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Polar motion measurement at the Observatoire de Lyon in the late nineteenth century

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ABSTRACT

The motion of geographic poles, predicted by Euler, was discovered at the end of the 1880s, mainly by German and American astronomers. However, French astronomers were strongly reluctant to accept the reality of this phenomenon. Indeed, all observations at the Observatoire de Paris converged toward non-detection of the polar motion. Science, as most fields of public life, was extremely centralized in France, and the Observatoire de Paris was still living on past glory gained in the field of classical astronomy. However, the directors who succeeded Urbain Le Verrier were doubtful about the accuracy of the observation in such an urban observatory, and were pushing for the construction of an observatory outside the city. At the same time, just after the French defeat of 1871, a wide decentralization of the universities started, and a few big regional cities were selected to host new observatories. In this paper we show how it is in one of these new observatories, in Lyon, that the polar motion was first observed in France, and how this was immediately recognized internationally. Although the weight of French Jacobinism kept the new observatories at an embryonic stage for many decades, this contribution to an internationally discussed problem shows how enthusiastically and efficiently work was carried out in the early years of French provincial observatories.

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1. Introduction

France is internationally renowned for its centralized structure. Although this centralization has relaxed in the last few decades, it was at its zenith in the late nineteenth century. Amongst all the public activities controlled by a central power was science, and all main institutions and universities were concentrated in Paris. Several observers were worried by this situation and the debate on the establishment of provincial universities started in the 1850s, when some scientists realized the inferiority of French higher education compared to that of their neighbors, including Germany whose rising nationalism was already considered a threat. The trauma of the 1871 defeat was a trigger for decentralizing the French universities. In a dozen cities, faculties were created or developed and gradually established as fully-fledged universities. Amongst all sciences, as we shall see later, astronomy particularly suffered from centralization. Besides the university decentralization, some cities (Algiers, Bordeaux, Lyons, Nice) were selected to host new observatories whilst those of Marseilles (formerly known as ''Observatoire de Paris in Marseille'') and Toulouse were consolidated. A physical astronomical observatory was also built at the time in Meudon, a suburb of Paris. An overview of the French provincial observatories in the 1880–1890s can be found in Le Guet Tully, De La Noë, and Samsaoud, (2008). Unfortunately, as demonstrated by Maison (2004), this decentralization remained unfinished was due not only to the very limited means available for the new observatories, but also to their subordination to central institutions such as the Academie des Sciences and the Observatoire de Paris. It would take several decades before the provincial observatories took their legitimate place in the scientific community. In fact, France did not catch up with international astronomy before the second half of the twentieth century, and

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due to this failed decentralization, provincial observatories would not be able to play their role in the recovery. However it would be unsound to assume that they took no part in the astronomical debates of the time.

It is difficult to get a clear idea of the value of early work from provincial observatories. Today, one of the common indexes used to evaluate the scientific activity of an institute is its number of publications in various fields. This kind of index may also be used by science historians to get an idea of the production of provincial observatories during their early years. This bibliometric work was partially done by Maison (2004), not in order to assess the value of the observatories' production, but to obtain a picture of their scientific specialties. However, using such a simple bibliometric index to evaluate the quality and the originality of scientific works is disputable, and it is more relevant to try to determine the content and impact of the publications. Here is a truism often forgotten in a time of quantitative evaluation: when one wants to evaluate the quality of a publication, there is no better method than to actually read it. This is a study we have undertaken with the early papers in the field of meridian observations at the Observatoire de Lyon.

In this article, we will present the first results of this work. The detailed analysis of the first publications showed that this institute took a significant and internationally acknowledged part in a controversial problem of the time: the motion of the Earth's rotational pole. We will also show that prior to this contribution, the reality of the phenomenon was generally rejected by French astronomers, particularly those of the Observatoire de Paris. This shows how a provincial observatory in its early years did play a key role as a counterweight to centralized science, a role it would not be able to keep in subsequent years.

A brief introduction of polar motion and the steps towards its discovery are described in the first two sections of this paper. The French reluctance is then discussed and the contribution of the Observatoire de Lyon, mainly by François Gonnessiat, to the debate within this context is detailed. Before concluding, we give an overview of the international response given to this contribution, as well as a short summary of Gonnessiat's path.

2. Introduction to polar motion

It is well known that the apparent circular motion of stars around the polar star is due to the rotation of the Earth around its axis. The intersections of this rotation axis with the celestial sphere are known as celestial poles. Astronomers in the antiquity already knew that these celestial poles are slowly moving in the sky. Thus, in a few thousands years, the polar star will be a simple star that will appear to move around a new pole. This effect, called precession, is a result of the slow motion of the Earth rotation axis with respect to the remote stars. The Earth's rotation axis is tilted by 23.5° with respect to the plane the Earth's orbit, and this axis describes a cone, just like a tap rotating on the ground. This motion is very slow and periodic: the axis completes a cycle every 26000 years. The physical cause of precession, discovered by Newton during the 18th century, is the non sphericity of the Earth and the combined actions of the Moon and the Sun on its equatorial bulge. In 1745, Bradley discovered another motion of the Earth's rotation axis: the nutation. The rotation axis, on top of the movement previously described, shows much faster and smaller oscillations called nutation, among which the largest is about 10000 times smaller than the precession motion and has a period of 18.6 years. Newton did not predict this effect, but the development of celestial mechanics during the eighteenth century, allowed d'Alembert to give a theoretical explanation of precession/nutation from a more detailed analysis of the luni-solar influence.

The effects previously discussed concern the movement of the Earth's rotation axis in relation to a celestial reference frame. It was thought that this axis was fixed in relation to the Earth itself. In other words its poles of rotation were assumed to be fixed on the Earth. However, in the middle of the eighteenth century, Euler showed that the instantaneous axis of rotation of an oblate spheroid could move with respect to this spheroid. The path of the pole is called the polhode. Unlike precession/nutation, it is independent of the lunisolar action, and is therefore called free nutation. In fact this movement is possible but not guaranteed. This is a proper mode that occurs only if it is excited. Its magnitude is not predictable *a priori* because it depends on the excitation mechanism, but its period is calculable and depends on the Earth's structure and shape.

In the early nineteenth century, the shape of the Earth was known quite accurately following measurement of the meridian arc near the north pole and the equator, and a period of 304 days was calculated. Today, we know that polar motion is the superposition of several components, mainly:

- A rotation of variable amplitude of about 0.2″ with a period of approximately 435 days
- An annual rotation of lower amplitude of less than 0.1″
- A secular shift westward of about 0.3″ per century

The superposition of the two rotations generates a spiral motion that opens and closes periodically. As will be shown, we owe to Seth Chandler the discovery of these two components. The motion of the poles is still a currently discussed topic, especially the excitation mechanism. Indeed one would expect it to be rapidly dampened. Various hypotheses have been offered, involving atmospheric and oceanic motions as well as motions in the internal constituents of the Earth. It was even recently been suggested that there might be a link between this motion and the existence of a concentration of exotic dark matter within the Earth (Portilho, 2009)! An international monitoring of the poles motion has been established: the Earth Orientation Center of the International Earth Rotation and Reference System Service routinely provides observational data describing the motion. Fig. 1 shows the displacement of the pole since 1900 for its secular average component, and between 2001 and 2006 for all its components (Fig. 1).

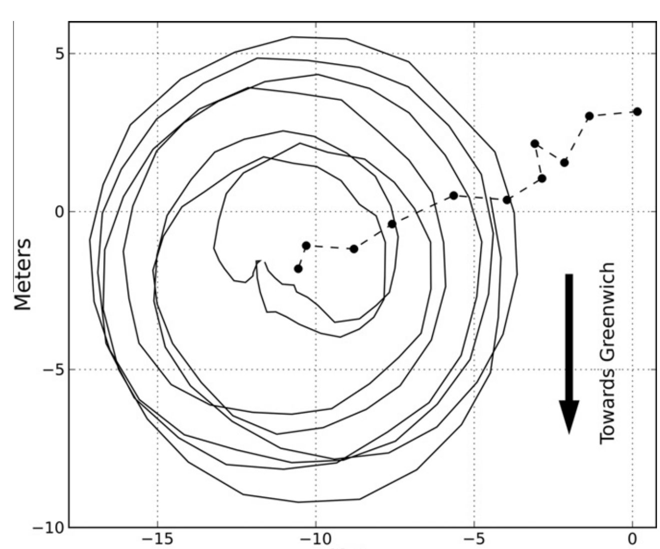

Fig. 1. Movement of Earth's geographic pole measured from 1900 to 2000 for its secular component, and from 2001 to 2009 for all its components. Data from the International Earth Orientation Center.

