Chapter 1
Precursors to IAU: Paris Observatory and the *Carte du Ciel* Project

Ileana Chinnici

Abstract The *Carte du Ciel* was the most extended project of international cooperation in the field of astronomy, from the end of the nineteenth to the middle of the twentieth century. Launched by Paris Observatory in 1887, it was aimed at photographing the whole sky vault in order to produce a Chart and a Catalogue of all visible stars. The required effort was underestimated for several reasons and the project could not be achieved in the form originally intended. However, its scientific and historical value is remarkably important, as it provided reference stars catalogues for well-known space astrometric missions in the twentieth century and paved the way to the establishment of the wide-world cooperation promoted by the International Astronomical Union.

1.1 Introduction

> The enterprise of the Astrophotographic Chart and Catalogue [has] paved the way to the international scientific cooperation and introduced the practice of astrophotography, revealing its obstacles, its methods, its limits.[1]

These words, pronounced in 1970 at the IAU General Assembly by French astronomer Paul Couderc (1899–1981), perfectly explain the role played by the *Carte du Ciel* project[2] in the history of astronomy. Launched by Paris Observatory in 1887, it was the first international scientific enterprise aimed at photographing the sky of both hemispheres and conceived as a worldwide effort, by the concurrent

[1] *L'entreprise de la carte et du catalogue photographiques du ciel [a] jeté les bases de la coopération internationale dans la science, introduit dans la pratique l'emploi de la photographie, montré ses difficultés, ses méthodes, ses limites.* (Couderc, 1971, p. 178)

[2] On the development of the project, see Chinnici, 1999, 2008b and Lamy, 2008.

I. Chinnici (✉)
INAF-Osservatorio Astronomico di Palermo, Palermo, Italy
e-mail: ileana.chinnici@inaf.it

T. Montmerle, D. Fauque (eds.), *Astronomers as Diplomats*, Historical & Cultural Astronomy, https://doi.org/10.1007/978-3-030-98625-4_1

cooperation of various observatories in many countries, under the leadership of France.

During the nineteenth century, scientific cooperation in astronomy was a recurrent idea; astronomers became more and more aware that it was necessary to distribute their work to obtain important results requiring extensive campaigns of observations.

An early example was the Lilienthal Society, also known as *Himmelspolizei*, established in Germany in 1800 to survey the ecliptical charts, in order to find the missing planet between Mars and Jupiter.[3] In 1871, the Italian Spectroscopical Society proposed a program of solar monitoring,[4] open to the international cooperation, that later inspired the establishment of the International Union for Cooperation in Solar Research.[5] In the last quarter of the century, the *Astronomische Gesellschaft* (established in 1863), by impulse of Friedrich Argelander (1799–1875), collaborated to the revision of the star catalogue known as *Bonner Durchmusterung*.

Of course, the development of astrophysics, which happened in the second half of the nineteenth century, thanks to the application of both techniques of spectroscopy and photography, increased the amount of collected data, and the need of a cooperative approach became more and more evident. Moreover, the resounding results of the astrophysical research were detracting the attention of the scientific community from traditional astronomy, based on celestial mechanics and astrometry.[6] In this context, the *Carte du Ciel* project intended to synthesize modernity and tradition, as it was an interesting attempt to extensively apply the modern technique of photography in the field of classical astronomy.

1.2 Preliminary Actions

Early astronomical photography was practiced in many countries around the half of the nineteenth century, by professional and non-professional (amateur) astronomers, who took daguerreotypes and photographs of celestial bodies and phenomena (Moon, Sun, eclipses, comets). The first proponent of a photographic map of the sky, in 1857, was a well-known English pioneer of astronomical photography, Warren de la Rue (1815–1889).[7] In the decades 1860–1880, early astrophotography con-

[3] It was Ceres, discovered in Palermo in 1801; the existence of the planet was expected, according to Titius-Bode empirical law (see Hoskin, 1993; Chinnici, 2011).

[4] See Chinnici, 2008a.

[5] See, for instance, Andersen et al., 2019, p. 6.

[6] Many classical astronomers were prejudiced against astrophysical studies: see Meadows, 1984, p. 61.

[7] See Chinnici, 1999, pp. 3–4.

Fig. 1.1 The Great Comet of 1882, photographed by David Gill at the Cape Observatory. The photograph shows many faint stars in the background, and stimulated the use of photography for astrometric studies. From Berry, 1898, facing p. 393

tributed to the development of solar physics[8] and stellar spectroscopy[9] and started to be quite regularly practiced in several important observatories of both hemispheres. In 1882, Edward Pickering (1846–1919), director of Harvard College Observatory, obtained some successful photographs of the northern sky hemisphere, with stars down to magnitude 6. The director of the Cape of Good Hope Observatory, sir David Gill (1843–1914), took excellent photographs of the Great Comet of 1882,[10] with many faint stars visible in the background (Fig. 1.1).

We may look at their studies like at seeds of the future *Carte du Ciel* enterprise, as they started to develop the necessary expertise in the field of astrophotography in their countries.

In France, Ernest B. Mouchez (1821–1892) (Fig. 1.2), director of Paris Observatory, decided to invest in this new technique. In 1879, he established an "atelier photographique" at the observatory[11] and asked famous opticians brothers Paul

[8] It is worth mentioning here the photographs of the 1860 total solar eclipse, obtained by De la Rue and Angelo Secchi (1818–1878) in Spain, which definitely confirmed the solar nature of the prominences (see Chinnici, 2019, pp. 183–186).

[9] In the 1870s, Henry Draper (1837–1882) in New York and William Huggins (see below) in London obtained early stellar spectrograms (see Hughes, 2013).

[10] The photography of the Great Comet of 1882 is considered a key event, that altered the character of astronomy and the nature of the observatories, by introducing the practice of photography in the astronomical research (see Dewhirst & Hoskin, 1999, pp. 252–253).

[11] It is worth mentioning that Paris Observatory did have a tradition in this field, as the first daguerreotype of the Sun was obtained there (see Meadows, 1970, p. 7).

Fig. 1.2 Admiral Ernest B. Mouchez, director of Paris Observatory, eminent organizer of the *Carte du Ciel* project. (Portrait by Nadar, © Bibliothèque de l'Observatoire de Paris)

(1848–1905) and Prosper Henry (1849–1903) to build high-quality instruments for astronomical photography; in 1884, they obtained excellent results with plates reproducing stars down to magnitude 12.

In the southern hemisphere, Sir David Gill was informed by another renowned English pioneer of astrophotography, William Huggins (1824–1910),[12] about the results obtained in Paris and wrote to Mouchez, asking for technical details of the lenses made by the Henrys.[13] A month later, he asked for a sample of the photographs; he wanted to evaluate their quality, in view of his purpose:

[12] Huggins and Gill were collaborating for obtaining photographs of the solar corona out of the eclipses; in 1885 Gill installed a Grubb coronograph at Cape Observatory for this aim (see Becker, 2011, pp. 208–210).

[13] See Gill to Mouchez, Dec. 23, 1884, in Chinnici, 1999, p. 4.

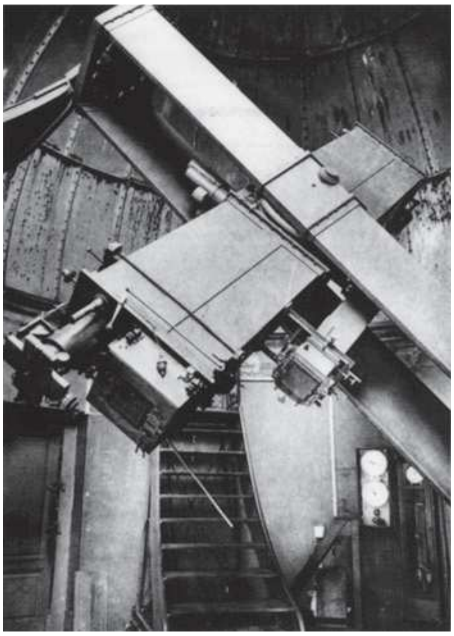

Fig. 1.3 The Henry-Gautier astrograph at Paris Observatory, type instrument for the *Carte du Ciel* photographic work. From Mouchez, 1886, p. 11

> I propose to make a complete and uniform series of Photographic Maps of the Southern Heavens, making also a Catalogue of approximate places and magnitudes from these maps. I feel sure that I can count upon your aid in this matter.[14]

Mouchez willingly sent him some sky photographs by the Henrys and, after praising their photographic work, expressed his conviction that "we shall obtain the complete solution for sky charts thanks to photography."[15]

For this aim, Mouchez commissioned the construction of an instrument of higher performance. The Henry brothers designed and built an astrograph consisting of two joined telescopes, one for visual observations (0,24 m aperture, 3,60 m focal length) and the other for photographic work (0,33 m aperture, 3,43 m focal length). It required a special mounting ("anglaise" type), permitting to completely rotate the instrument around the polar axis; the mounting was fabricated by a French maker, Pierre Gautier (1842–1909). The so-called "équatorial photographique Henry-Gautier" started to be operating in April 1885 at Paris Observatory (Fig. 1.3).

In the meantime, on February 23, Gill sent an important letter to Mouchez, in which he wrote:

[14] Gill to Mouchez, Jan. 18, 1885, in Chinnici, 1999, p. 4. Of course, Gill was mainly interested in southern hemisphere sky, whose best catalogues contained no more than about 130,000 stars - an exiguous number if compared with northern hemisphere star catalogues.

[15] ... *nous allons obtenir la solution complète des cartes célestes par la photographie* (Mouchez to Gill, Jan. 22, 1885 in Chinnici, 1999, p. 85).

> ... now that you have shown at Paris what can be done, we owe a duty to posterity to form a photographic astronomical library of the Heavens by the methods you have worked out. [...] The great point however is that the work should be undertaken on a carefully prepared plan and be continued on a uniform system with the same instrument, persistently and continuously [...] It is only in a great National Establishment that we can hope for such a long sustained systematic effort.[16]

Mouchez interpreted this letter by Gill as an encouragement. Enthusiastic about the first results obtained with the new instrument,[17] on May 11, 1885, the Director of Paris Observatory presented them to the Académie des Sciences, announcing:

> Today we may consider the long-lasting problem concerning the application of photography to obtain a sky chart of stars down to magnitudes 14 and 15 as being completely solved. [...] The first great problem that could be solved in a few years is the exact construction of a Carte du Ciel, namely the counting, classification and position of all stars visible with large instruments ...[18]

Mouchez also listed other studies which would have benefitted from celestial photography, such as those on asteroids, double and multiple stars, photometry, etc. and launched the idea of a sky chart as a project proposed by Gill:

> The capable and very active director of the Cape of Good Hope Observatory, Mr. Gill, was so impressed by the great importance of the advancements obtained by Mr. Henrys [...] that he immediately sent me a project to establish a cooperation of several observatories, in order to undertake together and as soon as possible the Carte du Ciel, which will be easily executable in six or eight years.[19]

In June, Gill wrote to Mouchez to be "very glad to enter into a scheme for a 'carte du ciel' in cooperation with you."[20]

Gill's support was a determining factor for the development of the project. Behind the scenes, he played a crucial role in guiding decisions and suggesting actions with skillful diplomatic ability, and prevented the failure of the project as a whole, succeeding in the completion of what was his own main aim—namely, the Astrographic Catalogue.

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[16] See Gill to Mouchez, Feb. 23, 1885, in Chinnici, 1999, pp. 83–85.

[17] See Mouchez to Gill, May 1, 1885, in Chinnici, 1999, p. 85.

