The *Carte du Ciel:* an early global cooperation project

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Resumen

La *Carte du Ciel* marcó un hito en la astronomía, ya que abrió el camino a la cooperación científica internacional y a la aplicación extensiva de la fotografía en astronomía. Este ambicioso proyecto fue concebido a finales del siglo XIX con el fin de obtener un mapa fotográfico detallado de toda la bóveda celeste (no lo consiguió, pero produjo un catálogo fotográfico completo de las estrellas, un resultado mucho más complejo, costoso y que requirió mucho tiempo). A pesar de sus fracasos, divergencias y retrasos, el proyecto *Carte du Ciel* desempeñó un papel importante en la construcción de una red de cooperación científica a escala mundial. En este sentido, puede considerarse un paradigma para las empresas científicas internacionales, donde los aspectos diplomáticos y pragmáticos coexisten y pueden influir en el resultado de los proyectos.

Palabras clave: astrofotografía, cooperación internacional, catálogos de estrellas, mapas estelares, *Carte du Ciel*.

Abstract

The *Carte du Ciel* made an epoch in astronomy as it paved the way to the international scientific cooperation and to the extensive application of photography in astronomy. This ambitious project was conceived at the end of the 19th century in order to obtain a detailed photographic chart of the entire sky vault (it failed in this respect, whereas produced a complete photographic star catalogue, by far a more complex, time) consuming and expensive result. Through failures, divergences, and delays, the *Carte du Ciel* project played an important role in building a network of scientific cooperation on a global scale. In this sense, it can be considered as a

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paradigm for the international scientific enterprises, where diplomatic and pragmatic aspects coexist and may influence the outcome of the projects.

Keywords: astrophotography, international cooperation, star catalogues, star charts, *Carte du Ciel*.

I. Introduction

> "The *Carte du Ciel* enterprise has established the foundations of the international scientific cooperation, has introduced the practice of astrophotography, revealing its obstacles, its methods, its limits" (Couderc, 1971).

These words by French astronomer Paul Couderc, pronounced at the General Assembly of the International Astronomical Union in 1970, perfectly resume and explain the role played by the *Carte du Ciel* project in the history of astronomy.

This wide international scientific enterprise was launched in 1887 from Paris Observatory [fig. 1], under the directorship of Admiral Ernest B. Mouchezand was the first attempt to produce a complete and detailed photographic chart and catalogue of both sky hemispheres. Since the beginning, it was conceived as a worldwide endeavor by the concurrent cooperation of various observatories in many countries, coordinated by the Paris Observatory. Without entering into technical details, described elsewhere (e. g. Chinnici 2008), this paper is mainly focused on the international dimension of the project.

Figure 1. General view of the Paris Observatory.
Source: *The Observatory,* vol. XXXVI, 1913.

II. Early international cooperation in astronomy

During the 19th century, scientific cooperation in astronomy was a recurrent idea, whenever extensive campaigns of observations and data processing were required. An early example was the Lilienthal Society (also known as Himmelspolizei) established in Germany in 1800 to survey the ecliptic star charts, in order to chase the suspected missing planet between Mars and Jupiter. The project was interrupted in 1801 by the unexpected discovery of Ceres at Palermo Observatory, but it was reshaped later. With the purpose of detecting asteroids, in fact, the Berlin Academy of Sciences launched a call to astronomers of all countries to revise different sky zones of the ecliptic, with a money award for those who completed in time the revision of their zone. This work resulted in the publication of the Akademische Sternkarten in the years 1830-1859. In the last quarter of the century, the Astronomische Gesellschaft was established in Heidelberg to revise the Bonner Durchmusterung catalogue and produce a new revised catalogue, known as AGK, the

best northern star catalogue at the end of the 19th century. In 1871, the Italian Spectroscopic Society proposed a programme of solar monitoring, open to international collaborators, that inspired the creation of the International Committee on Solar Research in the US in 1904. Of course, the application of spectroscopy and photography in astronomy increased the amount of collected data to be processed and consequently the need of a cooperative approach.

