# XI: The Brunners and Paul Gautier

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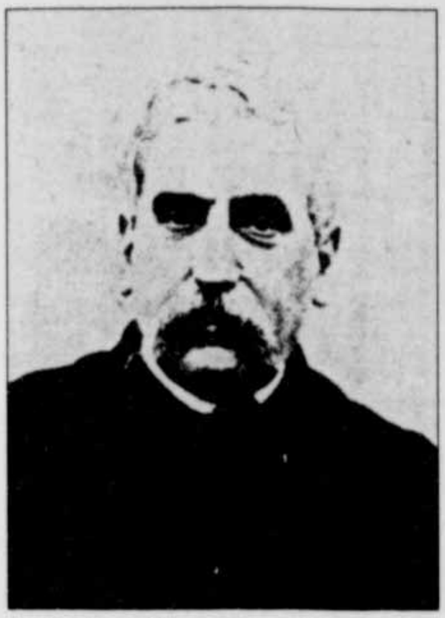

Fig.1 *Émile Brunner (From:* Musée retrospectif de la classe 15 à l'exposition universelle internationale de 1900 *(Paris, 1900).*

Fig.2 *Léon Brunner (From:* Musée retrospectif de la classe 15 à l'exposition universelle internationale de 1900 *(Paris, 1900).*

During the second half of 19th century only the best European and American makers were able to produce the high precision instruments required for accurate measurements in metrology, geodesy and astronomy.[1] In fact it was mainly in these fields where the instrument-maker's skill was mostly challenged in manufacturing top quality apparatus. Among the French makers of the first decades of the century the names of Gambey and Lerebours[2] were synonimous with excellence. Their skill and capability were further developed by people like the Brunners and P. Gautier. In the second half of 19th century they became the most important representatives of the French precision industry. Brunner *père* and his two sons specialized in geodetic, surveying and astronomical instruments, while P. Gautier became the most famous French maker of large astronomical instruments.

### The Brunners

*"Pour la construction des instruments de précision, construction et fini, c'est la maison Brunner frères qui peut prendre le premier rang."*[3] With these few clear words the reporter of the French workers of the precision industry judged the apparatus, which were exhibited by the Brunner brothers at the Paris exhibition of 1867. In fact the quality and the elegance of their instruments, the precision of their engraved scales, and the accuracy of their mechanical parts represented the highest standard of French activity in this field.

Johann Jakob Brunner (1769-1850) was a well regarded locksmith from the Swiss village of Balsthal in Canton Solothurn. One of his sons, Johann Josef Brunner (1804-1862),[4] became a famous instrument maker in Paris. He first spent some time as an apprentice in his father's workshop and then moved to Basel, where, during three years, he worked with a balance maker. In the evening he dedicated himself to the study of mathematics and drawing. At the age of 22 he went to Vienna and learned the art of instrument-making with Starke at the local polytechnical institution. Finally in 1828 he moved to Paris where he became known as Jean Brunner. He first worked with an instrument maker called Frédéric Hutzinger and then with the famous microscope maker Vincent Chevalier (1770-1841).[5] Brunner soon distinguished himself as one of the most active and skilful workers. During his spare time he also began to make his circular dividing engine, which, when completed, was successfully used for many years.[6] He probably opened his own workshop in the 1830s at 34, rue des Bernardin, and participated for the first time in 1839 in a French national exhibition when he was awarded a silver medal for his apparatus. At the next national exhibition of 1844 he displayed several instruments, such as theodolites, microscopes and magnetic compasses, but it was an astronomical circle of 60cm diameter which mostly impressed the jury. The divisions of the circle were found to be excellent, and Brunner won a gold medal. The success was repeated at the 1849 exhibition, where among several instruments such as sphærometers, declination compasses and levels, he also exhibited a clockwork-driven equatorial telescope. During these years he presented some of his instruments at the *Académie des Sciences* such as an astronomical repeating circle and a 'hypsogoniometer' in 1846, a theodolite and a telescopic level in 1847, a precision refractometer and a sphærometer in 1849.[7] The most famous French precision instrument maker of the time, Henry Prudence Gambey (1787-1847), who was in the commission which had to write a report about the astronomical circle, was very impressed by the quality of Brunner's instrument. Around 1845 the *Bureau des Longitudes* decided to install a large equatorial telescope in the observatory of Paris. Gambey was supposed to supply the instrument, but he could not fulfill the request because of his death in 1847. Brunner proposed to the *Bureau* a full-size wooden model of a parallactic mounting. The model was convincing and Brunner was given the task of building the apparatus.[8]

In the early 1850s, because of the need for a larger space for his new astronomical apparatus, Brunner moved his workshop from the rue des Bernardins to a larger one at 183, rue de Vaugirard. He and his successors remained there until the end of the century. Jean Brunner did not participate to the 1851 London universal exhibition, but in the stand of the *Conservatoire des Arts et Métiers* it was possible to admire one of his standard metres made of platinum. In the same year he presented several new surveying as well as optical instruments to the *Académie des Sciences* (a theodolite, a reflection goniometer and refractometer, an instrument for studying double refraction, a portable meridian instrument, and a level). In 1853 he became *artiste adjoint* of the *Bureau des Longitudes.*[9] It was a great honour because only the very best makers could hope to be appointed by this prestigious institution. In the same year he proposed a new meridian circle to the *Académie*, which was to be used by the French Navy during a hydrographic expedition to the Guadeloupe island, as well as a small universal equatorial telescope. The latter could be adjusted for every latitude.[10] At that time his