[18] *On peut considérer aujourd'hui le problème longtemps cherché, d'appliquer la Photographie à la construction de la* Carte du ciel *jusqu'aux étoiles de 14*^{e} *et 15*^{e} *grandeur, comme certainement résolu. [...] Le premier grand problème qui va pouvoir être résolu dans quelques années est la construction exacte de la* Carte du Ciel*, c'est-à-dire le dénombrement, le classement et la position de toutes les étoiles visibles avec les grands instruments ...* (Mouchez, 1885a, p. 1178–79)

[19] *L'habile et très actif directeur de l'Observatoire du Cap de Bonne-Espérance, M. Gill, a été si frappé de la grande importance des progrès réalisés par MM. Henry [...] qu'il m'a adressé immédiatement un projet pour établir une entente entre divers observatoires, afin d'entreprendre ensemble le plus tôt possible la* Carte du ciel*, qu'il serait facile d'exécuter ainsi en six ou huit années.* (Mouchez, 1885a, p. 1180) It is unclear whether Mouchez refers to the letter of February 23 or to another letter, probably lost. The February letter, actually, did not contain an explicit project of cooperation, but rather some suggestions about selected priorities in the photographic work, probably in order to pragmatically reduce the eventual colossal work.

[20] Gill to Mouchez, June 3, 1885, in Chinnici, 1999, p. 86.

1.3 In Search of Other Partners

Between June and July 1885, Mouchez started to contact other potential collaborators, looking for scientific support to his project. He sent an exploratory letter (Fig. 1.4a–b) to the main astronomical societies[21] as well as to his colleagues Edward C. Pickering (1846–1919), William Huggins, Luiz Cruls (1848–1908) and Otto W. Struve (1819–1905), respectively directors of the prestigious Observatories of Harvard College, Tulse Hill (London), Rio de Janeiro and Pulkovo, in order to ask their advice about the realization of a photographic sky chart. He joined a copy of the test plates that the Henrys had obtained, to show their excellent results. This important letter confirms that the project was conceived, since the beginning, as a widely international enterprise:

> . . . I send you a photographic plate of the Milky Way obtained with our new instrument [Henry-Gautier Astrograph] [. . .] In one-hour exposure, we obtain all the stars down to magnitude 15 on plates and 14 on paper [. . .] Since the plate covers a sky area of 7 square degrees, we would need 6 000 plates to cover the entire sky vault [. . .]
>
> Today the photographic sky chart is easy to achieve if 5 or 6 observatories well positioned in both hemispheres agree to carry out this extended and important work. It could be completed in six or eight years and we shall leave to future astronomers the exact representation of our sky at the end of the 19th century, with 20 or 25 million stars. [. . .]
>
> Please, consider this matter and let me know your advice.[22]

The recipients of the letter were appropriately chosen,[23] from a scientific and a geographic point of view. In Europe, Huggins was an expert of celestial photography and a friend of Gill and could support the British participation. Struve was a scientific authority, one of the most influential figures in the field of astrometry and could secure an important academic support. In America, Pickering was an expert and reputed astronomer, also interested in celestial photography. In Rio de Janeiro, Cruls had already offered his collaboration to Mouchez, after reading the

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[21] See, for instance, Mouchez, 1885b; Gill suggested to Mouchez, step by step, how to proceed in sending official invitations (see Gill to Mouchez, July 26, 1886, in Chinnici, 1999, p. 91).

[22] *. . . je vous envoie une épreuve photographique obtenue dans la Voie lactée avec notre nouvel appareil [l'équatorial photographique Henry-Gautier] [. . .]. En une heure de pose, nous obtenons toutes les étoiles jusqu'à la 15^e^ grandeur sur le cliché et jusqu'à la 14^e^ pour la reproduction sur papier. [. . .] L'épreuve représentant une superficie de 7 degrés carrés, il en faudrait 6000 semblables pour toute la voûte céleste [. . .]. La carte photographique du ciel est donc devenue aujourd'hui facilement exécutable si 5 ou 6 observatoires, bien choisis dans les deux hémisphères peuvent s'entendre pour entreprendre ce vaste et si important travail. Elle pourrait être exécutée en 6 ou 8 ans et nous lèguerions aux astronomes de l'avenir un état exact de notre ciel à la fin du 19^eme^ siècle où figureraient 20 ou 25 millions d'étoiles. [. . .] Je serais heureux si vous vouliez bien étudier un moment cette question et me faire connaître votre opinion.* (Mouchez to Pickering and Huggins, Paris, June 26, 1885; to Cruls and Struve, Paris, July 15, 1885, in Chinnici, 1999, pp. 4–5)

[23] Even if no documentary evidence has been found until now, it is highly possible that Gill contributed to compile the list of recipients; the letters were, in fact, sent with two different dates—this circumstance suggests that the original list was extended.

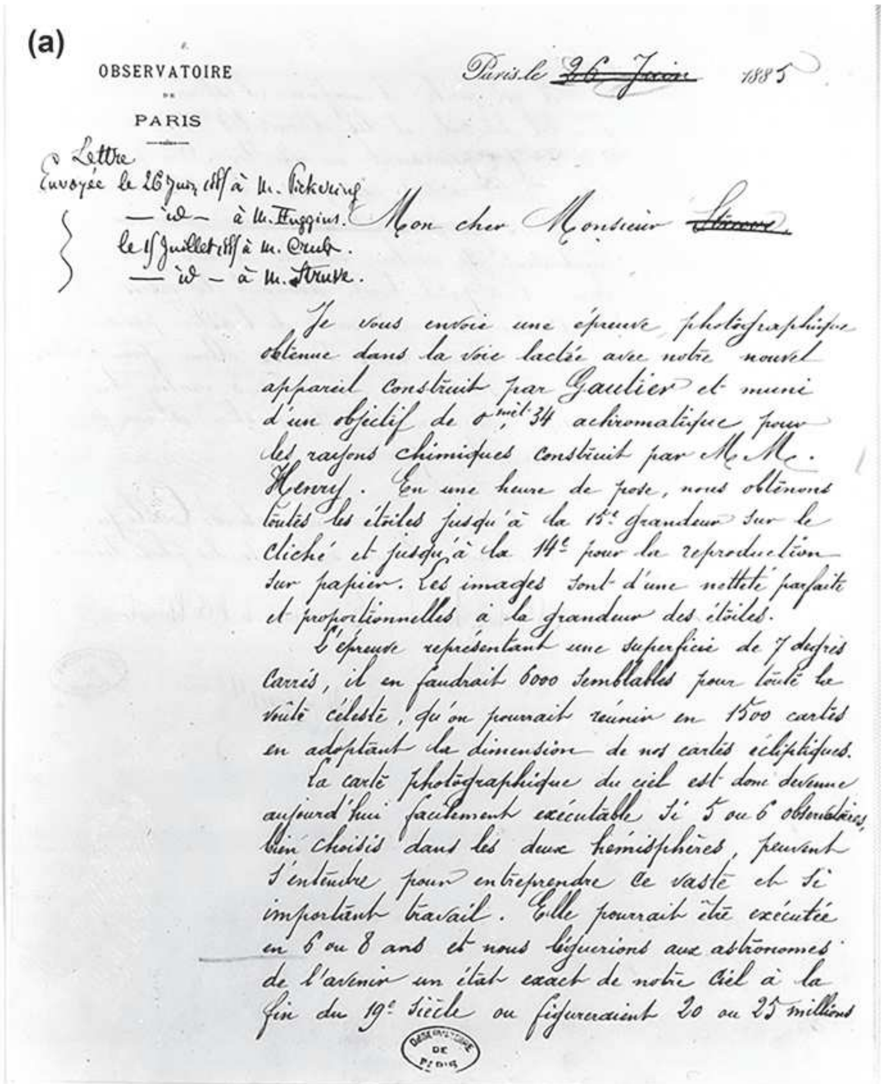
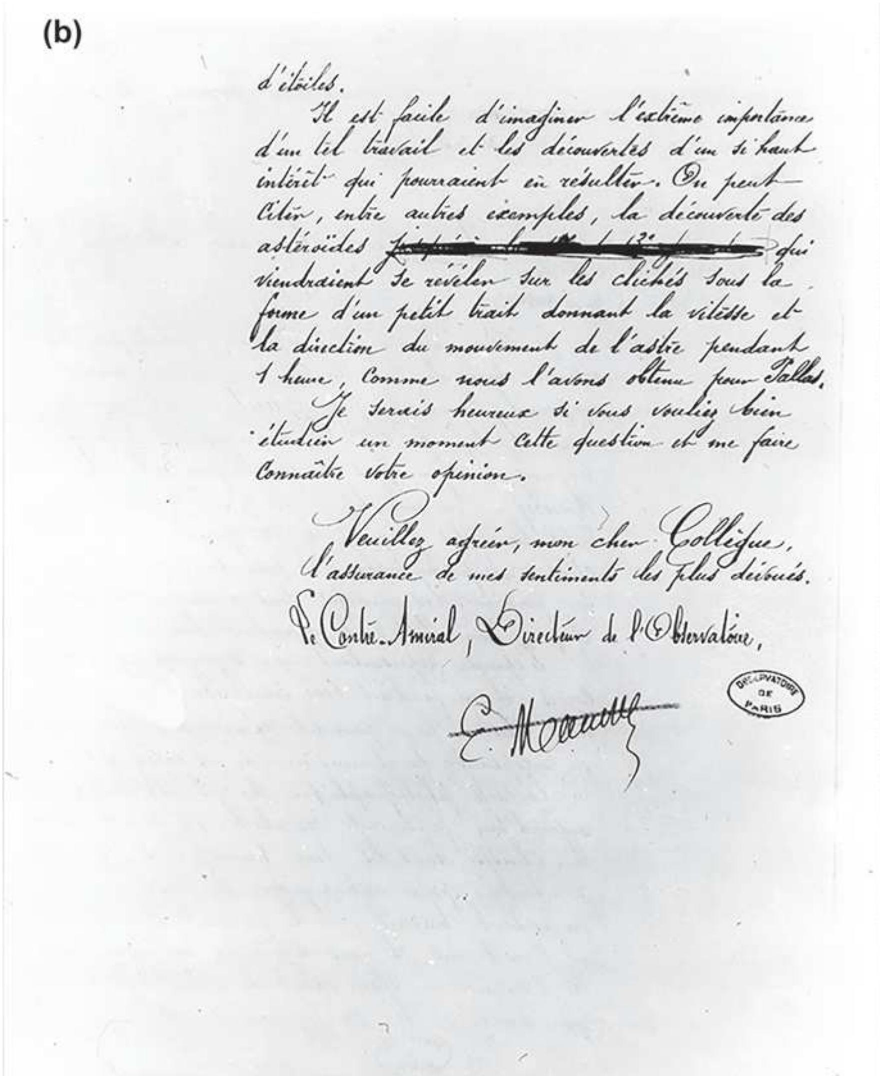


Fig. 1.4 (**a**) First page of the draft of the explorative letter by Mouchez about the proposal of making a photographic chart of the sky. (Mouchez to E. Pickering, Huggins, Cruls and Struve; © Bibliothèque de l'Observatoire de Paris)


(b)

d'étoiles.

Il est facile d'imaginer l'extrême importance d'un tel travail et les découvertes d'un si haut intérêt qui pourraient en résulter. On peut citer, entre autres exemples, la découverte des astéroïdes [illegible] qui viendraient se révéler sur les clichés sous la forme d'un petit trait donnant la vitesse et la direction du mouvement de l'astre pendant 1 heure, comme nous l'avons obtenu pour Pallas.