III. Origin and development of the *Carte du Ciel* project

Early astronomical photography was practiced in many countries around the half of the 19th century, by professional and non-professional reputed astronomers, such as Warren De la Rue and William Huggins in the UK, Henry Draper in the US, Father Angelo Secchi in Italy, Hippolyte Fizeau and Léon Foucault in France. They took daguerreotypes as well as photographs of the Moon, the Sun, total solar eclipses, comets and so on. We may look at their studies as the seeds of the future *Carte du Ciel* enterprise, as they started to develop astrophotographic techniques in their countries.
In the Southern hemisphere, sir David Gill, director of the Cape of Good Hope Observatory, obtained an excellent photograph of the Great Comet of 1882 and remarked that very faint stars were visible in the background. He hence started planning to make a photographic star map of the southern heavens.
In France, Mouchez (probably stimulated by Gill's results) decided to invest in astrophotography and established an "atelier photographique" at Paris Observatory. He asked famous opticians brothers Paul and Prosper Henry to build high-quality lenses for astronomical photography and in 1884 they successfully took photographs reproducing stars to magnitude 12. Gill was informed about thesephotographs and wrote to Mouchez, revealing his intentions:

> "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". (D. Gill to E. Mouchez, 18/01/1885 in Chinnici 1999, p. 82)

Stimulated by this request of collaboration, Mouchez commissioned to the Henry brothers an instrument of higher performance. They designed a double lens astrograph, consisting of two joined refractors, one for visual observations, the other for the photographic work. The mounting, constructed by French maker Paul Gautier, permitted to completely rotate the instrument around the polar axis. The so-called Henry-Gautier astrograph [fig. 2] started to be operating at Paris Observatory in 1885 and produced astonishing results, with stars to magnitude 15 visible on the plates.

Enthusiastic about these results, Mouchez presented the star photographs to the Académie des Sciences (Mouchez 1885), announcing that time was ready to make a complete photographic map of the sky. Encouraged by Gill, hestarted to search for partners, and sent explorative letters to the main astronomical societies as well as to some colleagues, appropriately chosen from a scientific and geographic point of view. He asked their advice about the making of a complete photographic sky chart, joining a copy of the plates obtained by the Henry brothers:

> "… I send you a photographic plate of the Milky Way obtained with our new instrument [Henry-Gautier Astrograph] […] In one hour exposure, we obtain allstars up 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" […].
>
> "The photographic sky chart is today 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 6 or 8 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 of stars." (E. Mouchez to E. C. Pickering, W. Huggins, L. Cruls and O. W. Struve, 26/06/1885 and 15/07/1885 in Chinnici 1999, pp. 4-5)