Throughout the nineteenth century, astronomers attempted to detect polar motion by observing the variation of astronomical latitudes. This variation was measured by routine observations of the apparent motions of some chosen stars. However, as discussed hereafter, the magnitude of the displacements to be observed is very small compared to the various sources of measurement error, and the quest would be long and the discussions tough before a conclusion was reached on the existence of the phenomenon.

3. Observational discovery of polar motion

Astronomers in the nineteenth century expected that polar motion would show a very small amplitude. Indeed, theoretical considerations showed that one should not expect angles greater than a few tenths of an arc second in the apparent stellar motion.

One of the main obstacles to the observation of the phenomenon is undoubtedly the effect of atmospheric refraction. Indeed, when a ray of light enters the atmosphere, its path is bent by the atmosphere, and this deviation depends mainly on the temperature and pressure of the air in the vicinity of the measuring instrument. The effect can be much more substantial than the expected variation of astronomical latitude and its correction requires accurate measurement of the temperature and barometric pressure. Great care must be taken in installing the instrument, in order to minimize the difference between the layers of air inside and outside the housing building. This atmospheric refraction effect was often invoked to contest the reality of the observed phenomena. Another source of criticism was the systematic instrumental errors which, when trying to measure such small angles, must be meticulously tracked and corrected, and require special skills from the observer.

During the nineteenth century, in every country in the world where precision astronomy was sufficiently advanced, many astronomers tried to show conclusively the variation of latitude. The subsequent reading of various publications on the subject could suggest that the effect was observed several times before the 1880s, and one can find a review of pre-discoveries of the phenomenon in a paper by Verdun and Beutler (2000). Indeed, it often happened that astronomical measurements of the latitude of a location gave conflicting results from one time to another. With the improvement of measurement accuracy over the century, and the development of mathematical models for precession, nutation and astronomical aberration[1], observations sometimes showed a systematic irreducible error that was, in fact, the change in astronomical latitude. It is not surprising that the discovery of this variation was not the result of dedicated research, but rather an attempt to explain these residual errors that vast amount of precautions did not manage to eliminate.

Although these residuals were sometimes interpreted as the effect of the variation of latitude, they did not formally prove it, and this hypothesis was far from convincing the scientific community. During the second half of the century however, the discrepancies found in the accurate measurements of latitudes made this issue more pressing, and during the Congress of the International Geodetic Association in Rome in 1883, the Italian astronomer Emanuele Fergola proposed to measure the latitude of two stations located on the same parallel, though at widely spaced longitudes. If the latitudes were really variable, one should see an increase in one station's astronomical latitude and a decrease in the other. The idea was approved, but not actually applied. What finally convinced the community (with the notable exception of French astronomers, on which we shall return) were the observations of the German astronomers and geodesists Küstner, Helmert and Albrecht and Chandler in the United States. We will also mention the observations of Gyldén and Nyrén at Pulkovo in Russia, which, if they displayed evidence of the existence of changes in latitudes, were not interpreted in this way at the time, and it is the discoveries of Chandler and Küstner that led to their reinterpretation.

From 1884 to 1886, Friedrich Küstner made a series of observations, using the large transit instrument of the Berlin Observatory to determine the constant of aberration. It is interesting to describe the method used, as it was one of the most popular of the time for such measurements: the Horrebow-Talcott method in which one observes pairs of stars symmetrically located about the zenith when they cross the meridian. A spirit level fixed on the telescope is used in order to level the instrument. One star of the pair is observed and the telescope is then rotated around its vertical axis to observe the second star. The difference of the zenith distances between the two stars is measured. One can easily show that this difference depends on the conventionally adopted polar distances of the two stars, the astronomical constants and the astronomical latitude. Measuring the evolution in time of the difference of zenith distances provides the variation of latitude, if such a variation exists. In this differential method, there is no need for an accurate reading of graduations on a circle. This was indeed one of the major drawbacks of the great meridian circles: a few tenths of an arcsecond in the sky corresponds to a few tenths of a micron on a 40-centimeter radius circle. This problem was however mitigated with long and fastidious examination of the circle graduations, and rotating the circle in order to average irregularities. Another advantage of the Horrebow-Talcott method was to limit the refraction effects. It is well known that refraction depends on the zenith distance of the target star. In this method, the two stars having nearly the same zenith distance, the difference between the zenith distances measured can be considered as mostly independent from refraction.

Analyzing his measurements, Kütsner realized that the aberration constant showed a variation of a few tenths of arcsecond. He waited until 1888 to publish these results, which he interpreted as an evidence of the variation of latitude (Küstner, 1888).

In the 1860s, German geodesists joined efforts in a project for the measure of a meridian arc in Central Europe. They created an organization, the Mitteleuropäische Gradmessung in 1864 under the leadership of General Baeyer. It brought together, besides the German states and Austria, several European countries: Belgium, Denmark, Holland, Italy, Russia, Sweden, Norway and Switzerland and became the first international scientific organization. In 1867, after the accession of Spain and Portugal, it was renamed as the Europäische Gradmessung. At the same time, French geodesy was being reorganized around the new measurement of the Paris meridian by the military geodesist François Perrier, who worked for the accession of France to the international organization; this was done in 1874 when H. Faye became member of its permanent commission. In 1886, the organization once again changed its name to become the International Association of Geodesy. In 1888, soon after the publication of Küstner's results, the organization decided to create a special commission dedicated to the study of the variation of latitudes. Despite the presence of the eminent French astronomer Félix Tisserand in the commission, the Germans were the first to create a methodic program for this study. They decided to measure continuously the latitude of several observatories in Berlin, Potsdam, Prague and Strasbourg (which was in Germany at the time). The geodesist Theodor Albrecht was given the responsibility to analyze the results. In 1890, he presented the results of three of the four stations (The Strasbourg measurements

[1] Astronomical aberration is an effect due to the orbital velocity of Earth and the velocity of light emitted by the star. The star appears to describe an ellipse on the sky, the flattening of which depends on the angle between the star's direction and the Earth orbital axis.