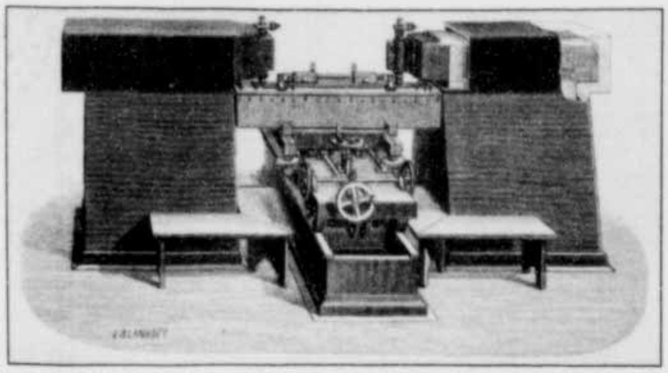

Fig.3 *Brunner's comparator at the Pavillon des Poids et Mesure in 1885. (From:* Travaux et mémoires du Bureau intérnational des poids et mesures, op.cit., *note 15, p.8).*

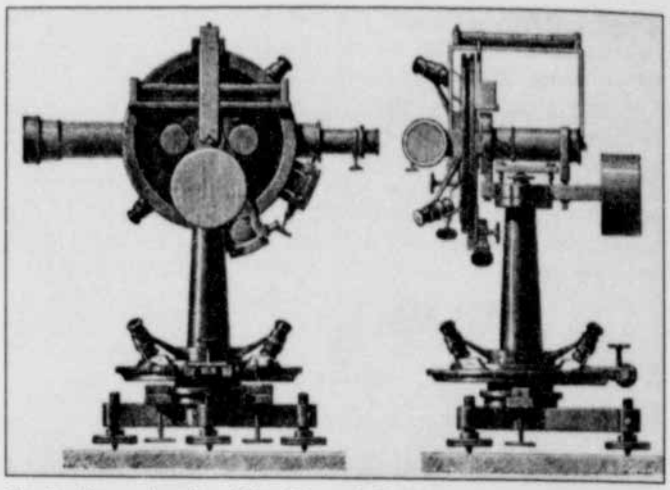

Fig.5 *Repeating theodolite (From: L.B. Francoeur,* op.cit., *note 20, pp.536).*

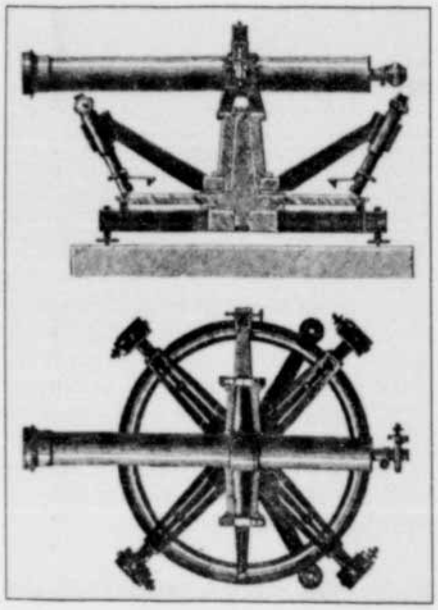

Fig.4 *Azimuth repeating circle (From: L.B. Francoeur,* op.cit., *note 20, pp.510).*

reputation was universally acknowledged and in 1855 he became member of the jury of Class VIII, Group 3 – scientific instruments – at the Paris universal exhibition. Despite the fact that because of this official rôle he could not receive a prize, Brunner nevertheless displayed several astronomical, optical as well as surveying apparatus. The most important one perhaps was an instrument for measuring the base of a triangulation, which was composed of a double (platinum and copper) rule of 4 metres with a couple of reading microscopes.[11] The apparatus, whose thermal dilatation had to be carefully studied, took about two years to be completed and tested. It was used for determining the base of the triangulation of Spain, which was connected to the French geodetic net. It seems that the error of measurement of a length of 2838 metres was only 2/10 of a mm. For his contribution to the realization of this project Brunner was made a chevalier of the order of Carlos III in 1858.[12]

Brunner not only developed a series of new instruments but he also made some of the precision machine tools and apparatus, such as a planing and filing machine, a comparator and a dividing engine, which were necessary in his workshop. In the later years of his life Jean Brunner became interested in the mechanical production of large objectives, but unfortunately he could not develop his trials.

Just before his death, Jean Brunner also participated at the London exhibition of 1862. He displayed together with several surveying and optical instruments, a meridian circle (42cm) for the viceroy of Egypt. Jean Brunner died in the same year and his sons Émile (1834-1895)[13], who had been the director of the firm for a few years (Fig.1), and Léon (1840-1894) continued the activities (Fig.2). The official name of the firm became then *Brunner Frères* and the two brothers constantly worked together, following their father's tradition. In fact in about 30 years of activity the Brunner brothers continued to invent, develop and improve surveying, geodetical and astronomical apparatus. In 1867 they were at the Paris exhibition with several instruments and also with a telescope (22cm aperture) for the observatory of Cairo. Again at the 1878 exhibition they displayed many interesting apparatus of the highest quality. Among the most successful Brunner's apparatus we recall the portable meridian circle and the azimuth instruments (32 and 42cm in diameter, and 4 reading microscopes) which were adopted by the army general and surveyor François Perrier (1833-1888) during a series of triangulations which connected France, Spain and Algeria. These invaluable instruments were constantly used with minor modifications until 1945![14] In 1874 the important expeditions which observed and photographed the passage of Venus on the sun in various locations of the globe were also equipped with Brunner's instruments. In the early 1880s the Brunners improved one of their instruments to determine magnetic declination, which was eventually used during an astronomical mission in Chili.[15]

