény, Hungary. Konkoly, Astrophotographie, 1887, p. 234+236.

years. The asteroid (443) was even named after the new method "Photographica" ([54], [32], here p. 150, [45]).
In cooperation with Carl Pulfrich (1858–1927), Zeiss, Jena, Wolf developed an instrument for easyer analysis of the numerous photographic plates. Pulfrich succeeded to find an asteroid during the first test, which Wolf had not discovered during his visual check of the plates; it was named after the method of discovery "Stereoscopia" [34]. In long articles Pulfrich described his comparator, which opened quite new research possibilities and numerous discovered of asteroids [35]. The first stereocomparator is in the Deutsches Museum (Inv.-Nr. 65885).

3. Wolf suggested the study of variable stars and collected photographic plates systematically in respect to documentation of the sky. For this task the stereocomparator was also an important instrument for discoveries; already in 1901 during a test ten new variables were found on photographic plates of the Orion nebula [57]. In 1904 a remarkable improvement of the stereocomparator took place, because Pulfrich replaced the stereo microscope by a single ocular; thus the blink comparator was invented [36]. This name was given due to its main application: Variable stars, which show up on a photographic plate as a smaller or larger disk (Schwärzungsscheibchen) according to their brightness, became prominent by blinking due to quickly switching back and forth between the photographic plates. During the analysis of the numerous photographic plates, which were recorded until the 1920s, thousands of variable stars were discovered, which are more interesting for the astrophysicist than the stars with constant brightness. Still a long time in the

20th century photographic objectives of short focal length served as instruments for sky survey and for the investigation of variable stars.[28]

6 Conclusion and Outlook

In the beginning normal portrait objectives were used for astrocameras, because they had a large field of view. They proved to be useful especially in the 1880s and 1890s. Wolf und Barnard succeeded to get spectacular results with them. In contrary the "Carte du ciel" refractor of the brothers Henry in Paris had a relatively small field of view, but it was achromatically corrected especially for photography ([30], here p. 19).

From 1890 the development of new universal objectives, the anastigmates, [26] (f/9) was successful, calculated by Paul Rudolph (1858–1935), Zeiss of Jena. This calculation was based on one hand on Ernst Abbe's calculation of apochromates in 1886; thus he could remove the secondary spectrum; i.e. not only two but even three colours are corrected. On the other hand this progress was made possible by the improvement of optical glass due to the glass works Schott in Jena [1], [17]. With the invention of the new Barium crown glass in 1886, which had a higher refraction index at a given dispersion (1.57–1.61 in comparison to the old crown with 1.51). In the first photographic catalogue of 1891 of the photographic department at Zeiss, founded in 1888, the objectives anastigmat (called protar since 1900) and triplet were introduced.[29] Soon the planar (1896), the unar (1901, 1:4,5) and finally the tessar (1902, 1:6.3, later f/4,5 to even f/2.7; 50° to 60°) were invented.[30] Because the original photo objectives for large astrographs were not so well usable due to strong absorption caused by the thick lenses made from high refractive glass, objectives were soon developed especially for astronomical purposes. Here low refractive glass was necessary in order to be transparent also

[28][43] Here the anastigmat objectives the tessar (86 mm/f = 300 mm) of Zeiss, the tachar (100 mm, f = 250 mm) of the Astro GmbH Berlin, the four lens objective (120 mm, f = 380 mm) of Zeiss and the Ernostar (135 mm, f = 240 mm) are discussed.

[29]Zeiss: Photographische Objetktive. 1891. (Zeiss Photoliste Nr. 1). Deutsches Museum Sondersammlung Zeiss FS, Kataloge und Prospekte 1891–1905, Mai 1891 (anastigmat, protar, triplet).

[30]Zeiss: Das Planar. Nachtrag zum Katalog über photographische Objective und optischphotographische Hilfsapparate von Juni 1897. Deutsches Museum Sondersammlung Zeiss FS, Katalogue und Prospekte, August 1897. Zeiss; Das Unar. 1901. P 28 XII 1901, 20.000d. Deutsches Museum Sondersammlung Zeiss FS, November 1901. Zeiss: Photo-Objektive – Palmos-Cameras. Deutsches Museum Sondersammlung Zeiss FS, 1905.

Also the objectives made by other firms were corrected for astigmatism: the double anastigmat or dagor (f/7,7 or f/6,3) made by E. v. Höegh of C. P. Goerz, Berlin. In 1898 the celor of Goerz, the dogmar of Goerz, in 1901 the Steinheil unofocal appeared on the market. In 1893 H. Dennis Taylor succeded to make an anastigmatic objective with field of vision flattening with classical kinds of glass called Cooke triplet (f/4,5, bis f/6,3). The Dallmeyer stigmat and the Steinheil orthostigmat are similar.

in the ultraviolet region. Due to the sensibility curve of the photographic material the exposure times could be shortened considerably in addition.

Regarding the photographically corrected astrographs the lens diameter of 40 cm was widest spread. Also Wolf had chosen in 1897 a photographic double refractor, the 16″ = 40 cm "Bruce telescope".[31] Around 1900 Zeiss started the development of astrographs, which soon were alone prominent on the market: from 1907 to 1912 the astro Petzval and the astro tessar was developed; the astro triplet appeared in 1914.

Paris	1885	34 cm/3.40 m	Standard astrograph, Brothers Henry
Bloemfontein	1893	61 cm/3.45	Astrograph Clark, Fecker
Heidelberg	1900	40 cm/2.00 m	Bruce telescope, Brashear, Grubb
Oak Ridge/Mass.	1910	40 cm/2.21 m	Petzval lens, Metcalf refractor
Hamburg	1911	34 cm/3.40 m	Lippert astrograph, Zeiss
Pulkovo	1924	12 cm/2.06 m	AG astrograph, Zeiss
Bonn, Hamburg	1924	8,5 cm/2,06 m	AG astrograph, Zeiss
Potsdam/Bolivia	1926	30 cm/1.50 m	Triplet objective, Zeiss

In addition to the astrographs since 1900 the reflectors were introduced, which had a much smaller field of view than portrait lenses. This was the reason that Wolf hesitated a long time to use a reflector. But soon it was clear that a reflector had large advantages for special analysis like the dissolving single stars in distant galaxies.

But besides astrographs and reflectors the portrait objectives proved as to be useful for special purposes until the 1920s.

> „Wolf erkannte schon sehr früh den Wert von photographischen Objektiven mit großen Gesichtsfeld, die es ermöglichen, große Flächenräume des Himmels auf einer einzigen Aufnahme scharf abzubilden. Damit stellte er sich freilich in Gegensatz zur Meinung der meisten anderen Astronomen (mit Ausnahme von Pickering [und Barnard]), die die Ansicht vertraten, daß solche Objektive, die von den Photographen bereits längst verwendet wurden, sich für exakte astronomische Arbeiten nicht eigneten. Aber Wolfs Ansicht erwies sich als richtig, gerade Aufnahmen mit solchen, große Flächen abbildenden Objektiven sind für die Weiterentwicklung der Astronomie von größter Bedeutung geworden, und die Erfolge Wolfs sind fast ohne Ausnahme auf die Verwendung dieser [Portrait-] Objektive zurückzuführen.“[32]

Thus the after-effect of Petzval's invention was perceiveable long in the 20th century.

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[31]Optical data of the Bruce telescope of Heidelberg observatory: 1 : 5, Petzval, Brashear, lenses made by Schott of Jena, with the help of May Pauly (1849–1917) checked by Zeiss of Jena, mounting by Grubb of Dublin.

[32][18], here p. 58.

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