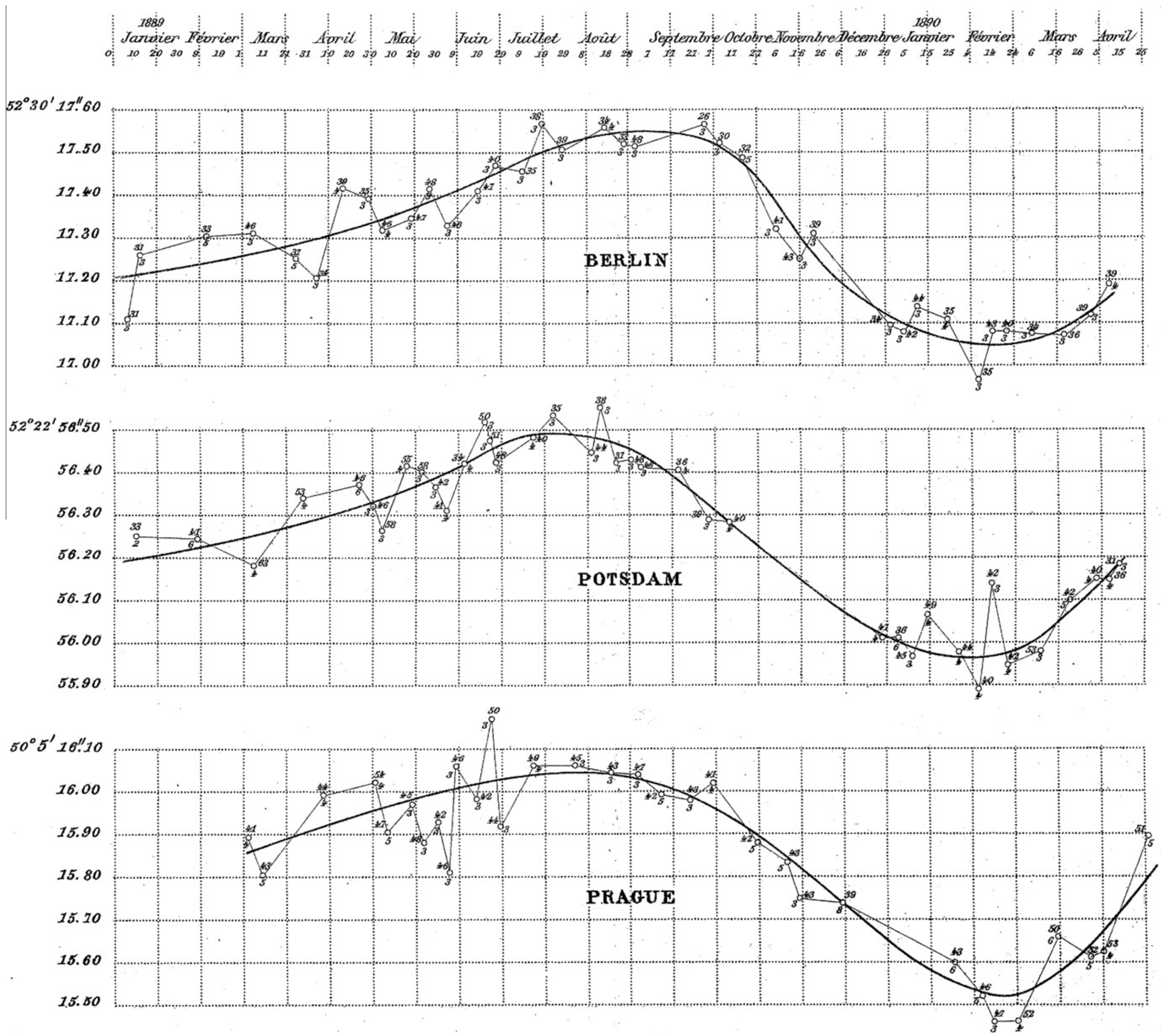

Fig. 2. Latitude variation from January 1889 to April 1890, measured at the observatories of Berlin, Potsdam and Prag. Reproduction of a figure published by Félix Tisserand in the Bulletin Astronomique 1891, volume 7, page 341.

were considered too inaccurate) to the International Association of Geodesy. Fig. 2 shows the three curves obtained, published in France in the Bulletin Astronomique by Félix Tisserand (1890). The consistency between the three measurements was a decisive argument, and although it did not rally the conviction of the whole community, it gave a solid observational basis to the phenomenon (Fig. 2)

In 1885, Seth Chandler had published the results of his measurements of latitude of the Harvard Observatory made with his own instrument: the almucantar (Chandler, 1885). This very original instrument, was basically a telescope floating on a bath of mercury in order to provide a natural vertical direction. The reference plane is no longer the meridian, but the small circle perpendicular to the meridian passing through the pole. The complete theory of this instrument was established in a volume of the University of Harvard's annals (Chandler, 1887).

This first series of measurements showed a variation of the latitude which Chandler refused to discuss: "There is manifested a slight tendency to system [in the difference to the mean latitude] which I note without comment. Whether it is due to personal or instrumental causes, or is simply fortuitous, can be told only from more extended observations".

The publication of Küstner's results probably encouraged Chandler in the certainty that the variation in the measured latitude observed at Harvard was real. In 1891 he published the first two papers of a series entitled "On the variation of latitude" in which he showed a period of 427 days for the variation of latitude, derived from his data and that of the Pulkovo and Washington observatories (Chandler 1891a,b). Pulkovo's observations were the work of Gyldén and Nyrén, who themselves were trying to find evidence of the latitude variation, but unfortunately failed in unambiguously interpreting their data. Chandler wrote in his second paper: "I now take up the observations with the Pulkowa vertical circle, which have been provocative of so much inquiry, so far without solution of the anomaly which they show, in regard of this question of latitude-variation." (Chandler, 1891b). He then performed a thorough analysis of all the data he had in hand, leading to his discovery. The 427 days component of the polar motion is still called Chandler nutation or Chandler wobble. As mentioned previously, a period of 306 days was expected in Euler's theory. The explanation for this difference was immediately understood by the great American astronomer and mathematician Simon Newcomb who noted that the calculation of Euler was done assuming a rigid Earth (Newcomb, 1891). If the Earth is considered as roughly as elastic as steel, the Chandlerian period is explained.

In the second article of the series, Chandler gave a decisive argument that won the agreement of the international scientific community. By comparing the Berlin and Harvard data obtained during the same period, he showed that the variations of latitude were of opposite direction: the latitude of Berlin decreased as Harvard's increased. A similar effect was also demonstrated between measures of Pulkovo and Washington. This is exactly the effect expected for two stations located approximately on the same parallel but at nearly opposite longitudes. The variation of latitudes was also found symmetric in 1892 by the German geodesists who added a temporary station in Honolulu to their network. However, for years there remained a core of skeptical scientists, led by French astronomers.

4. The reluctance of French astronomers

In 1890, Félix Tisserand summarized the state of research on the variation of latitudes (Tisserand, 1890). Küstner's results were then known, as well as the analysis of concordant results from Berlin, Prague and Potsdam published by Albrecht. In Tisserand's report, all these results were presented positively. He pointed out that Yvon Villarceau, a major French astronomer of the previous generation, had already reported a change in observed latitude of the Paris Observatory for which "he had not ventured to give any explanation". Tisserand concludes in his paper: "If we accept, what seems now very probable, that the variations are real, it would remain to find their cause. But we must adopt until further notice the cautious reserve of Villarceau. Besides the meteorological effects that we already discussed and to which we should add those of the Eulerian nutation, we could however speculate that, either for instruments or for the atmosphere, temperature plays a role, since the variations seem to follow the changing seasons. The theories of refraction assume a regular constitution of the atmosphere, a static state that is probably never achieved. We might ask whether it is possible that under certain influences, the layers of the atmosphere display a variable deformation with the seasons. It will likely take many studies before finding the solution to the problem".

This last argument was echoed by several astronomers of the Observatoire de Paris and became one of the main lines of attack against the supporters of the variation of latitudes. A. Gaillot, who had carried out the measurements analyzed by Villarceau, developed it in a letter to the Academie des Sciences in 1890 (Gaillot, 1890). The following year, he used a series of measurements of the latitude of the Observatoire de Paris obtained between 1854 and 1857, and concluded that "The observations we analyzed show no significant annual variation of latitude" (Gaillot, 1891). The need for an accurate and reliable measurement of the latitude of the observatory became urgent at the time. Périgaud, who was considered as one of the most experienced observers there, would spend several years on the problem. He had already published in 1888 a first series of measurements and concluded "that the latitude does not vary with the seasons since the results in October 1888 is identical to that previously acquired on the same instrument in June 1887" (Périgaud, 1888). In 1892, measurements on the large meridian circle of the Observatoire de Paris by Périgaud and Boquet (Boquet, 1892; Périgaud, 1892) also led to the non detection of the variation, and Boquet wrote "One sees in the progress of these numbers no evidence of the law that was believed to be discovered in other observatories". The director of the observatory at the time, Ernest Mouchez, could not stay silent on this result that kept Paris outside all the major observatories. In a note to the Academie des Sciences presented at a meeting on April 11, 1892, he briefly commented on the results of Boquet and Périgaud and concluded about the changes in latitude observed elsewhere that "the existence of this annual variation seems therefore to gain some confidence, but it seems far more natural for now to attribute it to still unknown variations of some of the elements used in the determination of latitudes, and mainly to the influence of temperature on the astronomical refractions, rather than to a real variation of the axis of the Earth" (Mouchez, 1892). Mouchez however takes the opportunity of this presentation to the Academy to point out that the physical conditions under which the Observatoire de Paris is located in the heart of the city are not propitious to accurate observations which would allow them to take a real part in "this delicate research". The question of the location of the Observatoire de Paris had been controversial for some time, and had already opposed, in the 1860s, the director Le Verrier to Villarceau who wanted to create a new observatory away from the city, precisely because of the difficulty to measure accurately the observatory's latitude (Le Verrier, 1868; Villarceau, 1868). Twenty years later, in 1888, Mouchez wrote a letter to the Academy "On the difficulties of obtaining the exact latitude of the Observatoire de Paris", in which he stressed the bad conditions for observation due to the irregularity of astronomical refractions over Paris (Mouchez, 1888). However, these remarks do not explain why the observations of Boquet and Périgaud, made at various times, seem to point to the same value of the latitude of the observatory with an accuracy better than a tenth of an arcsecond. One wonders if Mouchez was not a little ironic when he wrote "and the remarkable agreement of the three new results obtained by Mr. Périgaud proves much more the great skill of the observer than the absolute accuracy of the final result". The fact is, however, that until 1898 the observers at the Observatoire de Paris would see no variations in latitude in their observations. Mouchez concluded his 1888 note with the following remark "[These bad conditions] put us in a state of inferiority in comparison to any other observatory in France and abroad, all without exception today being located outside the cities", and it is not surprising that in 1893, the new director of the Observatoire de Paris, Félix Tisserand (who succeeded to Mouchez who died in 1892), asked the Observatoire de Lyon to study the variation of their latitude. Note however that as late as 1898, Périgaud published in the Observatoire de Paris' annals (and thus necessarily approved by the director), a memorandum that he concluded with: "As for the variation of latitude, the observations of the polar star from 1887 to 1894, do not confirm the law generally accepted, and neither provide any formal proof of its existence" (Périgaud, 1898).