In 1883 they completed the construction of a highly sophisticated comparator for the *Bureau Intérnational des Poids et Mesures*. It was a large apparatus (Fig.3) which was used to compare the standard metre with its copies. These copies had to be given to the different states which had signed the *Convention du mètre* of 1875.[16] The large machine[17], which was located in a thermally insulated double walled room, was fixed to a massive stone basement, independent from the rest of the building. The comparator had a couple of micrometer microscopes under which it was possible to displace two separate metre rules which were kept in a special metallic box on a moveable chariot. For this achievement Émile was awarded the cross of the *Légion d'Honneur*. At the same time the Brunner brothers manufactured some of the best French astronomical instruments, which were located in the observatories of Paris, Nice, Toulouse, Lisbon, Cairo, Lyon, Algiers, etc.[18] One of the most important of these was the large meridian circle for the observatory of Nice (aperture 20cm, focal length 320cm) which was installed in 1887.[19] Unfortunately this important instrument was scrapped in the 1960s when the observatory was reorganized.

Many geodetic and topographic instruments came out of Brunner's workshop. Transits, theodolites, azimuth circles, variation magnetic compasses, theodolites, levels, etc. were of the highest

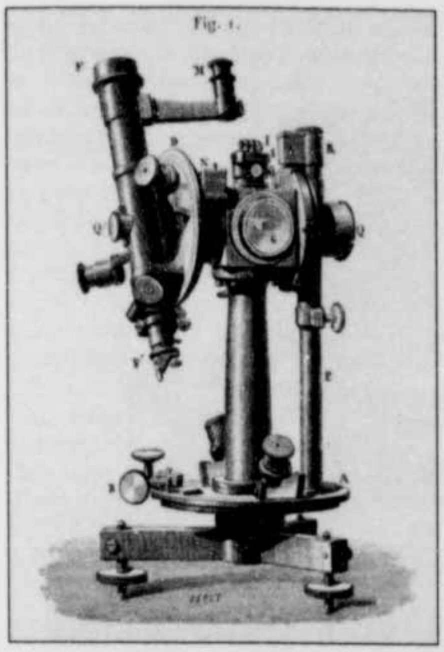

Fig.6 *Brunner's magnetic compass. With this instrument it was possible to determine the angle between the magnetic and the geographic meridians. (From: De Bernardière,* op.cit., *note 15, p.12).*

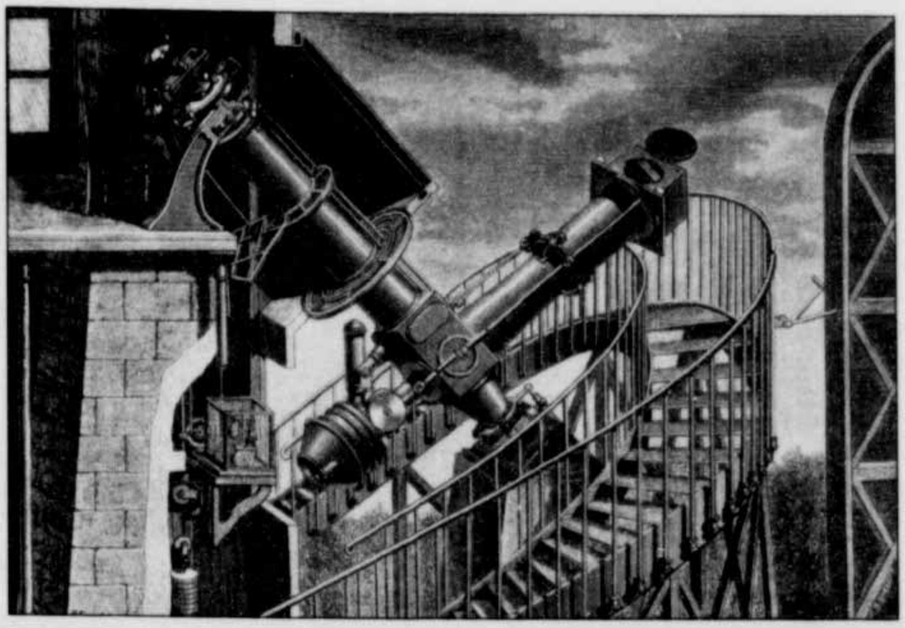

Fig.7 *The first* équatorial coudé *of the Paris observatory. (From: Ph. Gérigney, 'Les grand instruments de l'astronomie.* L'equatoral coudé *de l'observatoire de Paris',* L'Astronomie, *3 (1884), pp.216-225).*

quality and they represented the state of the art of the French precision industry (Figs.4-6).[20]

At the 1889 exhibition the geodetic instruments of the brothers Brunner, which were often made for the *Bureau des Longitudes*, were highly appreciated. Among these they also displayed their reversible pendulum, which had been proposed by commander Gilbert Defforges (1852-1915) for determining the gravity constant.[21]

Léon Brunner died in 1894 and his brother Émile one year later. Unfortunately, they did not have any successor (Émile had only a daughter) and the firm disappeared with them. Jean Brunner as well as his two sons and other members of the family are buried in the Parisian cemetery of Montparnasse.