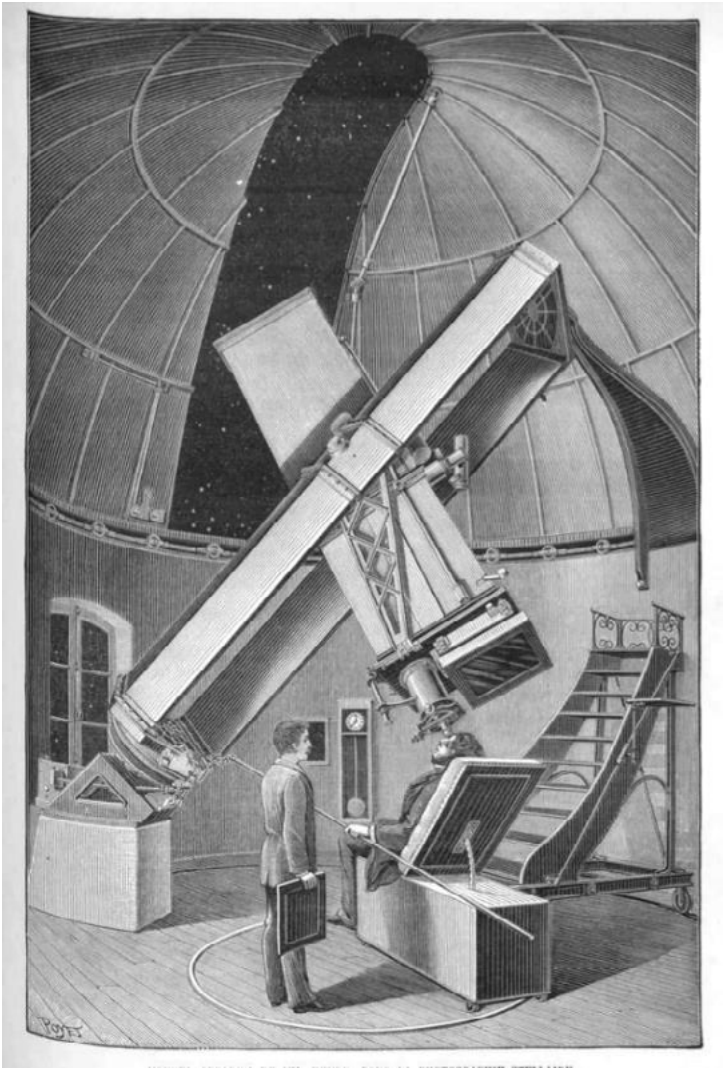

Figure 2. The Henry-Gautier astrograph. Source: *Bulletin hébdomadaire de l'Association Scientifique de France,* Paris, 1886.

Once he knew about their positive responses, Gill sent to Mouchez a draft of the project, recommending uniformity of the equipment and cooperation from other observatories:

> "… star charting […] must be begun on a plan carefully preconsidered in every detail and carried out by instruments and methods as far as possible absolutely identical." (D. Gill to E. Mouchez, 01/03/1886 in Chinnici 1999, p. 87)

Gill, with the collaboration of Dutch astronomer Jacobus C. Kapteyn, was working at his Cape Photographic Durchmusterung (Gill 1913) and was hence in a condition to give appropriate warnings and suggestions about the execution of the work. Of course, the project needed to be discussed with the potential participants and he proposed to held a conference in Paris in spring 1887: "… I think it would be essential to have a Conference and I would be glad to attend such a conference at Paris in March or April 1887." (D. Gill to E. Mouchez, *ibid.* p. 88)

The first astro-photographic conference was held in Paris in April 1887. Fifty-six astronomers from 18 countries, mostly European, attended the meeting, thanks to the important diplomatic effort made by the French Academy of Sciences, which made the invitations though the French diplomatic channels. Mouchez's opening speech, some howbombastic, expressed the awareness of undertaking an unprecedented and epoch-making enterprise:

> "… 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." (Mouchez 1887, original text in French)

The congress members decided to establish an International Standing Commission including the directors of the participant observatories and are stricted Executive Committee to draft the work plan and supervise the execution of the work. Both were formed by European astronomers (except for Edward C. Pickering from Harvard Observatory, US) and

presided by Mouchez. The Commission should have held its meetings every two years in Paris, but this biennial cadence will not be respected, becoming irregular after the third meeting.

It was clear that the *Carte du Ciel* was a hugely expensive project: the only total cost of the Henry-Gautier astrograph plus the machine for measuring the star position of the plates (the so-called *macromicromètre*) was 35,000 French francs (for comparison, the average annual salary of a French astronomer was around 300 FF). In addition, staff and publication costs should also be included. It was hence decided that all observatories being able to obtain financial support from their governments (at least for acquiring the instruments), would have joined the enterprise.

The original goal was to obtain a sky map covering the whole sky vault, with stars to the 14-15 magnitude, but at the second meeting of the Commission, in 1889, the execution of the projects appeared much more complex and expensive, due to the additional work for producing an astrophotographic catalogue with stars to the 11 magnitude [Table 1].

Chart	**Catalogue**
Magnitude limit: 14	Magnitude limit: 11
30-40,000,000 stars	4,000,000 stars
22,000 plates	22,000 plates
17-18 observatories	
Field: 2° x 2°	150-500 stars per plate
Scale: ~ 1 arcmin/mm	200-400,000 measurements
Estimated duration: 6-8 years	Estimated duration: 25 years

Table 1. Summary of the *Carte du Ciel* project

Of course, the astrographic catalogue, which was expected to contain about 4 million stars, would have been a breakthrough in comparison with the best catalogues available at that time, namely the Astronomische Gesellschaft catalogue with about 300,000 northern sky stars and the

Uranometría Argentina, made at Cordoba Observatory, with about 130,000 southern sky stars.