Apart from the effects of atmospheric refraction, errors related to the instrumentation itself constitutes the second line of attack against the discoverers of polar motion. The attack was led by the famous French physicist and astronomer Alfred Cornu. In a speech to the conference of the International Association of Geodesy held in Brussels in 1892, entitled "Several additional precautions in high accuracy astronomical observations" (Cornu, 1893), he repeats the argument concerning refraction, and adds a list of various sources of physical disturbance affecting the measures: accuracy of the spirit levels, regularity and thermal variation of the circles' graduations, and even the influence of the observer's hand temperature on the micrometer eyepiece. He concludes his presentation with this severe statement: "To summarize, it is clear from these examples (which could be multiplied by pushing further the analysis of the disturbances that differences of temperature, conductivity or elasticity delays may introduce on various astronomical instruments), that in the current observation methods, precautions taken to ensure the approximation of a tenth of an arcsecond are insufficient". While it is commendable to discuss all possible sources of errors in such delicate measurements, Cornu's is still very severe. He doesn't mention any concordant observations of various observatories, nor does he quote the results of the phase opposition between stations of opposite longitudes which were known at the time.

We must note however, that in the early 1890s, some well respected French scientists were convinced by the accumulation of evidence in favor of the polar motion. In 1892 the great astronomer Herve Faye, former president of the Academie des Sciences, who enjoyed an international reputation wrote: "The issue of variability of latitudes is a concern of high importance for astronomers and geodesists. The Academy will learn with interest that this issue appears to be resolved in the affirmative" (Faye, 1892).

It is not uninteresting to read the articles on the topic of polar motion in the popular science magazines of the time. The general journals such as "La Nature" or "La Revue Scientifique" presented in 1892 the phenomenon as an established fact. The tone is different in the popular astronomy journal, undoubtedly considered as a reference in the late nineteenth century: "L'Astronomie" by Camille Flammarion. In 1891 it published an anonymous article[2] "The variability of latitudes" in which most of the recent results were reported positively. The article is, however, followed by a postscript by Flammarion himself who wrote: "It seems highly probable that the difference in atmospheric refraction between winter and summer is the cause of the observed variation which therefore would be only apparent". There would be no more paper on this topic in "L'Astronomie" until 1894, when Tisserand presented the positive results obtained that year without mentioning the first observations of 1888 to 1891. The French amateur astronomer found sooner a more positive report of this discovery in the journal "Ciel et Terre", equivalent to "L'Astronomie" in Belgium. It read in 1892 "... the question of whether a motion of the Earth's axis causes a variation of latitude must be resolved affirmatively"[3] and all the following articles would share the same opinion.

Throughout the first half of the 1890s, the French incredulity is still strong, and during a meeting of the Boston Scientific Society, March 27, 1894, Chandler complaining about the French astronomers' reluctance seemed doubtful about his ability to convince them before some time. A report of this meeting contains this disillusioned sentence: "Another interesting point is that the French astronomers have been among the very last to allow that any such motion as the variation exists. At last they have prepared an instrument and are about to take some observations. It is curious that during the immediate future, the time during which they will be likely to work, the variation will be very small, and it would not be surprising if they should consider this to be further evidence that the motion does not exist" (Chandler, 1894).

5. Measurement of the latitude variation in Lyon

During the debate on the polar motion, the Observatoire de Lyon was still one of the very young provincial astronomical institutions created in the years 1870–1880 during the decentralization movement. Indeed, France was considerably behind in this matter, and if the major foreign countries all had several observatories, almost the entire French astronomical research was carried out in the Observatoire de Paris. This centralization was most fatal to the development of French astronomy during the second half of the nineteenth century, when Urbain Le Verrier became director of the observatory and was the most severe authoritarian. Even if one later tried to minimize his negative influence, eclipsed in history by his past glory, many testimonies remains of astronomers working under his orders, who rebelled against his sterilizing leadership. Le Verrier's shadow is present between the lines of the following text by Maurice Lœwy, referring to the activities of provincial observatories in 1880: "Amongst all sciences, astronomy has particularly suffered from the centralization of which it is perhaps the most striking example. For a long time indeed, and even in recent years, the Observatoire de Paris was in France the only institution of its kind where one could engage in the study of the great problems of experimental astronomy. This unique workers community, gathered under the absolute leadership of one, had the effect of subjugating individual initiatives to a constraint that paralyzed their growth and seriously prejudiced the general progress of the astronomical science" (Lœwy, 1882).

The Observatoire de Lyon was established by decree in 1878, but its instruments were not actually installed before 1880. For positional astronomy, there was a small Rigaud circle and mainly the big circle build by Eichens and funded by the famous philanthropist Bishoffsheim, who also funded the whole of the Observatoire de Nice. The observatory was erected on a site chosen by the military geodesist François Perrier in Saint-Genis-Laval, for geodetic operations (Faye, 1877). The municipality of Lyon, which participated in funding of the observatory, pushed to set up time distribution and meteorological services, and it was not before 1882 that the real astronomical observations started with the Eichens circle. Indeed, it must be said that all the observatory activities, astronomical, meteorological and those related to time distribution relied only on a very limited staff of three to five people in the 1880s. A characteristic of this staff was their young age compared to that of the Observatoire de Paris. The direction of the new provincial observatories had been given to several young astronomers who started their career in Paris under Le Verrier. In Lyon, Charles André aged 34 years, had been given the astronomy chair at the Lyon faculty in 1876, and was selected in 1878 to be the first director of the observatory. He personally hired local students, and the direction of meridian observations was then delegated in 1882 to a promising 26-years old student astronomer, François Gonnessiat, who would become an outstanding observer. In his report on the provincial observatories of 1882, Maurice Lœwy notes that "Mr. Gonnessiat demonstrates exceptional skills and knowledge in the execution of the high precision work: during his visit to the Observatoire de Lyon, the referee noted with pleasure the particular value of the research in which this astronomer is engaged" (Lœwy, 1883). Before examining what the research was, let's have a look at the author of this report. Maurice Lœwy was a brilliant Austrian astronomer who could not reach the position he deserved in his country because of his Jewish faith[4]. He was hired by Le Verrier at the Observatoire de Paris and was then naturalized as a French citizen. In the 1870s, after the fall of Le Verrier, he became one of the most influential astronomers in France and was even nominated director of the Observatoire de Paris in 1896. His opinion on the work done at the Observatoire de Lyon is therefore interesting to understand what was expected from the newly founded astronomical institutes. In his report, we read that the meridian observations in Lyon "relate primarily to the stars of lunar culmination". These observations consist in measuring the accurate positions of stars located in the Moon's path on the sky, and were of the highest interest for the geodesists. The first volume of the annals of the "Bureau des Longitudes" in 1877 contains an article by

[2] L'Astronomie, 1891. La variabilité des latitudes, pp. 139–145.