**Paul Gautier (1842-1909)**

Paul Ferdinand Gautier (1842-1909) was born in Paris from a modest bourgeois family.[22] At the age of thirteen he had to abandon school and start an apprenticeship. Meanwhile, he followed the geometry course at a drawing school in the rue de l'École de medicine. When he was about 18, he entered the precision instrument firm Secretan – the successor of Lerebour–[23] under the direct supervision of William Eichens (1818-1884), who, at the time, was the director of the company. In 1863 he went to Marseille, where he installed a reflecting telescope with an 80cm mirror, which had been manufactured by Secretan in close cooperation with the physicist Léon Foucault (1819-1868). In 1866 Gautier followed Eichens, who at the time was founding his own firm, which for about 15 years became one of the most important French workshops for the construction of astronomical instruments. Ten years later Gautier left Eichens and opened his own workshop at 24, rue d'Enfer. In 1878 Gautier participated for the first time in a Paris universal exhibition, where he presented a dividing engine.

In 1871 the astronomer Maurice Loewy (1833-1907) had proposed a special type of equatorial telescope (Fig.7), which was baptised the *équatorial coudé*.[24] The instrument had an inclined tube rotating on its equatorial axis, which was connected with an orthogonal tube bearing a rotating objective. The light entering the objective was reflected into the eyepiece by two perpendicular mirrors (one near the objective itself and the second one at the junction of the two tubes). With this instrument, which was supposed to be particularly stable, the eyepiece did not move, thus allowing the astronomer to observe the sky from a fixed observation place and it was also possible to install fixed ancillary apparatus near the objective such as spectroscopes, photometers, cameras, etc. Furthermore, the instrument did not need any large dome, which was normally complicated and expensive to build.[25] The first *coudé* (27cm of aperature) which was sponsored by the philantropist Raphäel Bischoffsheim (1823-1906),[26] was mounted at the *Observatoire de Paris* between 1879 and 1882. Between 1882 and 1892 six others *coudés* were built for the observatories of Vienna, Alger, Lyon, Besançon, Nice and a second one for the Paris observatory. Gautier built all these instruments, while the lenses were made by the French astronomer and opticians the brothers Paul (1848-1905) and Prosper Henry (1849-1903).[27] The second *coudé* of Paris, with an aperture of 60cm and a focal length of 18 metres, was the largest instrument of its kind ever built.[28] With this instrument it was possible to establish the *Atlas photographique de la lune* between 1894 and 1907. But the *coudé*, which certainly was an original and interesting instrument, also showed several inconveniences. For example, it was not very easy to adjust the declination because of the complexity of the movable mechanical parts.

In 1880 Gautier was finally able to buy the firm Eichens. At the 1889 Paris exhibition Gautier displayed a meridian circle with an aperture of 22cm and a focal length of 310cm for the observatory of La Plata as well as other instruments and the drawings for the *coudé*. In 1885 Gautier made a prototype[29] of an instrument which was subsequently improved, and was adopted for an ambitious project of the photographic mapping of the sky, the so-called *Carte du Ciel*.[30] The 'astrograph' was a double equatorial telescope with two parallel tubes. One had a photographic objective (33cm) and the other (25cm) a normal objective for direct visual observation. In this case, too, the optics of the instrument were made by the Henry brothers. The

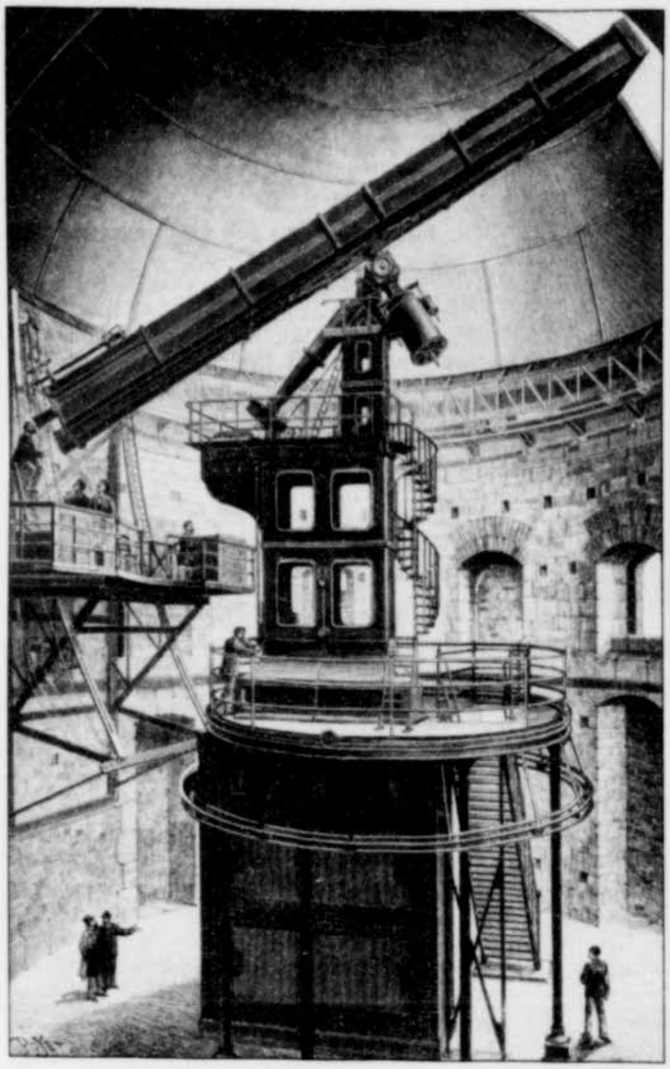

Fig.8 *The double equatorial of the observatory of Meudon. (From: G. Tissandier, 'La grande lunette de l'observatoire astronomique de Meudon',* La Nature *(1896), 1 semeter, pp.359-362).*