Je serais heureux si vous vouliez bien étudier un moment cette question et me faire connaître votre opinion.

Veuillez agréer, mon cher Collègue, l'assurance de mes sentiments les plus dévoués.

Le Contre-Amiral, Directeur de l'Observatoire,

E. Mouchez

Fig. 1.4 (**b**) Second page of the same draft. (Mouchez to E. Pickering, Huggins, Cruls Cruls and Struve; © Bibliothèque de l'Observatoire de Paris)

latter's communication to the Académie des Sciences[24]— his offer was certainly considered well grounded, as Mouchez knew that Cruls could count on the support

[24] See Cruls to Mouchez, June 12, 1885, in Chinnici, 1999, p. 318.

of the Emperor of Brazil, Pedro II de Alcantara (1825–1891), amateur photographer and astronomer and active sponsor of science.[25]

1.4 The First Astrographic Congress (1887)

From 1885 to 1887, the idea of realizing a photographic map of the sky spread around. Mouchez, the Henrys and Gill made an important preparatory campaign to promote the project. At the same time, in those years, astrophotography was progressively advancing, thanks to the contributions of amateur and professional astronomers in several countries.[26] Looking at the pages of the *Bulletin Astronomique* of 1885 and 1886, which also contained an international review of astronomical publications, it is easy to seize the ferment in this field. The letter by Mouchez stimulated the astronomical community; in January 1886, the Royal Astronomical Society dedicated a meeting to celestial photography, where the photographs by Henry were admired;[27] in February, Struve gave a talk to the Imperial Academy of Sciences of St. Petersburg, endorsing the initiative of Mouchez.[28]

Gill (Fig. 1.5) felt that the time was ready to prepare a carefully planned enterprise and, in March, wrote to Mouchez, proposing a draft of the project, consisting of two parts—a catalogue and a photographic map of the heavens—and the organization of an international congress in Paris in spring 1887.[29]

At Gill's suggestion, Mouchez involved the Académie des Sciences of Paris to send official invitations for the congress by the intermediary of the French Ministry of Foreign Affairs. Diplomacy came to the aid of science: from there on, all invitations related to the *Carte du Ciel* project passed through diplomatic channels—a skillful strategy, aimed at directly involving the Governments in providing the necessary investments for the participation. The epoch-making project, being an international endeavor and requiring considerable resources, implied political and diplomatic aspects.[30]

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[25] See Barman, 1999, pp. 117–118.

[26] It is worth mentioning, among others, the amateur astronomers Isaac Robert (1829–1904) and Andrew A. Common (see below) in England and the professional astronomer Wilhelm Oswald Lohse (1845–1915) at Potsdam Astrophysical Observatory, in Germany.

[27] See "Revue des publications astronomiques," *Bulletin Astronomique,* t. III (1886), pp. 151–153.

[28] See Struve, 1886.

[29] Gill to Mouchez, Mar. 1, 1886, in Chinnici, 1999, p.5. The letter by Gill was translated and published in order to be circulated (see Gill, 1886) and it provided a base for the discussion at the first congress.

[30] It is to be remarked that all overseas countries participating in the project had political connections with France; on the participation of these observatories in the *Carte du Ciel*, see the controversial book by Pyenson (1993): for Santiago Observatory, pp. 248–256; for La Plata and Cordoba Observatories, pp. 262–267; for Tacubaya Observatory, pp. 280–282; for Rio de Janeiro Observatory, pp. 288–289. A special mention is to be deserved to the Vatican Observatory,

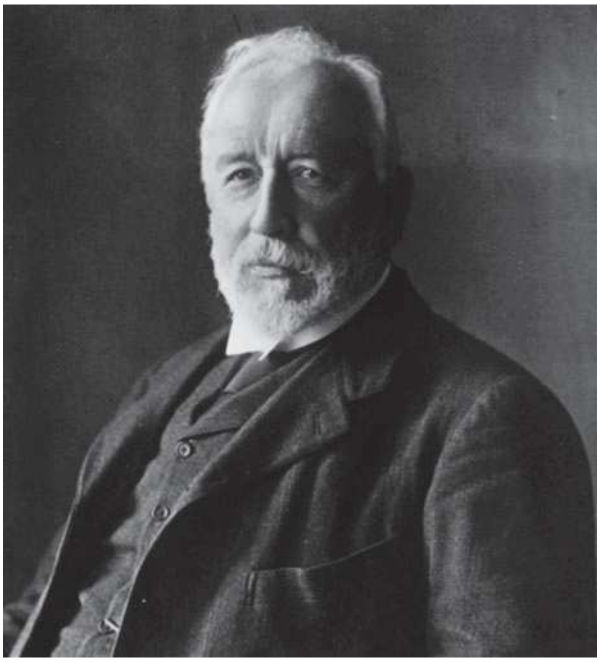

Fig. 1.5 David Gill, Royal Astronomer at the Cape of Good Hope, "éminence grise" of the *Carte du Ciel* project. From *The Observatory*, vol. XXXVII, 1914

The original list (of about 30–35 invited participants) was prepared by Mouchez and Struve, who spent a week in Paris in September 1886.[31] It also included the names of the most important instrument-makers, as suggested by Struve, and some names provided by Gill. Struve also suggested to send a provisional program of the questions to be discussed. The First Astrographic Congress—to be held at Paris Observatory (Fig. 1.6)—was conceived and organized as a scientific, politic, and social event (including gala dinner, dancing, decorations, etc.) under the enthusiastic direction of Mouchez.[32]

Fifty-five participants (twenty of them were French) from a dozen countries attended the meeting (Fig. 1.7).[33] It was an important diplomatic success for France, which played the role of leader country, with Paris Observatory as leading

which was established on purpose to participate in the *Carte du Ciel* project; this provided a scientific pretext (supported by France) for a political move to reaffirm the Vatican sovereignty and independence from the Italian Government (see Chinnici, 1999, pp. 460–464).

[31] See Mouchez to Gill, Sept. 20, 1886, in Chinnici pp. 92–93.

[32] For further details about the Congress, see Motais de Narbonne, 1988. Other information on the *Carte du Ciel* project can be found in Débarbat et al., 1988 (section "Historical Research").

[33] See Chinnici, 2008a, 2008b, pp. 23–24.

Fig. 1.6 A photograph of Paris Observatory at the beginning of the twentieth century. From *The Observatory*, vol. XXXVI, 1913

institution. Mouchez's opening speech may appear quite overblown, but it really expressed the awareness of doing an unprecedented endeavor:

> ... it is a great honor to host the first assembly opening this new era for the astronomical science. It will be a glorious and unforgettable date in the history of astronomy, as will be unforgettable the magnificent work that we want to transmit to the future generations, a work that can be defined as the most exact and complete inventory of the detectable universe at the end of the 19th century.[34]

After one week at work (16–25 April), the congress members established an International Permanent Commission including 11 members,[35] plus the directors

[34] ... *C'est un grand honneur (...) de recevoir la première assemblée où va s'inaugurer cette ère nouvelle pour la Science astronomique. Ce sera une date glorieuse et inoubliable dans son histoire, comme sera inoubliable dans l'histoire de l'Astronomie l'œuvre grandiose que nous voulons léguer aux générations futures, œuvre qu'on pourra définir comme l'inventaire exact et aussi complet que possible de l'univers perceptible à la fin du XIX*^e^ *siècle* (Congrès astrophotographique, 1887, p. 6)

[35] The first members of the International Permanent Commission, elected in 1887, were: David Gill from Cape of Good Hope Observatory, William H. Christie (1845–1922) from Greenwich Observatory, Carl H. Vogel (1841–1907) from Potsdam Observatory, Edmund Weiss (1837–1917) from Vienna Observatory, Otto W. Struve (1819–1905) from Pulkovo Observatory, Maurice Loewy (1833–1907) and Prosper Henry (1849–1903) both from Paris Observatory, Pietro Tacchini (1838–1905) from Collegio Romano Observatory in Rome, Nils Dunér (1839–1914) from Lund Observatory, Edward C. Pickering from Harvard College Observatory, and Jules C. Janssen (1824–1907) from Meudon Observatory.

Fig. 1.7 The first International Astrographic Congress, held in Paris in 1887; group photograph of the participants. (Photo by Nadar, © Bibliothèque de l'Observatoire de Paris)

of the participant observatories, and an Executive Committee of 9 members.[36] The 11 members of the Commission came from 7 European countries, plus South Africa (then a British colony) and the USA. The participation of observatories of different continents was crucial, since the project was intended to be global. France reinforced its leading position with five members in the Commission and three in the Committee, including the president of both, who was, of course, Mouchez.[37]

It was also decided that all observatories being able to obtain financial support from their governments to acquire the necessary instruments would have joined the enterprise.

[36] The first Executive Committee, elected in 1887, was composed by Mouchez (President), Christie, Dunér, Janssen, Struve, Tacchini (members), Gill, Loewy, Vogel (secretaries).

[37] This leadership was further reinforced by the participation of 4 French observatories over 18 participant observatories from other countries.

1.5 A Double Project: Chart and Catalogue

The second meeting of the Commission took place in 1889, again in Paris. Shape and sizes of the glass plates were fixed[38] as well as exposure times.[39] However, the execution of the *Carte du Ciel* project appeared to be more complex than expected, due to the additional work for the Catalogue, a much longer and expensive effort, which included the measurement of star coordinates in the plates, their reduction at the year 1900, and their publication. The original proposal by Mouchez was the execution of the Chart, but the Catalogue was an addition strongly required by Gill, who considered it more feasible and useful than the Chart itself. Actually, the second meeting was mainly devoted to the catalogue preparatory works. Gill wrote to Mouchez:

> I think you will find that the point capital will become not la carte photographique du ciel—in the sense of so many photographic plates of the sky—that will become effete long before the work is finished—[. . .]. It is the Catalogue, the organization for its execution, computation and publication which must cause the Astrophotographic Congress of Paris to be an Epoch in the History of Astronomy. That must be kept in view if the Committee desires to fulfil its functions in the most complete manner.[40]

Gill's proposal certainly made sense, because the best catalogues available at that time contained just a few hundred thousand stars: in comparison, the Astrographic Catalogue, which was expected to contain about four million stars, would have been a real breakthrough.[41]

This extension of the work implicated as well to extend the participation in the project to other observatories, which did not carry out the photographic work, but were involved in the preparation of a reference star catalogue (for instance, this was the case of Pulkovo Observatory, which in 1909 provided a list of stars in northern sky[42]), in the plates measurement operations and in the reduction calculations (this was the case of Edinburgh Observatory, whose astronomers measured and reduced

[38] The photographic plates were squares 16 x 16 cm; it was decided that a grid of small squares 5 x 5 mm, covering the central 13 x 13 cm area, would be impressioned in the plate, in order to facilitate the measurements of the star positions later.

[39] Each plate should have been exposed two or three times, so that each star could be identified by two or three points and not confused with defects or dust grains on the plates. The Commission also discussed how to preserve the exposed plates to be transmitted to the future generations of astronomers; the final decision was to use gravure on copper plates, but this operation was later carried out by only a few Observatories.

[40] Gill to Mouchez, Aug. 17, 1889, in Chinnici, 1999, p. 105.

[41] Bonner Durchmusterung, the most complete star catalogue of the northern sky, contained about 320,000 stars down to magnitude 9. For the southern sky, the most extended catalogues were the Uranometria Argentina (1879) by Gould, with about 50,000 stars down to magnitude 7 (declinations $-23°$ to $90°$) and the Sudliche Durchmusterung (1886) by Schonfeld, with about 120,000 stars (declinations $-1°$ to $-23°$).