[3] Ciel et Terre, 1892–1893, vol. 13. Les variations périodiques de la latitude, pp. 103–106.

[4] This fact is mentioned for instance in Lœwy's necrology written by Poincaré (1908).

Loewy: "Determination of the right ascensions of lunar culmination and longitude stars" (Lœwy, 1877). Note that Lœwy was not a geodesist, but was amongst those astronomers who saw in geodesy a mean of pushing positional astronomy to extreme accuracy. At the time he wrote this article he was working in close collaboration with Perrier, who was leading the new measurement of the meridian of France extended to Algeria. In the article, Lœwy explains the interest of these stars for the accurate determination of longitudes. He describes the construction of a catalogue of such stars based on observations in Paris and Greenwich, and stresses the need to combine observations from several stations in order to reduce systematic errors from each instrument. Of course, as a member of the "Bureau des Longitudes", he concludes with the hope he has on the measurements done in the brand new geodetic observatory of Montsouris in Paris: "The execution of this important research has been given to naval officers temporarily attached to the Observatoire de Montsouris. The results obtained in the first year allow us to presume that, owing to the efforts of this elite staff, the aim will quickly be reached". But, as can be read in his report on the provincial observatories in 1882, he kept in mind his idea of combining data from different locations, and a new observatory such as Lyon, equipped with modern instruments could be fruitfully used for similar operations. As mentioned previously, the site of Saint-Genis-Laval was primarily chosen for geodetic considerations, and several sources attest to the close links of the Lyon staff with geodesy.

Apart from these early studies, the major observation program in the early '80s was the determination of the absolute positions of fifteen circumpolar stars. By definition, these stars are those located near the celestial pole, so they never rise nor set, as the circle of their apparent path never crosses the horizon. They are thus observable throughout the year and are used as references for many measurements of precision astronomy. The needs of modern astronomy and geodesy always required the highest precision, and observers were seeking new methods to minimize the various sources of error. In 1883, Lœwy published a series of five papers at the Academie des Sciences describing two new methods for the determination of circumpolar stars coordinates. We don't know if this was at Lœwy's request, but one of these methods was immediately tested in Lyon. The first publications of the observatory concerning meridian measurements dealt with the comparison between Lœwy's method and those adopted in Lyon (André & Gonnessiat, 1883). Note that amongst the publications based on meridian measurements, only this first one was co-signed by André and Gonnessiat, all the subsequent ones being the work of Gonnessiat alone.

In 1885, the absolute right ascensions of 15 circumpolar stars were published (Gonnessiat, 1885), and in 1886 their absolute declinations as well as the observatory's latitude (Gonnessiat, 1886). Indeed, the determination of declination of stars, which corresponds to their angular height above the celestial equator, is closely related to the latitude of the observing site. In the short section concluding this article, Gonnessiat raised the question of the variability of latitude: "It is interesting to examine whether the obtained values for the latitude display variations depending

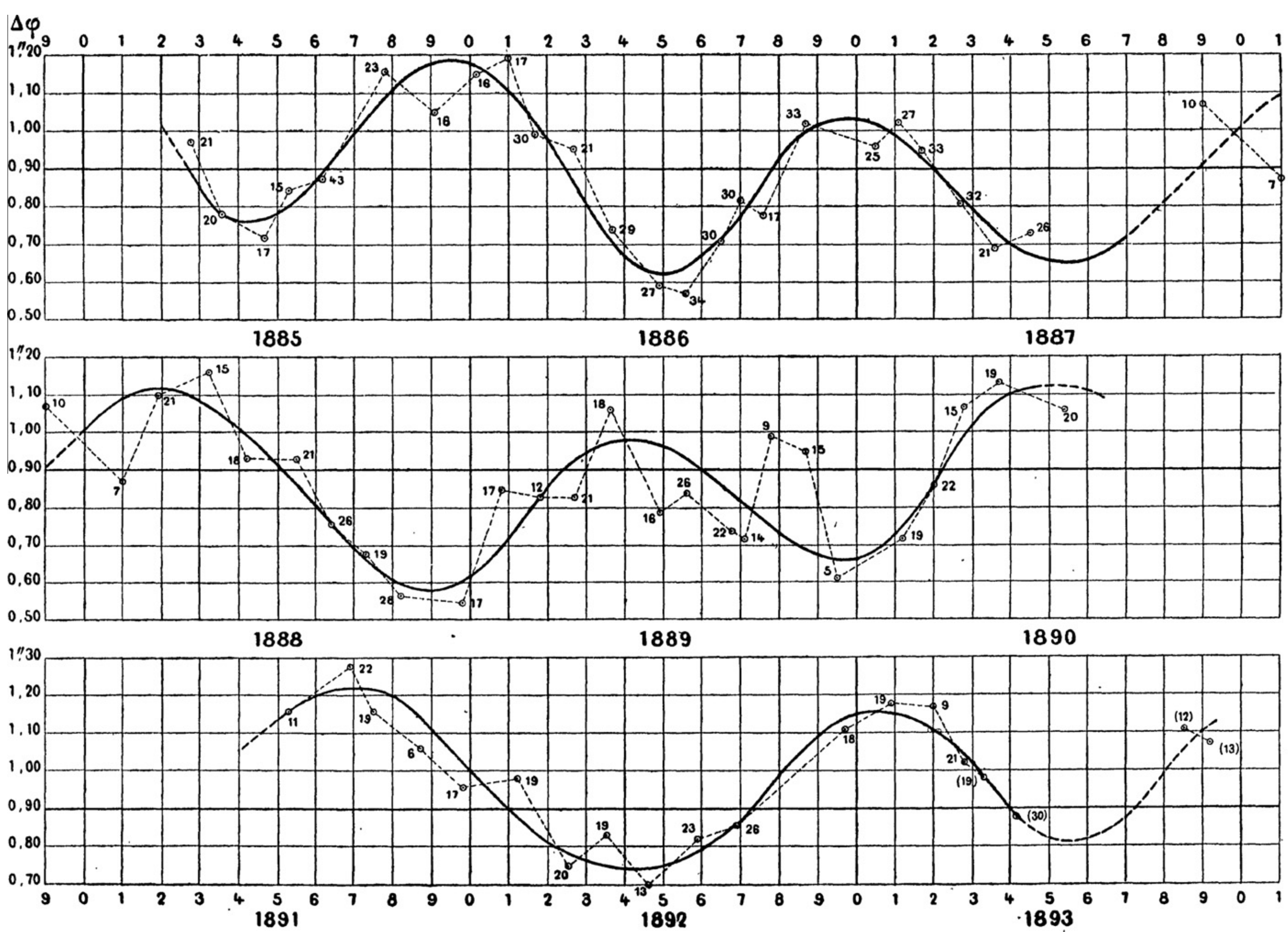

Fig. 3. Latitude variation measured at the Observatoire de Lyon from 1885 to 1893. Reproduction of a figure published by François Gonnessiat in the Bulletin Astronomique, 1894, volume 11, page 291.

on the season". Unfortunately, he answered negatively, although his data actually contained the information related to latitude variation, as he would understand later. It is out of the scope of the present paper to detail the reasons of Gonnessiat's misinterpretation. But, as mentioned before, declination and latitude are intimately linked in the equations and a dataset covering only one year of observation was not enough to disentangle the two quantities. Throughout the years after 1886, Gonnessiat continued to measure his sample of circumpolar stars and would then have the observational material to solve the problem. However, it might seem surprising that he did not reconsider this issue before 1893. Two important reasons led him to postpone a new study. As mentioned, the staff at the observatory was quite small, and all observations and data reduction relied on very few people. In the report on provincial observatories, one can see that the meridian observations activity was quite intense and could reach 145 nights a year. Furthermore we see how the reduction could be long: in his 1891 activity report, André wrote that the year 1890 had been devoted to the reduction of the data acquired in 1888 and 1889. It appears then that the data did accumulate from one year to another. There were no computation services as in other observatories, and in the archives of the observatory, we have found that the director had to pay external educated persons, such as the school teacher of Saint-Genis-Laval, to perform part of the computations. Apart from these tedious tasks of data collection and reduction, one must add that Gonnessiat began in 1889 a major work on the personal equation which would be the subject of his doctorate thesis in 1892.