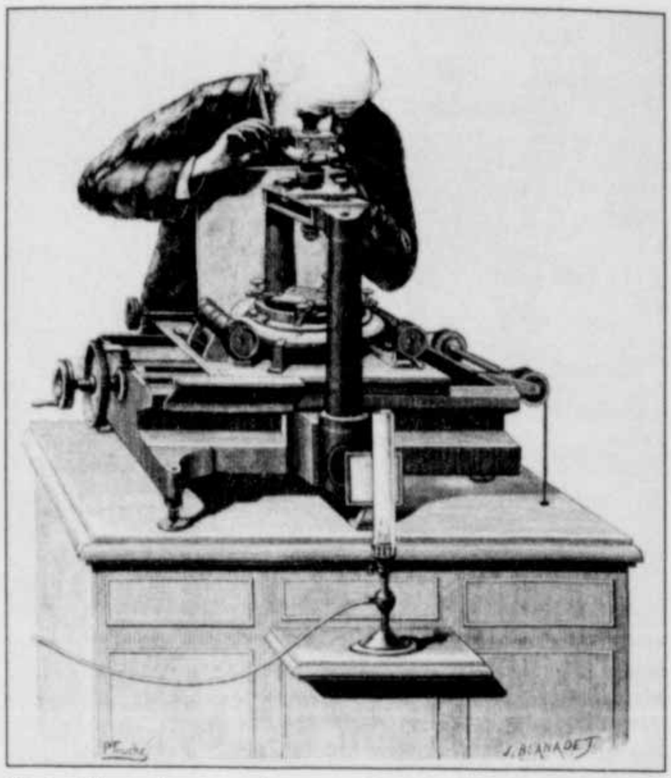

Fig.9 *Macromicrometer for measuring astronomical photographs. (From: Paul et Prosper Henry, 'Etoiles doubles et amas d'étoile mesurés par la photographie,* L'Astronomie, *5 (1886), pp.281-286).*

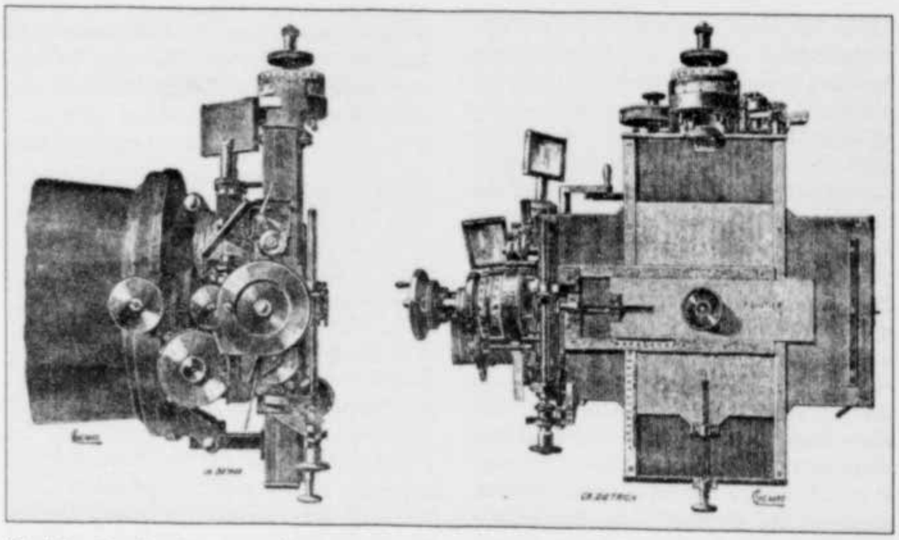

Fig.10 *Gautier 'impersonal' micrometer. (From: Repsold,* op.cit., *note 1, p.134).*

largest double equatorial of Gautier was built for the observatory of Meudon (focal length 16m, diameter of the objective 83 and 66cm). It is still the largest (Fig.8) in Europe and the third largest in the world. Gautier also traced the reticules on silvered glass plates which were used for measuring the astronomical photographs.[31]

Gautier improved many instruments related to astronomical research. These were often used during the most important astronomical missions of the time. He improved the mercury reflecting bath for nadir observations,[32] and he made a special 'macromicrometer' (Fig.9) for examining and measuring the photographic plates which were obtained with the astrographs,[33] and in 1892 he presented a new apparatus for the same task.[34] He also proposed an 'impersonal' micrometer (Fig.10) for reducing the subjective errors of the observer.[35] Thanks to his indefatigable work and his brilliant achievements Gautier was made a *Chevalier de la Légion d'Honneur* in 1889, and in 1897 was elected *membre artiste* of the *Bureau des Longitudes.*

Around 1900 Gautier was at the top of his career and he was employing about 40 workers in his workshop at 56, boulevard Arago.[36] At the time he had built 17 large equatorial telescopes, 7 *coudés*, 13 astrographs for the *Carte du*

*Ciel*, 3 refractors, 7 large meridian circles, 5 siderostats, 3 altazimuth telescopes, 7 portable meridian instruments and many other smaller telescopes and related astronomical apparatus.[37] These instruments not only equipped the most important French observatories but also could be found in many other countries such as China, Brazil, Argentina, Austria, Japan, Spain, etc. Gautier was certainly the most important French astronomical instrument maker and one of the most skilled and appreciated in the world.