Gill, therefore, who acted as a sort of éminence *grise* of the project, insisted on the importance of the catalogue:

> "…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 vue [by the Committee]." (Gill to Mouchez, 1889)

This change of programme, however, was strongly criticized by the astronomical community, especially in England. The pages of the journal *The Observatory* contain violent attack against Gill, who was considered responsible for having "illegally magnified" the scope of the work and "illegally substituted" a chart with a catalogue (*The Observatory*, 1891, pp. 184-185).

Nevertheless, little by little, the star map was left in the background, and the main attention was paid to the execution of the catalogue. In the third meeting, held in 1891, it was announced the participation of 18 observatories and assigned the sky zones to be photographed by each of them (Table 2).

From the list of the participant observatories, it is easy to infer that the geopolitical map of the project shows a mixing of countries with a consolidated tradition in astronomy, stable political situation and flourishing economy, and others having scarcity of resources, training, expertise and facilities, as well as political instability, whose observatories abandoned the project in the succeeding years.

As a whole, by also considering the observatories that replaced the withdrawals, the *Carte du Ciel* can be considered a worldwide project of scientific cooperation on a global scale, with participant observatories in all continents [Fig. 3].

+90° +65°	Greenwich	United Kingdom
+64° +55°	Vatican	Vatican
+54° +47°	Catania	Italy
+46° +40°	Helsingfors (= Helsinki)	Finland (part of the Russian Empire)
+39° +32°	Potsdam (later Uccle)	Germany
+31° +25°	Oxford	United Kingdom
+24° +18°	Paris	France
+17° +11°	Bordeaux	France
+10° +05°	Toulouse	France
+04° -02°	Algiers	Algeria (French colony)
-03° -09°	San Fernando	Spain
-10° -16°	Tacubaya (= Mexico City)	Mexico
-17° -23°	Santiago (later Hyderabad)	Chile
-24° -32°	La Plata (later Córdoba)	Argentina
-33° -40°	Rio do Janeiro	Brazil
-41° -51°	Cape of Good Hope	South Africa (UK colony)
-52° -64°	Sydney	Australia (UK colony)
-65° -90°	Melbourne	Australia (UK colony)

Table 2. Sky zones assigned to the participant observatories in 1891

It is striking, however, the absence of North American observatories in the list. Effectively, Edward C. Pickering, influential director of Harvard College Observatory, criticized the complexity of the project and preferred to make an alternative sky atlas on smaller scale, by using wide field cameras and short focal length telescopes, a work which he successfully achieved and published in 1890 (Pickering 1903).

IV. European observatories

France was, of course, the nation most involved in the *Carte du Ciel*, with four observatories taking part in the project, including the colonial one in Algiers [Fig. 4], whose astronomers played an important role in providing technical details about usage of screens and preservation of the plates.

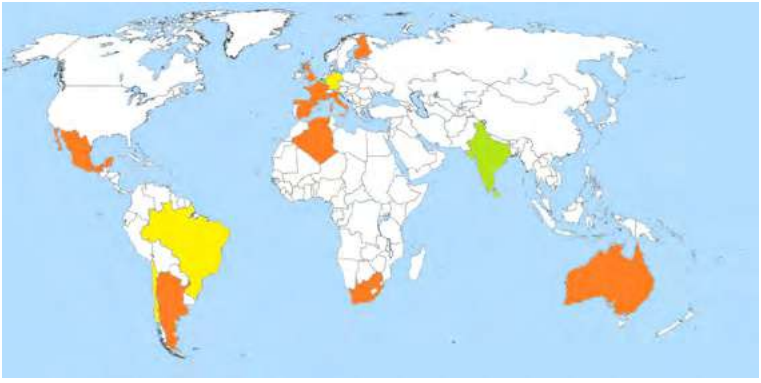

Figure 3. Map showing the global scale of the *Carte du Ciel* project. In orange and yellow, countries initially involved; in yellow, those that abandoned later; in green, those replacing the withdrawn ones. Credits: the author.