[42] The list was compiled by Oskar Backlund (1846–1916) and resulted from a previous catalogue, made in 1900, with an appendix of stars having been observed at the Odessa branch (see Dadaev, 1978, p. 51). For the southern sky, the list was compiled by Samuel S. Hough (1870–1923), who

the plates taken at Perth in 1900). Directly or indirectly, whether through the photographic work or the catalogue preparation, almost all national observatories of the participant countries (and even some private observatories, like the D'Abbadia "Castle-Observatory," near Hendaye in France) were involved in this worldwide project.

1.6 Work Plan and Guidelines

At the end of the third meeting, held in Paris in 1891, the project was sufficiently defined and almost ready to be carried out. It was hence officially announced the participation of 18 observatories and assigned the division of the sky zones for the photographic work (Appendix A); the beginning of the operations, for most of the participant observatories, was expected in summer 1891.

Astrographs fitting the *Carte du Ciel* purposes were acquired for the participant observatories by the respective governments. If we try to draft a geopolitical map of the project (Appendix B), it clearly appears a mixing of nations with a consolidated astronomical tradition, stable political situation and flourishing economy, and nations lacking of these important preliminary conditions. Consequently, this map indirectly shows which observatories were candidate to fail, due to the considerable financial effort that their participation implied in comparison with the scarcity of resources, training, expertise, facilities.

At the 1891 meeting, after four years of tests, the work plan was also fixed.[43] It was decided to take two series of photographic plates, one for the Chart, reproducing stars down to magnitude 14 (40 minutes exposure), and an additional series for the Catalogue, with stars down to magnitude 11 (5 minutes exposure): the resulting Astrographic Catalogue should have been the most accurate and complete star catalogue ever made.

The plates covered a sky field of $2°10'$,[44] (Fig. 1.8a, b) but only the central part was free of optical distortions and the usable field was consequently reduced to about 1°. Every participant observatory had to take over a thousand photographs for the Chart series and as many for the Catalogue. By supposing a hundred

succeeded Gill as director of the Cape Observatory. The Backlund-Hough list was a reference in astrometry for many years.

[43] The photographic work was carried out by astronomers (who learnt to use photographic means) or by assistants, possibly having some experience in photographic operations. Among the astronomers who greatly helped in the resolution of many technical questions, are to be mentioned Charles Trépied (see below), who studied the problem of establishing the photographical magnitude, and Hermann Carl Vogel, quite expert in photographic work, who provided a method for the impression of the grid in the plates (see note 38).

[44] In order to assemble the plates and make a double check of the star positions, it was originally decided that, the two Chart series were centered respectively on even and odd numbered declinations, so that the corner of one plate was coincident with the center of the other plate.

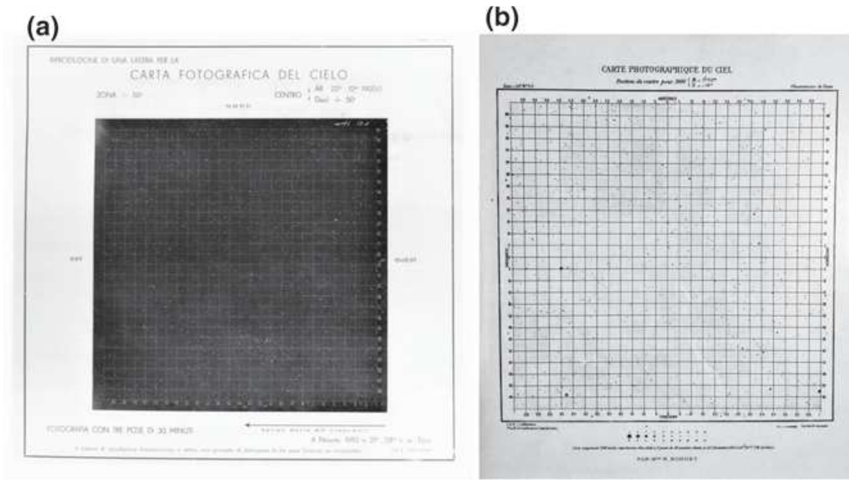

Fig. 1.8 (**a**) Reproduction on paper of a *Carte du Ciel* plate taken at Catania Observatory. From: Chinnici, 1999, pl. 16; (**b**) Typical *Carte du Ciel* chart; the printed negative was doubled in size. Courtesy of INAF-Palermo Astronomical Observatory LIbrary

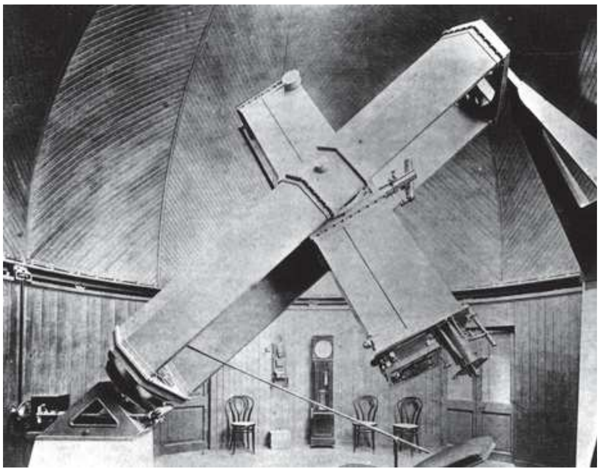

Fig. 1.9 The Henry-Gautier photographic equatorial installed at the Vatican Observatory, one of the most efficient participants in the *Carte du Ciel* project. From *Pubblicazioni della Specola Vaticana,* fasc. II, 1891

average useful nights per year, the whole photographic work was expected to be achieved in about six years. The Henry-Gautier photographic equatorial was chosen as instrument-type (Fig. 1.9): this was a significant success for the French optical industry.

The fourth meeting, in 1896, still in Paris, was also mainly devoted to the Catalogue; the Chart, little by little, drifted away, in the background, losing its original appeal.

1.7 Nationalism and Financial Interests

The countries having the highest number of observatories involved in the *Carte du Ciel* project were France and Great Britain.

In France, the *Carte du Ciel* project was an important opportunity to reinforce the decentralization process that led to the establishment of the Department Observatories (*observatoires de départements*[45]) in the last quarter of the nineteenth century.[46] Paris Observatory had always played a leading role, and old minor observatories (like Marseilles) were considered no more than simple astronomical stations. The establishment of the observatories of Bordeaux, Besançon, Lyon and Toulouse was an attempt to promote the departments and provide them some degree of independence from Paris. On the colonial side, the Algiers Observatory, strictly controlled by Paris, obtained considerable increases in the budget and a measure of independence from the local educational authorities, thanks to the participation in the Carte du Ciel project.[47] Consequently, the involvement of three of these observatories (Bordeaux, Toulouse, and Algiers) in the *Carte du Ciel* project was an opportunity to somehow legitimate their existence, provide them with first-class instruments and obtain additional resources.

While Paris Observatory was the pulsating heart of the whole project, the other three French Observatories would have supported it, in some sense ensuring the success of the project by the execution of a large part of the work. Of course, this strategy reinforced the leadership of France in the project—a leadership that remained unquestioned until the end of the project. All the Commission meetings were held at Paris Observatory and, at Struve's proposal,[48] the President of the Commission was, by default, the Director of Paris Observatory.

Of course, France had not only scientific but also financial interests in the project, especially for instrument-makers. Henry-Gautier astrographs were ordered for all participant French Observatories, as well as for Vatican, La Plata, Córdoba, Santiago, San Fernando, Rio de Janeiro and Uccle Observatories.[49] Photographic

[45] The French word "département" is taken here in the geographical sense ("Département de la Seine"), somewhat comparable to "counties" in the UK.

[46] See Chinnici, 2011.

[47] On the relevant participation of Algiers Observatory in the Carte du Ciel project, see Pyenson, 1993, pp. 96–99.

[48] See Beuf to Tisserand, Jan. 21, 1893, in Chinnici, 1999, p. 256.

[49] The Henrys also built the lenses for Helsinki astrograph, whose mount was constructed by German firm Repsold (see Donner to Mouchez, Sept. 12, 1889, in Chinnici, 1999, p. 226). Repsold

plates made by the Lumière brothers, which were very sensitive, were widely used, even outside of France.

The effort of the French observatories for completing the work assigned for both Chart and Catalogue was considerable (see Appendix C). Paris Observatory also paid a very high cost in terms of human resources. In about fifteen years, from 1892 to 1907, three Directors died—Mouchez (aged 71), Félix Tisserand (1845–1896) (aged 51) and Maurice Loewy (1833–1907) (aged 74), who guided the development of the project for about a decade, giving a determining impulse to its advancement.[50] This list can be extended, by adding in 1909 Auguste Fraissinet (1846–1909) (aged 63), very active secretary of the Observatory and invaluable assistant[51] in facilitating the execution of the project. It cannot be excluded that the prolonged stress resulted in a fatal outcome to their health. Of course, these close changes also affected the steadiness and continuity of the *Carte du Ciel* work.

1.8 Communication Strategies and Protectionism

Across the Channel, to secure the contribution from the British observatories, Gill was aware that he had to overcome two main difficulties. Firstly, it was necessary to convince the Government to finance their participation in the project. He succeeded in this purpose, by adopting a winning outreach strategy. Gill captured the public opinion by a series of lectures and publications, illustrating the successful results of astrophotography and its potentialities. He wrote to Mouchez:

> My lecture [on star charting by photography] was considered successful. The photographs [by the Henrys] were projected by electric light in a field 20 feet in diameter, and showed splendidly. I repeat the lecture at Oxford tomorrow. I think that with a little pressure from the outside public and the public papers the matter will now go forward.[52]

Gill obtained funds for the participation of the Royal Observatories of Greenwich and The Cape. Moreover, Oxford University Observatory as well as Australian colonial observatories[53] (Fig. 1.10) took part in the project: together with France, having four participant Observatories, the UK was the nation that mostly invested in the *Carte du Ciel* plan (see Appendix C).

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also built the mounting of the Potsdam photographic refractor, whose optics were commissioned to the German optical firm Steinheil (see Tsvetkova et al., 2009, p. 879).

[50] See Chinnici, 2007.

[51] See Baillaud to Thome, Oct. 17, 1908, in Chinnici, 1999, p. 201.

[52] Gill to Mouchez, June 5, 1887, in Chinnici, 1999, p. 97.

[53] The participation in the *Carte du Ciel* had a remarkable impact on the Australian observatories, and somehow secured their survival and independence (see Haynes et al., 1996, pp. 94–95: on Perth Observatory, pp. 91–92; on Melbourne Observatory, pp. 80–81; on Sydney Observatory, pp. 61–66).

Fig. 1.10 Sydney Observatory, among the Australian observatories the one that mostly contributed to the *Carte du Ciel* project. From Haynes et al., 1996

Secondly, it was necessary to convince the British Government to buy (French) refractors. Now, the purchase of those instruments was a rather complicated matter. First of all, Gill admitted that "there is unquestionably a prejudice in favor of the reflectors in England"[54]—but he was sure that the unsurpassed quality of the photographs obtained at Paris Observatory would have been decidedly convincing about the necessity of using refractors. Nevertheless, it was also necessary to take into account the competition between the optical industries of the two countries.