The 1900 Paris universal exhibition marked the triumph of Gautier, but, at the same time caused many financial problems for his firm.[38] Around 1896 the French politician and diplomat François Deslonde (1856-1922) had created the private society *L'Optique, Société Anonyme des grands telescopes* to finance the construction of a very large refractor. The gigantic instrument had to be presented at the 1900 Paris exhibition. The huge apparatus, which was ironically said to be able to show la *lune à un mètre*, was a real monster (Fig.11). Because of the planned dimension it would have been almost impossible and far too expensive to make a conventional equatorial instrument as well as a suitable movable dome for it. Thus, it was decided to build a fixed telescope with a siderostat. A 45 tons siderostat with a 2m silvered glass mirror directed the light in the 60 metres steel tube of 21 tons. The mirror and its mounting weighed 15 tons. They were floating on a mercury bath and were driven by a clockwork mechanism. The two interchangeable objectives (a visual and a photographic one), which weighed 900 kg each, had a diameter of 125cm and were installed on a special movable chariot.[39] These very large optical pieces were made by Gautier in a special thermally insulated workshop, where thanks to a double wooden wall the temperature was kept constant as far as possible. The necessary automatic polishing machines for the mirror and the lenses had been specially designed for the task by Gautier himself.

The instrument certainly attracted the curiosity of the visitors at the exhibition, because it was the most spectacular attraction of the *Palais de l'Optique*, and aroused the excitement of the scientific community. But unfortunately, the telescope was only used by the astronomer Eugène Antoniadi (1870-1944) for a few observation on nebulae.[40] Because of the lights of the *ville lumière*, because of the smoke of two large chimneys of the boilers of the exhibition and finally because of the political unrest in the town, the observations were quite difficult and the results of the observations were quite deceiving. A better location would certainly have allowed a far more satisfactory use of the instrument. After the exhibition the society, which owned the telescope had to support severe financial losses, and unsuccessfully tried to sell it to the French government. The telescope was dismantled and stored in the observatory of Meudon and after several years it was finally scrapped.[41]

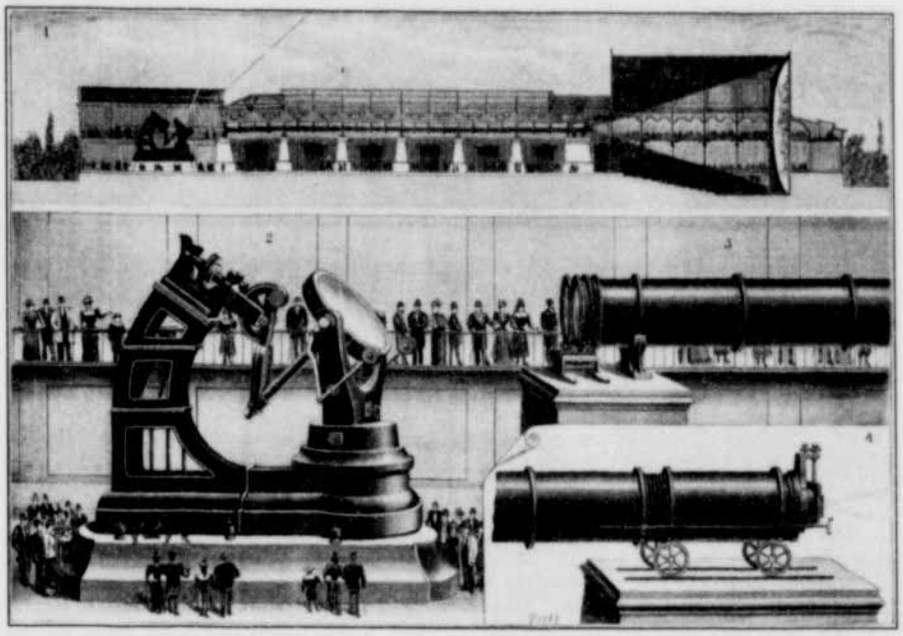

Fig.11 *An engraving showing the 1900 Paris exhibition telescope. The direct projection of the moon shown in the upper part of the illustration were never made. (From: L. Barré,* op.cit., *note 38).*

That was the sad end of Gautier's technical masterpiece which was the largest and the most useless refractor ever built. Nevertheless, Gautier's activities continued. He perfected a printing chronograph[42] and he provided several instruments for the observation of the 1905 eclipse. After the death of Gautier in 1909, the firm was subsequently bought by G. Prin in 1910. Finally the firms Secretan and Prin amalgamated under the trade name *Ets. Secretan, Epry, Jecquelin successeurs.*[43]

For his rôle in the development of large astronomical instruments Gautier can be considered one of the most important and successful French instrument makers of his time. His name, together with those of Grubb, Repsold, Cooke, Clark, Merz, Steinheil and a few others, indelibly marked the golden era of large refractors.

## Notes and References

1. Two works are fundamental in the history of 19th century astronomical and geodetical instruments: L. Ambronn, *Handbuch der astronomischen Instrumentenkunde* (Berlin, 1899); and J.A. Repsold, *Zur Geschichte der astronomischen Messwerkzeugen von 1830 bis um 1900* (Leipzig, 1914). See also H.C. King, *The History of the Telescope* (New York, 1979), of which the first ed. appeared in 1955, and A. Danjon, A. Couder, *Lunettes et télescopes* (Paris, 1979). The first ed. published in 1935. Many of the instruments mentioned in this article are illustrated and described in these books.