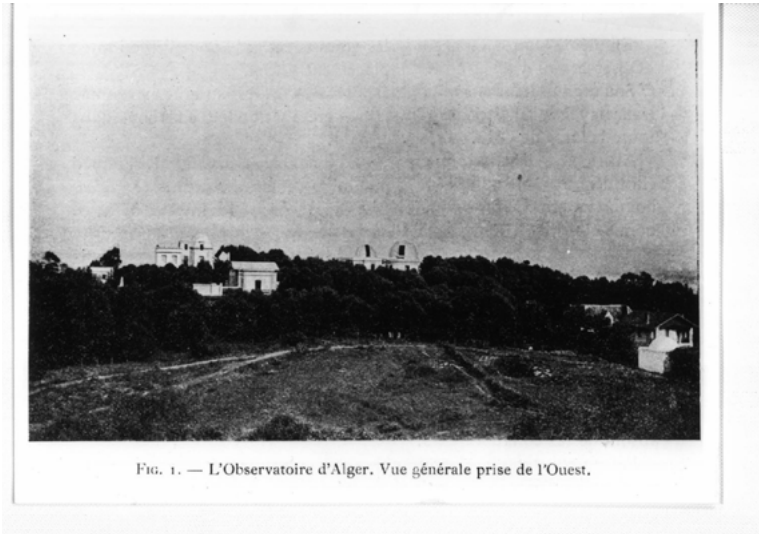

Figure 4. General view of the Observatory of Algiers.
Source: *Ciel et Terre*, vol. 32, 1911.

Paris Observatory was the pulsating heart of the project and the reference point for the participant observatories: it hosted all meetings of the Standing Commission; the director was by default the President of the Commission; a Central Bureau for plates measurement was also established there, in 1891 (see below). The other French observatories ensured the execution of a large part of the work and hence the leadership of France, which remained unquestioned until the end of the project. Moreover, Henry-Gautier astrographs were ordered not only from the French participant observatories but also for the Vatican, La Plata, Córdoba, Santiago, San Fernando, Rio do Janeiro and Uccle Observatories, namely 11 over a total of 18: a really successful result for the French industry of optical instruments. Photographic plates by Lumière brothers were also widely used for the *Carte du Ciel* work by many participant observatories, even out of France.

Regarding the British observatories, Gill obtained funds for the participation of the Observatories of Greenwich and Cape. Moreover, Oxford University as well as Australian observatories also took part in the project, so that, after France, the United Kingdom was the nation that

mostly invested in the *Carte du Ciel*. They had, however, to overcome, a major problem concerning the acquisition of the instruments. Dubliner maker Howard Grubb, in fact, fearing to miss a big business, threatened to raise a question in the Parliament if French astrographs were purchased for the British observatories. British astronomy, however, was mostly based on the use of reflecting rather than refracting telescopes. The *Carte du Ciel* astrographs required high-quality objective-lenses and Grubb had to work hard to obtain instruments comparable to those made by the Henrys [Fig. 5]. For this reason, the British observatories delayed the beginning of their work, although they regularly carried it out afterwords. Nationalism, protectionism, competition and financial interests, in the end, prevailed against the appropriateness of using identical instruments in all participant observatories.

Figure 5. The Grubb astrographic refractor at Greenwich Observatory.
Source: *Astrographic Catalogue 1900.0, Greenwich Section*, vol. I, 1904.

A few other European observatories used German optics by Steinheil and mounting by Repsold or other local makers. The observatories of Helsinki and San Fernando carried out quite regularly their work, whereas that of Catania met with many difficulties and delays; Potsdam

Observatory was the only European observatory that abandoned for lack of resources and was replaced by Uccle Observatory, in Belgium, in 1904.

A special mention is due to the Vatican Observatory, as it was established on purpose to participate in the *Carte du Ciel* project, as a reaction to the confiscation of the Papal observatories by the Italian government.