The purchase of French telescopes was in fact blocked by the intervention of Howard Grubb (1844–1931), Dubliner instrument-maker who intended to build the instruments for the British participating observatories. Grubb wrote to Gill:

> I shall be glad to hear from you as soon as possible about the details of the photographic telescopes. Are there not one or two of them to be made for Australia as well as for Greenwich and the Cape? Of course, the greater number I have to make, the less price I can make them for.[55]

Fearing to miss a big business, Grubb polemically questioned the acquisition of French astrographs, and threatened to rise a question in the Parliament if the instruments were ordered in France:

> Now I don't think there can be any reasonable doubt that these instruments can be made in our own Country at last as well, probably decidedly better, than in France and my estimate is lower than that of the Frenchmen. If therefore the Government send their orders to France they will have to be prepared with a good reason to do so as I shall certainly take steps to have the question raised in the House. I cannot however think it likely that the Government would go off hand and order instruments [. . .] without waiting for the advice of the two

[54] Gill to Mouchez, Mar. 23, 1887, in Chinnici, 1999, p. 95.

[55] H. Grubb to Gill, May 4, 1887, in Glass, 1997, p. 133.

> societies most interested; however, this matter has put me upon my guard and I think I had better be on the spot whenever any discussion comes on.[56]

Grubb obtained to build the astrographic telescopes for all participant British Observatories.[57] He quickly designed the mount in 1888,[58] but had to make several attempts for building 13-inch. Objective lenses, which could be appropriated for the photographic work.[59] Only in 1890, he could provide his astrographs with proper photographic objective lenses[60], which were delivered to British and colonial observatories participating in the *Carte du Ciel* project.[61]

1.9 Criticism, Disagreement, Competition

Gill's insistence on the importance of the Catalogue made clear to the astronomical community that the project was diverging from its original goal, which was the Chart. This provoked reactions of disapproval, especially from British astronomers Andrew A. Common (1841–1903) and Herbert H. Turner (1861–1930), editors of the journal *The Observatory*, that violently attacked Gill's position:

> We consider that the scope of the work has been illegally magnified, and a catalogue illegally substituted for a chart; and the meaning of the word illegal is that the decisions of the Committee on these points are, in our opinion, contrary to those of the real legislative body – the Congress of 1887 [...] « Ce qui me préoccupe surtout c'est de voir la tendance qui se manifeste dans la Conférence à vouloir toujours augmenter un travail déjà si considérable en lui-même » (Procès-verb., p. 51). We would respectfully associate ourselves with M. Cornu [Marie Alfred (1841–1902), French physicist] in his anxiety.[62]

In order to contrast these criticisms, in 1891 it was decided to give priority to the Chart plates; nevertheless, it was the work of the Catalogue that advanced, being strongly pushed by Gill, who considered that resolution just a compromise. In his opinion, maintaining the ambiguity of the Chart/Catalogue project was a strategy of French astronomers to obtain financial support from their government, being a chart

[56] H. Grubb to Gill, June 1, 1887, ibid., p. 134.

[57] Regarding the astrograph for Sydney Observatory, Grubb only built the optics, while the mechanic parts were made by local firms (see Haynes et al., 1996, p. 62).

[58] See Grubb, 1888, in Glass, 1997, p. 242.

[59] See Pritchard to Mouchez, July 18, 1889, in Chinnici, 1999, p. 276; also see Gill to Mouchez, Aug. 17, 1889, in Chinnici, 1999, p. 105. On Grubb's difficulties with the making of astrograph lenses, see Glass, 1997, pp. 146–149.

[60] The final version of Grubb astrograph's design was published in *Engineering* in 1890; see Glass, 1997, p. 150.

[61] A Grubb astrograph was also ordered for the (non-colonial) Tacubaya Observatory in Mexico; it required some optical corrections, which were made by Alvan Clark & Sons, renowned optical firm in Cambridge, Massachusetts (see Bartolucci, 2000, pp. 65–68).

[62] *The Observatory,* 1891, pp. 184–5.

Fig. 1.11 Edward C. Pickering, director of the Harvard College Observatory, the "great absent" in the *Carte du Ciel* project. From *Memorie della Società degli Spettroscopisti Italiani,* vol. VIII, 1919

much more appealing and inspiring than a catalogue, in front of the public opinion. He wrote to Pickering:

> . . . our true function is the Catalogue – indeed there was a motion very nearly carried out that we should leave the Chart aside and push on the Catalogue plates – And this would have been carried I believe but for the fact that the French astronomers want money from the Government for "personnel" to carry on the work, and that whilst the Chart appeals to the general public – and millions of stars appeal to the popular imagination, the solid work of a catalogue does not do so. Thus a compromise was reached which permitted the Frenchmen to say that the Chart was to be commenced at once, although the Catalogue plates were first to be pushed on.[63]

Additional doubts arose in the international astronomical community because of a somehow competing project. If we look at the list of participant Observatories (see Appendix A), it is striking the absence of North American Observatories. This can be explained by the fact that a similar project was ongoing at Harvard College Observatory, under the direction of Pickering (Fig. 1.11).[64]

[63] Gill to Pickering, Apr. 8, 1891, in Jones & Boyd, 1971, p. 210.

[64] As early as 1883, Pickering had planned to make a chart of the sky by photography, but he lacked funds. Two years later, however, he was able to buy an 8-inch photographic doublet, corrected and mounted by Alvan Clark & Sons, photographing stars as faint as the magnitude 14 (see Jones & Boyd, 1971, pp. 206–207). A few years later, he acquired a similar instrument for the station at Arequipa in Peru (see Holden, 1893).

In 1887, though invited, Pickering could not attend the Paris Congress but wrote a letter to the participants, proposing to use refractors of short focal length, with double object-glass (consisting of four lenses) for photographing the whole sky; the employment of such large-field cameras would have considerably reduced the effort and duration for the completion of the Chart.

This proposal was, however, rejected by the Congress participants, at Pickering's regret; Gill explained him why:

> Your letter to the Congress received much more consideration than you appear to think. [. . .] The question of the adoption of combinations giving very large fields, composed of 4 lenses was fully talked out [. . .]
>
> The scale of magnitude and accuracy to be attained were really the points which went against the 4-glass combination. Nothing less than 14th magnitude stars would satisfy a large number of members of the Congress and it was felt that if we go beyond 15 minutes of exposure we ran some risk of failure. To combine these conditions would have involved the use of lenses of 12 or 13 inch. aperture and 4 glass lenses of this aperture would have cost too much – indeed I do not know if we could get them made at all. [. . .] I hardly think you can use so large a field to advantage because of the changes in the differential refraction during exposure – the correction of a 4-glass objective is also a species of compromise and the law of distortion is probably troublesome to deal with. In fact the Congress was determined to do the work on a scale of accuracy and magnitude which appeared to exclude the use of double combinations.[65]

Actually, it is not to be excluded that Gill himself dissuaded the members of the Congress from accepting Pickering's proposal, being his main aim the Catalogue of stars down to magnitude 11—a result that could not be obtained with large-field combinations.

Pickering hence decided to do by himself, somehow challenging the Commission, and started to work at his competing project. In November 1888, he strongly appealed for "A Large Photographic Telescope" to be funded with 50,000 dollars, and in June 1889, he obtained a gift from Miss Catherine Wolfe Bruce (1816–1900), a wealthy philanthropist. Due to the extensive publicity given to Miss Bruce's contribution, the news reached the European astronomical community; the reaction of the British astronomers in the pages of *The Observatory* was vitriolic:

> . . . if Prof. Pickering is right in thinking that he can chart the whole sky in two or three years with a single telescope, then the combination of seventeen observatories to do the same work is all wrong . . .
>
> He has thrown out a distinct challenge, and matched himself against the rest of the world in the same undertaking. [. . .]
>
> . . . he has tacitly condemned the work of the International Conference before it is commenced, and claimed success for himself; whereas it is comparatively certain that the former work will be carried out, based as it is on definite work with a known instrument; while his own plan depends on that assumption, which has so often proved delusive, that a telescope may be multiplied by three.[66]

[65] Gill to Pickering, June 22, 1887, in Jones & Boyd, 1971, p. 209.

[66] Turner & Common, 1889, pp. 310–11.

Pickering, however, did not believe in the successful execution of the complex *Carte du Ciel* project and preferred to follow his own plans:

> . . . seventeen observatories have undertaken to photograph the entire sky with telescopes of the usual form thirteen inches diameter. Several years will be required for this work. They propose to photograph stars to the 14th magnitude. Our 8-inch telescope photographs fifteenth magnitude stars. The Bruce telescope can hardly fail to take as faint stars or to surpass the Paris photographs. If it succeeds as I anticipate it should take five to ten times as many stars [. . .] I do not feel that I am to blame if with one telescope we do more and better work than with seventeen of the usual form.[67]

Gill declared himself "disgusted"[68] by the attack in *The Observatory* and was quite convinced that Pickering's photographic map was more effective than the *Carte du Ciel* map; he wrote to him from Paris in 1891: "*. . . there is a pretty strong feeling that your chart will be a much better and more practical one that ours*"[69]—a further reason to insist on being the catalogue the true aim of the project.

The Bruce Photographic Telescope (24-inch aperture, 11-foot focal length), made by Alvan Clark & Sons, was ready in 1893.[70] Pickering planned to use it at Harvard to photograph the northern sky, then to move it to Arequipa, the southern branch of Harvard Observatory, to complete the photographic survey of the sky. Plates would be stored at Harvard in a fireproof building for examination and measurements.[71]

Pickering produced a Photographic Map of the sky of both hemispheres in 1903[72]; though small-scale, this is the first complete photographic sky map ever made. Pickering was so diplomatically cautious, however, as to avoid explicitly entering into competition with the *Carte du Ciel* project. He contented himself with less ambitious results: his 55 plates covered sky regions of about 30 x 30 degrees and reproduces stars down to magnitude 12. Moreover, Pickering clearly stated that the utility of these charts laid more on the measurement of photometric variations than of accurate positions:

> These photographs have proved unexpectedly useful here for determining the past as well as the present changes in light of variable stars, new stars and similar objects [. . .]. Of course,

[67] Pickering to Bruce, in Jones & Boyd, 1971, p. 275.

[68] Gill to Pickering, Nov. 4, 1889, in Jones & Boyd, p. 276.

[69] Gill to Pickering, Apr. 8, 1891, in Jones & Boyd, 1971, p. 210.

[70] See Holden, 1893. The Bruce telescope was operating until the half of the twentieth century and gave important services to astronomy, especially in the photograph of southern sky (see Jones & Boyd, 1971, pp. 285–286). The digitization of the collections of all photographic plates kept at Harvard (including the ones by Pickering) is currently ongoing (see DASCH project: https://projects.iq.harvard.edu/dasch).

[71] See Jones & Boyd, 1971, p. 272.

[72] The successful results obtained with the Bruce telescope induced Turner to retreat his position; once he saw that the southern observatories were delaying the photographic work, in 1897 he proposed to leave the photograph of the southern sky to Pickering—a recognition for the Harvard astronomer (see Jones & Boyd, 1971, p. 276).

> the small scale diminishes their value for measuring positions, although the minuteness of the images in part compensates for this difficulty.[73]

In the end, however, Pickering's doubts about the Carte du Ciel execution will prove to be well-founded. As we shall see below, the *Carte du Ciel* project, for the part concerning the Chart, will remain unachieved—only the astrographic catalogue was completed, though in a different version compared to the original plan, and with an incommensurably longer time (the last volume was published in 1964).

1.10 Desertions and Replacements

In about a decade, many observatories of Latin America abandoned the project and were replaced by others, that abandoned, on their turn, in the following decade. As it has been previously mentioned, this can be explained by the fact that some countries underestimated the effort, especially in terms of financial resources. Through their participation, they wished to seize the opportunity to acquire visibility and prestige in the international scientific (and political) context. On their turn, thanks to this opportunity, the participant Observatories hoped to obtain financial resources from their governments. They failed for many reasons: instability of their governments, financial crisis, difficulties in provisions, insufficient resources, inadequate directorships, etc.