The question of latitude variation became relevant again at the observatory in 1893. Tisserand, the new director of the Observatoire de Paris, who had been one of Gonnessiat's doctoral thesis referees, asked André to undertake an observing program of the polar star's accurate declination, to study the variation of Lyon's latitude. This program was set-up, but Gonnessiat also decided to summarize all his meridian observations from 1885 to 1893. The analysis of these data was published in a two-part article published in the "Bulletin Astronomique" in 1894 (Gonnessiat, 1894a,b). This paper would be the first in France to demonstrate the existence of variation of latitudes. Gonnessiat understood the reason for his earlier non detection. He realized that if he assumed a constant value of the observatory's latitude, a roughly periodic variation of the stars declinations was observed. Using an iterative technique, he finally came to a solution in which the declinations were fixed and the latitude was a variable. Fig. 3 is a copy of the original plot published in his paper, and shows the level of accuracy he reached even in the very first years of observation (Fig. 3). The period of 431 days is well demonstrated (compared to the 427 days of Chandler and 435 days adopted today), and the amplitude of about 0.2" also confirms other studies. Gonnessiat then tried to convince the French astronomers, and in 1898 published a new analysis of the last of Périgaud's negative results, which he explained as being mainly due to the imperfections of the meridian circle and to the fact, foretold four years before by Chandler, that at the time the measurements were made, the amplitude of the variation was minimal (Gonnessiat, 1898).

6. Reception of Gonnessiat's observations

Knowing Chandler's annoyance towards the resistance of French astronomers, it is not surprising to see the very positive reception he immediately gave to these new results, although they were published in French in a French journal. In 1895 he published a paper entitled "Note on the investigation of Gonessiat upon the variations of latitudes observed at Lyons" (Chandler, 1895a) in which he wrote: "Mr. Gonessiat has given the results of some very important researches on this subject, based upon his meridian-circle observations of fifteen circumpolar stars between 1885 and 1889. Their especial value consist in the fact that they cover an interval in which we have few other contemporaneous observations suitable for this purpose". In this note he used Gonnessiat's data to which he applied a least-squares method to adjust his own model and concluded: "The above remarkable agreement is strong testimony to the precision of Gonessiat's observations". The same year he once again used the Lyon data in a second paper: "On the annual term of the latitude variation from the Lyons observations" (Chandler, 1895b). Chandler would also use Gonnessiat's measurements in subsequent papers he published on this topic throughout the 1890s.

Amongst major internationally renowned names associated with the polar motion discovery, Chandler is not the only one who welcomed Gonnessiat's measurements. Theodor Albrecht, who was coordinating international measurements, compiled in 1897 data from 21 stations, including Lyon's data in his report on polar motion (Albrecht, 1898).

In a later report by Albrecht published in 1900, he kept only 14 stations including Lyon (Albrecht, 1900). However, Gonnessiat left the Observatoire de Lyon in 1900, when he was selected to assist the geodetic mission in charge of the new measurement of the equatorial meridian arc in Ecuador. He was then nominated as director of the Quito Observatory. André reports that his leaving "brought some confusion in the meridian service" of the observatory, that stopped completely any further contribution to the subject.

Amongst the international reactions, we note that Gonnessiat's paper was considered important enough to be immediately commented upon in the British journal Nature in their "astronomical column".

Let's see now the impact of Gonnessiat's paper on the French community. It is amusing to read this text by Jules Janssen, in 1896: "In France, apart from Mr. Gonessiat, we almost neglected the issue [...] We can say that the issue remains very obscure. It does not appear in any way from the observations, that the extremity of the earth's axis, if movements are actually recorded, describes a closed curve, and that this motion would be periodic" (Janssen, 1896). The successive failures of previous observations attempted in France are not even mentioned.

In 1900, Academician Octave Callandreau is much more positive in his "Annual Review of Astronomy to the Academy of Sciences" (Callandreau, 1900). Commenting about the international organization that was being set-up to study the polar motion, he notes: "If Mr. Gonnessiat, an astronomer at the Observatoire de Lyon, our colleague, had not taken the initiative to make observations in order to clarify the problem, our country would have taken no part in this research, however, crucial in this century.

There is a lesson to be learnt from this: observational astronomy, requiring the highest precision, does not in France hold the place it should; the art of observation is, quite wrongly, regarded as of secondary importance.

Without doubt, neither long training, nor special skills are necessary to obtain measurements of poor accuracy, and there are plenty of these, that rather hinder the progress of science. But if one tries to achieve a significant advance, such as to reduce the probable error of meridian passages from $0^s,05$ to $0^s,03$, and those of declinations from $0'',6$ to $0'',3$, as done by Mr. Kütsner at the Observatory of Bonn, it becomes a matter for which success needs art, a talent of organization, physical and even moral skills rarely met altogether". No doubt that after his work, Gonnessiat was regarded as one of those outstanding observers. The same year, Henri Poincaré, presenting the geodetic expedition in Ecuador wrote: "The French Government has made available to the Government of Ecuador for a period of five years one of our most skillful astronomers, Mr. Gonnessiat from the Observatoire de Lyon. This scientist will take the direction of the Observatory of Quito" (Poincaré, 1900).

7. Gonnessiat's path after leaving Observatoire de Lyon

It is beyond the scope of this paper to analyze the work and life of François Gonnessiat, this will be done in a forthcoming paper. However, one can give a quick overview of his career after leaving the Observatoire de Lyon.

As previously stated, Gonnessiat was chosen in 1900 to accompany the geodetic mission entrusted with the measurement of a meridian on the Equator. In Gonnessiat's application letter[5] as future Director of Quito's Observatory, we see that he had been encouraged by General Léon Bassot, then Chef du Service Géographique de l'Armée, and member of the International Association of Geodesy of which he would become Director in 1902. Bassot had been a close aide to General Perrier with whom he had conducted observations related to the determination of the "Méridienne de France" in the years 1870–1880. In this context, he was brought to work on the site of Saint-Genis-Laval before the founding of the Astronomical Observatory of Lyon. Therefore, Bassot knew Gonnessiat when he was a young student, and followed his progress as a skillful observer. A fairly detailed description of the mission to Ecuador can be found in an article by Martina Schiavon (2006).

The return from Ecuador was somewhat turbulent. After six years of absence, the Dean of the University supported by the rector of the Academy of Lyons, asked for the replacement of Gonnessiat by Jean Merlin, then assistant astronomer at the Observatoire de Lyon, as a lecturer in the faculty of sciences[6]. In July 1906, Gonnessiat had applied for the direction of the Observatoire de Bordeaux, but Luc Picart and Henry Bourget were selected as first and second choices by the vote of the Academie des Sciences[7]. At the end of 1906, Gonnessiat found himself with no affectation, and the Minister of Public Instruction, who had just appointed him Chevalier de la Légion d'Honneur, asked Lœwy, Director of the Observatoire de Paris, to hire him as assistant astronomer in his observatory. Lœwy convened the Board of the Observatory on October 19, 1907 to consider Gonnessiat's application, and the latter finally incorporated the Observatoire de Paris in November 1907[8].

The Parisian stay would be short. Gonnessiat and Gaston Fayet were given the responsibility of the big Eichens meridian circle, the near-twin of that of Lyon. They published a joint paper, "On Lœwy's method for the study of divided circles". In June 1907, the Director of the Observatory of Algiers, Charles Trépied died, and in August of the same year the Director of the Observatory of Marseilles, Stephan, retired. The candidates for their succession were Gonnessiat, Jean Mascart and Louis Fabry for Algiers[9], Bourget, Fabry and Ernest Esclangon for Marseille[10]. Gonnessiat, who did not apply for Marseilles, was appointed Director of the Observatoire d'Alger. Anecdotally, Lœwy who was the first Parisian astronomer to recognize the emerging talent of Gonnessiat, died during the council meeting convened to decide his appointment in Algiers (Poincaré, 1908).