V. Non-European observatories

Out of Europe, among the initial participants, only the Tacubaya Observatory in Mexico completed the photographic work. In about a decade, many observatories of Latin America abandoned the work and were replaced by others (Paolantonio and García 2009). At the beginning of the 20th century, La Plata Observatory [Fig. 6] was replaced by Cordoba (La Plata later provided reference stars catalogues for the *Carte du Ciel* astrographic catalogue; Rieznik 2011, chapters VI and VII) and Rio do Janeiro by Perth Observatory; the Santiago zone was reassigned to the Nizamiah Observatory in Hyderabad, India, being considered more reliable.

Figure 6. General view of the Observatory of La Plata.
Source: *Popular Astronomy*, N° 233, 1916.

It is important to remark that, in Latin America, the execution of the photographic work was successfully carried out where astronomers had already practiced astrophotography, namely in Tacubaya and Córdoba Observatories, the latter having published the *Fotografías Cordobesas,* the first extensive and systematic photographic survey of the southern sky, carried out from 1872 to 1884.

The desertions of the other observatories were due to many reasons. Some countries underestimated the required financial effort, others met with political instabilities, financial crises, difficulties in provisions, insufficient resources, inadequate directorship and so on. All these circumstances hampered or blocked the execution of the work. Their participation was sometimes unrealistic, mainly based on the desire to obtain additional resources from the governments and gain visibility and prestige in the international context.

A similar search for visibility and resources also drove the participation of some British colonial observatories, wishing to acquire scientific lustre (Haynes *et al.* 1996).

VI. An underestimated effort

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 accurate and delicate work should have been well standardized and coordinated. For this reason, Gill suggested the establishment of a Central Bureau and proposed to entrust this work to female staff to reduce the costs (D. Gill to E. Mouchez, 30/08/1891 in Chinnici 1999, p. 107).

The Central Bureau was established in Paris and directed by a woman astronomer, Dorothea Klumpke. Many observatories recruited women to measure the star coordinates on the plates (even the Vatican Observatory employed nuns), as they assured highly results at low cost, being trained in patient, accurate and repetitive work (like embroidery and needle work). In those very same years, at Harvard College Observatory, other women were measuring and classifying stellar spectra for another major project, the Henry Draper Memorial Catalogue. The contribution of all these women was crucial for the successful execution of both these

projects. Moreover, some observatories went in help of the others and assumed their measurement work (plates taken in Perth, for instance, were measured in Edinburgh).

At the beginning of the 20th century new interests, however, emerged in astronomy, notably in the field of galactic astronomy and cosmology and the initial enthusiasm about the *Carte du Ciel* faded away. The work revealed to be too expensive and time-consuming and risked to became obsolete. It was necessary to reshape the project and to re-motivate the participant observatories.

The impulse given by Maurice Loewy, once he became President of the Standing Commission, was decisive. The sky zones left vacant by the withdrawn observatories were reassigned and the work was optimized and reorganized. The resolutions taken in 1909 (establishment of three sub-commissions for the reference catalogue, the Eros' parallax and the Kapteyn Selected Areas) were aimed at giving new impetus and scientific sense to the project, by enlarging its horizon. The project fragmented, however, losing its consistency and unity.In adddition, after a considerable financial investment and about 30 volumes of the catalogue already published, the *Carte du Ciel* project was interrupted because of the catastrophic World War I. Most of the European observatories reduced or interrupted their activities, most of the staff was called up to arms, and finances were cut to sustain military operations. The project completion was seriously compromised. After the war, in 1919, the International Astronomical Union (IAU) was established with the explicit purpose to promote the international cooperation in the field of astronomical research.

The *Carte du Ciel* had paved the way to this new institution, as it had effectively created an international network and an organization method that facilitated the establishment of the IAU (Chinnici 2022). The completion of the work was entrusted to Commission 23, which replaced the Standing Commission. It was decided to give priority to the achievement of the catalogue. The support given by the IAU was determining, as the publication of the last 20 volumes was entirely financed by the IAU and in 1964 the catalogue work was completely published, although without the reduction of the coordinates (only made by Helsinki and Catania Observatories).