2. P. Brenni, 'H.P. Gambey', *Bulletin of the Scientific Instrument Society*, No.38 (1993), pp.11-13, and 'Lerebours et Secretan', ibid., No. 40 (1994), pp.3-6.

3. P. Sabrier, 'Rapport adressé à la commission d'encouragement par la délégation des ouvriers en instruments de précision', p.2, in *Rapport des délégations ouvrierères*, ed. A. Desvernay (Paris, 1867).

4. About the life of Jean Brunner see: Laugier, *Discours prononcé aux funèrailles de M. Brunner*, 'Annuaire du Bureau des Longitudes' (1863), pp.387-397.

5. P. Brenni, 'The Chevalier Dynasty', *Bulletin of the Scientific Instrument Society*, No.39 (1993), pp.11-14.

6. It seems that Madame Eve Veith-Brunner (1809-1880), the wife of the maker, dedicated a lot of her time to work with the engine. With it were also divided the scales of many instruments manufactured by other makers.

7. The 'hypsogoniometer' was a kind of surveying instrument. Most of the above mentioned instruments were not described in the *Comptes Rendus*. Only the astronomical circle was described by a report written by a special commission which included Gambey. See Laugier, 'Rapport sur un cercle astronomique de M. Brunner', *Comptes Rendus de l'Académie des Sciences*, **22** (1846), pp.527-528.

8. See F. Arago, *Astronomie populaire* (Paris, Leipzig, 1855), Vol. II, pp.37-39. This equatorial mounting is still in place at the observatory in

Paris with a refractor of 38cm aperture and a focal length of 9 metres. See S. Débarbat, S. Grillot, and J. Lévy, *L'Observatoire de Paris et son histoire (1667-1963)* (Paris, 1984).

9. At the time Lerebour was the other *artiste adjoint* while the instrument maker Louis Breguet (1804-1883) – the grand-son of the famous clockmaker Abraham – was the *artiste*.

10. See 'Correspondence', *Comptes Rendus de l'Académie des Sciences*, **37** (1853), pp.726-727.

11. J. Brunner, 'Appareil construit pour les opération au moyen desquelles on prolongera dans toute l'étendue et l'Espagne le réseau trigonométrique qui couvre la France', *Comptes Rendus de l'Académie des Sciences*, **34** (1857), pp.150-152. Also J.A. Repsold, *op.cit.*, note 1, p.126.

12. This order had been instituted by Don Carlos III of Spain in 1771.

13. About E. Brunner see J. Janssen, 'Allocution aux funérailles de M. Émile Brunner', *Annuaire du Bureau des longitudes* (1896), pp.F1-F5 and F. Tisserand, 'Allocution', ibid., pp.F5-F7.

14. J.J. Levallois, *Mesurer la terre, 300 ans de géodésie français* (Paris, 1988), pp.131-138 and also Repsold, *op.cit.*, note 1, p.130.

15. De Bernardière, *Mémoire adrèsse au Bureau des longitudes sur les determination magnétiques éffectuées pendant la mission chargée de l'observation du passage de Vénus au Chili* (Paris, 1884), pp.11-13.

16. H. Moreau, *Le système métrique* (Paris, 1975), pp.47-62.

17. For a description of the instrument see 'Le comparateur', *Travaux et mémoires du Bureau intérnational des poids et mesures*, **4** (1885), pp.8-16 and 69-70.

18. S. Grillot, 'Les instruments des observatoires français au 19e siècle', *L'Astronomie, Bulletin de la société astronomique de France*, **100** (1986), p.275-289.

19. See 'Circle méridien Brunner', *Annales de l'Observatoire de Nice*, **1** (1899), pp.67-78.

20. L.B. Francoeur, *Géodesie*, 4th ed. (Paris, 1879), pp.509-513 and 536-541.

21. See for example G. Defforges, 'Mesure de l'intensité absolue de la pesanteur à Breteuil', *Comptes Rendus de l'Académie des Sciences*, **105** (1892), pp.104-106.

22. About Gautier see H. Poincaré, 'Discours pour les funérailles de M. Paul Gautier', *Annuaire du Bureau des longitudes* (1911), pp.D1-D5, and D. Baillaud, 'Discours', ibid., pp.D6-D11. Also J.R. Lévy, 'Gautier Paul Ferdinand', *Dictionary of Scientific Biographies*, ed. C.C. Gillespie (New York, 1981), Vol. V, pp.315-316. Also 'Dossier Légion d'Honneur', Archives Nationales à Paris ($F^{12}5152$).

23. See P. Brenni, *op.cit.*, note 2.

24. M. Loewy, 'Sur un nouvel instrument équatorial', *Comptes Rendus de l'Académie des Sciences*, **73** (1871), pp.851-854.

25. A section of the building protecting this instrument was mounted on wheels and rails, and it was displaced when the *coudé* was used.

26. Bischoffsheim was the son of a very wealthy banker. He completely financed the construction of the *Observatoire de la Côte d'Azur* in Nice, which was built in the 1880s. Bischoffsheim also sponsored with his own money the construction of several astronomical instruments for the French observatories.