The management of an observatory such as Algiers was obviously quite different from that of Quito. As previously mentioned, in Quito Gonnessiat had to single handedly reorganize an abandoned observatory, and his observations were entirely dedicated to the geodesic mission for which he had been hired. Algiers was at that time the best observing site in France, and as such it was strongly involved in big projects such as the "Carte du Ciel", initiated in 1887 by Mouchez. The many episodes of this large project are documented in detail in a collective book directed by Jérôme Lamy (2008). Gonnessiat continued the work of his predecessor in this project, and Algiers was one of the first observatories to complete its part in 1919 (Saint-Martin, 2008). However, his long experience in astrometry led him in to modernize the observatory in this field. The Algiers Observatory benefited from all the technical advancements in positional astronomy under his leadership: upon arrival, he installed an impersonal micrometer on the meridian circle, and later on he was an important actor of the emerging photographic astrometry.

As Director, Gonnessiat suffered the same ills than in any other provincial observatories: the chronic shortage of staff and the disorganization caused by the World War I. The shortage of manpower in the Observatoire d'Alger was even more dramatic than anywhere else in France. As a first rank observing site, the observatory was involved in several international projects but did not receive special treatment compared to other provincial observatories. In 1920, Gonnessiat described this situation in a few sentences: "Thus, while young astronomers shrink before the difficulties of material life in our observatories, far off urban centers, Paris attracts and retains them by its unique position in all aspects. However, the Observatoire d'Alger also has international obligations. But there is gross disproportion between the very reduced staff in Algiers and the personnel of any categories available at the Observatoire de Paris. Is it impossible to achieve a more equitable distribution of staff?" (Gonnessiat, 1920). The answer to this question would unfortunately remain negative. Algiers would nonetheless produce high level scientific work in positional astronomy and provided a catalogue of stars which was internationally recognized. The observatory was also chosen, along with Shangaï and San-Diego, as one of the network's three primary nodes for the first worldwide campaign of longitudes determination in 1926. Gonnessiat, having reached the age of 70 that year, was kept in his directorial position until 1931. In his necrology, Georges Perrier wrote: "Because of Gonnessiat's special expertise in meridian observations, it did not seem possible to deprive the Observatory of its Director, and he was kept in his position until July 1931, only retiring when the computation and publication works related to the 1926 operations were achieved" (Perrier, 1934). He was then replaced by Joanny-Philippe Lagrula who had also trained in Lyon, and had succeeded Gonnessiat in the direction of the Observatory of Quito in 1906.

Gonnessiat published articles about photographic astrometry until his death in 1934 in Algiers. During his long Algerian period, he worked only sporadically on the variation of latitude. There are some indications of observations related to this topic in Algiers in the "Rapports sur les Observatoires Astronomiques de Province", though no significant publications were issued.

8. Conclusion

The contribution to the polar motion measurement has been without doubt one of the most important results of the Observatoire de Lyon during the early years. In 1896, Charles André himself mentioned it as some of the most significant contributions of the observatory. It was mainly the work of François Gonnessiat, a young and skillful astronomer who has now fallen into oblivion,

[5] Archives Nationales. F17-23844.
[6] Ibid.
[7] Comptes Rendus de l'Académie des Sciences, 1906, vol. 143, p. 203.
[8] Archives Nationales. F17-23844.
[9] Comptes Rendus de l'Académie des Sciences, 1907, Vol. 145, p. 856.
[10] Ibid. p. 855.

but whose destiny should one day be told. The exceptionally gifted son of a peasant family at the lowest level of the social ladder, who managed to integrate university through winding paths, to become one of the first astronomers of the new Observatoire de Lyon, and finally given the direction of the Quito and Algiers observatories. This kind of fate, quite uncommon even nowadays, was exceptional for someone born in 1856 in France under the second Empire. The meeting of Charles André for whom the creation of the new observatory would be his life, with this young student of relentless motivation is certainly the key to the successful work that would be led at the Observatoire de Lyon in the early years, despite the great practical difficulties in which provincial observatories were kept. The decentralization in fact, left very little autonomy to these new establishments. As explained before, the research program itself, if not directed, was closely overseen by the president of the inspection committee of the provincial observatories, a committee composed mainly of members of the Observatoire de Paris and the Academie des Sciences. The hiring of Gonnessiat by André is an example of this tight control. When André suggested this candidate in 1880 for the position of assistant astronomer, Lœwy, president of the control committee refused, arguing that the Observatoire de Paris had just created a School of High Astronomy, that should be the source for provincial observatories astronomers. Gonnessiat was hired at the lowest level as a "student astronomer" and remained in this position during five years, until his talent was recognized by Lœwy himself.

Gonnessiat's leaving for Ecuador in 1900 led to a break in his work. The position of director of the Observatory of Quito was in no way comparable to that of director of observatories in developed countries: The observatory was virtually a ghost observatory, established in 1873 by the president of the Republic of Ecuador Gabriel García Moreno with the help of German Jesuit astronomers. However, due to the political instability of the country, it was abandoned for several years. At the time, high level university education in Equator did not exist and Gonnessiat spent much of his energy training a local scientific elite and performing the work necessary to the geodetic mission. It is understandable that he no longer had the time to continue his previous researches, or even promote them. As Gonnessiat left Lyon for Quito, an international service for the measurement of latitudes variation was founded (Höpfner, 2000), to which he would not participate, and his own contribution to this problem was forgotten. The fact that even in Lyon, his work was very quickly forgotten is curious. There is no trace in the old collection of the library at the Observatoire de Lyon of the 130-pages memorandum devoted to the subject by Gonnessiat and cited by Radau in 1898 as being accepted for inclusion in the "Mémoire des savants étrangers" of the Academie des Sciences[11] (Radau, 1898). The library owns two volumes of compiled reprints dealing with latitudes, in which only appears the first paper from Gonnessiat where he did not detect a change in latitude. These compilations were carried out under the direction of André's successor: Jean Mascart. This occultation of Gonnessiat's work is surprizing, and one may wonder if it was deliberate or not. In 1908, when Gonnessiat was nominated director of Algiers observatory by the Academie des Sciences, almost all the directors of French observatories came from the centralized scientific elite formation system of the time, the "Ecole Normale Supérieure" (ENS) or the "Ecole Polytechnique"[12]. Gonnessiat himself had been a student at the Ecole Normale d'Instituteurs of the small town of Bourg-en-Bresse, a primary school teachers training school, which could be joined after primary school. He became a teacher and passed his baccalaureate, which allowed him to join the Lyon University and then to acquire his academic grades. This unusual academic background kept him away from any scientific network of influence of the time, and he probably did not get much help in promoting his work. In this context, the nomination of Gonnessiat against Mascart as director of the Algiers observatory could have offended Mascart, who was probably not eager to protect Gonnessiat's memory once he became director in Lyon in 1912.

Whatever the reason, this important contribution from the Observatoire de Lyon to a disputed astronomical debate of the late nineteenth century has been forgotten and is only now being rediscovered. It throws new light on the early activity of provincial observatories, hampered for decades in their development by the persistent weight of centralization. This example shows how enthusiastic and efficient the pioneer astronomers of these young observatories were, an enthusiasm that unfortunately would progressively be curbed by lack of means.

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References

Albrecht, T. (1898). *Bericht über den Stand der Erforschung der Breitenvariation im December 1897*. Berlin: Centralbureau der internationalen Erdmessung.
Albrecht, T. (1900). *Bericht über den Stand der Erforschung der Breitenvariation am Schlusse des Jahres 1899*. Berlin: Centralbureau der internationalen Erdmessung.
André, C., & Gonnessiat, F. (1883). Sur la détermination des ascensions droites des étoiles circompolaires. *Comptes Rendus de l'Académie des Sciences, 97*, 486.
Boquet, F. (1892). Sur une série de déterminations de la latitude, faites au grand cercle méridien de l'Observatoire de Paris. *Comptes Rendus de l'Académie des Sciences, 114*, 896.
Callandreau, O. (1900). Revue annuelle d'astronomie. *Revue générale des Sciences pures et appliquées, 11*, 746.
Chandler, S. (1885). On the latitude of Harvard College Observatory. *Astronomische Nachrichten, 112*, 113.
Chandler, S. (1887). The Almucantar. An investigation made at the observatory in 1884 and 1885. *Annals of Harvard College Observatory, 17*, 1.
Chandler, S. (1891a). On the variation of latitude, I. *Astronomical Journal, 11*, 59.
Chandler, S. (1891b). On the variation of latitude, II. *Astronomical Journal, 11*, 65.
Chandler, S. (1894). The variation of terrestrial latitude. *Publications of the Astronomical Society of the Pacific, 6*, 180.
Chandler, S. (1895a). Note on the investigations of Gonessiat upon the variations of latitude observed. *Astronomical Journal, 14*, 174.
Chandler, S. (1895b). On the annual term of the latitude-variation from the Lyons observations. *Astronomical Journal, 15*, 60.
Cornu, M. (1893). Sur la nécessité d'introduire diverses précautions additionnelles dans les observations astronomiques de haute précision. *Presented at the Dixième conférence générale de l'Association Géodésique Internationale*.