This situation was pragmatically foreseen by Gill, who kept ready to relieve the work of all Southern Hemisphere observatories.[74] He wrote to Mouchez in 1891:

> I am not in the least disquieted by the civil war in Chile[75] nor by the other troubles which you describe in Buenos Ayres. We shall get from these places precisely what I expected, viz. nothing at all.
>
> But why disquiet yourself? [...] It will not be a very serious matter if we have to undertake all the Southern Hemisphere ...[76]

It is here evident the different attitude of the two "fathers" of the *Carte du Ciel* project: Gill's approach was more realistic and pragmatic, whereas Mouchez had a real diplomatic approach; he wanted to maintain an ideal wide international participation, headed by France, and invested much of his time in this effort, though it costed delays and inefficiencies for the whole endeavor.

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[73] Pickering, 1903, p. 70.

[74] In 1909, after the death of Thome (see Appendix A), the completion of the work of Córdoba Observatory was assigned to the Cape Observatory.

[75] In 1891, a conflict between President José Manuel Balmaceda (1840–1891) and the Parliament members provoked a Civil War: it was won by the Parliament members who established a parliamentary republic. The country, however, experienced political instability until World War II.

[76] Gill to Mouchez, Aug. 30, 1891, in Chinnici, 1999, p. 107.

A similar search for visibility and prestige also drove the participation of some British colonial observatories; in a letter by astronomer William Ernest Cooke (1863–1947) to Colonial Secretary about the participation of Australian observatories in the *Carte du Ciel* project, this is clearly stated:

> The importance of this matter can scarcely be over-estimated.
>
> It is a direct invitation from the entire scientific world to participate in the greatest scientific work that has ever been undertaken in the world's history [...] ... we have the opportunity of acquiring scientific lustre.[77]

In the fifth Commission meeting, in 1900, no progress was reported from Santiago, La Plata[78] and Rio de Janeiro[79] Observatories; the last two ones were respectively replaced by Córdoba[80] and Perth[81] Observatories. In 1904, Uccle Observatory went in help of Potsdam Observatory, which could no more take long exposure Chart plates, because of lacking resources.[82]

In 1909, the Santiago Observatory seemed to be almost ready to start the work,[83] but in that year, during the sixth Commission meeting, the Santiago zone was

[77] Cooke to Colonial Secretary, 1896 in Haynes et al., 1996, p. 91.

[78] The situation at La Plata was alarming, as the photographic lens was broken and the Observatory was in abandoned conditions (see Thome to Loewy, Nov. 8, 1899, in Chinnici, 1999, pp. 171–172), probably even before the death of Director Beuf (see Appendix A), in 1898, who suffered from mental breakdown (see Beuf to Mouchez, Oct. 4 and 29, 1893, in Chinnici, 1999, pp. 252 and 256).

[79] In the 1890s Cruls had been engaged in the cartography of the central Brazil and in the project to move the Observatory from Rio de Janeiro to Santa Cruz, which was never achieved. In 1901 he was commissioned to determine the boundaries between Brazil and Bolivia; this was probably the reason that prevented him to carry out the *Carte du Ciel* work. The astrographic telescope was never mounted (see Paolantonio & García, 2019, p. 495).

[80] On the work carried out at Córdoba and, in general, on the participation of Latin American Observatories in the *Carte du Ciel* project, see Paolantonio & García, 2019.

[81] The participation of Perth Observatory was proposed in 1897 (see Cooke to Loewy, Sept. 14, 1897, in Chinnici, 1999, p. 300) and supported by the two Royal Astronomers at Greenwich and Cape, Christie and Gill (see Loewy to Cooke, Aug. 9, 1900, in Chinnici, 1999, pp. 302–303). The Commission assigned to Perth the sky zone previously assigned to Rio de Janeiro (see Loewy to Cooke, Aug. 9, 1900, in Chinnici, 1999, pp. 302–303).

[82] See Lecointe to Loewy, Nov. 21, 1904, and Fraissinet to Lecointe, Nov. 30, 1904, both in Chinnici, 1999, pp. 393–394. The entire declination zone, previously assigned to Potsdam, was re-photographed and the plates were measured by Oxford, Uccle and Hyderabad Observatories. For a global evaluation about the participation of Potsdam Observatory in the *Carte du Ciel* project, see Bigg, 2008.

[83] See Ristenpart to Baillaud, s.d. [1909], in Chinnici, 1999, p. 348. In 1900 the Santiago zone was assigned to a new Observatory to be established in Montevideo (see Loewy to Cooke, Aug. 9, 1900, in Chinnici, 1999, p. 302; letters to Loewy by Enrique Legrand [1861–1939], professor of cosmography at the University of Montevideo, are listed in Chinnici, 1999, p. 32). However, in a note dated 1909, Fraissinet wrote that nothing had been done by the Republic of Uruguay and the zone was hence ready to be reassigned to Santiago Observatory (Fraissinet to Loewy, s. d. [1909], *ibid.*). See also Paolantonio & García, 2019, p. 496.

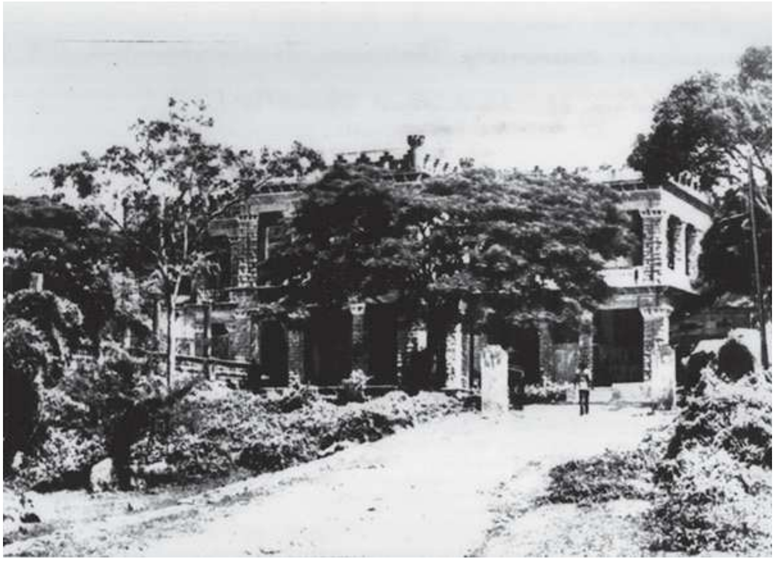

Fig. 1.12 Nizamiah Observatory at Hyderabad (India); in 1909 it took on the photographic work of the sky zone previously assigned to Santiago Observatory. From *Nizamiah Observatory Platinum Jubilee Souvenir 1908–1983*, 1983

assigned to Hyderabad Observatory (Fig. 1.12), which was realistically considered most reliable.[84]

1.11 The Establishment of a Central Bureau for Measurements

The photographic work was just a part of the entire project. A major effort, regarding the Catalogue, was the measurement of the star coordinates on the plates, their conversion into equatorial coordinates and their reduction to the year 1900. This required to recruit additional personnel and instruments—a special apparatus, the macromicrometer[85] (Fig. 1.13), was devised to be used for these measurement operations—but many Observatories could not afford further costs. Moreover, it

[84] The participation of Hyderabad Observatory was solicited by Oxford Observatory (see Prashad to Turner, Aug. 15, 1908, in Chinnici, 1999, p. 240).

[85] There were several types of macromicrometers, designed by Gautier, Turner, and Repsold, which were respectively supplied for French, British, and German participant observatories (see *Bulletin* . . . 1909, p. 513; on the evolution of the instruments for plates measurements, see Fauque, 1988). The most used macromicrometer, by Gautier, is described in the annual report of Paris Observatory for 1892 (see Tisserand, 1893, pp. 15–16).

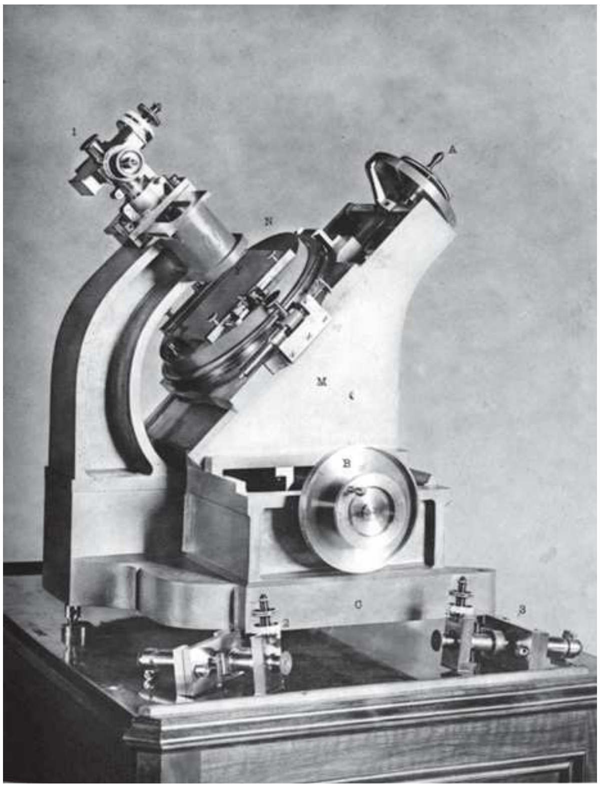

Fig. 1.13 Gautier macromicrometer, designed in 1892 for measuring the coordinates of the stars on the plates. From *Pubblicazioni della Specola Vaticana,* vol. IV, 1894

was important that this accurate and delicate work was well standardized and coordinated.

For this reason, Gill suggested the establishment of a Central Bureau for the measuring operations and proposed to entrust this work to women:

> The measurement of the plates is another matter—and I feel convinced it can be best and most economically done in a Central Bureau. Of course, if we can get the money there is no reason why we should not make the measures here, but women's work for this purpose can be procured in Europe at so much less cost than here, and could be so effectually organized and so economically supervised in a single establishment, that I am convinced we shall all be ultimately compelled to adopt that method of working.[86]

This suggestion by Gill was taken into account by many observatories, who recruited female staff to measure the star coordinates on the plates.[87] Being trained

[86] Gill to Mouchez, Aug. 30, 1891, in Chinnici, 1999, p. 107.

[87] On the employment of women in French astronomical observatories, see Lamy, 2006.

Fig. 1.14 Nuns measuring the Carte du Ciel plates with macromicrometers at the Vatican Observatory. Courtesy of Vatican Observatory Historical Archives

in accurate and precise work (embroidery and needlework were part of the usual female background at that time), women assured highly reliable results at low cost. Even the Vatican Observatory employed nuns (Fig. 1.14) for this work;[88] female staff was also employed at Harvard College Observatory, for measuring and classifying stellar spectra for another major project, the Henry Draper Catalogue.[89]

A tribute is here to be paid to Dorothea Klumpke (1861–1942), the first director of the Bureau des Mesures, which was established in 1891 (Fig. 1.15), and to all women of Paris Observatory and other observatories, who contributed to the *Carte du Ciel* Astrographic Catalogue as well as to the development of the Harvard classification scheme of stellar spectra, thanks to their patient, repetitive, accurate work.

As it has been previously mentioned, many observatories which were not involved in the photographic work, helped with plates measurement and calculations for the conversion from rectangular (Cartesian) into equatorial coordinates as well as with their reduction to the year 1900, while others provided the reference star catalogue. All these circumstances explain why the *Carte du Ciel* can really be defined a "global" scientific enterprise.