27. The Henry brothers had a common career as astronomers as well as opticians. Their work was remarkable and their skill universally appreciated. They developed and made most of the objective lenses for the seventeen photographic equatorial telescopes which were used for establishing the monumental *Carte du Ciel*. They also produced many different devices as well as the great 78cm objective for the telescope of the Nice observatory as well as the 83 and 62cm objectives of the telescope of Meudon. Most of the instruments made by Gautier were equipped with lenses which had been made by the Henrys.

28. Not all the *coudés* survive today. The small one of the Paris observatory was scrapped in the 1970s, the largest one is now dismantled and stored at the *Cité des Sciences et de l'Industrie*. The largest one which is still functioning is at the observatory of Nice. About the story of the seven *coudés* see Th. Weimar, 'Un instrument en voie de disparition: l'equaltorial coudé', *Journal of History of Astronomy*, **13** (1982), pp.110-118, and F. Manning, 'Histoire scientifique et technique de l'équatorial coudé', Paris, 1981. (It is a typescript with also many photocopies of original articles. It can be found at the *Médiathèque d'histoire des sciences* of the *Cité des Sciences et de l'Industrie* in Paris). See also *Annales de l'Observatoire de Paris Mémoires*, **21** (1893).

29. This prototype was made by Gautier at his own expense.

30. Thanks to the success of the astrograph in 1887 the admiral and astronomer Ernest Mouchez (1821-1892) organized in Paris an international conference, where it was decided to establish a general photographic map of the sky. The work was carried out by 18 different observatories, which were equipped with similar instruments. See Th. Weimar, *Brève histoire de la Carte du Ciel en France* (Paris, 1987).

31. P. Gautier, 'Sur un procédé de construction des vis de haute précision pour les appareils de mesure de la carte du ciel', *Comptes Rendus de l'Académie des Sciences*, **112** (1891), pp.991-992.

32. Périgaud, 'Nouveau bain de mercure, pour l'observation du nadir', *Comptes Rendus de l'Académie des Sciences*, **106** (1888), pp.919-920.

33. E. Mouchez, 'Macro micromètre' in *Rapport annuel sur l'état de l'observatoire de Paris pour l'année 1866* (Paris, 1887), pp.11-13. This instrument, which unfortunately was scrapped at the end of the 1960s, was also used for a very peculiar examination: the writing on a sheet of paper (the *bordereau*), which was a fundamental document in the famous Dreyfus affair, was examined with the macromicrometer. See S. Débarbat, 'An unusual use of an astronomical instrument: the Dreyfus Affair and the Paris "Macro-micromètre', *Journal for the History of Astronomy*, **27** (1996), pp.45-52.

34. See 'Appareil de mesure', *Rapport annuel sur l'état de l'observatoire de Paris pour l'année 1892* (Paris, 1893), pp.15-16. Gautier also wrote 'Mire a disque mobile autour d'un cercle vertical', *Bulletin Astronomique*, **7** (1890), pp.97-98.

35. See Repsold, *op.cit.*, note 1, p.134.

36. See 'Légion d'Honneur', Archives Nationales de Paris ($F^{12}5152$). Gautier probably moved to the new address in the 1880s.

37. A complete list of the most important instruments built by Gautier before 1901 can be found in *L'industrie française des instruments de précision, Catalogue* (Paris, 1901-1902, reprinted by Brieux in 1980), pp.111 and 113-118.

38. P. gautier, 'Sur le grand sidérostat de 1900', *Seances de la Société française de physique* (1899), pp.29-50, this article was also reproduced (almost identical) in the *Annuaire du Bureau des longitudes* (1899), pp.C1-C26 and in *Mémoires de la société des ingénieurs civils*, 1 (1899), pp.757-775. P. Gautier, 'Construction d'un miroir plan de 2 m de diamètre per des procédés mécaniques', *Comptes Rendus de l'Académie des sciences*, **128** (1899), pp.1373-1375. See also E. Gautier, 'La grande lunette de 1900', *L'année scientifique et industrielle*, **44** (1900), pp.19-22; L. Barré, 'La grande lunette de 1900', *La Nature*, I semester (1899), pp.167-170; A. Berget, *Le ciel* (Paris, 1923), pp.196-197 and 'The Great Paris Telescope Fiasco, in J. Ashbrook, *The Astronomical Scrapbook* (Cambridge, 1984), pp.179-183.

39. For the exhibition only the photographic objective was ready. The optical glass for the objective was provided by the company Parra-Mantois & Cie of Paris, which also produce the glass for the 105cm telescope of the Yerkes Observatory. This firm had been founded at the end of the 1820s by Henry Guinand, son and successor of the famous glass maker Pierre Louis Guinand (1748-1824).

40. Antoniadi judged excellent the mechanical functioning of the siderostat, see: E. Antoniadi, 'L'étude des nébuleuses dans la grande lunette de l'exposition', *Bulletin de la Société astronomique de France* (1900), pp.375-376, 385-387 and 459-460.

41. The glass disk of the siderostat, which is not silvered anymore, is today preserved at the *Observatoire de Paris*. I was not able to find if and where the objective survives.

42. F. Boquet, 'Chronographe de P. Gautier', *Bulletin astronomique*, **22** (1905), pp.270-283. He also wrote 'Expérience faite sur le cercle du jardin de l'Observatoire', ibid., **18** (1901), pp.217-218.

43. M. Daumas, *Scientific Instruments of the Seventeenth and Eighteenth Centuries* (New York: Praeger Publishers, 1972), p.285, note 185. (Translated and edited by M. Holbrook, first edition Paris 1953).