The chart [Fig. 7] met with a different fate. After many decades elapsed, its completion was considered obsolete, due to the development of Schmidt cameras, and it was abandoned. About a half of the chart plates (with longer exposure than the catalogue plates) were either never taken or

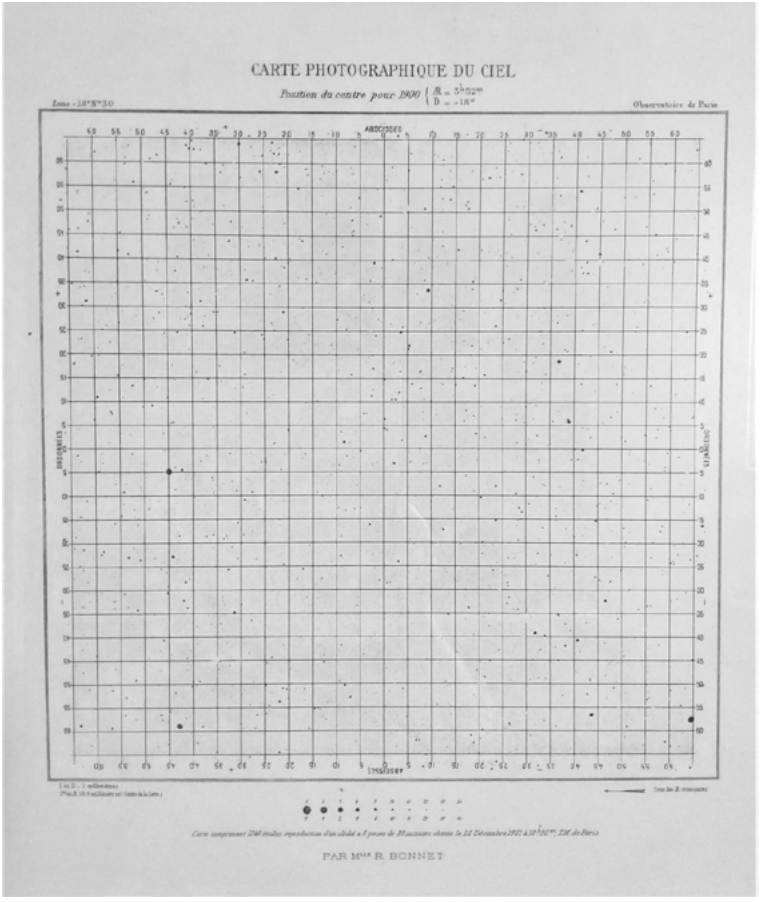

Figure 7. A typical reproduction of a *Carte du Ciel* plate on special light cardboard. Source: INAF-Osservatorio Astronomico di Palermo, Historical Archives.

never printed (Randazzo 2017), as the printing procedure was much expensive. In the IAU General Assembly of 1970 it wasdefinitely decided to leave the chart unachieved. Commission 23 (*Carte du Ciel*) merged with Commission 24 (Parallaxes & proper motions) into a new Commission 24 (Photographic Astrometry).

Sixty years later than expected, the *Carte du Ciel* enterprise finally come to an end, with a mix of success (the completion of the Astrographic Catalogue) and failures (the non-achievement of the map).

VII. Concluding remarks

The *Carte du Ciel* project was an ambitious but premature endeavor. It was marked by an increasing complexity and undermined by a number of predictable weak points (ambiguity and diversity of purposes, non-homogeneous instruments, management failures, unsolved technical questions, different political and economic situations of the participant countries) and unpredictable diverging factors (political instability of the governments, world conflicts, development of new technologies - e. g., Schmidt cameras, new scientific frontiers (e. g., extra-galactic astronomy). These elements (and probably others too) were responsible for the unacceptably long time of execution and the incompletion of the original project. The *Carte du Ciel* can hence be considered a paradigmatic case for scientific enterprises, as it shows how much these factors may impact on the execution of a large international project. Mostly important, it has provided a model of organization for the international astronomical community, being the first example of international scientific cooperation on a worldwide scale.

Moreover, this gigantic effort has left an important scientific legacy. In the 1990s, the Astrographic Catalogue was digitized at the US Naval Observatory and made available as AC2000; it found important applications in the construction of the reference catalogue for the ESA astrometric mission Hipparcos.

Couderc was definitely right in affirming:

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. (Couderc, 1971)

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