[88] The four Sisters of the Holy Child Mary congregation who measured the star positions on the plates were Emilia Ponzoni, Regina Colombo, Concetta Finardi and Luigia Panceri (see Glatz, 2016).

[89] On women in US astronomical observatories, see, for instance, Mack, 1993 and Sobel, 2016.

Fig. 1.15 Dorothea Klumpke (sitting), director of the female staff of the Bureau Central des Mesures at Paris Observatory, ca. 1894, with three of her collaborators (© Bibliothèque de l'Observatoire de Paris). See also Randazzo, 1998, p. 26

1.12 The Fragmentation of the Project

At the beginning of the twentieth century, new interests were emerging in astronomy, notably in the fields of galactic astronomy and cosmology. In 1906 Kapteyn's selected areas,[90] in 1909, Eros parallax measurements drove the attention of the international astronomical community. The initial enthusiasm about the *Carte du Ciel* was fading away, the work revealed to be too expensive and time-consuming; it was necessary to reshape the project to re-motivate

[90] The Dutch astronomer Jacobus Cornelius Kapteyn (1851–1922) selected areas of sky (approximately 1° × 1°) to study of the structure of the Milky Way and the galactic pole regions. In each area the magnitudes, colours, spectral types, and proper motions of the stars were measured to as faint an apparent magnitude as possible.

the participant observatories. This was the challenge that expected Benjamin Baillaud (1848–1934), new director of Paris Observatory after the death of Loewy in 1908. The appointment of Baillaud, former director of Toulouse Observatory, was far from being haphazard. Having efficiently directed one of the French participant observatories, he had the necessary expertise, relationships, and scientific authority to lead the project. At Gill's proposal,[91] Baillaud was chosen as President of the Astrographic Commission, likewise his predecessors. As usual, Gill suggested invitations, date and program of the next meeting, to be held in 1909, hoping to advance at least in the achievement of the Catalogue.[92]

The new topics which interested the astronomical community were somehow discussed and included in the *Carte du Ciel* plans, with the purpose of updating and restyling the project, which appeared by then obsolete. Reinserting the project in the astronomical research mainstream of that time, of course, implied to further delay the achievement of the original project—actually, to drift away from its initial program. The project fragmented into subprojects, thus losing its consistency and unity. The numerous resolutions taken by the Commission at the 1909 meeting—including the establishment of three sub-commissions on reference star catalogue, Eros parallax and special (galactic) studies—clearly showed this fragmentation. Definitely, these resolutions can be regarded as a compromise, aimed at giving a new impulse to the project, by enlarging its horizon.

However, after a considerable financial investment, in terms of instruments, staff and volumes publication (about 30 volumes), the *Carte du Ciel* project was interrupted by the catastrophic event of World War I. At that moment, only the Oxford Observatory had almost entirely concluded its work, including the publication of its section of the Astrographic Catalogue. Almost all participant Observatories reduced or interrupted their activities; mostly of the staff was called up to arms, and finances were cut to sustain military operations. Only the Vatican Observatory, not being involved in the conflict, could regularly work during the War.[93] In those years, due to the heavy economic consequences for many countries, being the Observatories lacking of financial and human resources, the project completion was seriously compromised.

[91] See Circular by Gill, s. d. [1908] in Chinnici, 1999, pp., 122–123; see also Gill to Baillaud, Mar. 4, 1908, in Chinnici, 1999, p. 125.

[92] See letters by Gill to Baillaud in Chinnici, 1999, pp. 125–129.

[93] During the Great War, the Vatican Observatory advanced very much in the photographic work, taking advantage from the daily blackout in Rome to capture excellent quality plates. On the participation of the Vatican Observatory in the *Carte du Ciel* project, see Chinnici, 1999, pp. 460–464.

Fig. 1.16 Benjamin Baillaud, director of Paris Observatory, first President of the IAU in 1919. From *L'Astronomie* 1934, p. 537

1.13 Actions of the IAU

After the war, in 1919, the International Astronomical Union (IAU) was established, with the purpose to promote the international cooperation in the field of the astronomical research. In the reports of the Interallied Conference held in London in 1918, which preceded the establishment of IAU, it was explicitly stated that the new association "will doubtless result from the union" of the *Carte du Ciel* Commission, the Solar Research Union and other bodies.[94]

The *Carte du Ciel* had effectively created an international network that facilitated the IAU establishment. Its organization methods, with almost regular periodical meetings, resolutions, vote by nation—as in a sort of international 'parliament'[95] of astronomers—was a model that could be easily adopted by the IAU, which hence "benefited from the established reputation of the *Carte du Ciel*."[96]

It was therefore quite obvious that the first President of IAU would be Benjamin Baillaud (Fig. 1.16)—a choice that expressed continuity with the *Carte du Ciel* Commission. He had acquired expertise to guide and coordinate a wide community of astronomers—and could also ensure that the project itself be completed.

[94] See Blaauw 1994, p. 49.

[95] See Lamy 2011, p. 197.

[96] See Andersen et al., 2019, p. 14.

The completion of the work was entrusted to Commission 23 "*Carte du Ciel*" (with Herbert H. Turner as the first president), which replaced the International Permanent Commission, and decided to give priority to the achievement of the Catalogue. The support by IAU was determining: the publication of the last twenty volumes of the Catalogue was entirely financed by IAU. Thanks to this financial support, in 1964, the last volume of the catalogue was published—at last, the Catalogue had been completed.

The Chart met with a different fate. After many decades elapsed, the technical development and the new astronomical frontiers had rendered the completion of the Chart obsolete—and it was abandoned. In the IAU General Assembly, held in 1970 in Brighton, it was definitely decided to leave the Chart unachieved (see Appendix D).

Before its discontinuation, IAU Commission 23 presented an important summary report about the project,[97] and identified in some technical aspects (exposure duration, reproduction on metal of the plates, etc.) the main reasons for the delay accumulated during the execution of the Chart. The Commission recognized, at the same time, that its conclusion was by then out of purpose:

> Undoubtedly, the situation of the Chart would have been better if, in the decade 1920-30, we were not becoming aware that the structure of the Universe is revealed thanks to stars much fainter than those recorded in the Chart: in the plates of the Chart we find very few galaxies. Moreover, the invention of Schmidt telescopes, giving better images in a field of 36 square degrees, than those of the Chart in a field of 4 degrees, has allowed to rapidly publish atlases like the Sky Atlas, where stars down to at least magnitude 20 are countable. [. . .] These atlases fulfill the aims of the founders much better than the original Chart.[98]

The report about the Catalogue was more favorable:

> Fortunately, the Astrographic Catalogue, which at the beginning was considered ancillary, has had a better destiny, though late; today it promises many applications and its collection of ancient plates is a unique documentary source.[99]

Consequently, as a result of the IAU General Assembly in Brighton, Commission 23 merged with Commission 24 ("Parallaxes and proper motions") into a new Com-

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97 See Couderc, 1971.

98 *La situation de la Carte aurait sans doute été meilleure si, dès la décennie 1920–30, il n'était devenu évident que la structure de l'Univers se découvre grâce à des astres beaucoup plus faibles que ceux que la Carte enregistre: sur les clichés de la carte on trouve bien peu de galaxies. Enfin, l'invention des télescopes de Schmidt, qui donnent dans des champs de 36 degrés carrés des images meilleures que celles des champs de 4° de la Carte, a permis de publier rapidement des atlas comme le Sky Atlas, où figurent les astres jusqu'à la magnitude 20 au moins (. . .). Ces atlas remplissent les désirs des fondateurs de la* Carte du Ciel *beaucoup mieux que la Carte initiale.* (Couderc, 1971, p. 173)

99 *Heureusement, le Catalogue photographique, qui, au début, paraissait une opération accessoire, a connu un destin meilleur, quoique tardif; il donne aujourd'hui la promesse d'applications nombreuses et la collection de ses clichés anciens est une source de documents encore unique.* (Ibid.)

mission 24 ("Photographic Astrometry"). About sixty years later than expected, the *Carte du Ciel* enterprise finally come to an end.

1.14 Later Issues

The *Carte du Ciel* project appears today as an ambitious but premature endeavor, undermined by a number of weak points (see Sect. 1.15).

However, later issues have not frustrated this impressive effort. In 2000, Commission 24 merged with Commission 8 ("Positional Astronomy") into a new Commission 8 ("Astrometry") having a Working Group on the *Carte du Ciel*, that in 2006 was merged with the IAU Preservation and Digitization Photographic Plates (PDPP) Task Group.[100]

In fact, at the turn of the current century, the *Carte du Ciel* became again of interest for astronomers, as the historical plates acquired a high scientific value for astrometric studies. In the 1990s, the Astrographic Catalogue was digitized at US Naval Observatory—paradoxically in that country that did not participate in the *Carte du Ciel*—and made available as AC 2000;[101] it found important applications in the construction of ACT (Astrographic Catalog/Tycho) reference catalogue[102] and Tycho-2,[103] both resulting from ESA's astrometric satellite *Hipparcos*. The scientific interest of the *Carte du Ciel* plates is still standing, due to the current mission of ESA's astrometric satellite *Gaia,* launched in 2013.

Today, however, only a few observatories still preserve their *Carte du Ciel* plates in good conditions. In many others, most of the photographic plates were reported as damaged or destroyed since the 1950s. A few groups have tried to apply modern methods to digitize the *Carte du Ciel* plates and extract useful information from them.[104] This means that preserving the *Carte du Ciel* plates is still important and useful for science, and probably it is time for a survey of the existing plates[105] and a joint project for their conservation, hopefully to be promoted by IAU.

[100] See Griffin, 2009. Due to the recent IAU reorganization, PDPP is currently a Working Group of IAU Commission B2 (Data and Documentation).

[101] See Urban et al., 1998a.

[102] See Urban et al., 1998b.

[103] Tycho-2 contains proper motions derived from a comparison with the Astrographic Catalogue and over a hundred ground-based astrometric catalogues. See Hog et al., 2000.

[104] It is worth mentioning that at Paris Observatory, in the 1980s, *Carte du Ciel* plates were scanned to study proper motions (with MAMA machine - "Machine Automatique à Mesurer pour l'Astronomie" - now discontinued; see Guibert, 1988); digitizations of *Carte du Ciel* plates have been also made at Bordeaux, Vatican, Uccle, Potsdam, San Fernando, Córdoba, Helsinki and encouraged by interesting recent studies (see Lehtinen et al., 2018).

[105] See Randazzo & Isaksson, 2020.

1.15 Concluding Remarks

The *Carte du Ciel* project seemed to be an affordable challenge for the astronomers of the late nineteenth century, and it arose a worldwide interest and enthusiasm in the astronomical community. Nevertheless, it was marked by an increasing complexity, due to several—expected and unexpected—factors, that led to its partial failure.

We try here to identify some weak points of the project (partly predictable from the beginning), and some unexpected diverging factors:

- Ambiguity and diversity of purposes (the *Carte du Ciel* project was somehow torn in two by a sort of internal tension/competition between Chart and Catalogue).
- Non-homogeneous equipment (the participant Observatories were not equipped with one and the same astrograph, because of the interests of local makers).
- Management failures and open technical questions (many logistic and technical problems were under-evaluated, and the preparatory tests were probably insufficient; moreover, the instruments in use became soon obsolete, as a result of the development of new technologies—i.e., Schmidt cameras).
- Different political and economic situations of the participant Countries (in many cases, the adhesion to the project was given without sufficient disposable resources, due to the political instability of the governments).
- World conflicts (they provoked the interruption of the work and the loose of many human and financial resources).
- New scientific frontiers (galactic and extra-galactic astronomy and astrophysics became the most advanced research topics at the beginning of the twentieth century—astrometric catalogues and maps were focused on selected areas, rather than on the entire sky vault).