[11] The "Mémoire des savants étrangers" were published by the Academie des Sciences. They contained results from scientists who were not members of the Academy, but considered of first importance.

[12] In fact, they came mainly from ENS (Baillaud in Paris, Picart in Bordeaux, Cosserat in Toulouse, André in Lyon, to whom would succeed another former ENS student: Mascart in 1912). The only Polytechnician is Bassot in Nice. The exceptions are Bourget in Marseilles, who is however the son of a University professor and Lebeuf in Besançon, educated at the School of Astronomy founded by Mouchez at the Observatoire de Paris. When Strasbourg would be returned to France, a director from the ENS would be installed in 1919 (Esclangon), to whom would succeed in 1929 another former ENS student (Danjon). It was not until 1917 that another non-typical observatory director would be nominated: Fayet in Nice, from the next generation (he was 18 years younger than Gonnessiat).

Faye, H. (1877). Communication du Bureau des Longitudes, relative à de nouvelles opérations de Géodésie astronomiques. *Comptes Rendus de l'Académie des Sciences, 85*, 359.

Faye, H. (1892). Sur les variations périodiques de la latitude, d'après une Lettre de M. Helmert aux membres de la commission permanente de l'Association géodésique internationale. *Comptes Rendus de l'Académie des Sciences, 114*, 703.

Gaillot, A. (1890). Sur les variations constatées dans les observations de la latitude d'un même lieu. *Comptes Rendus de l'Académie des Sciences, 111*, 559.

Gaillot, A. (1891). Sur les variations observées de la latitude d'un même lieu. *Comptes Rendus de l'Académie des Sciences, 112*, 651.

Gonnessiat, F. (1885). Mémoires et observations. Sur la détermination des ascensions droites absolues des étoiles circumpolaires. *Bulletin Astronomique, 2*, 213.

Gonnessiat (1886). Latitude de l'observatoire de Lyon; Déclinaisons absolues d'étoiles circompolaires. *Bulletin Astronomique, 3*, 569.

Gonnessiat (1894a). Mémoires et observations. Sur les variations de la latitude à l'observatoire de Lyon. *Bulletin Astronomique, 11*, 241.

Gonnessiat (1894b). Mémoires et observations. Sur les variations de la latitude à l'observatoire de Lyon [Suite et fin]. *Bulletin Astronomique, 11*, 291.

Gonnessiat, F. (1898). Mémoires et observations. Sur les déterminations de latitude effectuées par M. Périgaud au cercle Gambey de l'Observatoire de Paris. *Bulletin Astronomique, 15*, 161.

Gonnessiat, F. (1921). Observatoire d'Alger. In *Rapports sur les Observatoires Astronomiques de Province,* (pp. 5–15). Paris, Imprimerie Nationale.

Höpfner, J. (2000). The International Latitude Service – A historical review, from the beginning to its foundation in 1899 and the period until 1922. *Surveys in Geophysics, 21*, 521.

Janssen, J. (1896). Les progrès de l'astronomie. *Bulletin de la Société Astronomique de France, 10*, 139.

Küstner, F. (1888). Neue Methode zur Bestimmung der Aberrations-Constante nebst Untersuchungen über die Veränderlichkeit der Polhöhe. *Beobachtungs-Ergebnisse der Koniglichen Sternwarte zu Berlin*, *3*, 1.

Lamy, J. (2008). *La Carte du Ciel: Histoire et actualité d'un projet scientifique international* (EDP Sciences Editions.).

Le Guet Tully, F., De La Noë, J., & Samsaoud, H. (2008). L'Opération de la Carte du Ciel dans les contextes institutionnels et techniques de la fin du XIXè siècle. In Jérôme Lamy editor (Ed.), *La Carte du Ciel : Histoire et actualité d'un projet scientifique international*. EDP Science Editions.

Le Verrier, U. (1868). L'Observatoire impérial de Paris, sa situation et son avenir. *Comptes Rendus de l'Académie des Sciences, 66*, 21.

Lœwy, M. (1877). Détermination des ascensions droites des étoiles de culmination lunaire et de longitude. *Annales du Bureau des Longitudes, 1*, B3.

Lœwy, M. (1882). *Rapport sur les observatoires astronomiques de province*. Année 1881, p. 4.

Lœwy, M. (1883). *Rapport sur les observatoires astronomiques de province*. Année 1882. p. 16.

Maison, L. (2004). *La fondation et les premiers travaux de l'observatoire de Bordeaux (1871–1906): Histoire d'une réorientation scientifique*. PhD Thesis. Université Bordeaux 1.

Mouchez, E. B. (1888). Sur la difficulté d'obtenir la latitude exacte de l'observatoire de Paris. *Comptes Rendus de l'Académie des Sciences, 107*, 848.

Mouchez, E. B. (1892). Sur une nouvelle détermination de la latitude de l'Observatoire de Paris. *Comptes Rendus de l'Académie des Sciences, 114*, 865.

Newcomb, S. (1891). On the periodic variation of latitude, and the observations with the Washington primevertical transit. *Astronomical Journal, 11*, 81.

Périgaud, M. (1888). Sur une triple détermination de la latitude du cercle de Gambey. *Comptes Rendus de l'Académie des Sciences, 107*, 722.

Périgaud, M. (1892). Sur la latitude obtenue à l'aide du grand cercle méridien de l'Observatoire de Paris. *Comptes Rendus de l'Académie des Sciences, 114*, 895.

Périgaud, M. (1898). Cercle de Gambey. Observations de 1887 a 1894. *Annales de l'Observatoire de Paris, 41*, D1.

Perrier, G. (1934). François Gonnessiat (1856-1934). *Bulletin Géodésique, 44*, 298–311.

Poincaré, H. (1900). La révision de l'arc méridien de Quito. *Revue générale des Sciences pures et appliquées, 11*, 925.

Poincaré, H. (1908). *Notice nécrologique sur M. Maurice Lœwy*. Annuaire pour l'an 1908 publié par le Bureau des Longitudes, p. D1.

Portilho, O. (2009). On a possible connection between Chandler wobble and dark matter. *Brazilian Journal of Physics, 39*, 1.

Radau, R. (1898). Rapport sur un mémoire de M. Gonnessiat, intitulé: "Recherches sur la loi des variations de latitude". *Comptes Rendus de l'Académie des Sciences, 126*, 710.

Saint-Martin, A. (2008). La phase critique de la Carte du Ciel à Paris. In Jérôme Lamy editor (Ed.), *La Carte du Ciel: : Histoire et actualité d'un projet scientifique international*. EDP Sciences Editions.

Schiavon, M. (2006). Les officiers géodésiens du Service géographique de l'armée et la mesure de l'arc de méridien de Quito (1901–1906). *Histoire & Measure, XXI-2*, 55.

Tisserand, F. (1890). La question de la variabilité des latitudes devant l'association géodésique internationale. *Bulletin Astronomique, 7*, 341.

Verdun, A., & Beutler, G. (2000). Early Observational Evidence of Polar Motion. In IAU Colloquium 178: *Polar motion: historical and scientific problems.* Astronomical Society of the Pacific conference series (Vol. 208, pp. 67–81).

Villarceau, Y. (1868). Note à l'Académie. *Comptes Rendus de l'Académie des Sciences, 66*, 17.