All these elements—and probably others too—were responsible for the unacceptably long time of execution and the incompletion of the original project, which seems to have been conceived too early to be fully successful.

Moreover, the huge cost that the *Carte du Ciel* execution required (see Appendix C) impacted on the development of the astrophysical research in the participating Observatories (and countries) by distracting resources. This increased the gap with the USA, where astronomy turned into astrophysics earlier that elsewhere, facilitated by the lack of a tradition in classical astronomy, cultivated for centuries in the European Observatories. In some sense, the *Carte du Ciel* was a dream of the last European classical astronomers, formed in the tradition of cataloguing and mapping the sky; through this immense shared effort, they have left a sort of scientific monument to the future generations and, mostly important, a model of organization for the international astronomical community. Being the first example of international scientific cooperation on a worldwide scale, the *Carte du Ciel* did in fact prefigure the IAU, which will be animated by the same spirit of collaboration in the scientific research.

We may conclude by coming back to Couderc's words:

> The *Carte du Ciel* enterprise has established the foundations of the international scientific cooperation, has introduced the application of photography, showing its difficulties, its methods, its limits. Our gratitude is to be deserved to those who have generously cooperated to it, and the results that the Catalogue is expected to provide in a near future, will certainly justify their perseverance.[106]

May the intuition and tenacity of the men who collaborated in this daring scientific project be always kept in memory.

Acknowledgments I wish to thank Thierry Montmerle (IAP, Paris) for his invitation and encouragement to write this contribution. I am grateful to Nicole Capitaine (Observatoire de Paris), for welcoming my training stay at Paris Observatory in the 1990s, and mostly indebted to Suzanne Débarbat (Observatoire de Paris), who was my supervisor during that stay: nothing about the *Carte du Ciel* would have been written by me without her friendly support.

Let me thank as well Olga B. Dluzhnevskaya (Institute of Astronomy RAS, Moscow) for her kind help in finding information about the contribution of Russian Observatories.

Appendix A

List of participant Observatories and distribution of the photographic work (1891)

Sky zones	Observatories	(*)	Directors at the moment of the assignation
+90° +65°	Greenwich	(°)	William Henry Mahoney CHRISTIE (1845–1922)
+64° +55°	Vatican	(″)	Fr. Francesco DENZA (1834–1894)
+54° +47°	Catania	(1)	Annibale RICCÒ (1844–1919)
+46° +40°	Helsingfors (= Helsinki)	(2)	Anders Severin DONNER (1854–1938)
+39° +32°	Potsdam	(3)	Hermann Carl VOGEL (1841–1907)
	(later Uccle)	(″)	Georges LECOINTE (1869–1929)
+31° +25°	Oxford	(°)	Rev. Charles PRITCHARD (1808–1893)
+24° +18°	Paris	(″)	Ernest Barthélemy MOUCHEZ (1821–1892)
+17° +11°	Bordeaux	(″)	Georges RAYET (1839–1906)
+10° +05°	Toulouse	(″)	Benjamin BAILLAUD (1848–1934)
+04° −02°	Algiers	(″)	Charles TRÉPIED (1845–1907)
−03° −09°	San Fernando	(″)	Cecilio PUJAZÓN Y GARCÍA (1833–1891)
−10° −16°	Tacubaya (= Mexico City)	(4)	Ángel ANGUIANO (1840–1921)
−17° −23°	Santiago	(″)	Jean Albert OBRECHT HUBER (1858–1924)[a]

(continued)

[106] *L'entreprise de la Carte et du Catalogue [. . .] n'en a pas moins jeté les bases de la coopération Internationale dans la science, introduit dans la pratique l'emploi de la photographie, montré ses difficultés, ses méthodes, ses limites. A ceux qui y ont coopéré avec désintéressement, il convient de penser avec gratitude et les résultats que fournira, dans un proche avenir, le Catalogue, justifieront assurément leur persévérance.* (Couderc, 1971, p. 178)

Sky zones	Observatories	(*)	Directors at the moment of the assignation
	(later Hyderabad)	(5)	Arthur Brunel CHATWOOD (1866–1915)
−24° −32°	La Plata	(//)	Francisco BEUF (1834–1899)
	(later Córdoba)	(//)	John Macon THOME (1843–1908)
−33° −40°	Rio de Janeiro	(//)	Louis Ferdinand CRULS (1848–1908)
	(later Perth)	(°)	William Ernest COOKE (1863–1947)
−41° −51°	Cape of Good Hope	(°)	David GILL (1843–1914)
−52° −64°	Sydney	(6)	Henry Chamberlain RUSSELL (1836–1907)
−65° −90°	Melbourne (later Sydney)	(°)	Robert Louis John ELLERY (1827–1908)

(*) Type of Astrographs:
(//) Henry-Gautier
(°) Grubb
(1) Steinheil (optics), Salmoiraghi (mechanics)
(2) Henry (optics), Repsold (mechanics)
(3) Steinheil (optics), Repsold (mechanics)
(4) Grubb (lens corrected by Alvan Clark & Sons)
(5) Cooke (guide telescope by Grubb)
(6) Grubb (optics), Mort Docks Engineering Co. & Atlas Engineering Co. (mechanics)
[a]The interest in the participation of Santiago Observatory was manifested in 1887 by the preceding director, José Ignacio Vergara Urzúa (1837–1889), who died two years later. In 1908, the Santiago Observatory again offered its collaboration, under the directorship of Friedrich Wilhelm Ristenpart (1868–1913).

Appendix B

Geopolitical map of the Carte du Ciel *project: nations, regencies, observatories involved in the photographic work (Fig. 1.17)*

- UK (Queen Victoria)
  - Royal Observatory, Greenwich
  - Oxford University Observatory
  - Royal Observatory, Cape of Good Hope
  - Melbourne Observatory, Australia
  - Sydney Observatory, Australia
  - Perth Observatory, Australia
- Kingdom of Italy (King Umberto I)
  - Osservatorio Astrofisico di Catania
- Vatican State (Pope Leo XIII)
  - Specola Vaticana

- Russian Empire (Czar Alexander III)
  - Kejserliga Alexanders-Universetets Astronomiska Observatorium, Helsingfors (today Helsinki—in Finland, at that time part of the Russian Empire)
- German Empire (Emperor Frederick III, in June 1888, succeeded by Wilhelm II)
  - Astrophysikalische Observatorium, Potsdam
- French Third Republic (President Jules Grévy, in December 1887, replaced by Sadi Carnot)
  - Observatoire de Paris
  - Observatoire de Bordeaux
  - Observatoire de Toulouse
  - Observatoire d'Alger
- Kingdom of Spain (King Alfonso XIII of Spain)
  - Instituto y Observatorio de Marina de San Fernando (near Cadiz)
- Republic of Mexico (President Porfirio Díaz)
  - Observatorio Astronómico Nacional Mexicano, Tacubaya (near Mexico City)
- Republic of Chile (President José Manuel Balmaceda)
  - Observatorio Astronómico Nacional, Santiago del Chile
- Republic of Argentina (President Miguel Juárez Celman, in 1898 Julio Argentino Roca)
  - Observatorio Astronómico de La Plata
  - Observatorio Astronómico, Córdoba
- Empire of Brazil (Emperor Pedro II)
  - Imperial Observatorio, Rio de Janeiro
- Kingdom of Belgium (King Leopold II)
  - Observatoire Royal de Belgique, Uccle
- Hyderabad State, India (under British Paramountcy) (Nizam Asaf Jah VI)
  - Nizamiah Observatory, Hyderabad

Fig. 1.17 Non-European Observatories participating in the *Carte du Ciel* project: in red, those included in the original 1891 list; blue dots, those which adhered later. Background map: https://fr.wikipedia.org/wiki/Fichier:A_large_blank_world_map_with_oceans_marked_in_blue_planisferio_en_blanco.svg

Appendix C

Summary of the main Carte du Ciel *costs*

Final Report:
- 22 participant Observatories (photographic work)
- Time employed: 20–40 years per person
- 150 volumes published
- 4,600,000 star positions measured
- 8,600,000 coordinates *x, y* measured

COSTS (on average) per Observatory (FF = French Francs)
- Instruments: 40,000 FF (in 1899)
- Photographs and measurements: 250,000 FF (12 plates = 7 FF, 1893)
- Publications: 500,000 FF
- Staff average cost = 15,000 FF (in 1898)
- Publications, materials, and measurements annual costs = 21,000 FF (in 1899)

Total Cost
- Photographs and measurements: 6,000,000 FF
- Publications (Chart and Catalogue): 12,000,000 FF

For comparison: *Average annual salary of an astronomer: 300 FF (in 1893); cost of a measured plate: 200 FF*

French Observatories
- Total number of plates: 5000
- Total amount of Chart costs: 1,000,000 FF
- Total cost for printing 12 volumes x 4 Observatories: 500,000 FF

British Observatories
- Price of Grubb Astrograph: £. 1500 (37,500 FF)
- Catalogue: 2,000,000 stars, estimated duration: 25 years

Estimated cost: 250,000 FF (£. 10,000) per year (£. 1 = 25 FF)

Appendix D

List of printed Chart plates: (from: http://www.astropa.inaf.it/carte-du-ciel/by Donatella Randazzo)

Sky zone	Assigned to	Carried out by	Sky charts
+90° to +65°	Greenwich		All charts printed
+64° to +55°	Vatican		Heliogravures for 1/3 of +55°, +56°, +57°; the remaining printed on photographic paper
+54° to +47°	Catania		NONE
+46° to +40°	Helsingfors		NONE
+39° to +32°	Potsdam	Uccle	Heliogravures for the entire zone printed and distributed by Uccle
+31° to +25°	Oxford		NONE
+24° to +18°	Paris		Heliogravures for the even zones +18°, +20°, + 22°, +24°
+17° to +11°	Bordeaux		Heliogravures for the even zones +12°, +14°, +16°
+11° to +05°	Toulouse		Heliogravures for the odd zones +5°, +7°, +9°
+04° to −02°	Algiers		Heliogravures for the odd zones −1°,+1 °,+3°
−03° to −09°	San Fernando		Heliogravures for the odd zones −5°, −7 °, −9°
−10° to −16°	Tacubaya		Heliogravures for the zones −11°, −13 °, −15°, −16 °
−17° to −23°	Santiago	Hyderabad	NONE
−24° to −32°	La Plata	Córdoba	Heliogravures for the zone −25° only
−33° to −40°	Rio de Janeiro	Perth	NONE
−41° to −51°	Cape of Good Hope		NONE
−52° to −64°	Sydney		NONE
−65° to −90°	Melbourne		NONE

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Ileana Chinnici is astronomer at INAF-Palermo Astronomical Observatory. Her main research field is history of nineteenth-century astronomy and astrophysics. She has published the correspondence related to the *Carte du Ciel* project that is preserved in Paris Observatory archives.

She is currently member of the Organizing Committee of IAU Commission 3 (“History of Astronomy”) and from 2006 to 2012 chair of the Working Group “Archives” of the Commission.

She is author of books and articles in specialized journals; her recent biography of Angelo Secchi, Jesuit and pioneer of astrophysics, has been awarded the Osterbrock Book Prize 2021.

She is also scientific advisor of Palermo Observatory heritage, including the museum and the historical library and archive, and adjoint scholar at Vatican Observatory.